ZAMBIA ENVIRONMENTAL MANAGEMENT AGENCY

THE REPUBLIC OF ZAMBIA

Conservation Plan for Lukanga Swamp and Upper Kafue Basin

Progress Report No. 4

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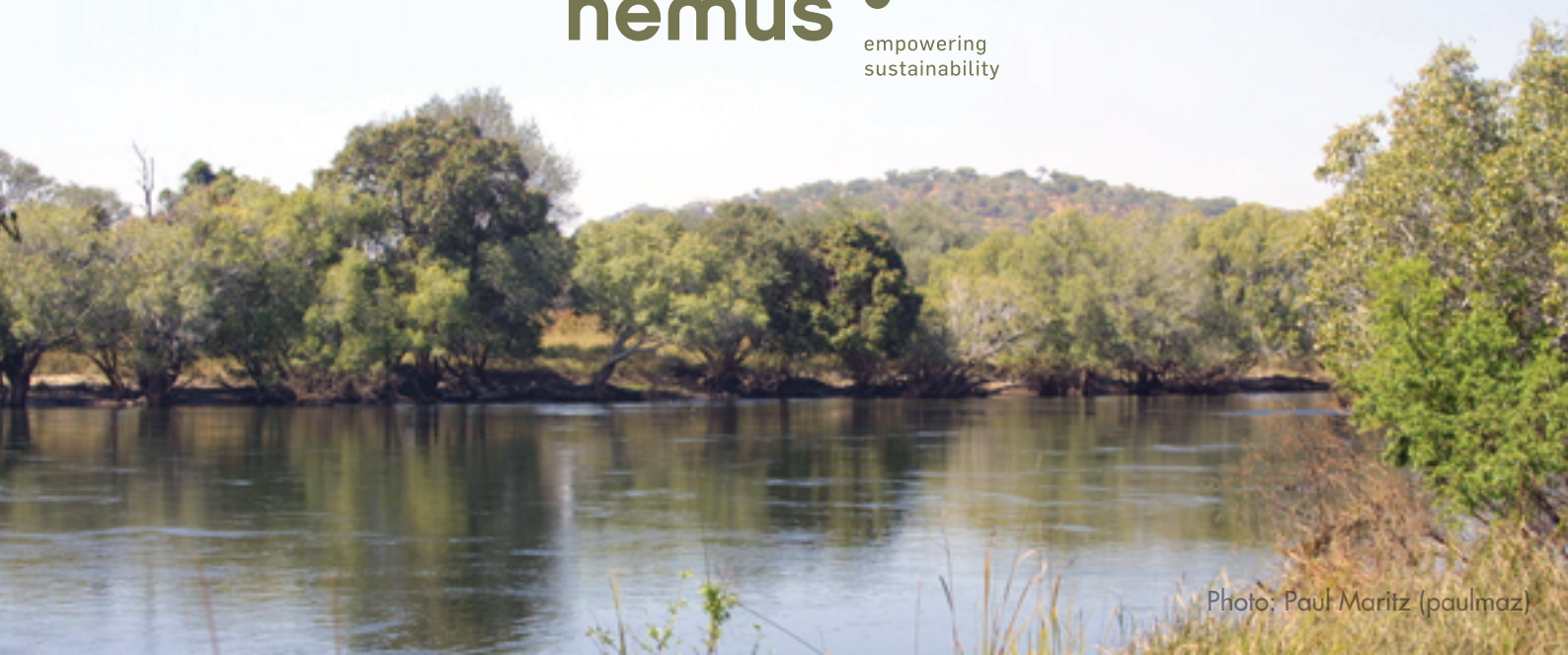


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CONSERVATION PLAN FOR LUKANGA SWAMP AND UPPER KAFUE BASIN

Progress Report No. 4

TABLE OF CONTENTS

Executive summary xi

Foreword I

1. Introduction 3

2. Conservation planning framework 7

2.1. Planning and legal framework 7

2.2. Stakeholders mapping and engagement 17

2.2.1. Stakeholders 18

2.2.2. Consultation methods 20

2.2.3. Stakeholder engagement actions 23

2.2.4. Lukanga Conservation Plan website 26

2.3. Vision and approach to the Lukanga Conservation Plan 30

3. Description – Upper Kafue, Lukanga Swamp and its catchment baseline 31

3.1. Climate 31

3.2. Hydrology 33

3.2.1. The upper and mid Kafue 34

3.2.2. The lower Kafue and the Kafue Flats 35

3.2.3. The Lukanga Swamp and its catchment 36

3.3. Hydrodynamics of the Lukanga Swamp and its catchment 48
3.4. Geology 49
3.5. Hydrogeology 51
3.5.1. Groundwater at the scale of the Kafue Basin 51
3.5.2. Groundwater at the scale of the Lukanga Swamp and its catchment 55
3.6. Environmental quality 64
3.6.1. Introduction, scope and methodology 64
3.6.2. Groundwater (well water) 66
3.6.3. Surface water 70
3.6.4. Sediment 79
3.6.5. Leaves 91
3.6.6. Discussion 93
3.7. Ecology 99
3.7.1. Introduction; scope and methodology 99
3.7.2. Designated areas for the protection of biodiversity 101
3.7.3. Land-cover 103
3.7.4. Lukanga Swamp 108
3.8. Socioeconomics 138
3.8.1. Population and demography (1969-2035) 139
3.8.2. Economic activities 145
3.9. Governance 148
4. Evaluation 153
4.1. Diagnostic – assessment of wetland values 153
4.1.1. Hydrological and biogeochemical values 153
4.1.2. Ecological values 159
4.2. Ecosystem services assessment 175
4.2.1. Selection of ecosystem services 175
4.2.2. Economic valuation 181

5. Objectives 185

5.1. Conservation objectives 185

5.2. Historical trends and drivers of change 193

5.2.1. Past trends 193

5.2.2. Drivers of change and related impacts 221

5.3. Indicators and Environmental Cost-Benefit Analysis (ECBA) 261

5.3.1. Problem definition 262

5.3.2. Identification of relevant impacts 263

5.3.3. Physical quantification of relevant impacts 264

5.3.4. Monetary valuation of relevant impacts 272

5.3.5. Discounting costs and benefit flows 278

5.3.6. Sensitivity analysis 279

6. Assessment – Future scenarios and decision-making framework 281

6.1. Baseline scenario 281

6.2. Scenario with 10% deforestation 290

6.3. Scenario with 15% deforestation 294

6.4. Scenario with 20% deforestation 298

6.5. Scenario with 25% deforestation 302

6.6. Conclusion and decision-making framework 307

7. Conclusion 309

8. References 315

Appendixes 335

Appendix 1 – Stakeholder consultation – Focus group discussions held in Chilwa Island, Chipepo, Mulongoti, Shamputa, Waya, and Mpusu/Chisoka communities, October 2020: questionnaires

Appendix 2 – Environmental quality assessment

Appendix 3 – Ecological assessment

LIST OF TABLES

Table 1 – Policy documents relevant to wetland conservation 7
Table 2 – Wetland management legal framework 14
Table 3 – Main stakeholders engaged during the development of the conservation plan 18
Table 4 – Different types of aquifers present in the Kafue River Basin 51
Table 5 – Stratigraphic Succession of lithologies found in the Lukanga Swamp catchment with hydrogeological interest 57
Table 6 – Comparison of concentrations and physical-chemical properties of water well to guidelines for drinking water 66
Table 7 – List of all 14 groundwater samples and parameters that exceed (or stand below for the case of pH) guideline values for drinking purposes 68
Table 8 – Guideline and standard values for different water uses 71
Table 9 – Analysis of surface water samples for different water uses considering different guidelines values 73
Table 10 – Specific weight and grain-size classification of sediment samples collected in the Lukanga Swamp Area and Upper Kafue River Basin 80
Table 11 – Spearman correlations between metals and organic carbon and grain-size parameters 83
Table 12 – Percentage of sediment samples above the ERL and ERM 85
Table 13 – Summary of results for the sediment enrichment factors 87
Table 14 – Elemental concentration in composite leaf samples (in mg/kg) 91
Table 15 – Comparison of average concentrations found in leaves with those from leaves of *Phragmites* spp. in natural and constructed wetlands around the world 92
Table 16 – Macro-habitats of the Lukanga Ramsar site and surrounding area 110
Table 17 – Population for Central Province districts crossed by the plan areas (1969-2010) 140
Table 18 – Population for Copperbelt Province districts crossed by the plan areas (1969-2010) 141
Table 19 – Total population projections for Central Province districts crossed by the plan areas (2011-2035) (Medium Variant projection) 142
Table 20 – Total population projections for Copperbelt Province districts crossed by the plan areas (2011-2035) (Medium Variant projection) 143
Table 21 – Percent distribution of the population (*De jure*) by age group for Central Province, Copperbelt Province and Zambia (2010) 144
Table 22 – Economic activities performed by those living in Kabosha, by gender 146
Table 23 – Economic activities performed by those living in Muchoko, by gender 147
Table 24 – Main economic activity(ies) performed by some specific social groupings 147
Table 25 – Perception on the population of different tribes in Muchoko 149
Table 26 – Perception on the population of different tribes in Kabosha 150
Table 27 – Ecological relevance of hydrological and biogeochemical values 153
Table 28 – Ecological state of hydrological and biogeochemical values 154
Table 29 – Classification of hydrological and biogeochemical values from the Lukanga Swamp and its catchment 155
Table 30 – Ecological relevance 159
Table 31 – Ecological state 160
Table 32 – Classification of the Lukanga site's habitats 161
Table 33 – Prioritization of flora and fauna 164
Table 34 – Main threats affecting the conservation of the site's values 167
Table 35 – Invasive alien species 172
Table 36 – Ecosystem services and goods identified in the Lukanga Swamp and its catchment, following the CICES v5.1 classification 176
Table 37 – Equivalence of the selected ecosystem services and goods to the MA and TEEB ecosystem services classification and assessment frameworks 179
Table 38 – General ecosystem services identified as they relate to the TEV value types 183
Table 39 – Comprehensive ecosystem services identified as they relate to the TEV value types of use 184
Table 40 – Conservation objectives and targets for prioritary ecological values 186
Table 41 – Distribution of agricultural households by type of activity (2018) 194

Table 42 – Production of copper in Zambia per mine and province (2016-2018) 198
Table 43 – Results from the satellite image analysis undertaken by MEDEEM Zambia in the scope of the weed control project 207
Table 44 – Degradation indicators observed in the wetland in September and October 2019 214
Table 45 – Fire statistics of different vegetation types and land-use categories (for the 8-year period 2001-2008, for Zambia) 226
Table 46 – Fish landings from the capture Fishery on the Lukanga Swamps 236
Table 47 – Closed fishing season reports 244
Table 48 – Indigenous fruit trees and their uses 250
Table 49 – Risks and potential impacts for different sectors in Zambia 260
Table 50 – Comprehensive ecosystem services identified in Lukanga Swamp and its catchment and indicators of physical quantification 264
Table 51 – Selected valuation techniques for Lukanga Swamp's benefits 273
Table 52 – Baseline scenario valuation – 10^3 USD/ year (2050) 282
Table 53 – 10% deforestation scenario valuation – 10^3 USD/ year (2050) 290
Table 54 – 15% deforestation scenario valuation – 10^3 USD/ year (2050) 294
Table 55 – 20% deforestation scenario valuation – 10^3 USD/ year (2050) 298
Table 56 – 25% deforestation scenario valuation – 10^3 USD/ year (2050) 302
Table 57 – Total valuation for scenarios considered – 10^3 USD/ year (2050) 308

LIST OF FIGURES

Figure 1 – Location of Lukanga Swamp and complementary plan areas; administrative and hydrographic frameworks 4
Figure 2 – Lukanga Conservation Plan Website: homepage 26
Figure 3 – Lukanga Conservation Plan Website: background/presentation 27
Figure 4 – Lukanga Conservation Plan Website: planning (including the work schedule) 28
Figure 5 – Lukanga Conservation Plan Website: Scoping and data collection phase (including downloads of available reports) 29
Figure 6 – Lukanga Conservation Plan Website: Participation form 29
Figure 7 – Mean monthly rainfall and potential evapotranspiration (Penman-Monteith) derived from the FAO Loc-Clim database 31
Figure 8 – Location of the Kafue River basin 33
Figure 9 – Lukanga Swamp RAMSAR Site 37
Figure 10 – Hydrological network associated with the Lukanga Swamp 38
Figure 11 – Mufukushi river near Mpunde in October 2019 (northwards view) 39
Figure 12 – Lukanga river near Shamputa in October 2019 (southwards view) 39
Figure 13 – Water balance in the Lukanga Swamp 41
Figure 14 – Lukanga river (to the West); establishes the connection between the swamp and the Kafue river 42
Figure 15 – Lukanga river (to the East); establishes the connection between the swamp and the Kafue river 42
Figure 16 – Surface water level at Chilwa Island and at Twenty Village in the Lukanga Swamp, from 1961 to 1987 43
Figure 17 – Water level in the Lukanga swamp based on satellite altimetry 44
Figure 18 – Annual inflow into Lukanga Swamp 45
Figure 19 – Average annual water yield in Lukanga watershed (2000 – 2015) 45
Figure 20 – Water balance with annual totals (left), and the mean monthly values (right) comparing Kafue River flow (20 km upstream of Lukanga swamps), Lukanga watershed inflow, outflow to the Kafue River (from the Lukanga) and over flow from the Kafue to the Lukanga 46
Figure 21 – Geological Map of Zambia with location of Lukanga Swamp sub-catchment and Kafue River Basin upstream 49
Figure 22 – Geological setting of Lukanga Swamp and its sub-catchment, with major dislocation zones 50
Figure 23 – Different aquifer types in the Kafue River Basin 54
Figure 24 – Part of the Hydrogeological Map of Zambia 1:1,500,000 for the region comprising the Lukanga Swamp and Upper Kafue River Basin 56
Figure 25 – Schematic section through schist of unit D as an aquifer 58
Figure 26 – Regional groundwater flow in the Lukanga Swamp catchment 62
Figure 27 – Local groundwater flow in Kabwe close to the limit of the Lukanga catchment 63
Figure 28 – Fisherman and grazing animals from the Lukanga Swamp 70
Figure 29 – Sediment texture classification triangle plot for sediment samples collected in the Lukanga Swamp area and Upper Kafue River Basin 81
Figure 30 – Sediment sampling stations 4 (a), 18 (b) and 19 (c) 88
Figure 31 – EF(Co) in sediments collected in the Kafue River and selected tributaries 89
Figure 32 – EF(Cu) in sediments collected in the Kafue River and selected tributaries 90
Figure 33 – Sites visited in September and October 2019 for ground truthing of cartographic units 100
Figure 34 – Contextualization of the Lukanga Swamp in Zambia's national network of protected areas 101
Figure 35 – Important Bird Areas of Zambia 102
Figure 36 – Upper Kafue basin and Lukanga subcatchment land cover 105
Figure 37 – Lukanga swamp land cover 107
Figure 38 – Permanent swamp macro-habitat: A. floating aquatic macrophytes; B. emergent macrophytes 113

Figure 39 – Edaphic grassland habitat at the end of the dry season 115
Figure 40 – Termitaria macro-habitat; here, the extensive plain north of the Lukanga river and downstream of the swamp 117
Figure 41 – On top, the Lukanga river upstream from the swamp, flowing through Mpunde; on the bottom, the same river, downstream from the swamp, flowing towards the confluence with the Kafue 119
Figure 42 – Lake habitat; here, the lake off the village of Kabosha 121
Figure 43 – Submerged macrophyte *Najas* sp. in Lake Suye, off Chilwa island 123
Figure 44 – General aspects of the forest land macro-habitat 125
Figure 45 – Anthropic landscapes surrounding the Lukanga Swamp 129
Figure 46 – Percent distribution of the population (*De jure*) by gender for Central Province, Copperbelt Province and Zambia (2010) 144
Figure 47 – The setting of CICES in the cascade model 181
Figure 48 – Rural, urban and total population projections (2011-2035) 193
Figure 49 – Trend of agricultural area planted in Central and Copperbelt provinces 195
Figure 50 – Total cattle raised in Central and Copperbelt provinces and Zambia (2011; 2018) 195
Figure 51 – Inshore fish catch in Lukanga and total in Zambia (2001-2014) 196
Figure 52 – Exports of copper in Zambia (2001-2018) 197
Figure 53 – Production of copper in Zambia (2001-2018) 197
Figure 54 – Available discharge at Itezhi-Tezhi hydropower facility between 1978 and 2014 199
Figure 55 – Satellite images from 1984 (left) and 2015 (right) demonstrating the evolution of anthropogenic landscapes across the southwest quadrant of the swamp (LS: Lukanga swamp) 203
Figure 56 – Area of forest loss between 2001 and 2019 205
Figure 57 – Area of forest loss in four-year periods between 2001 and 2019 206
Figure 58 – Evolution of the area of different land covers in the swamp 208
Figure 59 – Field observations of the aquatic weed Salvinia molesta, in September and October 2019 209
Figure 60 – Vegetation map of the Flora Zambesiaca area (north sheet) 211
Figure 61 – Observed changes in annual average temperature from 1901–2012, derived from a linear trend 217
Figure 62 – Observed changes in annual average precipitation from 1951–2010, derived from a linear trend 219
Figure 63 – Distribution pattern of fire frequency in Zamia; based on Barbosa, Stroppiana, and Grégoire (1999); Red for areas burnt annually, white for areas that burn once in 2-3 years, and green for areas that burn in 3-4 years; the location of the Lukanga swamp is marked in yellow 224
Figure 64 – "Fig.6. Density of fires per square kilometer [per year], plotted over the mean % burnt area for Southern Africa. […] Fire density and burned area seem to be related" 225
Figure 65 – Late dry season fires and burnt vegetation in the swamp (top), floodplain (bottom left), and woodland (bottom right) 228
Figure 66 – Livestock grazing and drinking on the swamp's edges and floodplain grassland, upstream (top) and downstream (bottom) of the swamp, during the dry season 232
Figure 67 – Livestock density in the plan area 233
Figure 68 – Different methods for adding value to the fish product prior to its commercialization: on the left, firewood for smoking fish in Kabosha; on the right, sun drying in Moongo 235
Figure 69 – Historical catches on the Lukanga swamp between 1990 and 2014. Data for the year of 1992 is missing due to a cholera outbreak, and 1996 for unknown reasons 236
Figure 70 – Fishing camp in the region of Waya (14°19'43.3200"S, 027°56'09.1680"E) 238
Figure 71 – Dugout canoes in Waya 240
Figure 72 – Mosquito net being used by local fishermen 242
Figure 73 – Traditional harvesting of *Cyperus papyrus* culms and stems as raw material for the fabrication of matts, in the banks of the Lukanga River, just before the confluence between this and Kafue river, near the settlement of Moongo 246
Figure 74 – Roots sold for medicinal uses on a roadside market 248
Figure 75 – Awareness raising material 253
Figure 76 – *S. molesta* infestation in a channel off Kabosha (left) and Chilwa (right) in late 2019, showcasing the impacts on light penetration and navigation 255
Figure 77 – Observed and simulated variations in past and projected future annual average temperature over Southern African Development Community (SADC) 257

Figure 78 – Economic value of timber in Lukanga Swamp Sub-catchment (baseline scenario, 3% discount rate, USD/ year – 2050) 283
Figure 79 – Economic value of fuelwood in Lukanga Swamp Sub-catchment (baseline scenario, 3% discount rate, USD/ year – 2050) 284
Figure 80 – Economic value of wildlife services in Lukanga Swamp Sub-catchment (baseline scenario, 3% discount rate, USD/ year – 2050) 285
Figure 81 – Economic value of water services in Lukanga Swamp Sub-catchment (baseline scenario, 3% discount rate, USD/ year – 2050) 286
287
Figure 82 – Economic value of hazard mitigation services in Lukanga Swamp Sub-catchment (baseline scenario, 3% discount rate, USD/ year – 2050) 287
289
Figure 83 – Total ecosystem services value per area* (baseline scenario, 3% discount rate, USD/ year – 2050) 289
Figure 84 – Economic value of timber in Lukanga Swamp Sub-catchment (10% deforestation scenario, 3% discount rate, USD/ year – 2050) 292
Figure 85 – Total ecosystem services value per area* (10% deforestation scenario, 3% discount rate, USD/ year – 2050) 293
Figure 86 – Economic value of timber in Lukanga Swamp Sub-catchment (15% deforestation scenario, 3% discount rate, USD/ year – 2050) 296
Figure 87 – Total ecosystem services value per area* (15% deforestation scenario, 3% discount rate, USD/ year – 2050) 297
Figure 88 – Economic value of timber in Lukanga Swamp Sub-catchment (20% deforestation scenario, 3% discount rate, USD/ year – 2050) 300
Figure 89 – Total ecosystem services value per area* (20% deforestation scenario, 3% discount rate, USD/ year – 2050) 301
Figure 90 – Economic value of timber in Lukanga Swamp Sub-catchment (25% deforestation scenario, 3% discount rate, USD/ year – 2050) 304
Figure 91 – Total ecosystem services value per area* (25% deforestation scenario, 3% discount rate, USD/ year – 2050) 305
306
Figure 92 – Service providing the greatest economic value* (25% deforestation scenario, 3% discount rate, USD/ year – 2050) 306

ACRONYMS

BOD – Biochemical oxygen demand
CMIP – Coupled Model Intercomparison Project
COD – Chemical oxygen demand
CR – Critically Endangered
CSO – Central Statistical Office
DAHITI – Database for Hydrological Time Series of Inland Waters
DNPW – Department of National Parks and Wildlife
DO – Dissolved oxygen
DoF – Department of Fisheries
ECBA – Environmental Cost-Benefit Analysis
EN – Endangered
ERL – "Effects Range-Low"
ERM – "Effects Range-Medium"
ES – Ecosystem Services
FAO – Food and Agriculture Organization
FGD – Focus Groups Discussion
FRA – Forest Resource Assessment
GCM – General Circulation Model or Global Climate Model
GMA – Game Management Area
HCB – Hexachlorobenzene
HCH – Hexachlorocyclohexanes
IBA – Important Bird Area
IIED – International Institute for Environment and Development
ILUA – Integrated Land-Use Assessment
IPCC – Intergovernmental Panel on Climate Change
IUCN – International Union for Conservation of Nature
LC – Least Concern
LCCS – Land Cover Classification System
LMP – Lukanga Management Plan
MA – Millennium Ecosystem Assessment
MCDSS – Ministry of Community Development and Social Services
MCM – million cubic metres
MFL – Ministry of Fisheries and Livestock
MLNR – Ministry of Lands and Natural Resources
MMMD – Ministry of Mines and Minerals Development
MWDSEP – Ministry of Water Development, Sanitation and Environmental Protection
NBSAP – National Biodiversity Strategy and Action Plan
NCCRS – National Climate Change Response Strategy
NGP – National Gender Policy
NHSP – National Health Strategic Plan
NOAA – National Oceanic Atmospheric Administration
NP – National Park
NPCC – National Policy on Climate Change
NPV – Net Present Value
NT – Near Threatened
PAH – Polycyclic Aromatic Hydrocarbons
PCB – Polychlorinated Biphenyl
PV – Present Value
RCP – Representative Concentration Pathway
SADC – Southern African Development Community
SNAP – Second National Agricultural Policy
SQG – sediment quality guideline
SWAT – Soil & Water Assessment Tool
TEEB – The Economics of Ecosystems and Biodiversity
TEV – Total Economic Value
UKRB – Upper Kafue River Basin
UNFCCC – United Nations Framework Convention on Climate Change
VU – Vulnerable
WARMA – Water Resources Management Authority
WB – World Bank
WHO – World Health Organization
WWF – World Wildlife Fund for Nature
ZABS – Zambia Bureau of Standards
ZEMA – Zambia Environmental Management Agency
ZMERIP – Zambia Mining and Environmental Remediation and Improvement Programme
ZS – Zambian Standard

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Executive summary

This document is Progress Report No. 4 of the Consultancy for the Development of a Conservation Plan for Lukanga Swamp and Upper Kafue Basin, conducted by Nemus – Gestão e Requalificação Ambiental, Lda., for Zambia Environmental Management Agency.

The main purpose of the consultancy is to develop a Conservation Plan for the Lukanga Swamp considering all the impacts that may arise from its catchment and the Upper Kafue Basin.

The Conservation Plan's development comprises six phases:

- *Phase 1: Planning;*
- *Phase 2: Scoping and data collection*
- *Phase 3: Characterisation and assessment;*
- *Phase 4: Development of tools and recommendations for management (Integration);*
- *Phase 5: Presentation and dissemination of results;*
- *Phase 6: Final presentation and capacity building.*

Progress Report No. 4 (D5) is the first of three reports to be submitted in Phase 4 and aims to present the progress and results achieved so far, including:

- *Stakeholders mapping and engagement; key stakeholders and institutions were invited to the consultation workshops; key information holders were met and key informant interviews and focus group discussions with local communities were conducted; these were carried out in two occasions, with distinct goals: for a general socioeconomic characterization of the communities and to perceive their dependence on (or conflicts / malfunctions regarding) ecosystem services (December 2019) and to collect specific data to support the quantification and valuation of the benefits derived from the ecosystems in and around the Lukanga Swamp (October 2020);*

- *Baseline of Lukanga Swamp, its catchment and Kafue River Basin upstream, including climate assessment, hydrology, hydrodynamics (of the Lukanga Swamp and its catchment), geology, hydrogeology, environmental quality (based on surface and groundwater quality, sediment and leaf*

sampling and analyses), ecology, socioeconomics and governance, based on literature review and field visits, including field sampling and observation, key informant interviews and focus group discussions;

- *Assessment of wetland values (diagnostic); the (hydrological, biogeochemical and ecological) "values" associated with the wetland were identified and classified according to an ecological value scale; the habitats of highest value were found to be the permanent swamp and the edaphic grassland, particularly towards the west, followed by forested land (where it is less degraded), riparian vegetation and lakes; the threats to the healthy functioning and conservation of these values were also identified;*

- *Ecosystem services assessment; ecosystem services and goods (ES) provided by the biophysical elements of Lukanga Swamp and its catchment were identified following the Common International Classification of Ecosystem Services (CICES) V5.1, the Millennium Ecosystem Assessment (MA) and The Economics of Ecosystems and Biodiversity (TEEB) frameworks; examples of relevant ecosystems providing those services were identified; benefits to be considered in the valuation of ecosystem services were categorized according to their Total Economic Value (TEV) types;*

- *Identification of conservation objectives, targets and indicators for prioritary ecological values (ecological components deemed of "very high" and "high" value), like permanent swamp, grasslands, benthic macroinvertebrates, phytoplankton and zooplankton, fish assemblages, aquatic macrophytes, waterbirds and other avifauna, wild ungulates (very high value), forested land and riparian vegetation (high value);*

- *Identification of historical trends on both the socioeconomic (population growth, growth of agricultural area, growth of inshore fishing and intensification of mining activities) and biophysical environments (changes in the hydrological regime and hydrodynamics of lukanga swamp and its catchment; water and sediment/soil quality degradation; land cover change; biodiversity loss; deterioration of conditions; climate change); drivers of change (population growth, climate change) of ecosystem condition and related impacts (land conversion; overharvesting/exploitation; introduction of exotic species);*

- *Indicators and methodology for the Environmental Cost-Benefit Analysis (ECBA); the methodology for the monetary valuation of wetland values under different scenarios was described, including: Problem definition (what are the objectives, what are the alternatives / management solutions and over what time period); Identification of relevant impacts; Physical quantification of relevant impacts; Monetary valuation of relevant impacts; Discounting costs and benefit flows; Sensitivity analysis. Co$ting Nature (version 3), a tool/model developed by King's College London and AmbioTEK CIC, selected to support the ECBA and decision-making under the Conservation Plan for Lukanga Swamp and Upper Kafue Basin, was also introduced;*

- *Assessment of future scenarios and of the proposed decision-making framework, using Co$ting Nature; the results of the assessment/valuation for each scenario were presented and discussed, namely the baseline, 10% deforestation, 15% deforestation, 20% deforestation and 25% deforestation scenarios; valuations for two discount rates (3% and 10%) were also calculated and presented; total valuation for these scenarios is between $502,535 (103 USD) per year, in 2050, in the baseline scenario, and $197,165 (103 USD) in the 25% deforestation scenario, for a 3% discount rate. For a 10% discount rate, the values range from $49,776 (103 USD), in the baseline scenario, and $29,972 (103 USD), in the 25% deforestation scenario). The use of Co$ting Nature tool makes it possible to further expand the number and variety of scenarios to be evaluated so, Co$ting Nature was further described, as well the available policy options to evaluate different scenarios.*

In this context, Progress Report No. 4 presents Part I of the Draft Conservation Plan for Lukanga Swamp and Upper Kafue Basin, comprising the following chapters:

- *Conservation planning framework;*
- *Description – Upper Kafue, Lukanga Swamp and its catchment baseline;*
- *Evaluation;*
- *Objectives;*
- *Assessment – Future scenarios and decision-making framework.*

Part II of the Draft Conservation Plan, comprising the Action Plan, will be the object of Progress Report No. 5 (D6). The Draft Conservation Plan for Lukanga Swamp and Upper Kafue Basin, integrating, reviewing and updating Parts I and II according to comments from ZEMA and other relevant stakeholders, as well as stakeholder consultation actions conducted thus far, will be the object of the Draft Report (D7).

The development of the Conservation Plan is therefore on track, according to the updated work schedule approved in October 2020.

Regarding the overall objective of the Conservation Plan for Lukanga Swamp – generate both qualitative and quantitative data and tools required to support the participatory management of the area –, a relevant amount of both qualitative and quantitative data has already been compiled and collected; also, its analysis allowed the selection or development of tools (e.g., Environmental Cost-Benefit Analysis, Co$ting Nature, the Lukanga Conservation Plan website) that will support the participatory management of the area. The Lukanga Conservation Plan website has been updated throughout the consultancy and allows for the reception of inputs.

The body of information collected and analysed and these tools, whose preliminary results are shown in this report, will allow the assessment of different conservation scenarios and actions to maximize the benefits provided by the swamp and thus improve the quality of life of the populations that depend upon these resources, while protecting existing natural ecosystems.

Foreword

The Draft Conservation Plan for Lukanga Swamp and Upper Kafue Basin, developed by Nemus – Gestão e Requalificação Ambiental, Lda., for Zambia Environmental Management Agency (ZEMA) is structured as follows:

Part I

1. Introduction
2. Conservation planning framework
3. Description – Upper Kafue, Lukanga Swamp and its catchment baseline
4. Evaluation
5. Objectives
6. Assessment – Future scenarios and decision-making framework

Part II

7. Action Plan
8. Conclusion
9. References

Appendixes

Progress Report No. 4 (D5) presents Part I of the Draft Conservation Plan. Phase 4 of the development of the Plan aims at the "development of tools and recommendations for management (integration)" and this first report (out of three) presents the selected tools (e.g., Environmental Cost-Benefit Analysis, Co$ting Nature) for the assessment of future scenarios and decision-making, as well as their preliminary results. Co$ting Nature (version 3), a tool/model provided by King's College London and AmbioTEK CIC (Mulligan, 2018) was selected because:

- it was created as a testbed for the development and implementation of conservation strategies focused on improving ecosystem services;
- it incorporates detailed spatial datasets at 1-square km and 1-hectare resolution for the entire World, spatial models for biophysical and socioeconomic processes along with scenarios for climate and land use;
- it maps 13 ecosystem services and then combines them with different analyses (current pressure, future threats, biodiversity and delphic conservation priority) to produce an assessment of priority areas for conservation;
- it values and examines the impacts – in terms of change in ecosystem services – and implications for beneficiaries (global and local);
- it calculates a baseline for ecosystem service provision and allows a series of interventions or scenarios of change (user priorities for conservation and

ecosystem services; different economic valuation matrix per ecosystem service; various land use change scenarios, including different settings for deforestation) to understand their impact on ecosystem service delivery.

These tools will support the subsequent recommendation of conservation actions and are the main component of the decision-making framework. Though they were applied for Lukanga Swamp catchment (the plan area expected to have the most impact on the swamp's provision of ecosystem services, according to the baseline), subsequent analyses and recommendations will focus the entire Kafue River Basin upstream, given the scope of the Conservation Plan.

Part II of the Draft Conservation Plan will be presented in Progress Report No. 5 (D6) and will essentially comprise the Action Plan (chapter 7):

7.1. Wetland conservation strategy

7.2. Revision of the Lukanga Swamp Catchment Management Plan
- 7.2.1. Ecological zoning
- 7.2.2. Management strategies

7.3. Environmental monitoring plan
- 7.3.1. Monitoring parameters
- 7.3.2. Spatial distribution of sampling stations
- 7.3.3. Sampling frequency
- 7.3.4. Sampling and data collection methods
- 7.3.5. Data analysis methods and criteria
- 7.3.6. Monitoring plan revision criteria and frequency

7.4. Capacity Building Action Plan
- 7.4.1. Target stakeholders
- 7.4.2. Roles and responsibilities
- 7.4.3. Course on the application of the decision-making tool (T1)
- 7.4.4. Course on the implementation of the monitoring plan (T2)
- 7.4.5. Seminar (S1)
- 7.4.6. Training material
- 7.4.7. Awareness raising material

7.5. Implementation and follow up
- 7.5.1. Implementation schedule
- 7.5.2. Institutional arrangement
- 7.5.3. Follow up

The Draft Conservation Plan for Lukanga Swamp and Upper Kafue Basin, integrating, reviewing and updating Parts I and II, will be the object of the Draft Report (D7). It will take into account comments from ZEMA and other relevant stakeholders, stakeholder consultation actions conducted thus far, as well as potentially new insites from the field sampling campaign planned to characterise the wet season.

1. Introduction

The present document presents Part I of the Draft Conservation Plan for Lukanga Swamp and Upper Kafue Basin, conducted by Nemus – Gestão e Requalificação Ambiental, Lda., for Zambia Environmental Management Agency (ZEMA).

The Plan, aiming to consider all the impacts that may arise from Lukanga's catchment and Upper Kafue Basin, is developed with the support of the World Bank (WB), under the Zambia Mining and Environmental Remediation and Improvement Programme (ZMERIP).

The focus of the Conservation Plan is Lukanga Swamp, located within the Central Province, in the east bank of the Kafue River and developing in a shallow circular depression of a generally flat area, extending over parts of the Kapiri Mposhi, Chibombo and Mpongwe Districts (Ramsar, 2005).

Lukanga Swamp is one of Zambia's key wetlands, whose ecological value is demonstrated by its classification since 2005 as both a Ramsar site (No. 1580), by the Ramsar Convention on Wetlands, and as an Important Bird Area (ZM020), by BirdLife International (BirdLife International, 2019). It is also economically important, given that it is estimated that about 60,000 people live in, or close to, the wetland and that products derived from fishing, hunting, and agriculture, support a hinterland population of some 6.1 million people (Ramsar Sites Information Service, 2005 in McCartney *et al*., 2011).

"Lukanga Swamps Ramsar Site" (coordinates: 14°24'S 27°37'E – Ramsar, 2005; Figure 1) constitutes the core of the wider conservation area included in the Conservation Plan. The plan areas also include a 10 km conservation buffer of the Ramsar site for increased protection of the key biodiversity and conservation areas.

Complementary areas, to take into account the sources of impacts on Lukanga Swamp and its catchment, include Lukanga Swamp sub-catchment and Kafue River Basin upstream, all represented in Figure 1. Wider context analyses consider all the districts crossed by the above plan areas:

- Chililabombwe, Chingola, Kalulushi, Kitwe, Luanshya, Lufwanyama, Masaiti, Mpongwe, Mufulira and Ndola districts, in Copperbelt Province;
- Chibombo, Kabwe, Kapiri Mposhi, Mumbwa and Ngabwe districts, in Central Province.

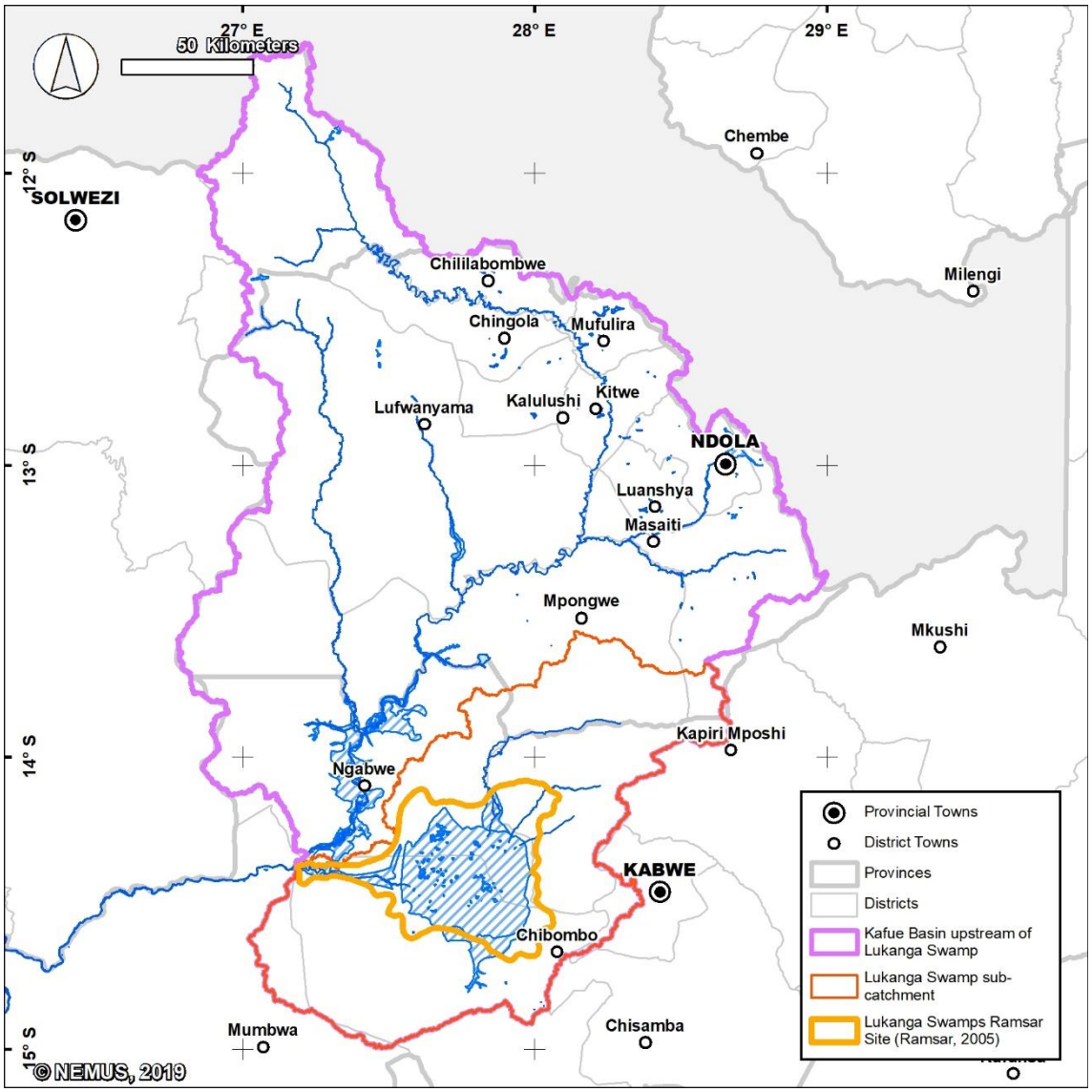


Figure 1 – Location of Lukanga Swamp and complementary plan areas; administrative and hydrographic frameworks

Part I of the Draft Conservation Plan for Lukanga Swamp and Upper Kafue Basin is organised according to the following structure:

- Introduction (Chapter 1);
- Conservation planning framework (Chapter 2);
- Description – Upper Kafue, Lukanga Swamp and its catchment baseline (Chapter 3);
- Evaluation (Chapter 4);
- Objectives (Chapter 5);
- Assessment – Future scenarios and decision-making framework (Chapter 6);
- Conclusion (Chapter 7);
- References (Chapter 8);
- Appendixes.

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2. Conservation planning framework

2.1. Planning and legal framework

The main government policies relevant to wetland conservation are summarised in Table 1.

Table 1 – Policy documents relevant to wetland conservation

Policy document	Description / goals relevant to wetland conservation
Lukanga Management Plan (LMP – Chabwela *et al*., 2010)	The vision of the LMP is "to have a well-managed Lukanga Wetland and catchment area that significantly contributes to the local and national economy, and provides goods and services that enhance the social wellbeing for current and future generations without compromising environmental integrity by 2030".
National Policy on Wetlands (Ministry of Lands and Natural Resources, 2018)	The vision of the Policy is "a functional, productive and resilient wetland system that will contribute to addressing climate change maintenance of biodiversity, provision of ecosystem goods and services and sustainable livelihoods". In order to achieve the vision, the overall objective of this Policy is to preserve and conserve wetland resources and protect the wetland environment in order to ensure sustainable utilization of Zambia's wetlands. In pursuit of this overall objective, the two thematic areas of focus for this policy are (1) wetland conservation and protection and (2) sustainable socio-economic utilisation.

Policy document	Description / goals relevant to wetland conservation
Vision 2030 (Government of the Republic of Zambia, 2006)	The National Long-Term Vision 2030 (Vision 2030) is Zambia's first ever written long-term plan, expressing Zambians' aspirations by the year 2030. The Vision is operationalised through five-year development plans starting with the Fifth National Development Plan (2006-2010). The Zambian people's vision is to become "A Prosperous Middle-Income Nation by 2030". Sector visions and targets/goals include: • "Clean and safe water supply and sanitation for all by 2030" with "Fully integrated and sustainable water resource management" • "A productive environment and well conserved natural resources for sustainable socioeconomic development by 2030"
Seventh National Development Plan 2017-2021 (Ministry of National Development Planning, 2017)	The Seventh National Development Plan departs from sectoral-based planning to an integrated (multisectoral) development approach under the theme "Accelerating development efforts towards the Vision 2030 without leaving anyone behind". Under "Development Outcome 7: Improved water resources development and management", several strategies will be undertaken during the Plan period to address water development and management challenges with a view to increasing availability of water resources for utilisation by productive sectors, for enhanced health of the ecosystem and sustainable economic growth.

Policy document	Description / goals relevant to wetland conservation
National Water Policy (Ministry of Energy and Water Development, 2010)	The National Water Policy of 2010 is a revision of the National Water Policy (1994) in order to provide a comprehensive framework for sustainable development, management and utilisation of the water resources. It envisages to embrace modern principles of water resources management and to deal with the daunting challenges of poverty reduction. Its Vision is “To optimally harness water resources for the efficient and sustainable utilisation of this natural resource to enhance economic productivity and reduce poverty”. The Policy recommends the implementation of measures to address challenges such as “Climate Change” (one of the “Cross-sectoral issues” identified), including the following: • Assessing and monitoring the potential impact of climate change on ecosystems especially woodlands, forests and wetlands; • Supply of clean and safe water to communities to prevent water borne diseases that come with floods/droughts; • Developing and promoting alternative energy sources to fuel-wood and technologies in order to reduce the use of fuel-wood and woodlands, forests and wetlands.
National Policy on Environment (Government of the Republic of Zambia, 2007)	The overall vision of the National Policy on Environment is to provide a framework management guide for the management of Zambia’s environment and natural resources so as to ensure that they are managed on a sustainable basis and retain their integrity to support the needs of the current and future generation without compromising either of the two. Underlying the entire Policy is the Government's commitment to reduce poverty and achieve sustainable development for the Nation as a whole on the basis of "development without destruction". Among the guiding principles it is stated that “When biotic resources are used, it will ensure that such use will be wise, sustainable and consistent with maintaining the integrity of ecosystems and ecological processes”. One of the proposed strategies for the water sector is to “Review existing information on wetlands and dambos and, where necessary, undertake further studies in order to develop guidelines for their proper utilisation”.

Policy document	Description / goals relevant to wetland conservation
Second National Biodiversity Strategy and Action Plan (NBSAP-2) – 2015-2025 (Ministry of Lands, Natural Resources and Environmental Protection, 2014)	Zambia's NBSAP-2 covers the period 2015-2025, and its vision is "By 2025, biodiversity is valued, conserved, restored and wisely used, maintaining ecosystem services, sustaining a healthy environment and delivering benefits essential for all Zambians and the Zambian economy." The Strategic Goals and Targets of Zambia's NBSAP2 include reducing the direct pressures on biodiversity and promoting sustainable use (Strategic Goal B), aiming that "By 2025, areas under agriculture, aquaculture and forestry (…) are managed sustainably, ensuring conservation of biodiversity" (Target 7). One of the "Strategic Interventions" under Target 7 is to "Promote management of wildfires in biodiversity areas such as forests, GMAs, NPs and wetlands".
National Policy on Climate Change 2016 (NPCC; Ministry of Lands, Natural Resources, and Environmental Protection, 2016)	The NPCC has been developed to support and facilitate a coordinated response to climate change issues in the country. It also aims to contribute to the achievement of the overall objective of the United Nations Framework Convention on Climate Change (UNFCCC) which is "stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system". Specific objectives include: • To promote mainstreaming of climate change into policies, plans and strategies at all levels in order to account for Climate Change risks and opportunities in decision making and implementation; • To promote investments in climate resilient and low carbon development pathways in order to generate co-benefits and provide incentives for addressing climate change more effectively.

Policy document	Description / goals relevant to wetland conservation
National Climate Change Response Strategy (NCCRS – Government of the Republic of Zambia – Ministry of Tourism, Environment and Natural Resources, 2010)	The NCCRS has also been developed to support and facilitate a coordinated response to climate change issues in the country. The NCCRS' mission is "to ensure that the most vulnerable sectors of the economy are climate proofed, and sustainable development achieved through the promotion of low carbon development pathways." In the long term the goal is to ensure climate change is mainstreamed in all sectors by 2030. The objectives of the NCCRS' are related to priority sectoral adaptation and mitigation actions needed to achieve the Strategy's vision of a Prosperous Climate Change Resilient Economy. They include: • Land Use (Agriculture and Forestry): To develop sustainable land use systems to enhance agricultural production and ensure food security under the changing climate; • Water: To ensure sustainable management and resiliency of water resources under the changing climate; • Health and Social Infrastructure: To protect people and health from climate change and climate variability; • Mainstreaming: To mainstream climate change in all the key sectors of the economy.
National Food and Nutrition Policy (Ministry of Health, 2006)	The principal goal of the National Food and Nutrition Policy is to achieve sustainable food and nutrition security and to eliminate all forms of malnutrition in order to have a well-nourished and healthy population that can effectively contribute to national economic development. Policy (specific) objectives include: • To develop and implement policies and programmes that will ensure adequate nutrition, food security, food quality and safety at individual, household, community and national level; • To incorporate nutrition issues into developmental programmes.

Policy document	Description / goals relevant to wetland conservation
Second National Agricultural Policy (SNAP – Ministry of Agriculture and Ministry of Fisheries and Livestock, 2016); fisheries policy currently falls within the National Agricultural Policy, though a stand-alone fisheries policy is being developed (Ministry of Fisheries and Livestock in SADC Secretariat, 2016)	This Policy is the responsibility of the Ministries of Agriculture, and that of Fisheries and Livestock, providing policy guidelines for the development of the agriculture sector – which refers to crops, livestock and fisheries sub-sectors – in Zambia. Furthermore, the SNAP seeks to be in line with the new political environment in the country. The Vision of the Second National Agricultural Policy is: "An efficient, competitive and sustainable agricultural sector, which assures food and nutrition security, increased employment opportunities and incomes." Objective 8 of the SNAP – "To promote the sustainable management and use of natural resources" – includes the following measures: • Decentralize capture fisheries management to communities; • Promote sustainable utilization of rangeland (grassland ecosystem) and pastures for livestock production; • Promote sustainable fishing methods; • Promote programmes and appropriate technologies/methods for sustainable utilization of fisheries resources.
National Health Policy (Government of the Republic of Zambia, 2012) and National Health Strategic Plan 2017-2021 (NHSP – Ministry of Health, 2017)	General objectives of the National Health Policy include promoting "awareness among Government employees and the community at large that, health problems can only be adequately solved through multi-sectoral collaboration involving such sectors as Education, Agriculture, Water, Private Sector". Specific objectives include promoting "hygiene, universal access to safe water, acceptable sanitation and food safety in order to reduce the incidence of environmentally related diseases" and scaling-up interventions aimed at combating and controlling communicable diseases, including prevention, treatment and care.

Policy document	Description / goals relevant to wetland conservation
National Gender Policy 2014 (Ministry of Gender and Child Development, 2014)	This policy is the revised version of the National Gender Policy (NGP) of 2000. The ultimate objective of this Policy is to create a Zambian society which has achieved the Vision of 'A nation where there is gender equity and equality for sustainable development'. One of its guiding principles is "accountability for gender mainstreaming", meaning that "stakeholders both public and private are required to account for gender mainstreaming in the implementation of their policies, programmes and activities.
National Tourism Policy (Ministry of Tourism and Arts, 2015) and Zambia Tourism Master Plan 2018-2038 (ZTMP – Ministry of Tourism and Arts, 2017)	The purpose of the revised National Tourism Policy is to provide a strategic framework for the sustainable development of tourism in Zambia so that the sector realizes its full potential. One of its guiding principles is that local communities should share in the management and revenues of ecotourism in order to enhance the protection of the environment and all fauna and flora. Though Lukanga Swamp is off of the ten Tourism Destination Areas (TDAs) identified by the ZTMP, wetlands and particularly Ramsar wetland sites are mentioned as one of the three types of protected areas when describing the natural resources of the country, in which tourism is largely based.

Additionally, as a **Ramsar site** Lukanga Swamp is also governed by the 1971 International Treaty on Wetlands (Mapedza *et al.,* 2012).

Table 2 summarises the wetland management legal framework, outlining the enabling Acts and a brief description of each one of them.

Table 2 – Wetland management legal framework

Enabling Act	Relevance of the legislation to wetland conservation and/or management
Water Resources Management Act No. 21 of 2011	The Act provides for the protection, preservation and conservation of **wetlands** and headwaters.
Environmental Management Act No. 12 of 2011	The Act provides for declaration of **wetlands** as ecologically sensitive areas and for their protection.
Fisheries Act No. 22 of 2011	The Act provides for the sustainable development of fisheries and a precautionary approach in fisheries management, conservation, utilisation and development, stating that any area of a commercial fishing area may be declared as a fisheries reserve if the Minister considers that special measures are necessary to "protect, preserve or rehabilitate the fish habitat, related ecosystems including **wetlands**, lakes, lagoons, nursery and spawning areas, which are essential to maintaining the integrity of an ecosystem, species or assemblages of species".
Lands Act of 1995 (Chapter 184 of the Laws of Zambia; date of consolidation/reprint: 2006)	The Act provides for the management and administration of land in Zambia on which **wetlands** are located.
The Forests Act No. 4 of 2015	The Act provides for protection and conservation of forests and trees which in turn protect **wetlands**.
The Wildlife Act No. 15 of 2015	The Act provides for the implementation of the **Convention on Wetlands of International Importance** especially as Waterfowl Habitat, the Convention on Biological Diversity, the Lusaka Agreement on Cooperative Enforcement Operations Directed at Illegal Trade in Wild Fauna and Flora and other international instruments to which Zambia is party.
Zambia Development Agency Act No. 11 of 2006	The Act establishes the Zambia Development Agency and the Trade and Industrial Development Fund and makes provision in general for economic development in Zambia. Before authorizing development, the Board of the Agency shall have regard to, among other things, the **impact the proposed investment is likely to have on the environment** and, where necessary, the measures proposed to deal with an adverse environmental consequence.
National Heritage Conservation Commission Act No. 173 of 1989	The Act provides for the **conservation of ancient, cultural and natural heritage**, relics and other objects of aesthetic, historical, prehistorical, archaeological or scientific interest.

Enabling Act	Relevance of the legislation to wetland conservation and/or management
Disaster Management Act No. 13 of 2010	The Act establishes and provides for the maintenance and operation of a system for the anticipation, preparedness, prevention, coordination, mitigation and management of disaster situations and the organisation of relief and recovery from disasters; provides for the declaration of disasters; provides for **the responsibilities and involvement of the members of the public in disaster management**.
Public Health Act of 1930 (2006) (Chapter 295 of the Laws of Zambia)	The Act provides for the prevention and suppression of diseases and generally to regulate **all matters connected with public health** in Zambia.
Mines and minerals Act No. 11 of 2015	The Act revises the law relating to the exploration for, mining and processing of, minerals and provides for safety, health and environmental protection in mining operations. It establishes, for instance, that "**where any harm or damage is caused to the environment or biological diversity, compensation shall include the cost of reinstatement, rehabilitation or clean-up measures** which are incurred and where applicable, the costs of preventive measures".
Local Government Act No.2 of 2019	The Act provides for an integrated local government system; gives effect to the decentralisation of functions, responsibilities and services at all levels of local government; ensure democratic participation in, and control of, decision making by the people at the local level; revises the **functions of local authorities; provides for the role of traditional leadership** in democratic governance.
The Urban and Regional Planning Act No. 3 of 2015	An Act to establish procedures for integrated planning in a devolved system of governance so as to ensure multi-sector cooperation, coordination and involvement of different levels of ministries, provincial administration, local authorities, traditional leaders and other stakeholders in urban and regional planning; ensure **sustainable urban and rural development by promoting environmental, social and economic sustainability in development initiatives** and controls at all levels of urban and regional planning.

Enabling Act	Relevance of the legislation to wetland conservation and/or management
Tourism and Hospitality Act No. 13 of 2015	The Act provides for the sustainable development of the tourism industry through effective tourism planning, management, promotion and coordination to ensure sustainable tourism. This includes ensuring "that **tourism does not deprive local communities and wildlife of access to land resources, especially along the banks and shores of rivers, dams, lagoons and lakes** which they need for their livelihood and survival".

Source: National Policy on Wetlands (2018).

2.2. Stakeholders mapping and engagement

Stakeholder engagement and public consultation are essential throughout the development of the Conservation Plan for Lukanga Swamp and Upper Kafue Basin, to assess and validate the data and methodologies used, as well as their results.

Indeed, ensuring the involvement of institutional stakeholders, but also the population, is a key step for success and it presents mutual benefits: the population is more bound to accept the plan if the people feel they were listened to and the assessment gains extra insight into the subjects analysed because people provide valuable information, regarding their reality, hopes and needs.

Ultimately, these actions aim to guarantee the appropriation of the plan by the managing entities, for a successful implementation of the conservation plan.

Hence, institutional stakeholders and interested parties' involvement is crucial, as early as in the definition of the ecosystems, ecosystem services, indicators and assessment methods, that is, as early as in the scoping phase.

That is why a Stakeholder Engagement Plan was proposed at the Plan's inception, detailing the stakeholder groups and their representatives to be consulted (section 2.2.1) and the methods of consultation (section 2.2.2) to be used, including Workshops, Interviews and focus group discussions and a Seminar.

Stakeholder engagement was hindered between March and September 2020 because of the COVID-19 pandemic. As soon as COVID-19 restrictions were relaxed the focus group discussions with local communities were resumed, in October 2020. Stakeholder engagement actions conducted to date are presented in section 2.2.3.

Stakeholder involvement is ongoing through the Lukanga Conservation Plan Website (section 2.2.4), recently updated to disclose more information about the plan, and to allow the reception of inputs, aiming to promote stakeholder engagement.

2.2.1. Stakeholders

The stakeholder groups and their representatives engaged throughout the development of the Conservation Plan are presented in the table below.

Table 3 – Main stakeholders engaged during the development of the conservation plan

Stakeholder groups	Stakeholders
Government institutions	• Ministry of Mines and Minerals Development; Geological Survey Department; Mines Development Department; Mines Safety Department • Ministry of Water Development, Sanitation and Environmental Protection; Department of Water Resources Development • Ministry of Lands and Natural Resources; Department of Climate Change and Natural Resources; Forestry Department • Ministry of National Development and Planning • Ministry of Agriculture; Extension Services for Kafue; Office for Central Zambia • Ministry of Fisheries and Livestock • Ministry of Community Development and Social Welfare • Ministry of Chiefs and Traditional Affairs • Department of National Parks and Wildlife (DNPW) of the Ministry of Tourism and Arts • Ministry of Health; Radiation Protection Authority • Other national, provincial and district administrative authorities, such as Chililabombwe, Chingola, Kalulushi, Kitwe, Luanshya, Lufwanyama, Masaiti, Mpongwe, Mufulira, Ndola (Copperbelt Province), Chibombo, Kabwe, Kapiri Mposhi, Mumbwa and Ngabwe (Central Province) District Councils
Regulators	• Zambia Environmental Management Agency (ZEMA) • Water Resources Management Authority (WARMA)

Stakeholder groups	Stakeholders
Industry	Mining operators such as: • Caledonia Mining Corporation Plc. • China Nonferrous Metal Mining (Group) Co Ltd. • Konkola Copper Mines Plc (subsidiary of Vedanta Resources Plc) • African Rainbow Minerals • First Quantum Minerals Ltd. • Glencore International Plc.; Mopani Copper Mines (MCM) • Berkeley Mineral Resources Plc. • Jinchuan Group International Resources Co. Ltd • Chambishi Metals • Chambishi Copper Smelting Company • Luanshya Copper Mines (LCM) • Lubambe Copper Mine Limited Representatives from the agro-industry sector in UKRB Zambia National Farmers Union
Traditional authorities and/or community representatives	• Village Management Committees (VMC), traditional authorities and other Lukanga Swamp's community representatives • Fishers and fisheries management committees • Farmers and farmer associations' representatives • Other entities involved in the governance of natural resources, such as water users' associations, Joint Forest Management Committees and Community Resources Boards
Civil society in general, including Non-Governmental Organisations, academic and research institutions	• The Nature Conservancy (TNC) • WWF Zambia • Action Aid Zambia • Zambia Climate Change Network • Zambia Land Alliance • Agricultural Consultative Forum (ACF) • University of Zambia; Institute of Economic and Social Research; School of Mines • Zambia Institute for Policy Analysis and Research • Zambia Community Based Natural Resource Management (CBNRM) Forum • BirdWatch Zambia • Copperbelt university • Mulungushi University (Kabwe)

2.2.2. Consultation methods

2.2.2.1. Workshops

The development of the conservation plan included key workshops for discussion of preliminary findings, results and recommendations:

- Stakeholder consultation workshops W1-2, on the scope of the study (ecosystem types, services, indicators and assessment methods selection);
- Stakeholder consultation workshop W3, for presentation and discussion of Progress Report No. 4 (D5);
- Stakeholder consultation workshop W4, for presentation and discussion of the Draft Report (D7).

The workshops aimed at discussing critical results of the plan development among key stakeholders; obtaining contributions for adjustment and validation of deliverables; follow-up of the work carried out. The workshops participants included a selection of 40 representatives from the lists above (section 2.2.1), addressing the following framework of representatives:

- 10 representatives of government institutions (national, provincial and municipal);
- 2 representatives from regulating institutions;
- 10 representatives from the industry sector;
- 10 representatives of traditional authorities and/or community representatives
- 8 representatives from the civil society (including 4 representatives of NGOs, 2 representatives of civic associations, and 2 representatives from academia/research).

Each workshop included expository methods (presentation of work in preparation and results update), direct and indirect interrogative methods and active methods of dialogue, discussion of ideas and sharing of opinions.

2.2.2.2. Interviews and focus group discussions

Focus group discussions, rather than questionnaires, allow for the participants to express experiences and opinions, which in turn allows for complexities about relationships, opinions and specific processes to surface.

This method is often used in the early stages of research, as it allows for an unrestricted exploration of local contexts in order to better define the research question, or, in the present context, the key aspects to be assessed.

That is why focus group discussions, as well as interviews, were conducted.

Interviews focused key stakeholders from the list in section 2.2.1 and aimed to present the scope and objectives of the plan, as well as to gather concerns regarding the sustainable development of Lukanga Swamp, its catchment and UKRB. Stakeholder mapping for these initiatives was carried out in agreement with ZEMA (like for the workshops and the seminar) and players with responsibilities in natural resources management in the region and information holders were privileged:

- 44% representatives of government institutions (national, provincial and municipal);
- 6% representatives from regulating institutions (WARMA);
- 17% representatives from the industry sector (such as Zambia National Farmers Union, Zambia Chamber of Mines and Zambia Chamber of Commerce and Industry);
- 22% representatives of traditional authorities and/or community representatives;
- 11% representatives from the civil society (NGOs).

Focus group discussions aimed to get a deeper understanding of the communities living within the catchment area and/or to collect primary information for the development of the conservation plan. These events included expository methods (presentation of work in preparation), direct or indirect interrogative methods and/or active methods of dialogue and debate. Issues addressed included:

- Conservation plan's objectives and institutions involved;
- General socioeconomic information to characterize the communities and their dependence on (or conflicts / malfunctions regarding) ecosystem services, for instance,

- General information about the community (population number, origin, structure, migration patterns);
- Economic activities undertaken in the community;
- Uses of Lukanga Swamp, symptoms and causes of degradation;
- Infrastructure availability;
- Health and gender issues;

- Specific data to support the quantification and valuation of the benefits derived from the ecosystems in and around the Lukanga.

2.2.2.3. Seminar

The Final Report was the object of a seminar in Lusaka to inform a broader audience of the conservation plan's main features and to have the document validated by the different stakeholders.

The seminar participants included a selection of about 50 representatives from the list above (section 2.2.1), with the following institutional framework:

- 20 representatives of government institutions (national, provincial and municipal);
- 2 representatives from regulating institutions;
- 8 representatives from the industry sector;
- 10 representatives of traditional authorities and/or community representatives
- 10 representatives from the civil society (including 4 representatives of NGOs, 2 representatives of civic associations, and 4 representatives from academia/research).

2.2.3. Stakeholder engagement actions

The stakeholder engagement actions conducted include:

- **Interviews with key stakeholders**
  1. ZEMA, Copperbelt Office (Ndola, 11th October 2019);
  2. Zambia National Farmers Union, Copperbelt Office (Kalulushi, 11th October 2019);
  3. Chamber of Commerce, Copperbelt Office (Kitwe, 11th October 2019);
  4. Copperbelt University, School of Mines and Mineral Sciences (Kitwe, 15th October 2019);
  5. Water Resources Management Authority (WARMA) (Lusaka, 30th October 2019);
  6. BirdWatch Zambia (Lusaka, 30th October 2019; online meeting/call, 20th February 2020);
  7. Misenge Environmental and Technical Services Limited (Kalulushi, 31st October 2019);
  8. Department of National Parks Wildlife (online meeting/call, 11th February 2020);
- **Community interviews**
  1. Chiyokoma and Muweshi / Moongo area, 17th October 2019;
  2. Kabosha Village, 18th October 2019;
  3. Waya Village, 19th October 2019;
  4. Kaswende Village, 20th October 2019;
  5. Chishimu Village, on the upland of Chilwa Island, 21st October 2019;
- **Stakeholder consultation workshops**
  - W1 – Lusaka, 29th October 2019;
  - W2 – Kitwe, 1st November 2019;
- **Focus group discussions** with local communities
  - Kabosha and Muchoko fishing camps, Chiyuni area, Chibombo district, 18th to 22nd December 2019;
  - Chilwa Island (Ngabwe), Shamputa, Chipepo, Mulongoti, Waya (Kapiri Mposhi district), Mpuso (Mumbwa), 13th to 19th October 2020.

- **Formal requests for specific information**, by letter/email:
    1. Agricultural Consultative Forum;
    2. BirdWatch Zambia;
    3. Chambishi Copper Smelter;
    4. Chibombo Town Council;
    5. Chingola Municipal Council;
    6. Copperbelt University – School of Mines and Mineral Sciences;
    7. Kabwe Municipal Council;
    8. Kapiri Mposhi Town Council;
    9. Kitwe City Council;
    10. Konkola Copper Mines;
    11. Lukanga Water Supply & Sanitation Company Limited;
    12. Ministry of Agriculture;
    13. MCDSS – Social Welfare Department;
    14. MFL – Fisheries office for Central Province; Department of Fisheries
    15. MLNR – Department of Climate Change and Natural Resources;
    16. MLNR – Environment and Natural Resources Management Department;
    17. MLNR – Forestry Department;
    18. MMMD – Mines Safety Department;
    19. MWDSEP – Department of Water Resources Development;
    20. Misenge Environmental and Technical Services Limited;
    21. Mopani Copper Mines;
    22. Mufulira Municipal Council;
    23. Mulonga Water and Sewerage Company;
    24. NFC Africa Mining;
    25. Ngabwe Town Council;
    26. Nkana Water and Sewerage Company;
    27. Provincial Chiefs and Traditional Affairs office for Central province;
    28. University of Zambia – Institute of Economic and Social Research;
    29. Water Resources Management Authority;
    30. WWF-Zambia;
    31. Zambia Climate Change Network;
    32. Zambia Land Alliance.

Written records from the stakeholder and community interviews and a report of the first stakeholder consultation workshops were presented in Progress Report No. 1.

A report with the results from the Focus Group Discussions held with traditional leaders of communities in Chiyuni area, Chibombo district, between the 18th and the 22nd December 2019 was presented in Progress Report No. 2.

The questionnaires filled during the 12 Focus Group Discussions held in Chilwa Island (Ngabwe), Shamputa, Chipepo, Mulongoti, Waya (Kapiri Mposhi district) and Mpuso (Mumbwa) communities, between the 13th and the 19th October 2020, are presented in Appendix 1.

Only the Social Welfare Department (of the Ministry of Community Development and Social Services), Lukanga Water Supply & Sanitation Company Limited, Mulonga Water and Sewerage Company, NFC Africa Mining, Konkola Copper Mines PLC, the Department of National Parks and Wildlife, BirdWatch Zambia and the Department of Fisheries in Central Province provided information in response to the formal requests.

2.2.4. Lukanga Conservation Plan website

To help disclose information about the conservation plan, aiming to gather the stakeholders' interest and encourage their involvement, a website was created: **https://lukanga-swamp.nemus-consulting.com/**.

The following screenshots show the layout and some of the content and functionalities of the website. The social importance of the website should be emphasized given both its possibilities to disseminate as well as to collect information relevant to the conservation plan. It is an instrument of social participation and stakeholder engagement.

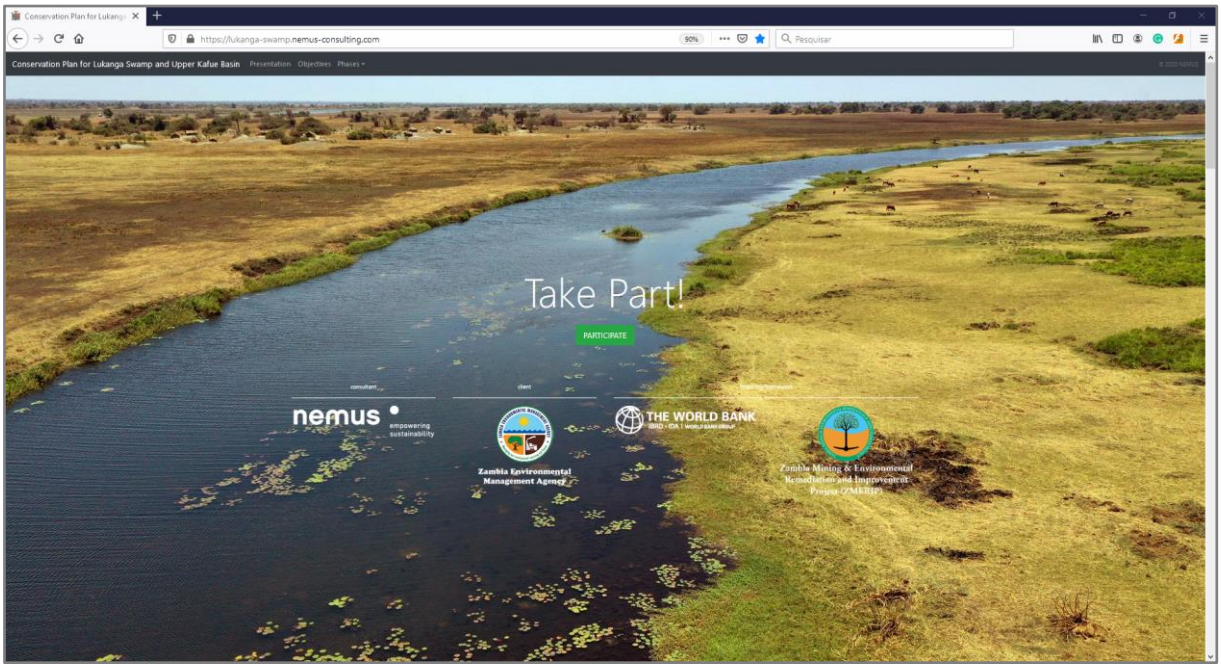


Figure 2 – Lukanga Conservation Plan Website: homepage

Besides the background/context (Figure 3) and the objectives of the conservation plan, the website includes the main goals, conclusions and reports of each phase of the development of the conservation plan (Figure 4 and Figure 5), upon ZEMA's approval and permission to post. It also facilitates interactivity, namely posing of questions, doubts, opinions, suggestions and recommendations.

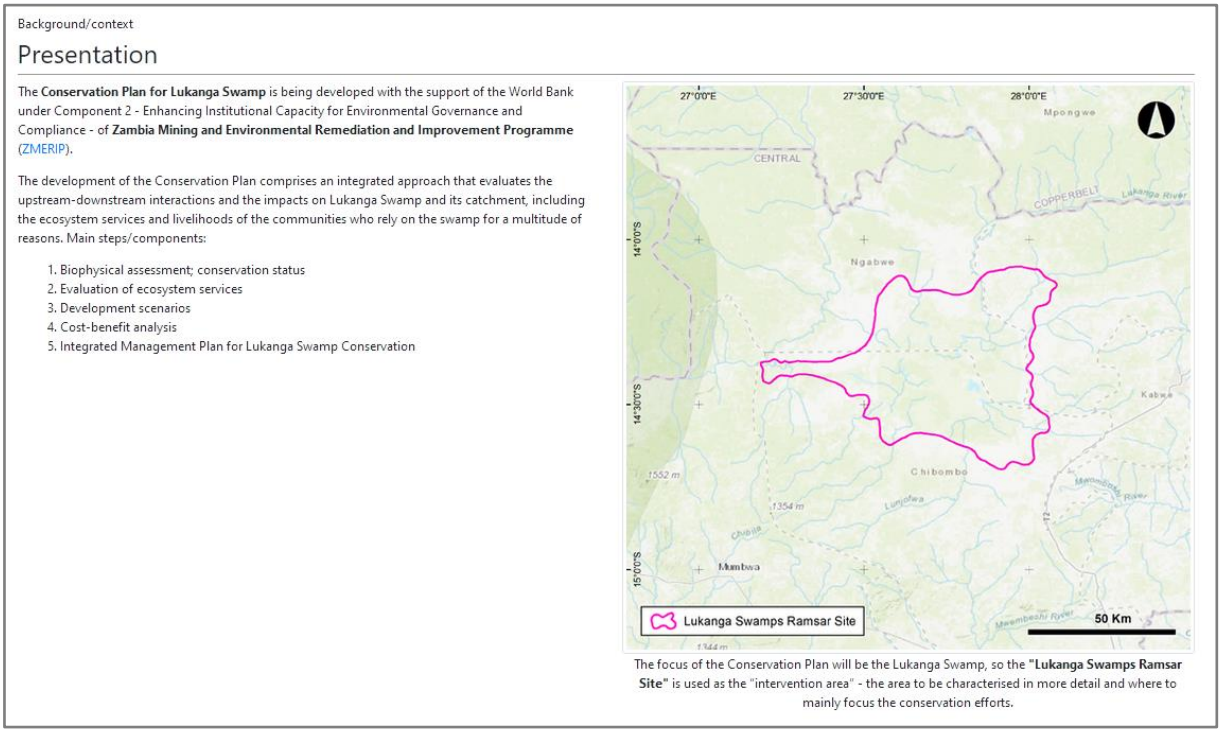


Figure 3 – Lukanga Conservation Plan Website: background/presentation

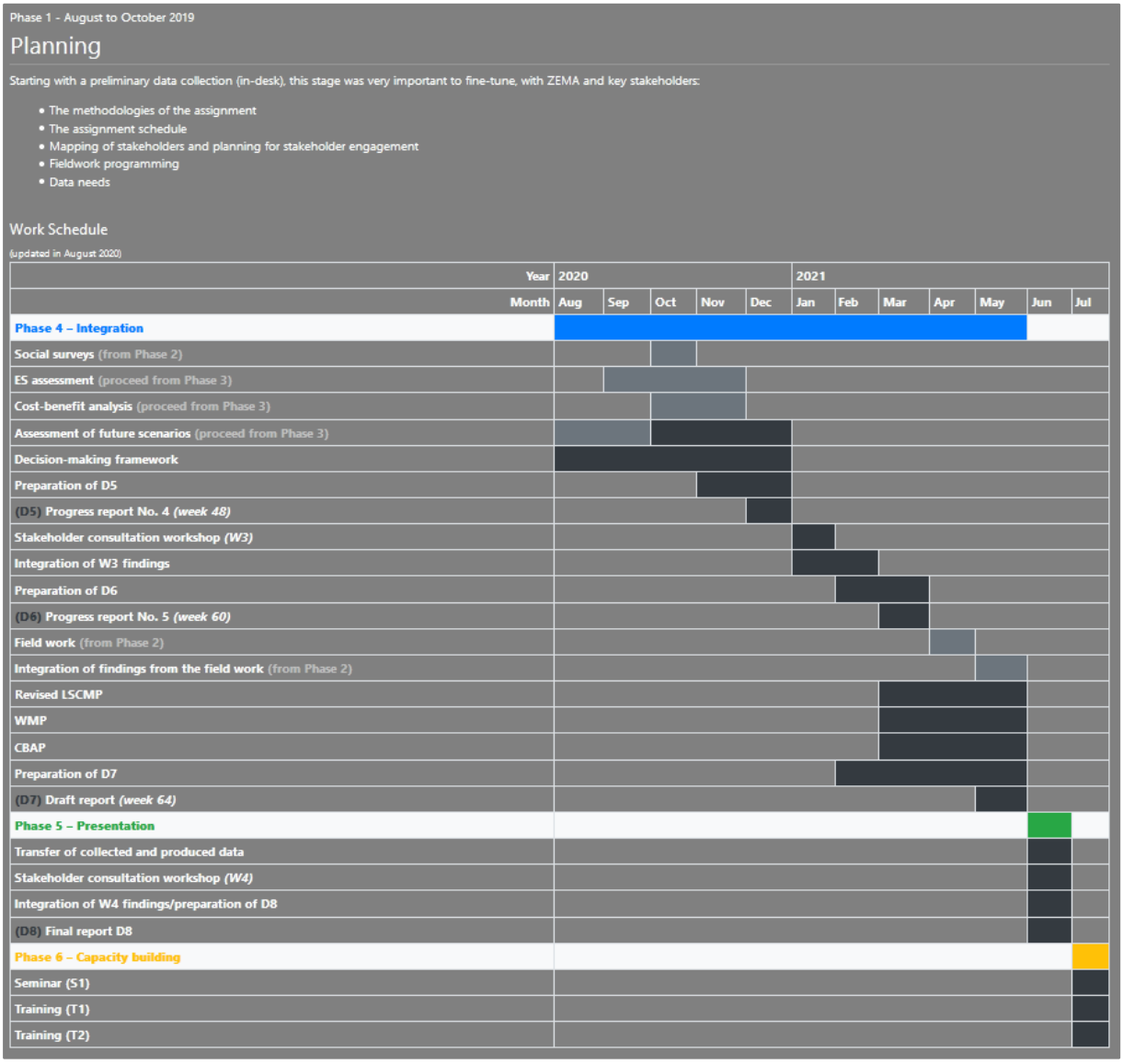


Figure 4 – Lukanga Conservation Plan Website: planning (including the work schedule)

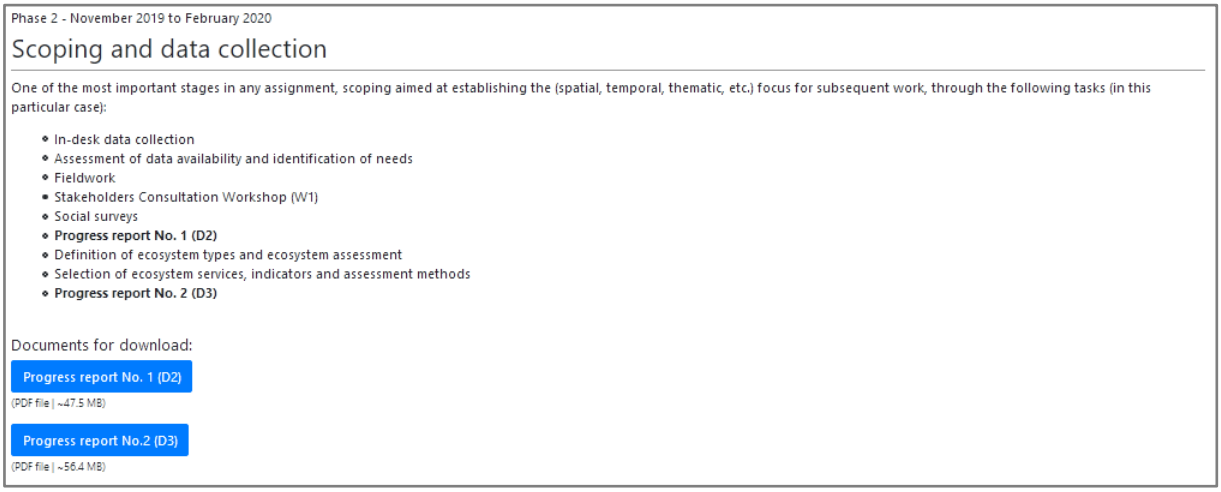


Figure 5 – Lukanga Conservation Plan Website: Scoping and data collection phase (including downloads of available reports)

The Lukanga Conservation Plan website also allows for the reception of inputs (Figure 6).

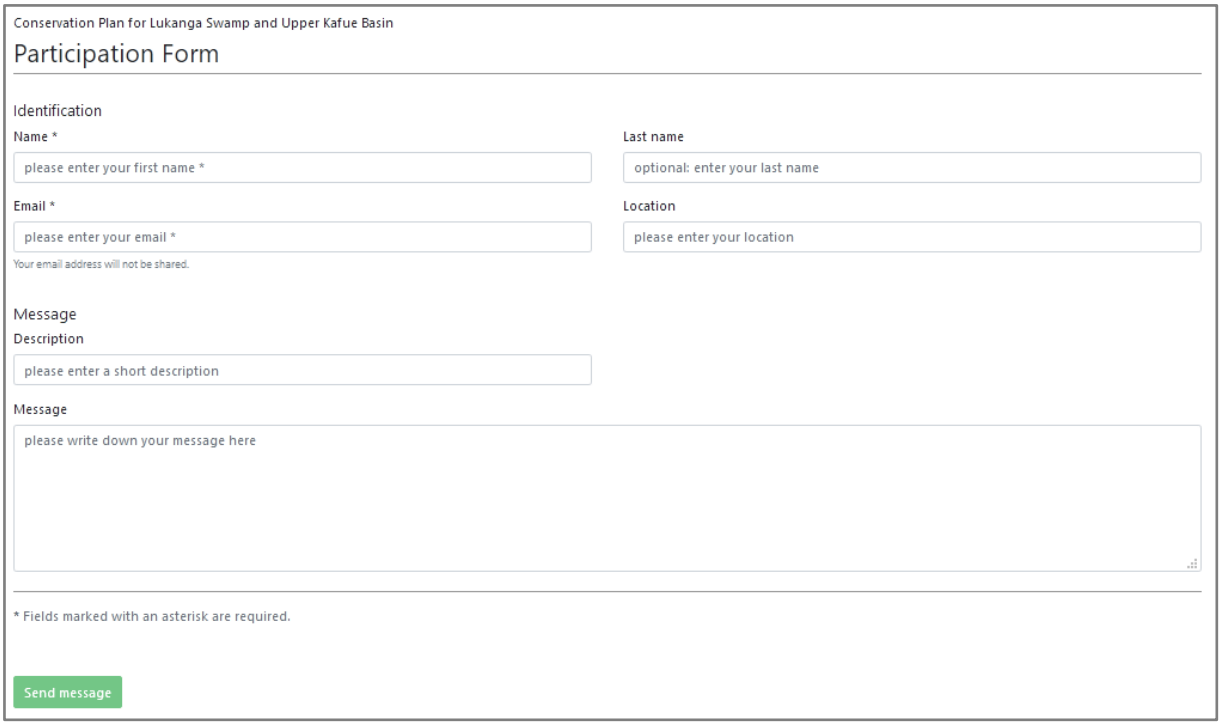


Figure 6 – Lukanga Conservation Plan Website: Participation form

2.3. Vision and approach to the Lukanga Conservation Plan

The Conservation Plan for Lukanga Swamp and Upper Kafue Basin envisions a sustainable, integrated and participated planning of Lukanga Swamp, its catchment and Kafue riber basin upstream that addresses human well-being and balances trade-offs among stakeholders, while sustaining and enhancing the Ecosystem Services (ES) provided by the wetland.

In this context, the development of the Conservation Plan aimed at collecting qualitative and quantitative data (Phases 1 to 3) and providing the (modelling) tools (Phase 4) to support an informed cross sectoral decision-making and participatory conservation/management (Phases 5 and 6; plan implementation) of the study area:

- Phase 1: Planning;
- Phase 2: Scoping and data collection
- Phase 3: Characterisation and assessment;
- Phase 4: Development of tools and recommendations for management;
- Phase 5: Presentation and dissemination of results;
- Phase 6: Final presentation and capacity building.

The Conservation Plan is also expected to review/revise the Lukanga Swamp Catchment Management Plan, “developed for implementation covering 25 years from 2010 to 2035, and (…) scheduled for short-term (2010-2015), medium term (2016-2026) and long term (2026-2035)” (Chabwela *et al*., 2010). So, the time frames proposed for implementation of the Conservation Plan for Lukanga Swamp and Upper Kafue Basin are as follows:

- Short-term (2021-2025);
- Medium-term (2026-2035);
- Long-term (2036-2050).

3. Description – Upper Kafue, Lukanga Swamp and its catchment baseline

3.1. Climate

In central Zambian territory there are two main seasons, the rainy season (November to March) corresponding to summer, and the dry season (April to October/November), corresponding to winter (e.g. Jones, 1972; World Bank, 2020). The area of the Lukanga Swamp is no exception as shown in Figure 7.

Some authors choose to divide the dry season into two different sub seasons, cool dry season (May-August) and hot dry season (September-November) (British Geological Survey, 2001).



Source: McCartney (2007). Note: arithmetic mean of data from 5 climate stations (distanced from the swamp between 84 km and 97 km)

Figure 7 – Mean monthly rainfall and potential evapotranspiration (Penman-Monteith) derived from the FAO Loc-Clim database

The wet season extends from November to March. Mean annual precipitation for the catchment varies from approximately 900 mm in the vicinity of the swamp to 1,400 mm in the vicinity of the source of the Lukanga River in the north (ZWA, 2005 in McCartney, 2007). However, the rainfall pattern is irregular with significant variation from one year to the next and often several concurrent years of below average rainfall. There is high inter-annual variation and mean annual rainfall is significantly influenced by a small number of very wet years (*e.g.*, 1926, 1962, 1969, 1978 and 2001).

There are long periods of below average rainfall (e.g. 1970-1973 and 1987-1994). Potential evapotranspiration exceeds rainfall in all months, except December to February (Figure 7). Average temperatures in the wet season range from 20-23°C and from 16-19°C in the cool part of the dry season (May to August) and from 23-25°C in the hot part of the dry season (September to October).

3.2. Hydrology

The **Kafue river** is the longest and largest river that flows entirely within Zambian territory, travelling along approximately 1300 km north to south of central western region (CSO, 2018). The river crosses Copperbelt, Central, Lusaka and Southern Provinces and is a major tributary to the Zambezi River (Norrgren, 2000).

The **Kafue river basin** is one of Zambia's six major catchments, covering an area of approximately 156 thousand square kilometres (20% of Zambia's total land – WARMA, 2019; Figure 8). This river basin contributes 8.4% to the country's total surface water potential (CSO, 2018).



Source: International Water Security Network (2017).

Figure 8 – Location of the Kafue River basin

The Catchment is subdivided into 2 collective basins: Upper and Lower Kafue Catchments. The **Upper Kafue River Basin** (**UKRB**) comprises the region upstream of the Machiya Ferry Discharge station and spanning the Copperbelt and Central Provinces, with about 33,480 km^2.

The gently undulating plateau area in the northern part of the Kafue Basin possess a complex drainage system. The major factor governing the annual hydrological cycle is the seasonal rainfall. In the northern part of the Kafue Basin total annual rainfall is up to twice as much as in the southern part. This, together with the fact that all important tributaries from this area reach the Kafue river upstream of Kafue Hook, implies that a large proportion of the total river discharge (~80%) already passes at this point. Downstream of Itezi-tezi, where the river flows through the Kafue Flats, the capacity of its channel is small and large areas are flooded annually.

3.2.1. The upper and mid Kafue

In October, the hydrological year starts with the river generally at its lowest level. With the onset of the rains in the northern part of the basin, normally around November, the water level of the upper Kafue starts to rise. As the rainy season progresses the water level of the river rises accordingly until maximum discharges are reached at the height of the rains in January/February. The flood proceeds quite fast down to Itezi-tezi, where maximum water levels are reached in March. At Itezi-tezi the flood used to be held back by the constriction of the valley, but at present the main regulating factor here is an artificial one: the Itezi-tezi dam.

Naturally, annual differences in the amount of rainfall, which can be quite large, result in proportionate fluctuations in maximum discharges. Between 1952 and 1965 maximum discharges at Itezi-tezi varied from 745 m3/s in 1960 to 2662 m3/s in 1963. The duration of the flood is similarly determined by the amount of rainfall as well as by spread of the rains over the season.

Important in the hydrology of the Upper Kafue are a number of floodplain and swamp areas, two of which, the Lukanga and Busanga Swamp, are of particular interest because their outflow serve as baseflow to the Kafue.

3.2.2. The lower Kafue and the Kafue Flats

Downstream of Itezi-tezi the Kafue river enters the Kafue Flats. The catchment area of the Kafue Flats is quite small (45 000 km2) and the annual rainfall low. This implicates that the water balance of the Flats largely depends on the discharges at Itezi-tezi. The channel capacity of the Kafue in the Flats area is small, approximately 170 m3/s, and thus, when discharges at Itezi-tezi are in excess of this amount flooding occurs. Flood levels and with it the total area flooded, as well as the duration of flooding are again mainly defined by the inflow at Itezi-tezi. From Itezi-tezi the flood slowly passes on to Kafue Gorge where it arrives between June and August.

At present the water balance of the Flats has been radically changed by the construction of the dams upstream and downstream of the Flats. The presence of the water works resulted in the following modifications of the natural flooding cycle:

- A decrease of the temporarily flooded area;
- An increase of the permanently flooded area;
- A delay in the start of the flooding caused by the river;
- A reduction of the flooding speed.

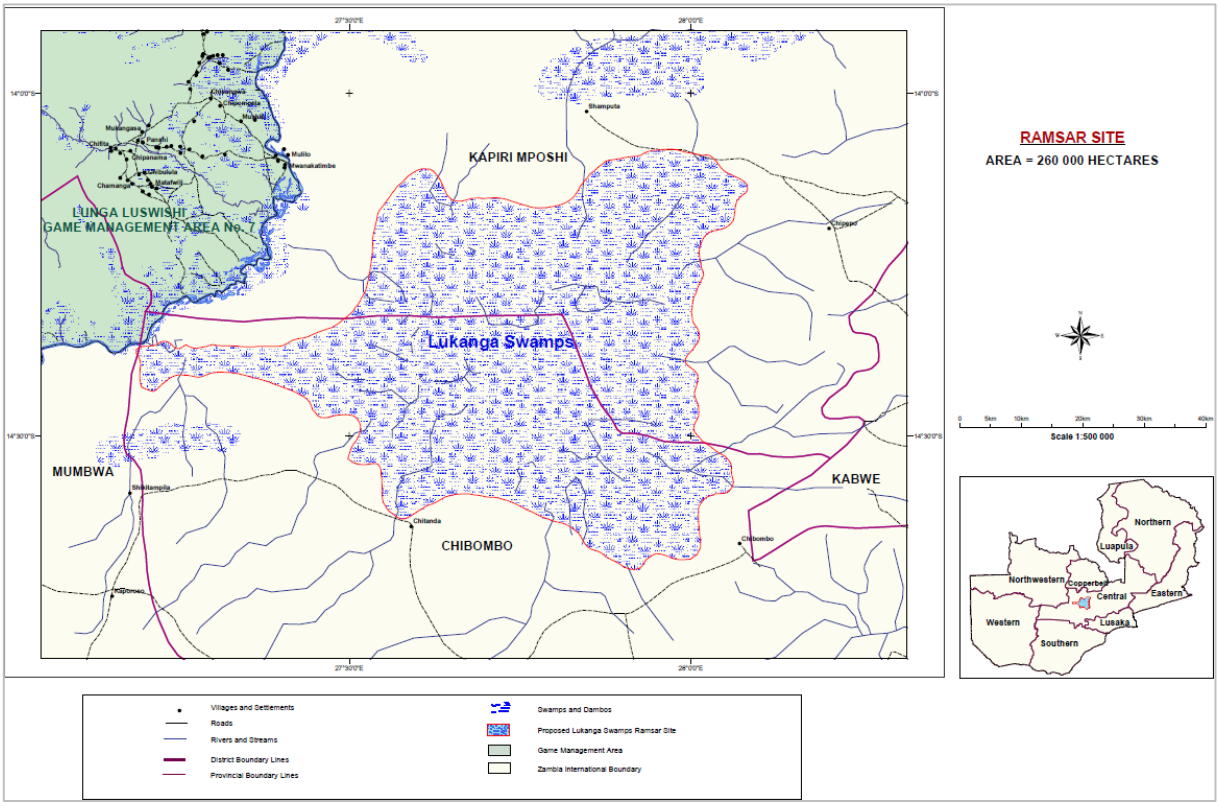
3.2.3. The Lukanga Swamp and its catchment

3.2.3.1. Characterisation of the Lukanga Swamp

In the central region of Zambia, the Kafue crosses a flattened area where it meanders and forms intricate wetland systems composed of permanent water bodies and floodplains, which include ecologically important systems, such as the Kafue Flats and the Lukanga Swamp.

One of Zambia's key wetlands, the Lukanga Swamp develops in a shallow circular depression of a generally flat area (Figure 9 and Figure 13), not exceeding 6.1 m of water depth (even during wet season), and forms the largest permanent water body of the Kafue basin.

Although named a swamp, the wetland comprises a treeless lake and a marsh ecosystem – an intricate maze of reeds, pools, channels, and larger bodies of open water, covering an area of approximately 1,800 km^2 (McCartney *et al.*, 2011). The wetland comprises two major types: palustrine (i.e. marsh) and lacustrine (i.e. open water). The palustrine wetland covers approximately 95% of the area and includes: stands dominated by reeds mixed grass, cattail/reed-mace, and termitaria grasslands. The lacustrine area comprises about 5% of the total wetland.



Source: Ramsar (2005).

Figure 9 – Lukanga Swamp RAMSAR Site

The Lukanga wetland is located within the Central Province, covering nearly 3,290 km^2 (during the rainy season) at an elevation of about 1,100 m, in the east bank of the Kafue River and extending over parts of the Kapiri Mposhi, Chibombo and Mpongwe Districts (Ramsar, 2005).

The Lukanga Swamp has a catchment area of about 13,460 km^2 (Hunink *et al.*, 2017), which is relatively flat area, with elevation levels varying between 1,100 m and 1,400 above sea level.

Main water sources to the Lukanga are direct rainfall, inflow from tributary streams and spill over from the Kafue River during extreme events (Ramsar, 2005). According to Hunink *et al.* (2017), surface water received by overflow from the Kafue during floods is limited (between 0 and 6%) compared to the overall water balance of the wetland.

The main river flowing into the Lukanga swamp is the Lukanga River, a tributary of the Kafue River (Figure 10). The Lukanga River flows into the swamp in the central north

part and then out again in the south-western corner through the so called Lukanga channel. Other smaller rivers like Mundu, Mufukushi and Chiyuni also flow into the swamp (Figure 10), but many of these are ephemeral.

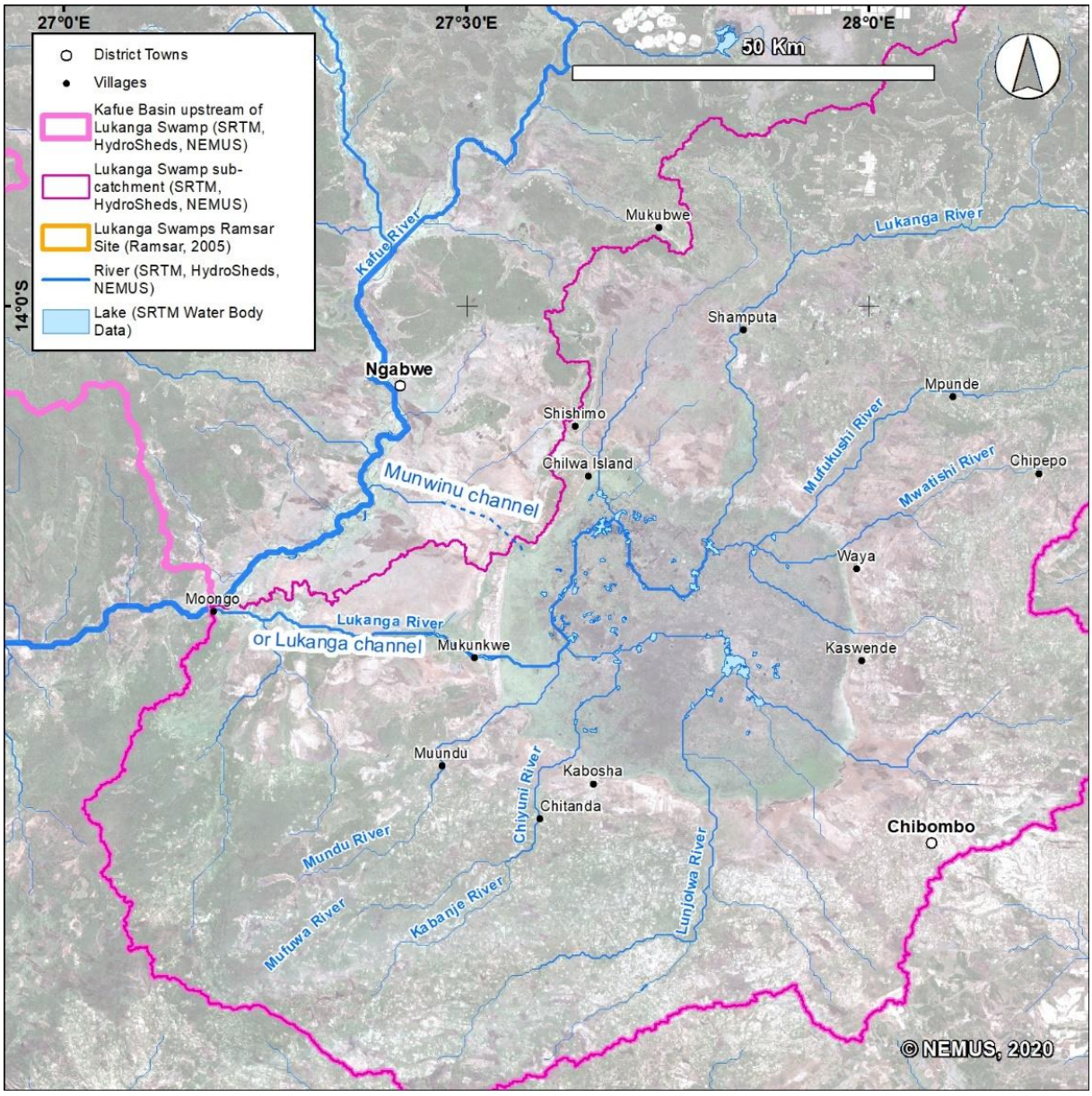


Figure 10 – Hydrological network associated with the Lukanga Swamp

Field visits in September and October 2019 allowed to confirm that those small streams North and West of Chibombo and the Mwatishi river (near Chipepo) were dry. While Mundu and Chiyuni rivers showed notorious surface flow towards the swamp, the Mufukushi river (near Mpunde) had a series of open water patches not connected in the

surface (Figure 11). It seemed clear that subsurface circulation was connecting these patches along the riverbed.



Source: Nemus (2019).

Figure 11 – Mufukushi river near Mpunde in October 2019 (northwards view)

Despite being the main river flowing into the swamp, by the end of the dry season of 2019 the Lukanga river had also open water patches not continuously linked in the surface in the area close to Shamputa (Figure 12).

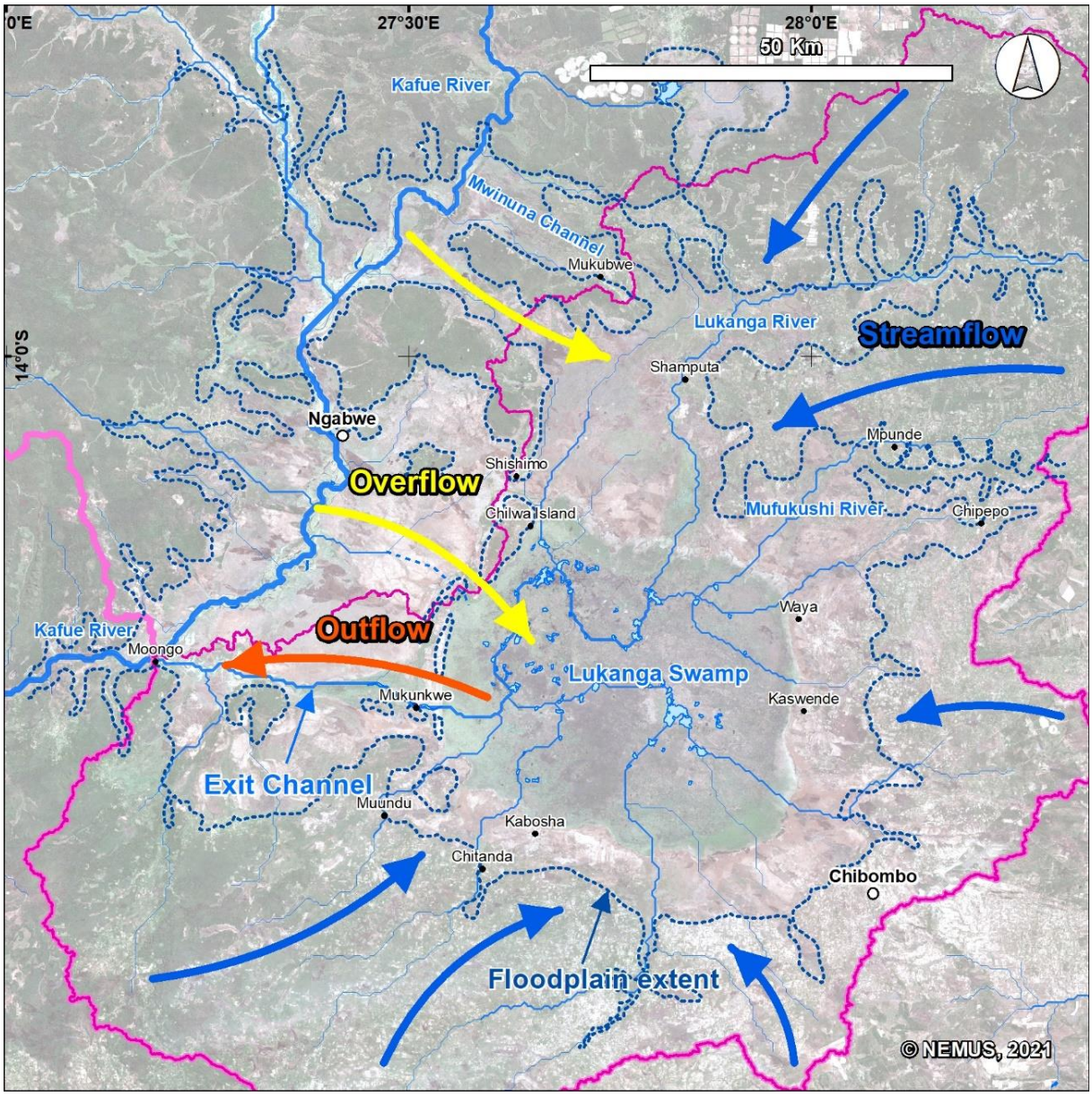


Source: Nemus (2019).
Note: in the picture one may see the open water patch ending

Figure 12 – Lukanga river near Shamputa in October 2019 (southwards view)

3.2.3.2. Hydrological characterisation of the Lukanga Swamp

The Lukanga Swamp functions like a sponge, absorbing water that comes in during the wet season (or from the periodically flooding of the Kafue through overflow), releasing it slowly during the dry period. Figure 13 shows the water balance between the Lukanga Swamp, the Kafue river, the Lukanga River and the Mufukushi River (which are part of the Lukanga watershed). The blue arrows represent the water received from the Lukanga watershed, the red arrow the water leaving the swamp to the Kafue river, and the yellow arrows indicate areas with occasional overflow during flood events. These flows not only occur as surface flows, but also as sub-surface flows.



Notes:
Streamflow – Water inflow from the Lukanga watershed;
Overflow – Occasional surface overflow from Kafue during flood events, and subsurface flow from the Kafue river floodplain to the Lukanga samps;
Outflow – Flow leaving swamp through exit channel to Kafue and subsurface flow between Kafue alluvial subsurface and swamp subsurface.
Source: adapted from Hunink *et al*. (2017).

Figure 13 – Water balance in the Lukanga Swamp

The Lukanga swamp has a very high annual inflow variability. Due to its characteristics as a nature-based reservoir, the swamp stores water during a wet year and releases part of it during the following year. This role as a "sponge" is especially important at a monthly scale, since the climate in the region has very pronounced dry and wet seasons, with

hardly any precipitation from May to September and high volumes of rainfall in the rainy season, especially in December and January.

The Lukanga Swamp and its watershed are significant contributors to the Kafue River Basin. In fact, around 1/3 of the water flowing downstream of the Lukanga Swamp comes from the swamp. Hence, the Lukanga Swamp and its watershed are a very important asset for downstream water users in the Kafue River Basin (Hunink *et al*., 2017).



Source: Nemus (July 2019).

Figure 14 – Lukanga river (to the West); establishes the connection between the swamp and the Kafue river

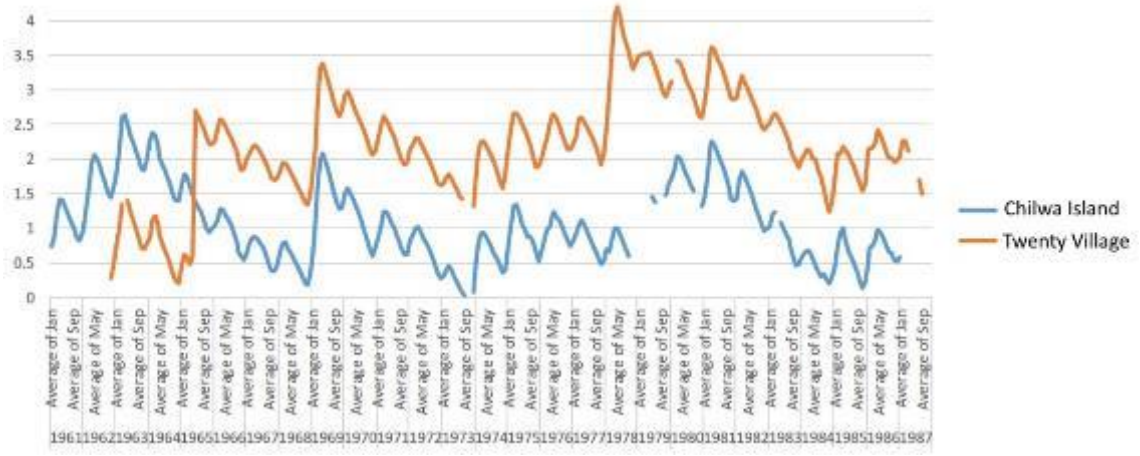


Source: Nemus (July 2019).

Figure 15 – Lukanga river (to the East); establishes the connection between the swamp and the Kafue river

3.2.3.3. Historic water levels in the swamp

Historic water levels in the swamp cover a period from 1959 to 1988 in three different stations: at the Kafue-Lukanga confluence (1962-1971); at the Twenty Village in the Lukanga Swamp (1962-1988); at the Chilwa Island (1959-1986).



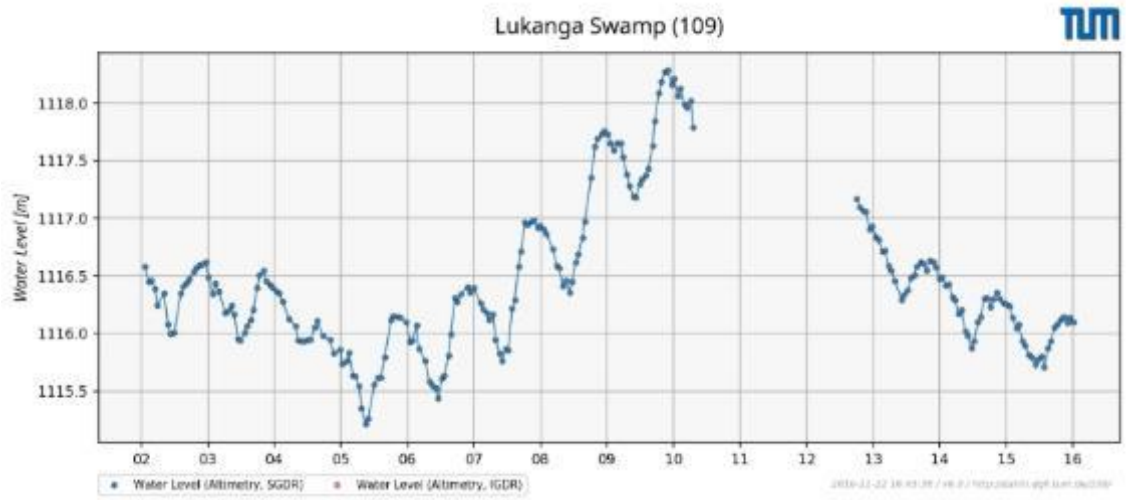
Source: Adapted from Hunink *et al.* (2017).

Figure 16 – Surface water level at Chilwa Island and at Twenty Village in the Lukanga Swamp, from 1961 to 1987

The historic data available on water levels show a seasonal pattern superimposed on trends of around 5 years – decreasing or increasing.

According to the DAHITI database, water levels in the swamp between 2002 and 2016 confirm this behaviour. For the period with available data, three periods with interannual trends in water levels can be distinguished (Figure 17):

- September-2002 to December-2006 was a period with an overall decrease of water levels. For the swamp this corresponds to a decrease in volume of approximately 4,000 MCM (million cubic metres).
- In 2007 water levels started to increase. The interannual positive trend was maintained up to October-2010. This increase corresponds to an additional volume of about 7,000 MCM. In this period, open water surface is also relatively high – possibly because the vegetation needs some time to adapt to these high-water levels.
- The third period with available data ranged from March-2013 to November-2015. As in the first period, this was characterised by a declining interannual trend.



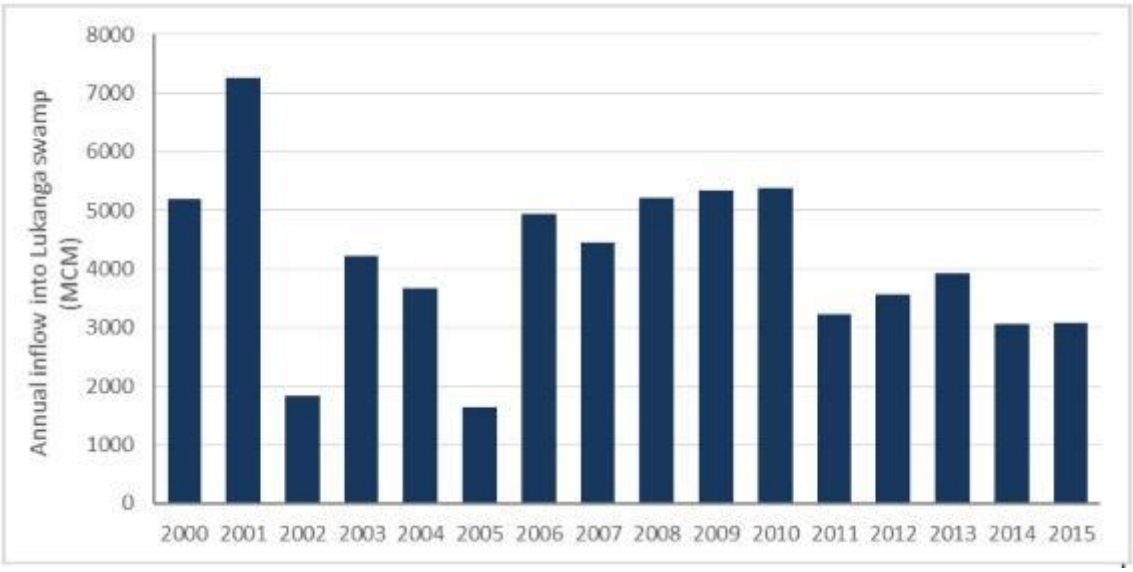
Source: DAHITI database.

Figure 17 – Water level in the Lukanga swamp based on satellite altimetry

3.2.3.4. Inflow to the Lukanga Swamp

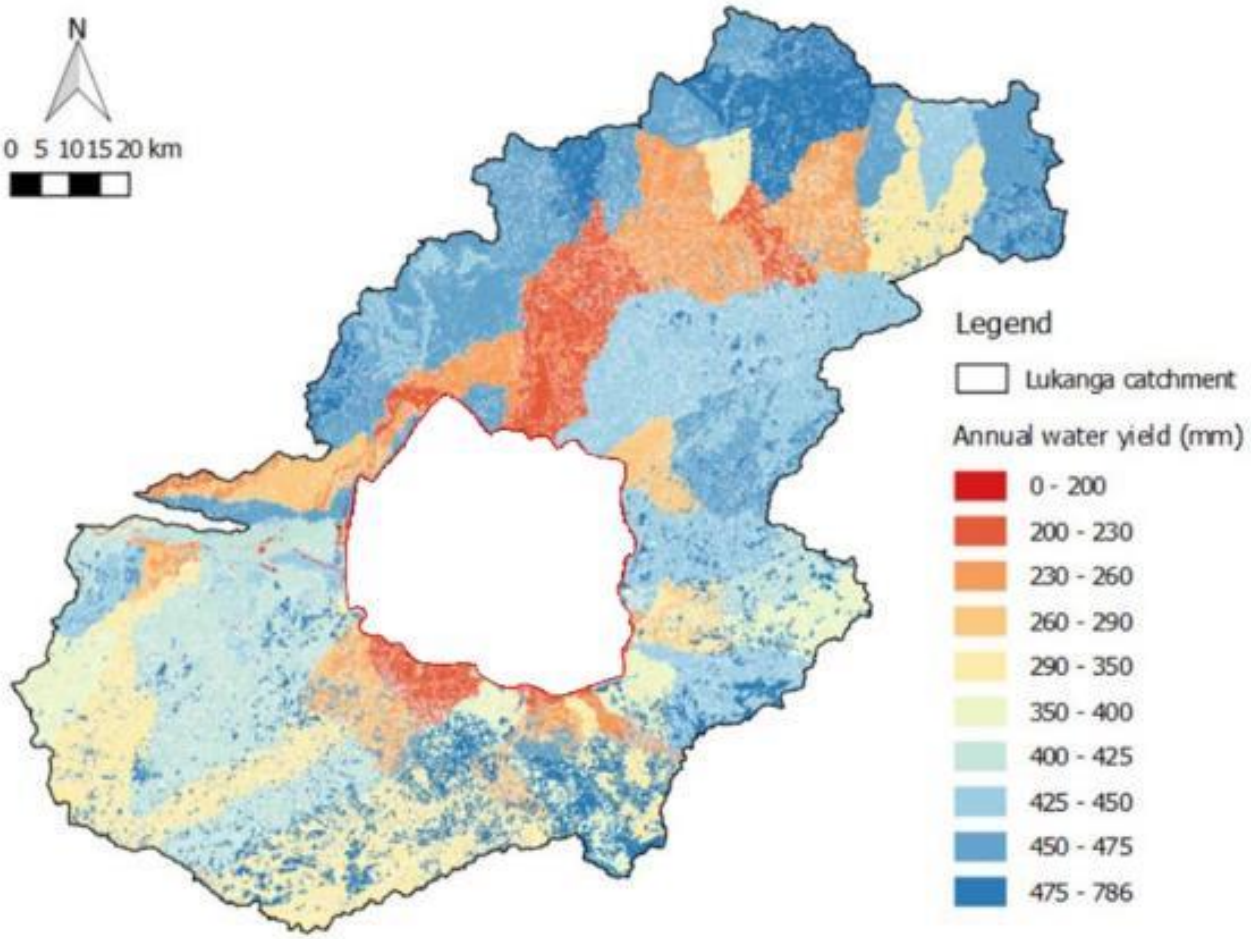
Simulations done with SWAT in Hunink *et al.* (2017) show that the inflow into the swamp varies substantially between years. The fluctuations are quite large, ranging from 1,634 MCM (164 mm) in 2005 to 7,250 MCM (729 mm) in 2001 (Figure 18). This is caused by variations in precipitation and temperature. The average annual inflow is 4,122 MCM (400 mm).

Figure 19 shows the spatial distribution of total water yield (water flowing into open water bodies) in the Lukanga catchment, which variations are especially a function of differences in land use, slope and soil. As can be seen, especially the far north of the Lukanga watershed is a major source of water, which is a consequence of relatively high precipitation levels.



Source: Hunink *et al.* (2017).

Figure 18 – Annual inflow into Lukanga Swamp



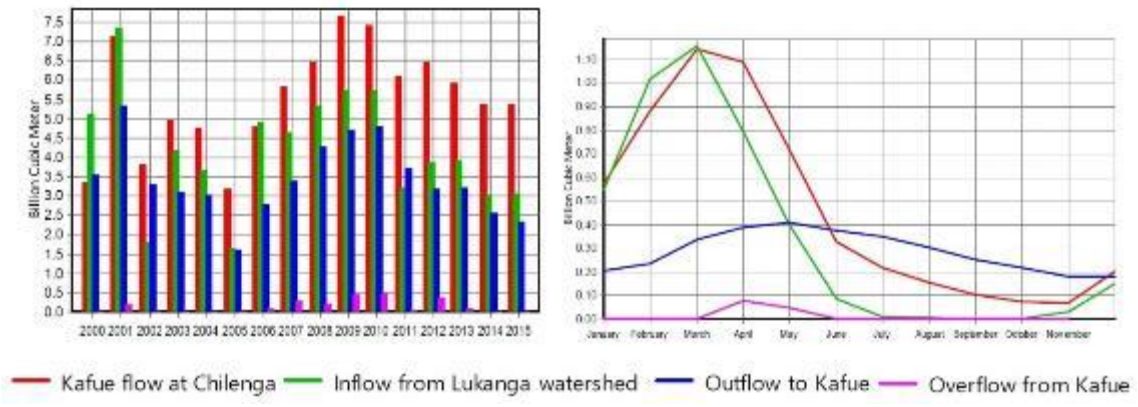
Source: Hunink *et al.* (2017).

Figure 19 – Average annual water yield in Lukanga watershed (2000 – 2015)

3.2.3.5. Water balance of the Lukanga Swamp

The annual variability in the Kafue river is considerable: during some years Kafue river flows are around 7,000 MCM, while in dry years it can be less than half (3,000 MCM). For the Lukanga watershed, the variability is even higher: the highest volume during the period reached (2001) is around 7,000 MCM, while in a dry year (2005) only around 1,600 MCM is flowing into the swamps (Figure 20).

To understand the importance of the Lukanga Swamp flow in the Kafue river one may investigate the wettest and driest years of the study. In the wettest year in the study period (2001) shows that the Kafue annual river flow of about 7,000 MCM, is the same as the Lukanga watershed provides. From this 7,000 MCM entering the swamp, around 5,000 MCM flows to the Kafue River. That means that just downstream of the swamp, that year approximately 40% of the Kafue flow originates from the swamp (5,000/(5,000+7,000)=41%). In a dry year (2005) even about one third of the water flowing in the Kafue river downstream of the swamp, is coming from the swamp (1,500/(1,500+3,000)=33%). The swamp always plays an important role in terms of water inputs into to the Kafue River.



Source: Hunink *et al.* (2017).

Figure 20 – Water balance with annual totals (left), and the mean monthly values (right) comparing Kafue River flow (20 km upstream of Lukanga swamps), Lukanga watershed inflow, outflow to the Kafue River (from the Lukanga) and over flow from the Kafue to the Lukanga

When comparing the monthly pattern of inflow (green lines) and outflow (blue lines) (Figure 20), it becomes very evident how the swamp retains water received during the high-flow period and releases it slowly during the dry months. Clearly, the swamp acts as a natural reservoir: reducing within-year variability of inflows and providing a more

consistent outflow to the Kafue river basin. In summary, the swamp reduces high flows, and increases low flows.

According to this analysis, overflow during high floods occurs in about half of the years, although in some years this overflow is quite limited. Maximum amounts are approximately 500 MCM (in 2010). This is about 7% of the flow in the Kafue river (Chilenga upstream). This suggests that during such a wet year, about 7% of the polluted load in the Kafue is potentially filtered and deposited in the swamp. In dry years, this effect is not occurring.

3.3. Hydrodynamics of the Lukanga Swamp and its catchment

According to some authors (*e.g.* Seagrief, 1962 in McCartney, 2007) at times of high flow the Kafue River causes water in the Lukanga River to backup into the swamp and during very high floods, the Kafue River itself overflows into them.

However, in Mwanza *et al.* (2019) surface water exchange between the Kafue River and the Lukanga Swamp through the Munwinu (north) and Lukanga (south) channels (Figure 10) is determined by using historical water levels observed over a period of 81 months.

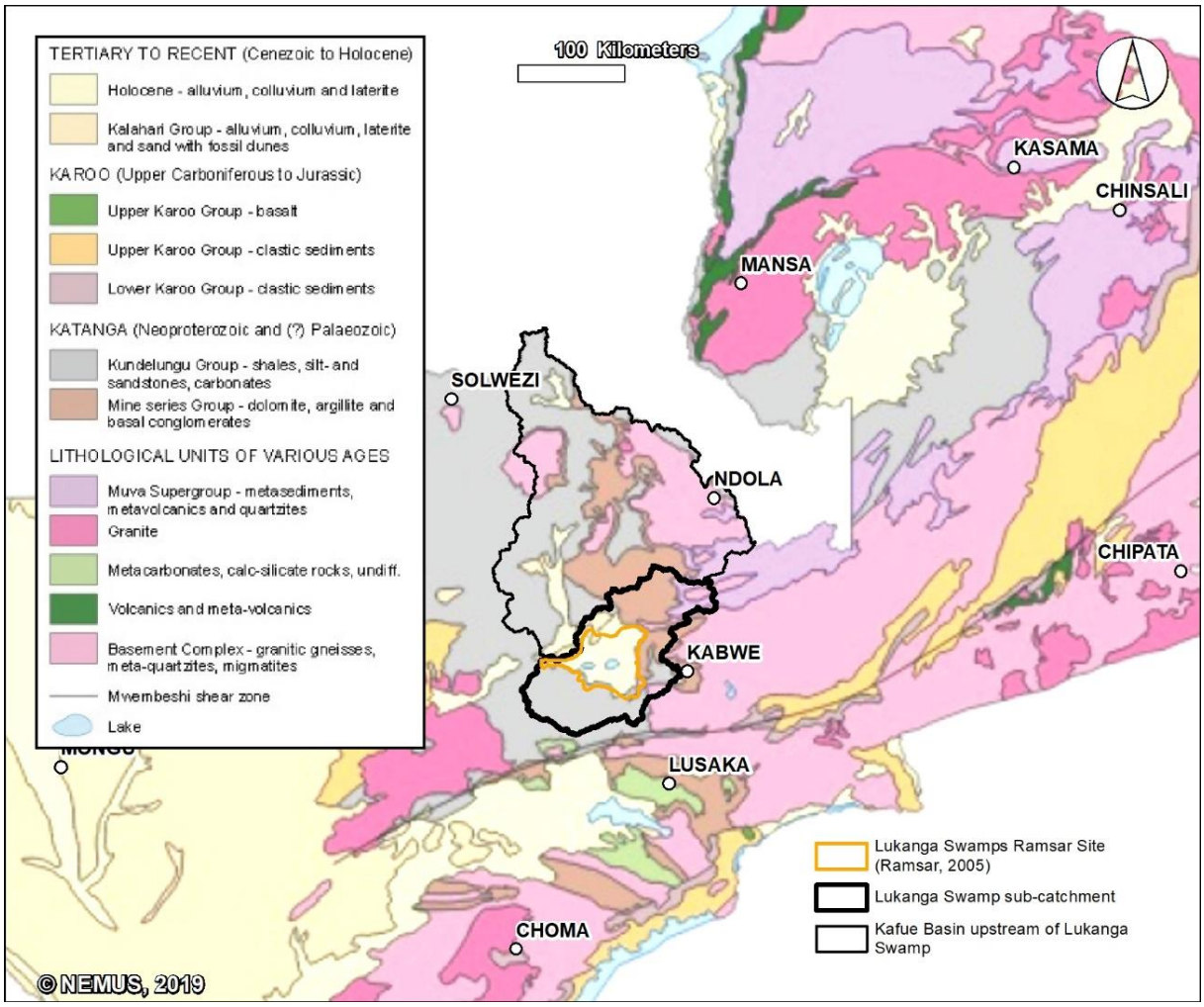
The authors conclude that there is flow through the Munwinu channel towards the swamp mostly during the period from January to June. There is usually no flow between July and December, and there is no flow from the swamp to the river through this channel. Along the Lukanga channel, there is flow towards the river throughout the year and nothing in the opposite direction (towards the swamp).

As seen in section 3.6 - Environmental quality, surface water characteristics are not constant throughout the swamp. Higher concentration of salts and organic matter in the East part of the swamp suggest that residence time of water in that part of the swamp is higher. As seen above, the far north of the Lukanga watershed which drains to the centre of the swamp is a major source of water. In addition, main rivers in the south drain also to the West part of the swamp. Additional inputs of water from Kafue River overflows also come from the West and Northwest.

Between 2000 and 2015, the total sediment load entering the swamp was 0.38 mega tonnes per year on average. Assuming a specific weight of the sediment particles of 1,237 kg / m^3, this corresponds with a volume of 0.31 MCM that is subtracted from the swamp storage capacity each year due to sedimentation. This is negligible compared to the volume of water generally stored in the swamp (4,000 – 7,000 MCM). Even after 100 years with this sedimentation rate, the swamp would lose less than 1% of its capacity (Hunink *et al*., 2017).

3.4. Geology

The oldest rocks outcropping in the Upper Kafue River Basin are part of the crystalline Precambrian basement complex (Figure 21), in this case composed of granitic gneisses, meta-quartzites, migmatites and others. In this area, outcrops from the Katanga Supergroup also dominate. The deposition of the Katanga Supergroup came afterwards, and it includes in this area the Kundelungu Group (shales, silt- and sandstone, carbonates) and the Mine Series Group (dolomite, argillite and basal conglomerates).

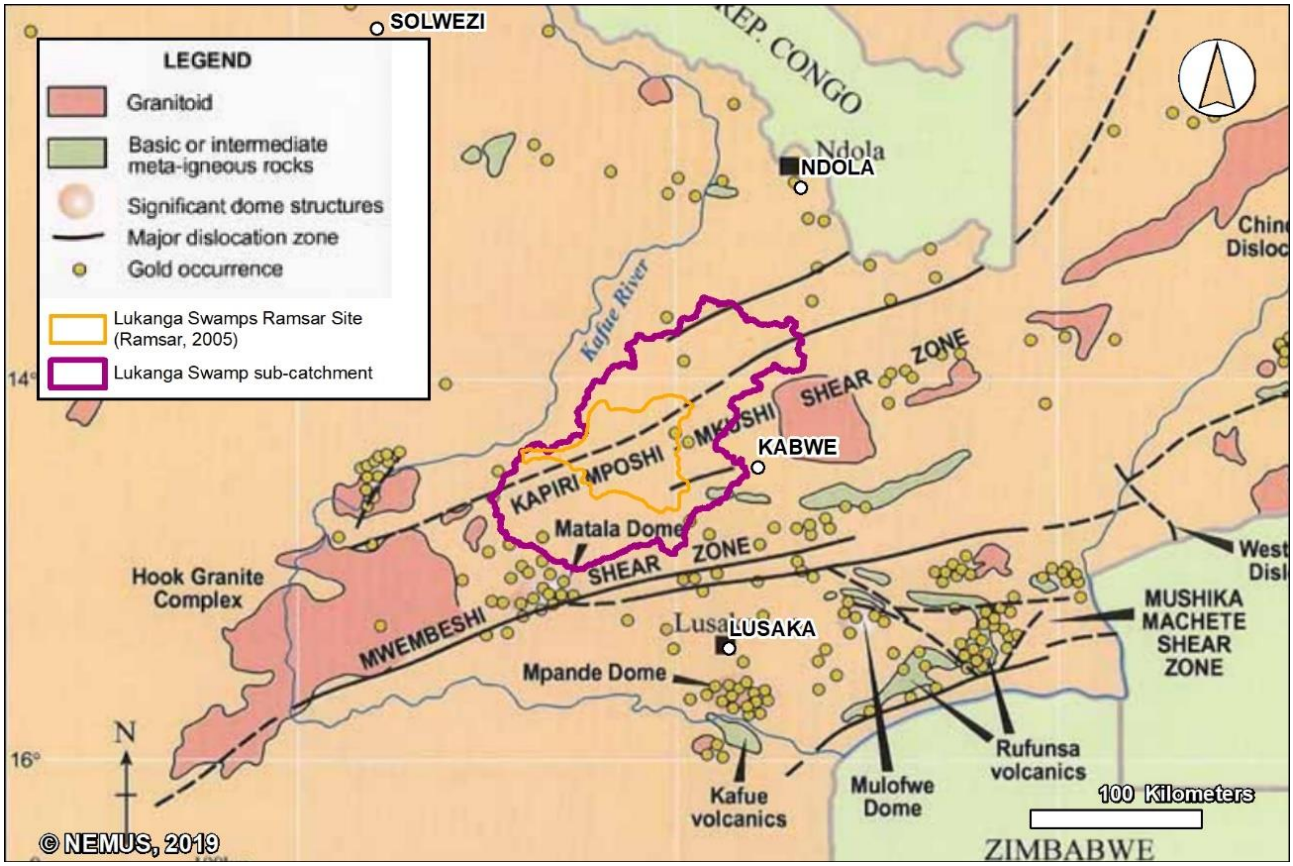


Source: Adapted from WARMA & BGR (2018).

Figure 21 – Geological Map of Zambia with location of Lukanga Swamp sub-catchment and Kafue River Basin upstream

In the Lukanga Swamp Catchment, sediment deposits from the Holocene occur in addition to outcrops from the Katanga Supergroup.

Below these sediment deposits there is an interpreted fault crossing the Lukanga Swamp, according to the geological setting of Zambia (Figure 22). However, these structures have minimal or no interference on the surface hydrology.



Source: Adapted from Liyungu (n.d.).

Figure 22 – Geological setting of Lukanga Swamp and its sub-catchment, with major dislocation zones

The diversified lithologies that compose the Upper Kafue River Basin and Lukanga Swamp Catchment will, on the other hand, be reflected in the different types of aquifers occurring in the area.

3.5. Hydrogeology

3.5.1. Groundwater at the scale of the Kafue Basin

There are extensive aquifers in the Kafue River Basin, particularly in the areas of the Copperbelt and Lusaka. Limited exploitation of these aquifers has taken place. Groundwater has been used on a local scale for urban water supply (in Mazabuka and in the Copperbelt) and for rural water supply, but surface water sources have formed the predominant source of supply (Scott Wilson Piésold, 2003).

Aquifers in the Kafue River Basin are classified into three main types (JICA-MEWD 1995):

- Aquifers where groundwater flow is mainly through fractures, fissures and/or discontinuities, classed as either highly or locally productive. Highly productive aquifers occur mostly in karstic limestones/marbles on the Copperbelt and stretching down into the Lusaka area;
- Aquifers where intergranular groundwater flow is dominant, and which occur mainly in alluvial soils and Tertiary sand deposits;
- Low yielding weathered and/or fractured aquifers with limited potential, which are largely in the Basement complex, and some in igneous rocks.

According to the British Geological Survey's Africa Groundwater Atlas (BGS, 2020) the Kafue River Basin is composed by different aquifer types and associated productivities (Table 4 and Source: NEMUS (2020)

Figure 23).

Table 4 – Different types of aquifers present in the Kafue River Basin

Type of Aquifer	Productivity	Geology	% (Area – km2)
Basement	Low to Moderate	Basement Complex: undifferentiated	23.1 (36,634)
Consolidated Sedimentary Aquifers with Fracture Flow	High	Katanga Supergroup	49.4 (78,267)
Consolidated sedimentary aquifers with fracture flow	Low - High	Muva Supergroup	0.4 (585)

Type of Aquifer	Productivity	Geology	% (Area – km2)
Consolidated Sedimentary Aquifer with Intergranular & Fracture Flow	High (Variable)	Lower + Upper Karoo Group	5.0 (7,884)
Unconsolidated: Intergranular Flow	Low to Moderate	Quaternary Alluvium + Tertiary (Kalahari Group)	22.1 (35,048)

3.5.1.1. Crystalline basement rocks

The second most common aquifer type refers to crystalline basement rocks, mostly granitic, and sometimes gabbro and others. The aquifer properties of crystalline basement aquifers are controlled by the depth of the weathered profile (regolith) and the degree of fracturing of unweathered bedrock. Fractured bedrock alone cannot sustain usable yields without the storage capacity of the overlying regolith.

The regolith is typically 10 m to 15 m thick but can be up to 30 m thick. Below this, the unweathered bedrock can be fractured to depths of about 60 - 70 m (United Nations 1989 *in* BGS, 2020). The water table is usually 20 m to 30 m below the ground surface. Boreholes tend to be 50 m to 60 m deep. An average transmissivity value of 5.7 m²/day is given. Yields are typically very low to low: between 0.2 and 2 l/s. One study reported the average yield from 106 boreholes to be 1.4 l/s, with 44% of the boreholes yielding less than 1 l/s and just 3% yielding 3 l/s or more (United Nations, 1989 *in* BGS, 2020).

3.5.1.2. Katanga Supergroup

Roughly half of the Kafue River Basin's area is composed of aquifers from the Katanga Supergroup forming consolidated sedimentary aquifers with fracture flow. The Upper Roan Dolomite and Kundelungu Limestone of the Katanga Supergroup form highly productive aquifers in which fractures provide the dominant permeability and storage.

The aquifers are mostly between 15 and 50 m thick. The water table is generally from 20 to 35 m below ground surface. The aquifers are usually unconfined. The maximum borehole depth is 50 to 70 m, with water occasionally struck at depths as great as 120

to 150 m. Transmissivity values of up to 800 to 1000 m²/day are reported (United Nations, 1989 *in* BGS, 2020). In terms of water quantity, normally these aquifers are classified as good to very good yields in dolomites and limestones and lower yields in other lithologies. Yields are typically high: one study of 190 boreholes found an average yield of 6 l/s, with some boreholes known to yield 10-20 l/s and even more than 50 l/s. The highest yielding boreholes are in the areas of Lusaka, Ndola, Kabwe and Mpongwe. In terms of water quality, sometimes water is classified as hard water due to high dissolved calcium. In most cases there is direct recharge and sometimes also focussed recharge from runoff from higher ground.

Other formations in the Katanga Supergroup, including the undifferentiated Kundelungu and Lower Roan Quartzites, and the formations of the Muva Supergroup, typically form locally productive aquifers. Yields typically between 0.1 and 10 l/s and recharge occurs directly through fractures.

3.5.1.3. Upper and Lower Karoo Groups

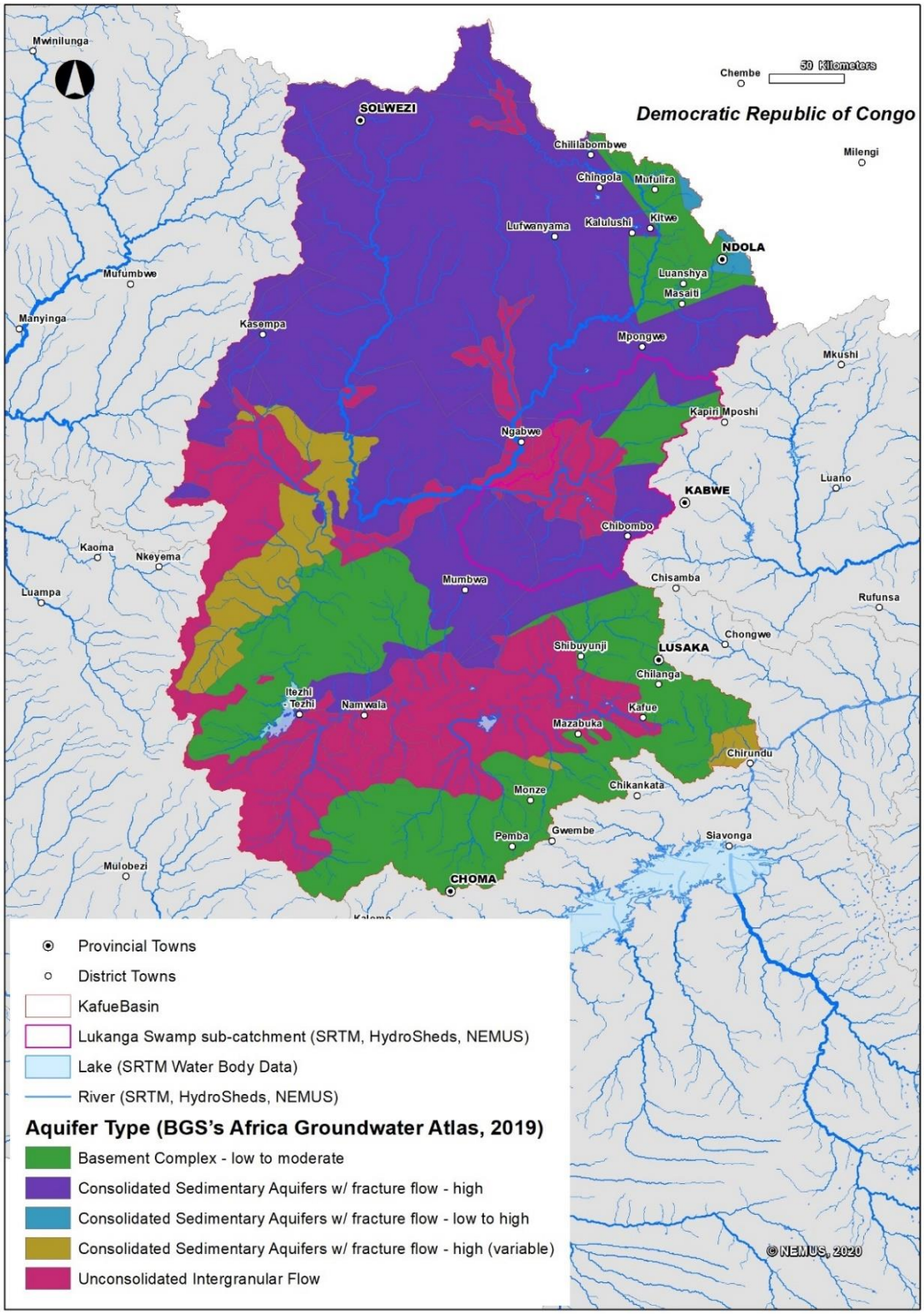
Sandstones in the Karoo sequence form high porosity, high permeability aquifers. Most groundwater flow is in fractures but there is significant intergranular flow. The aquifers are typically unconfined, but occasionally confined. The water table is often between 15 m to 20 m below ground surface. Yields of up to 15 l/s are possible.

Shales, mudstones and other fine grained lithologies in the Karoo sequence typically form low productivity aquifers, with yields of 0.2 l/s to 2 l/s.

3.5.1.4. Kalahari Group (Tertiary)

This aquifer comprises 20 m to 40 m of unconsolidated sands, which are usually unconfined. Flow and storage are intergranular. The water table is usually at a depth of about 10 m to 20 m below ground surface, but sometimes is as much as 30 m deep. Yields of 0.2 l/s to 5 l/s are obtainable.

Recharge is largely direct from rainfall. In terms of water quality in some cases water is brackish.



Source: NEMUS (2020)

Figure 23 – Different aquifer types in the Kafue River Basin

3.5.2. Groundwater at the scale of the Lukanga Swamp and its catchment

The diversified lithologies that compose the Upper Kafue River Basin and Lukanga Swamp Catchment will be reflected in the different types of aquifers occurring in the area.

Figure 24 shows that locally productive fissured aquifers are generalized in the area. Highly productive aquifers are generally related to carbonate rocks and are represented in dark green in Figure 24.

The Lukanga Swamp is set over a vast aquifer, classified as moderately productive, in which intergranular flow is significant. Most of the aquifer occurs in the swamp but it also occupies areas outside the swamp, particularly in the West and North parts of the aquifer (*e.g.* Chilwa Island) and also along the Kafue River.

The aquifer is composed of Quaternary alluvium and Tertiary deposits (Kalahari Group). This last geological unit occurs outside the swamp the northwest and west of the aquifer. Chilwa island and the elevated limits of the swamp in the West are composed of tertiary deposits. The swamp area is hydraulically connected to the Kafue river through surface water (Figure 14) and most likely through groundwater as well.

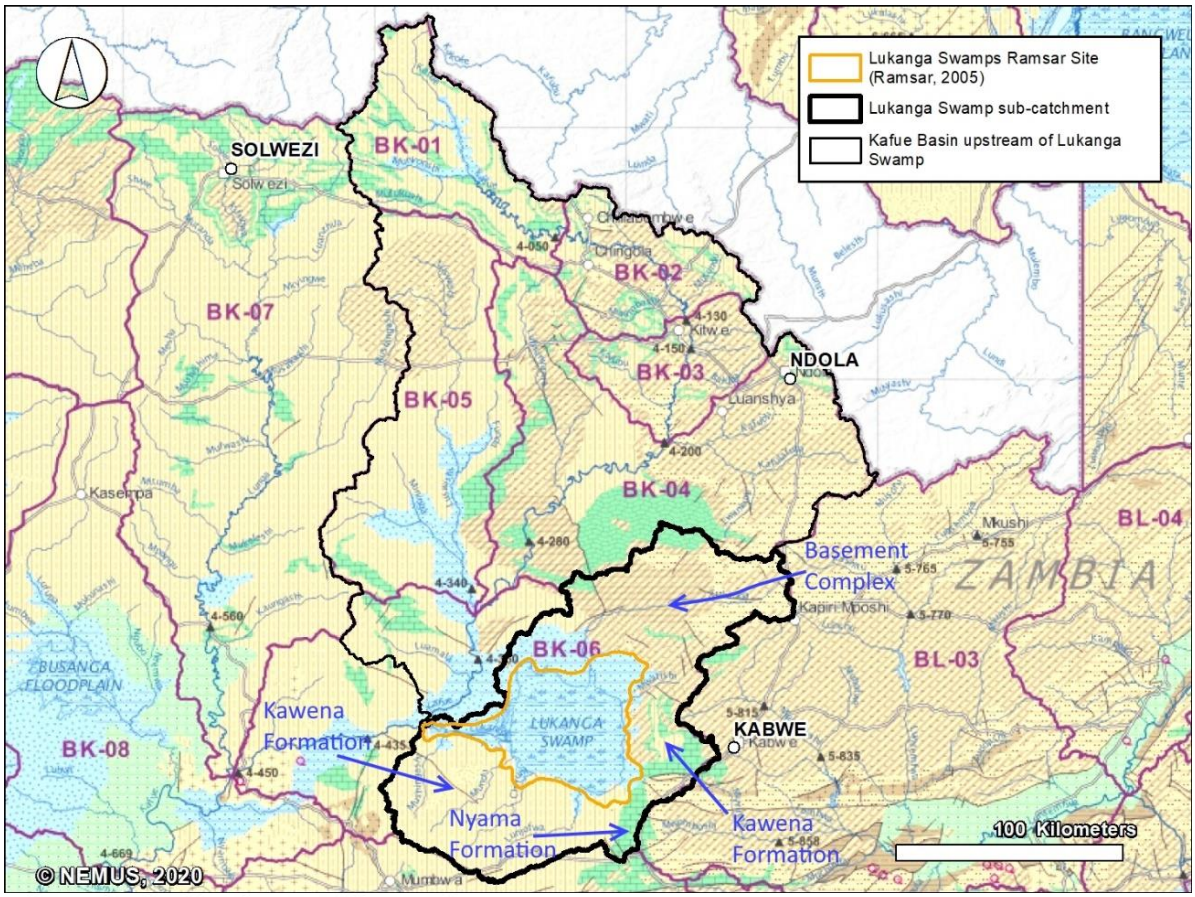
It is probable that the recharge of this aquifer comes from the Kafue river when water levels are high, from Tertiary deposits and from the margins of the swamp during the wet season when the water levels in the swamp increase. Horizontal recharge seems to come also from adjacent aquifers as seen below when referring to regional groundwater flow.

The previous aquifer is almost surrounded by aquifers from the Katanga Supergroup with the exception of the Chipepo and Mpunde areas, and the area half-way between this last village and Shamputa which is occupied by undifferentiated Basement Complex rocks (Source: NEMUS (2020)

Figure 23).

In the area the Katanga Supergroup can be divided in two general aquifers: the Kawena Formation and to the Nyama Formation.

The folded bedrock composing the Kawena Formation shows a low grade of metamorphism and is grouped into an upper and a lower member. The lower member (Kawena Argillite) consists of fine-grained often siliceous argillite which is a highly indurated mudstone. The upper member (Kawena Sandstone) predominately consists of grits – a hard, coarse-grained, siliceous sandstone – and feldspathic and calcareous ironbanded sandstones, and siltstones (Vrana, 1974).



Groundwater Development Prospect

Aquifers in which intergranular flow is significant

	B	Moderately productive, intergranular, predominately unconsolidated aquifer (0,1 - 15 l/s) (mainly alluvial sands and gravels & Kalahari Group)

Aquifers in which flow is dominantly in fissures, channels or discontinuities

	C	Highly productive aquifer (0,1 - 70 l/s) (mainly Upper Roan dolomite and Kundelungu limestone)
	D	Moderately productive, fissured aquifer (0,1 - 15 l/s) (mainly Karoo sandstones)
	E	Locally productive, fissured aquifer (0,1 - 10 l/s) (mainly undifferentiated Kundelungu, Lower Roan quartzites, Muva sediment granites)

Aquifers of limited potential or regions without significant groundwater

	E - F	Stratum with intermediate characteristics (0 - 2 l/s) (mainly low yielding formations of Karoo basalts, Mine series shales and basement gneiss)
	F	Unproductive formations (mainly Karoo shales, metamorphic and igneous rocks)

Source: Adapted from WARMA & BGR (2018).
Note: black line delineates the Lukanga Swamp catchment.

Figure 24 – Part of the Hydrogeological Map of Zambia 1:1,500,000 for the region comprising the Lukanga Swamp and Upper Kafue River Basin

Carbonate rocks of the Nyama Formation are classified as aquifers of moderate to high potential. The high permeability of the carbonate rocks is due to karstification, a process of solution and chemical but also mechanical weathering by infiltration of water, whereby surface features such as dolines, sinkholes and pinnacles ("karrenfelder"), and a subterranean drainage network consisting of solution cavities, channels and shafts develop. Karstification is a common feature of all calcareous units of the area (Vrana, 1974).

The proposed stratigraphic sequence is shown in Table 5.

Table 5 – Stratigraphic Succession of lithologies found in the Lukanga Swamp catchment with hydrogeological interest

Unit	Lithology		
E-	Massive dolomites and limestones with minor schists and quartzites	Nyama Formation	Part of the Katanga System
D-	Schists, phyllites and shales	Kawena Formation	
C-	Basel Group Conglomerates, grits, arkose and minor dolomites		
---------- Unconformity ----------			
B-	Feldspathic granote gneiss with minor schists	BASEMENT COMPLEX	

Source: Adapted from Jones, 1972.

3.5.2.1. Unit D – Schists of the Kawena Formation

Hydrologically this unit is a composite aquifer covering the vertical variations in lithology schematically shown in Figure 25. Progressive weathering of the schist destroys the fracture porosity and produces abundant clay size particles. Thus, the top-most zones of the schist saprolite are characterized by high inter granular porosity, low specific yield and low permeability. Frequently drillers' borehole logs show groundwater to be semi-confined by this clay zone.

The underlying less severely weathered schist saprolite, nominally lying between 15 and 36 m is the zone of maximum porosity, specific yield and permeability. Typically, borehole yields fail to increase proportionally after an optimum depth of about 54 m is reached.

These variations in hydraulic properties and groundwater occurrence within what is considered as the schist aquifer makes any attempt to define the aquifer thickness

impossible. With the data available it is also impossible to sub-divide the schist aquifer into its horizontal components each with its own coefficient of transmissivity.

Most old hand-dug wells obtain their water from the soil and laterite zones. Water is perched in these zones during the rainy season but subsequently part of it reaches the water table by interflow of direct infiltration.

Except near quartz veins no obvious lateral variations have been identified. The aquifer appears hydraulically isotropic, this is reflected in a uniform distribution of borehole specific capacities.

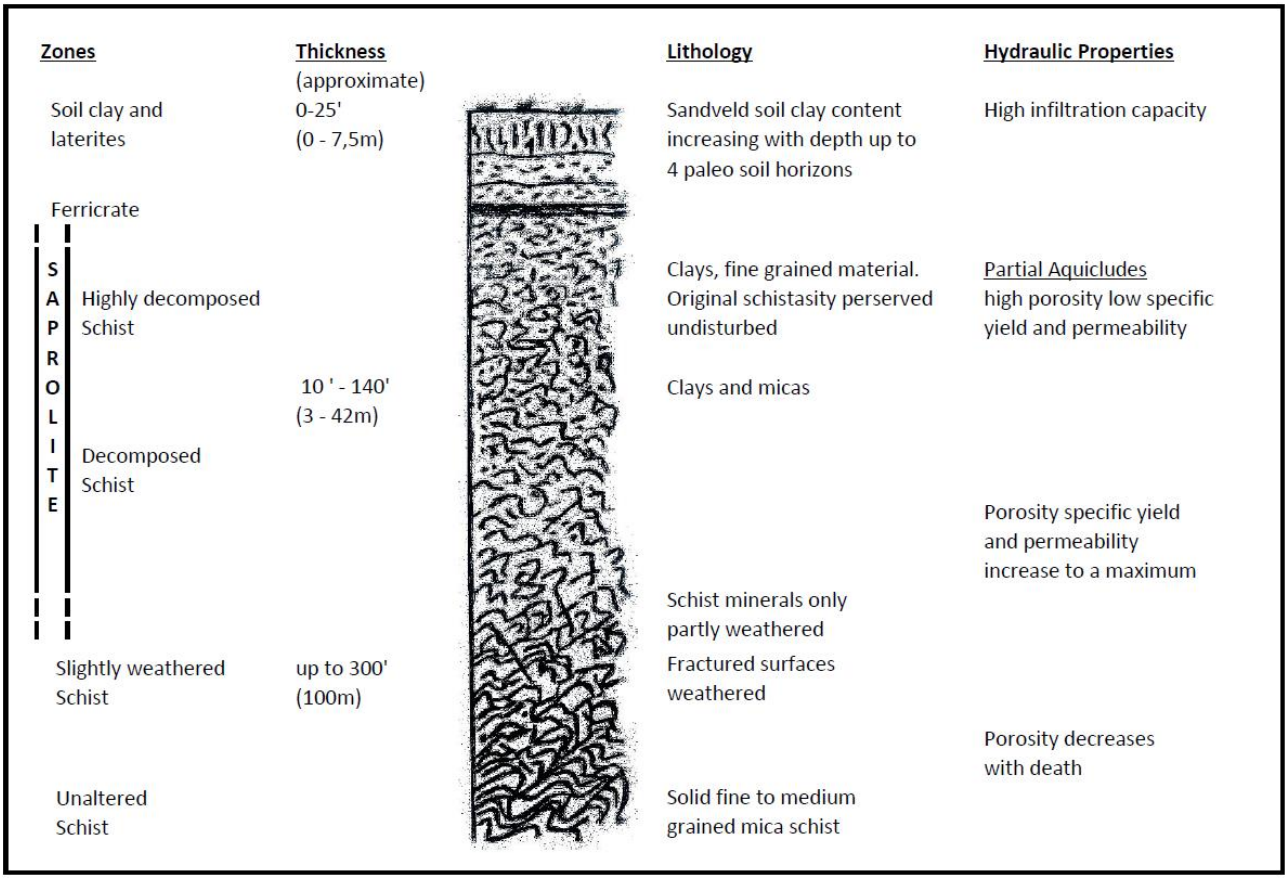


Figure 25 – Schematic section through schist of unit D as an aquifer

Considering the 27 records of boreholes drilled in this unit reported in Hadwen (1972), the theoretical median borehole yield is 1.14 l/s. The higher yielding boreholes would frequently be associated with quartz.

Discharge of groundwater from this aquifer into the highly transmissive dolomites and limestones of Unit E is also important. Topographically lower, the carbonates are in

hydraulic continuity with the schists. However, locally horizontal recharge from the limestone into the schist occurs when groundwater levels in the limestone are high. The flow reverses as levels in the limestone drop, so the schist adjacent provide storage for groundwater, a part of which ultimately flows back to the limestones.

3.5.2.2. Unit E – The Dolomites and Limestones of the Nyama Formation

In the plan area the dolomites and limestones of this unit appear to share identical hydraulic properties. Therefore, for hydrogeological purposes both dolomites and limestones will be grouped together and called limestone irrespective of their precise mineralogical composition.

It is emphasized that the limestones are strongly karstic with abundant solution features are recorded throughout the area, with both ancient and modern solution features. Across much of the area the karst is buried under a heavy overburden.

Individual pieces of the recrystallized limestone have low discrete porosity and for practical purposes, zero permeability. The limestones are massive, the groundwater is contained in fissures and joints. The fissuring and jointing are thought to be entirely of tectonic or secondary origin, no bedding planes have been identified at Broken Hill Mine (Whyte, 1966).

The fissures and joints can be broadly grouped as horizontal or vertical. Hydraulically, the horizontal group contribute most to the transmissivity of the aquifer. The vertical group aid infiltration; though there has been a tendency for those near the surface to become filled or partly filled with clays and laterite. Such material derived from the overburden has been recorded in logs for cored pilot holes at depths higher than 90 m.

Many large solution cavities have been found in exposures and boreholes. The fissure systems are unevenly distributed and have been selectively enlarged by groundwater flow. Solution enlarged fissures have been encountered in mineral exploration boreholes at depths of 105 m. But without knowing the absolute base level for the palaeokarst systems, it is impossible to estimate an effective base for the aquifer. It is also impossible to define the aquifer thickness.

From the specific capacity frequency graphs of 32 boreholes records the theoretical median borehole yield for this aquifer is near 11.37 l/s. At present (1972) the highest

yielding borehole in this unit is 300 mm in diameter and produces 75.8 l/s. This borehole is undoubtedly capable of producing more than 126.3 l/s.

Hadwen (1972) in discussing the hydrogeology of the Kakontwe Limestone at Ndola was able to differentiate between areas of vertical and lateral re-charge to this aquifer: direct vertical infiltration was deemed possible in areas where the overburden is less than 3 m thick.

According to Jones (1972) the close correlation between rainfall and water table rises in the area lead to accepting that direct vertical infiltration into the limestones readily occurs when the overburden is less than 3 m thick. The area of Unit E with less than 3 m of overburden is problematical, but it is estimated to be between 40% and 50% of the total outcrop.

Where the overburden exceeds 3 m in thickness direct infiltration becomes increasingly restricted. No surface runoff, however, is recorded. The rainwater instead collects in large shallow depressions that occur across the unit. As previously noted, these depressions may represent old sink or collapse areas which have become choked with fine impervious material. It is possible that some infiltration takes place through the floors of these depressions, but most of the rainwater is trapped and lost to infiltration by evaporation.

3.5.2.3. Regional groundwater flow in the Lukanga Swamp catchment

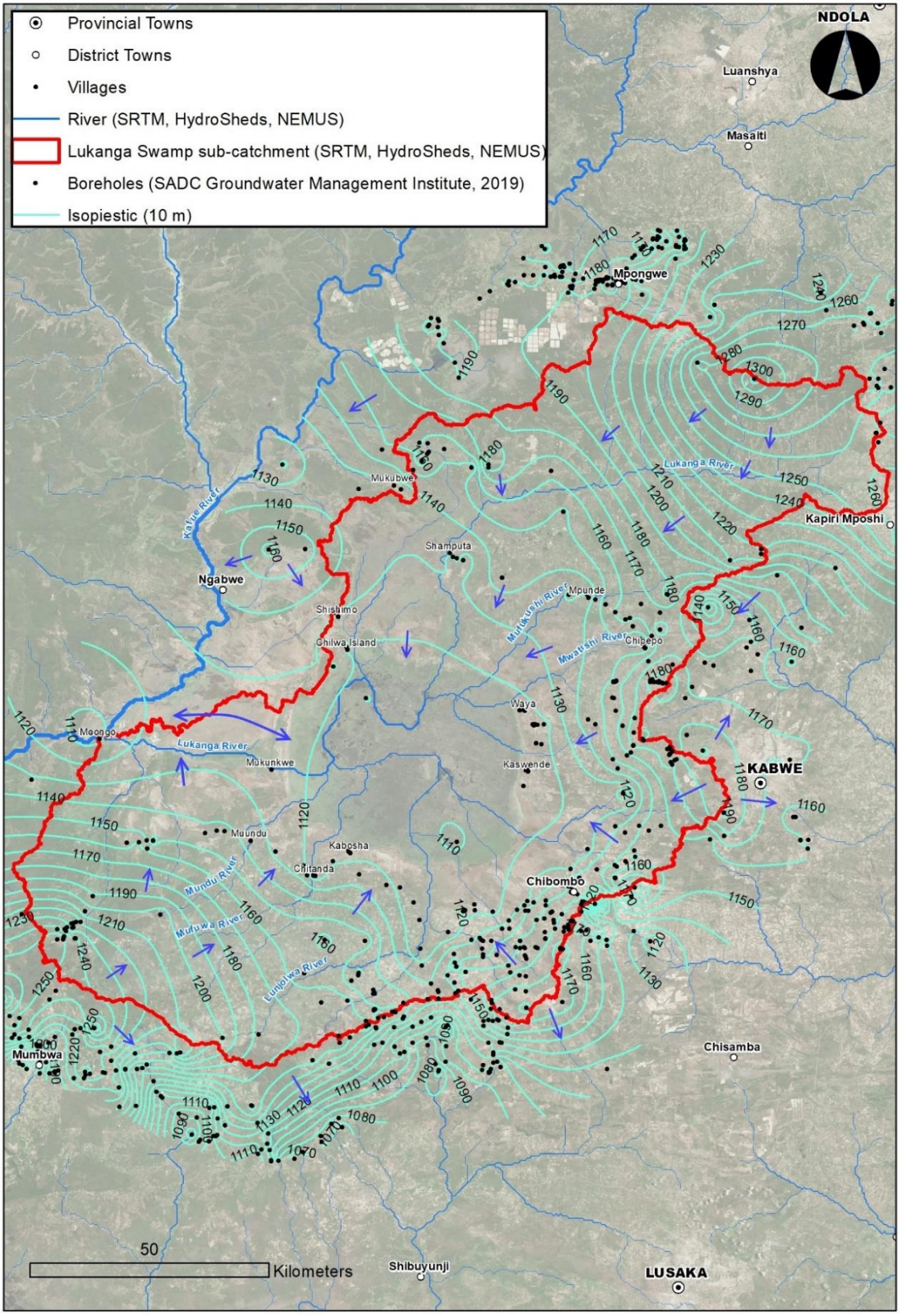
Assuming there is hydraulic connectivity throughout all superficial aquifers from the Lukanga Swamp, the regional groundwater flow pattern was achieved by using a database of boreholes from SADC.

There was no date associated to the static water levels, so it was assumed that these levels refer to the level verified when the borehole was dogged. In any case, the results show a coherent and more or less expected pattern, considering that the flow follows the topographic surface of the area (Figure 26).

The most interesting features highlighted by the regional groundwater pattern are:

- In general, groundwater in the Lukanga catchment flows towards the Swamp;

- Groundwater flow between the swamp and the Kafue River seems to be dependent on water levels on each one of these; possible there are flows in both ways.
- In the eastern and southern part of the catchment the topographic summit coincides with the groundwater divide, while some western parts groundwater flow seems to flow outside the catchment towards the Kafue river.



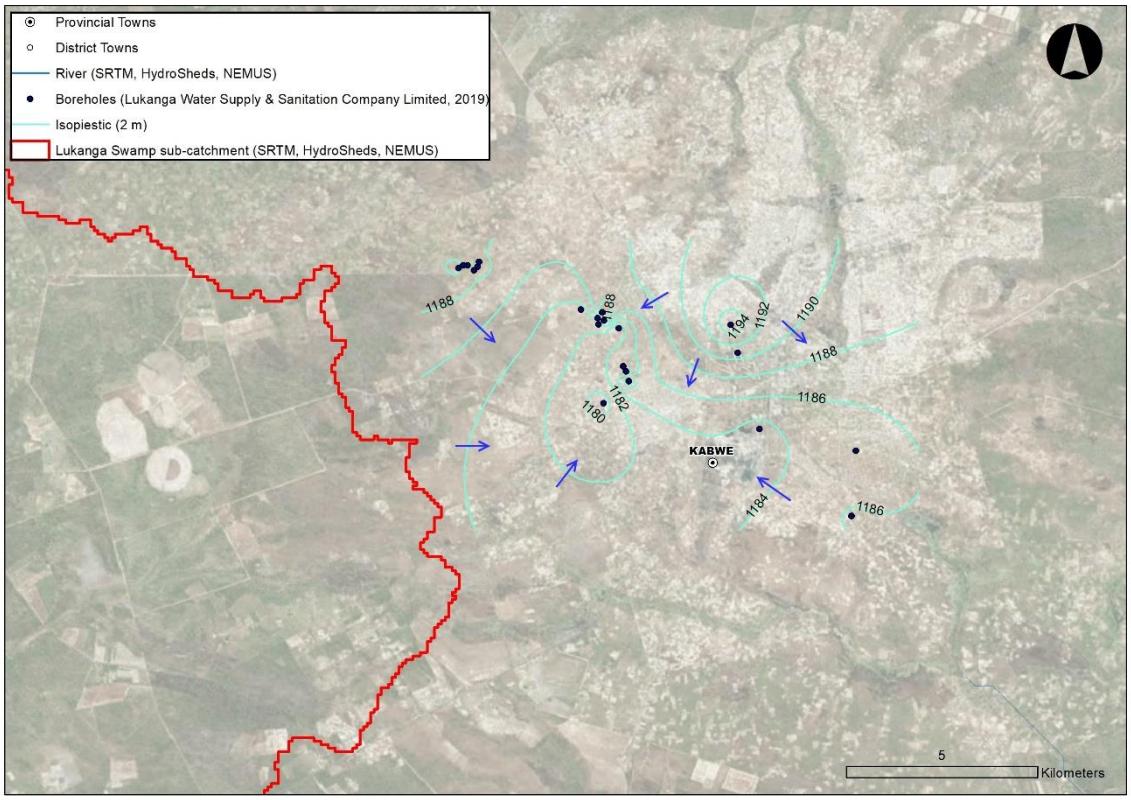
Source: NEMUS (2020)

Figure 26 – Regional groundwater flow in the Lukanga Swamp catchment

In Hunink *et al.* (2017) the authors point out that groundwater coming from the Kabwe area (with lead mines) could bring metals into the swamp though groundwater and that this subject should be further studied in the future.

The coincidence between the topographic summit with the groundwater divide near Kabwe in Figure 26 indicates that groundwater from the area does not come into the catchment of the Lukanga Swamp.

In addition, static water levels recorded in the same period of 2017 in the Kabwe area by the Lukanga Water Supply & Sanitation Company Limited show the same pattern with groundwater flowing towards the city (Figure 27).



Note: all the area depicted in the figure is composed of Katanga Super group rocks; static water levels were recorded in same period of 2017.
Source: NEMUS (2020)

Figure 27 – Local groundwater flow in Kabwe close to the limit of the Lukanga catchment

Despite the above, the possibility of a deeper flow that goes west from Kabwe cannot be ruled out. However, this hypothesis seems unlikely given the relatively flat topography and the geology of the area.

3.6. Environmental quality

3.6.1. Introduction, scope and methodology

That ecosystem services of the Lukanga Swamp have been degraded over the past decades is undisputed (*e.g.,* McCartney *et al*., 2011). However, the factors that have led to this degradation are not always clear. Chemical pollution is highlighted in some documents (*e.g.,* Terms of Reference for conducting this Conservation Plan) as one of these drivers, together with others such as loss of natural habitat, unsustainable resource use, drying of the wetlands, droughts, and overgrowing of weeds.

Within the context of the present Plan, the current state of the Lukanga Swamp was evaluated in what concerns chemical pollution in different media. It includes the Upper Kafue Basin as it is directly linked to the area of interest and may function as a source of chemicals to the swamp. In the Plan the main results and conclusions are shown; the complete assessment is presented in Appendix 2.

This assessment allowed understanding if chemical pollution is a driver of ecosystem services' degradation in the Lukanga Swamp, possible sources for those potential chemicals and stablishing measures to minimize the degradation.

The assessment of the contamination existing in the Lukanga Swamp and Kafue basin upstream uses primary data specifically obtained for this purpose, but also data from other previous studies that have been carried out in Zambia, particularly in the Copperbelt area or in the Lukanga Swamp (e.g. Pettersson, 2002; Kříbek *et al*., 2011; Hunink *et al*., 2017).

Physical and chemical data were obtained in surface water, groundwater, stream/swamp sediments and leaves from *Phragmites* spp in two campaigns conducted in September and October 2019.

General procedures used in those campaigns and their results are presented in the sections below.

3.6.1.1. Field sampling and sample preparation

The two field campaigns were done between 6 and 14 of September 2019 and between 10 and 23 of October 2019.

During these campaigns the following type and number of samples were collected:

- Surface water (42 samples);
- Groundwater (14 samples);
- Stream/swamp sediments (21 samples);
- Leaves (*Phragmites* spp.) (10 samples).

The location of sampling points for the different media are depicted in Appendix 1. The station reference may use “Oc” or “S” after the station number as an indication of the month when the sample was collected: October or September 2019, respectively.

Surface water was collected in streams from the Upper Kafue River Basin or at the Lukanga Swamp area (including the actual swamp and streams draining into it). In the Upper Kafue River Basin, the sampling focused on the streams affected by mining activities, however the other basins (Lufwanyama, Luswishi and Kafulafuta rivers) were also sampled.

Groundwater was collected in wells from villages surrounding the Lukanga Swamp since is not reasonable that groundwater from the Upper Kafue River Basin affects the Lukanga Swamp.

Sediment samples were collected in the two main areas: Lukanga Swamp area and areas of the Copperbelt Province more affected by mining activities. It was not possible to collect sediment samples in the inner part of the swamp because its floor is covered by a thick layer of plant material.

Leaves of *Phragmites* spp. were collected in the Lukanga Swamp area and at the Copperbelt province. Sampling of leaves in the Copperbelt will allow to understand how this plant behaves in areas where contents of metals are certainly high in the soil. Stations where leaves were collected were also sampled for surface water.

Field sampling and procedures are further detailed in the complete assessment (Appendix 2).

3.6.2. Groundwater (well water)

Fourteen groundwater samples were collected in wells from villages around the Lukanga Swamp.

According to the hydrogeological map, samples were collected in wells dug in different lithological units: Basement Complex: undifferentiated (1), Katanga Supergroup (8), Quaternary Alluvium (4) and Tertiary: Kalahari Group (1).

All but one (24S) sampled wells are used for drinking purposes. All wells are used also for irrigation, and washing of clothes, utensils, and tools. In terms of water quality, since the most demanding water use is human consumption, guideline values summarised in Zambian Standard (ZS) 190:2010 and/or in the World Health Organization (WHO) Guidelines for Drinking-water Quality (2011) are used to assess the suitability of this use.

Below the results are summarised according to the guidelines for drinking water.

Table 6 – Comparison of concentrations and physical-chemical properties of water well to guidelines for drinking water

Parameter	Entity	Guideline	Results
pH	ZS	6.5 – 8.0	Six wells fail to attend this guideline for having values lower than 6.5 (8bS, 16S, 24S, 25S, 26S, 28S);
Conductivity	ZS	< 1500 µS/cm	All comply
Phosphorus	ZS	< 1 mg/l	All comply
Nitrates	ZS/WHO	< 44.3 and 50 mg/l, respectively	Three wells exceed these concentrations: 28S (between Muundu and Mukunkwe), 29S (north of Chibombo) and 20S (between Waya and Kabwe), with 80.7 mg/l, 67.9 mg/l and 61.0 mg/l, respectively.
Hg and As	ZS/WHO	< 0.001 and 0.01 mg/l, respectively	Concentrations are consistently below detection limits, 0.3 mg/l and 0.2 mg/l, respectively. It is still unknown if these samples are good for drinking purposes considering these elements.
Cd	ZS/WHO	< 0.003 mg/l	Threshold exceeded in 10 samples out of 14. The four remaining samples have concentrations below the detection limits (0.005 mg/l).

Parameter	Entity	Guideline	Results
Co	ZS	< 0.5 mg/l	6 samples have higher concentrations than this value: 20S (north of Chibombo), 22S (Kaswende), 24S (Kaswende), 25S (Shishimo), 27S (in the road between Muundu and Moongo), 29S (north of Chibombo).
Cr	ZS	< 0.05 mg/l	3 samples have higher concentrations than this value: 24S (Kaswende), 25S (Shishimo), 29S (north of Chibombo).
Cu	ZS/WHO	< 2.0 mg/l	All concentrations are below the threshold
Ni	WHO	< 0.07 mg/l	6 samples have higher concentrations than this value: 13 (between Shamputa and Mukubwe), 20 (north of Chibombo), 23 (between Shamputa and Mukubwe), 25S (Shishimo), 27 (in the road between Muundu and Moongo), 29S (north of Chibombo).
Pb	ZS/WHO	< 0.01 mg/l	12 samples have concentrations above the threshold value. The remaining two samples show values below the detection limits (0.02 mg/l).
Zn	ZS	< 3 mg/l	All samples show concentrations of Zn below the threshold value

Since the ZS and WHO Guidelines for Drinking-water Quality do not refer threshold values for COD and BOD, European standards were used as indicative, just to have an idea on how the results stand for this purpose:

- Chemical oxygen demand (COD) is constantly below 4 mg/l. In European standards it must be below 30 mg/l to be able to be treated for consumption.
- Biochemical oxygen demand (BOD) is commonly below 1 mg/l. Only samples 5S (north of Chipepo), 23S (between Shamputa and Mukubwe), 25S (Shishimo) show 1 mg/l, 1 mg/l and 2 mg/l, respectively. In European standards, it must below 3 mg/l for minimal treatment (physical and disinfection) before consumption.

The following table summarises the parameters that do not respect guideline values for water for drinking purposes (ZS, WHO). As one may see from the table, the main problem of the quality of groundwater is related with concentrations of metals, particularly of Cd and Pb. High concentrations of nitrates and low pH also occur in some groundwater samples.

Table 7 – List of all 14 groundwater samples and parameters that exceed (or stand below for the case of pH) guideline values for drinking purposes

Samples	Parameters
5S – North of Chipepo	Cd, Pb(?)
8bS – South of Mpunde	Cd, pH, Pb
9S – Waya	Cd(?), Pb
13S – Between Mukubwe and Shamputa	Cd, Pb, Ni
16S – Ngabwe	Cd, pH, Pb
20S – North of Chibombo	Cd, Nitrates, Pb, Co, Ni
22S – Kaswende	Cd(?), Pb, Co
23S – Between Mukubwe and Shamputa	Cd, Pb, Ni
24S – Kaswende	Cd(?), pH, Pb, Co
25S – Shishimo	Cd, pH, Pb, Co, Ni
26S – Kabosha	Cd(?), pH, Pb
27S – Road between Moongo and Muundu	Cd, Pb, Co, Ni
28S – Between Muundu and Mukunkwe	Cd, pH, Nitrates, Pb(?)
29S – Between Waya and Kabwe	Cd, Nitrates, Pb, Co, Ni

Note: (?) - means that detection limit is higher than guideline value

3.6.2.1. Assessment of contamination

A) Nitrates

Natural nitrate levels in groundwater are generally very low (typically less than 10 mg/l NO_3), but nitrate concentrations grow due to human activities, such as agriculture, industry, domestic effluents, and emissions from combustion engines.

Except for the well from Ngabwe (0.04 mg/l) and perhaps the one from Kabosha (5.07 mg/l) the others show concentrations of nitrates that certainly reveal influence of human activities. Nitrate concentrations vary significantly, but levels in well water are often higher than those in surface water and, unless heavily influenced by surface water, are less likely to fluctuate. Concentrations often approach or exceed 50 mg/l where there

are significant sources of contamination (WHO, 2017). Considering the land use in the study area, these human activities refer essentially to agriculture and domestic effluents.

Results suggest that nitrates tend to be higher in wells located outside villages (cf. Appendix 1), which implies that agriculture (use of fertilizers) has higher effects on nitrates concentrations than domestic effluents.

B) Organic contamination

BOD and COD also have low values in all wells, indicating low amount of oxidizable pollutants in the water. Phosphorus shows also relatively low concentrations and higher values (>0.1 mg/l in four samples) are accompanied by high concentrations of nitrates, which indicates that inputs of phosphorus must be coming also from the agriculture activities. However, phosphorus concentrations are not yet considered high.

There is no sign of enrichment of organic compounds such as PAH, HCB or HCH.

C) Trace metals

Concentrations of certain metals (Ni, Cr, Co) are high in analysed groundwater samples (when compared to average surface water samples). The exception refers to two analysed wells dug in the Basement Complex (undifferentiated) which show low contents of Cr, Cu and Co, and low conductivity values.

In general, while Cr and Co may show higher concentrations in groundwater due to enrichment of these metals in rocks and soils from the Katanga Supergroup, other metals such as Pb, Zn, Ni and Cd may be coming also from fertilizers used.

3.6.3. Surface water

Fishing is obviously the main activity practiced in the swamp, and fishermen use its water for drinking purposes while in the swamp. Surface water of the Lukanga Swamp and streams draining into the swamp are also used for drinking by grazing animals and bathing/recreational use.



Figure 28 – Fisherman and grazing animals from the Lukanga Swamp

Table 8 shows standard and guideline values for different parameters in water for drinking and irrigation purposes. Guideline values defined for minimum environmental quality defined in European Standards were also used to have reference values for COD, BOD and P, and have a less demanding perspective on water quality.

Table 8 – Guideline and standard values for different water uses

Parameter	Drinking water		Irrigation water	Minimum Environmental Quality
	Zambian Standard	WHO Guideline	FAO Guideline	European Standards
pH	6.5 – 8.5	6.5 – 8.5	6.5 – 8.4	5.0 – 9.0
Conductivity (µS/cm)	1500	-	700 - 3000**	-
Chemical Oxygen Demand (mg/L)	-	-	-	30.0***
Biochemical Oxygen Demand (mg/L)	-	-	-	5.0
Nitrates (NO3-)	44.3	50	22.15 – 132.9**	-
Phosphorus	-	-	-	1.0
As (mg/l)	0.01	0.01	0.1¥	0.1
Cd (µg/L)	0.003	0.003	0.01¥	0.01
Cr (mg/L)	0.05	0.05	0.1¥	0.05
Co (mg/l)	0.5	-	0.05¥	-
Cu (mg/l)	1.0	2.0	0.2¥	0.1
Hg (mg/l)	0.001	0.006	-	0.001
Pb (mg/L)	0.01	0.01	5¥	0.05
Zn (mg/L)	3.0	-	2.0¥	0.5

Notes: ǂ Maximum values recommended assuming there will be physical treatment and disinfection of the water to be potable;
* Recommended maximum value assuming physical and chemical treatment for tuning and disinfection of the water to be potable
** Interval corresponds to “slight to moderate” degree of restriction class; ¥ Recommended Maximum Concentration; *** According to European Standards, it must be below 30 mg/l to be able to be treated for human consumption

Almost all water samples have problems for the different uses analysed. Exceptions are 1Oc (Kafubu River – upstream from Luanshya River), 15Oc (Lubengele Stream), 18Oc (Kafue River – upstream from Chingola, and immediately upstream from the public water abstraction plant) (Table 9).

Upstream from sample 18Oc in the Kafue River, samples 11Oc and 12 Oc do not respect the minimum environmental quality of European Standards and this is due to BOD, COD, Cu and BOD, respectively. The same happens to sample 10Oc (BOD), located downstream from sample 18Oc and upstream from Kitwe. However, according to the analysed parameters and to the Zambian Standard and WHO guidelines this water could be used for drinking purposes. Note that microbiological parameters were not analysed. According to FAO guidelines this water could also be used for irrigation.

Downstream from Kitwe, samples 8Oc and 5Oc are in the “slight to moderate” degree of restriction class for irrigation due to pH. The former is also restricted for drinking purposes because of pH. Both samples and samples 6Oc and 7Oc (located in the Kafue River downstream from 5Oc) do not respect the minimum environmental quality of European standards because of BOD.

In the Kafubu River Basin, as referred above, sample 1Oc respects all guidelines analysed. Downstream from that area all three samples fail to reach the minimum environmental quality of European standards because of BOD (3Oc, 4Oc, 22Oc) and COD (22Oc).

A similar situation occurs in samples collected from the Lufwanyama and Luswishi rivers because of high values of BOD.

Samples collected in the Kafue River close to the Lukanga Swamp fail all the water uses because of concentrations of Cd, Cu and Pb.

Inside the swamp only two inner samples (25Oc and 26Oc) show good results for drinking purposes. Note however that microbiological parameters were not analysed. Sample 25Oc also shows good results for irrigation purposes. None of the samples would pass the minimum environmental quality of European standards and this is because of BOD, COD and P in the inner samples and because of metals in outer samples.

Table 9 – Analysis of surface water samples for different water uses considering different guidelines values

Sta./Param.	pH	Cond.	COD	BOD	NO3-	P	As	Cd	Cr	Co	Cu	Hg	Pb	Zn	S/GNC
1S	8.26	483	<4	<1	10.05	0.0031	<0.2	0.23	0.009	0.0009	0.3247	<0.3	0.2664	0.2247	**ZS** (Cd, Pb) **WHO** (Cd, Pb) **FAO** (Cu) **ES** (Cu)
2S	7.62	268	<4	1	0.13	0.0034	<0.2	0.41	0.002	0.0600	0.1034	<0.3	1.346	<0.002	**ZS** (Cd, Pb) **WHO** (Cd, Pb) **FAO** (Cd, Co) **ES** (Cd, Cu, Pb)
3S	7.51	218	13	1	21.45	0.0012	<0.2	0.17	0.003	0.001	0.207	<0.3	0.7376	0.3348	**ZS** (Cd, Pb) **WHO** (Cd, Pb) **FAO** (Cd, Cu) **ES** (Cd, Cu, Pb)
4S	7.51	474	<4	<1	30.54	0.3023	<0.2	0.23	0.001	0.0021	0.0618	<0.3	0.8018	0.1177	**ZS** (Cd, Pb) **WHO** (Cd, Pb) **FAO** (Cd, NO3) **ES** (Cd, Pb)
6S	6.64	347	43	1	4.01	0.043	<0.2	<0.005	0.014	<0.0005	0.0521	<0.3	0.3473	0.2153	**ZS** (Pb) **WHO** (Pb) FAO **ES** (COD, Pb)
7S	6.94	283	23	4	11.23	0.0071	<0.2	0.11	0.0041	0.0891	0.0843	<0.3	1.856	0.3516	**ZS** (Cd, Pb) **WHO** (Cd, Pb) **FAO** (Cd, Co) **ES** (Cd, Pb)
8aS	7.89	684	39	<1	10	0.0065	<0.2	0.24	0.0001	0.102	0.088	<0.3	0.8624	0.295	**ZS** (Cd, Pb) **WHO** (Cd, Pb) **FAO** (Cd, Co) **ES** (Cd, COD. Pb)
10S	7.34	161	8	1	11.9	0.0065	<0.2	0.05	0.0145	0.0369	0.6669	<0.3	0.0467	0.9794	**ZS** (Cd, Pb) **WHO** (Cd, Pb) **FAO** (Cd, Cu) **ES** (Cd, Cu, Zn)
11S	7.18	196	17	1	17.01	0.0002	<0.2	0.22	0.0021	<0.0005	0.0646	<0.3	0.9295	<0.002	**ZS** (Cd, Pb) **WHO** (Cd, Pb) **FAO** (Cd) **ES** (Cd, Pb)
12S	7.43	320	4	<1	12.87	0.034	<0.2	0.03	0.0011	<0.0005	0.0891	<0.3	1.089	0.4835	**ZS** (Cd, Pb) **WHO** (Cd, Pb) **FAO** (Cd) **ES** (Cd, Pb)
14S	8.36	505	<4	1	14.76	0.002	<0.2	0.19	<0.0001	0.1002	0.0591	<0.3	1.203	0.2149	**ZS** (Cd, Pb) **WHO** (Cd, Pb) **FAO** (Cd, Co) **ES** (Cd, Pb)

Notes: Conductivity is expressed in µS/cm and the other are in mg/l; S/GNC – Standard/Guideline Non-Compliance; dark orange cells: values failing water quality standards used; light orange cells: values below the detection limits.

Table 9 – Analysis of surface water samples for different water uses considering different guidelines values (cont.)

Sta./Param.	pH	Cond.	COD	BOD	NO3-	P	As	Cd	Cr	Co	Cu	Hg	Pb	Zn	S/GNC
15S	7.21	707	<4	<1	0.0067	0.024	<0.2	<0.005	0.0084	0.0177	0.0773	<0.3	1.244	0.6944	**ZS** (Cd, Pb) **WHO** (Cd, Pb) **FAO** (Cond.) **ES** (Pb, Zn)
18S	7.48	452	<4	<1	53.56	0.0932	<0.2	0.10	<0.0001	0.0129	0.957	<0.3	1.157	0.0933	**ZS** (Cd, Pb, NO3) **WHO** (Cd, Pb, NO3) **FAO** (Cd, Cu, NO3) **ES** (Cd, Cu, Pb)
21S	8.05	1324	85	<1	104.08	0.174	<0.2	0.23	<0.0001	0.0125	0.0746	<0.3	0.8908	0.3269	**ZS** (Cd, NO3, Pb) **WHO** (Cd, NO3, Pb) **FAO** (Cd, Cond, NO3) **ES** (Cd, COD, Pb)
1Oc	6.86	398	2.5	1.4	1.54	0.3	< 0.01	< 0.001	< 0.001	< 0.001	< 0.01	< 0.05	< 0.01	< 0.006	ZS WHO FAO ES
2Oc	6.94	393	19	11.1	1.21	0.2	< 0.01	< 0.001	< 0.001	< 0.001	< 0.01	< 0.05	< 0.01	< 0.006	ZS WHO FAO **ES** (BOD)
3Oc	7.2	391	13	10.8	1.90	0.3	< 0.01	< 0.001	< 0.001	< 0.001	< 0.01	< 0.05	< 0.01	< 0.006	ZS WHO FAO **ES** (BOD)
4Oc	6.95	349	17	8.6	1.64	0.2	< 0.01	< 0.001	< 0.001	< 0.001	< 0.01	< 0.05	< 0.01	< 0.006	ZS WHO FAO **ES** (BOD)
5Oc	8.47	576	26	11.1	1.36	0.2	< 0.01	< 0.001	< 0.001	0.002	0.02	< 0.05	< 0.01	< 0.006	ZS WHO **FAO** (pH) **ES** (BOD)
6Oc	8.16	552	15	14.7	1.66	0.6	< 0.01	< 0.001	< 0.001	< 0.001	< 0.01	< 0.05	< 0.01	< 0.006	ZS WHO FAO **ES** (BOD)
7Oc	8.13	533	29	25.6	1.80	0.2	< 0.01	< 0.001	< 0.001	< 0.001	< 0.01	< 0.05	< 0.01	0.089	ZS WHO FAO **ES** (BOD)
8Oc	6.16	628	14	11.4	3.95	0.7	< 0.01	< 0.001	< 0.001	0.014	< 0.01	< 0.05	< 0.01	< 0.006	**ZS** (pH) **WHO** (pH) **FAO** (pH) **ES** (BOD)

Notes: Conductivity is expressed in µS/cm and the other are in mg/l; S/GNC – Standard/Guideline Non-Compliance; dark orange cells: values failing water quality standards used; light orange cells: values below the detection limits.

Table 9 – Analysis of surface water samples for different water uses considering different guidelines values (cont.)

Sta./Param.	pH	Cond.	COD	BOD	NO3-	P	As	Cd	Cr	Co	Cu	Hg	Pb	Zn	S/GNC
9Oc	8.67	1785	22	5.4	7.76	< 0.1	< 0.01	< 0.001	< 0.001	0.098	0.66	< 0.05	< 0.01	< 0.006	**ZS** (Cond, pH) **WHO** (pH) **FAO** (Cond, Co, Cu, pH) **ES** (BOD, Cu)
10Oc	7.73	590	19	13	2.01	0.1	< 0.01	< 0.001	< 0.001	0.001	0.03	< 0.05	< 0.01	< 0.006	ZS WHO FAO **ES** (BOD)
11Oc	7.76	528	56	9.2	2.25	0.3	< 0.01	< 0.001	< 0.001	0.016	0.17	< 0.05	< 0.01	< 0.006	ZS WHO FAO **ES** (COD, Cu, BOD)
12Oc	7.96	221	20	6.6	1.05	0.4	< 0.01	< 0.001	< 0.001	< 0.001	< 0.01	< 0.05	0.01	< 0.006	ZS WHO FAO **ES** (BOD)
13Oc	8.1	423	16	11.9	1.50	0.4	< 0.01	< 0.001	< 0.001	< 0.001	< 0.01	< 0.05	< 0.01	< 0.006	ZS WHO FAO **ES** (BOD)
14Oc	7.87	431	15	11.4	1.31	0.2	< 0.01	< 0.001	< 0.001	< 0.001	< 0.01	< 0.05	< 0.01	0.007	ZS WHO FAO **ES** (BOD)
15Oc	7.46	230	14	3.3	2.08	0.3	< 0.01	< 0.001	< 0.001	< 0.001	0.03	< 0.05	< 0.01	< 0.006	ZS WHO FAO ES
16Oc	7.36	1079	50	10.3	1.57	0.4	< 0.01	< 0.001	< 0.001	0.025	0.13	< 0.05	< 0.01	< 0.006	ZS WHO **FAO** (Cond) **ES** (BOD, COD, Cu)
17Oc	7.49	6039	40	12	1.81	0.5	< 0.01	< 0.001	< 0.001	4.997	0.42	< 0.05	0.02	0.024	**ZS** (Co, Pb, Cond) **WHO** (Pb) **FAO** (Co, Cu, Cond) **ES** (Cu, COD)
18Oc	8.01	493	13	1.3	2.35	0.2	< 0.01	< 0.001	< 0.001	0.014	0.08	< 0.05	< 0.01	< 0.006	ZS WHO FAO ES
19Oc	7.4	552	25	21.8	15.05	0.5	< 0.01	< 0.001	< 0.001	0.005	0.11	< 0.05	< 0.01	< 0.006	ZS WHO FAO **ES** (BOD, Cu)

Notes: Conductivity is expressed in µS/cm and the other are in mg/l; S/GNC – Standard/Guideline Non-Compliance; dark orange cells: values failing water quality standards used; light orange cells: values below the detection limits.

Table 9 – Analysis of surface water samples for different water uses considering different guidelines values (cont.)

Sta./Param.	pH	Cond.	COD	BOD	NO3-	P	As	Cd	Cr	Co	Cu	Hg	Pb	Zn	S/GNC
20Oc	7.84	47	19	13.6	0.28	0.5	< 0.01	< 0.001	< 0.001	< 0.001	< 0.01	< 0.05	< 0.01	0.029	ZS WHO FAO **ES** (BOD)
21Oc	7.84	248	21	13.6	0.95	0.5	< 0.01	< 0.001	< 0.001	< 0.001	< 0.01	< 0.05	< 0.01	< 0.006	ZS WHO FAO **ES** (BOD)
22Oc	8	389	37	10.8	0.95	0.6	< 0.01	< 0.001	< 0.001	< 0.001	< 0.01	< 0.05	< 0.01	< 0.006	ZS WHO FAO **ES** (COD, BOD)
23Oc	7.26	1646	16	11.9	2.23	0.3	< 0.01	< 0.001	< 0.001	0.016	< 0.01	< 0.05	< 0.01	< 0.006	**ZS** (Cond) WHO **FAO** (Cond) **ES** (BOD)
24Oc	7.5	646	36	22.9	2.70	0.8	< 0.01	< 0.001	< 0.001	0.001	< 0.01	< 0.05	< 0.01	< 0.006	ZS WHO FAO **ES** (COD, BOD)
25Oc	7.93	410	27	8.7	3.23	0.62	< 0.01	0.001	< 0.001	0.002	< 0.01	< 0.05	< 0.01	0.012	ZS WHO FAO **ES** (BOD)
26Oc	7.85	789	49	14.8	3.54	1.04	< 0.01	< 0.001	< 0.001	< 0.001	< 0.01	< 0.05	< 0.01	0.014	ZS WHO **FAO** (Cond) **ES** (COD, BOD, P)
27Oc	8.02	1263	121	12.0	6.37	1.50	< 0.01	< 0.001	< 0.001	< 0.001	< 0.01	< 0.05	< 0.01	0.034	**ZS** (Cond) WHO **FAO** (Cond) **ES** (COD, BOD, P)
28Oc	9.12	269	15	6.5	1.41	0.39	< 0.01	< 0.001	< 0.001	< 0.001	< 0.01	< 0.05	< 0.01	< 0.006	**ZS** (pH) **WHO** (pH) **FAO** (pH) **ES** (BOD)

Notes: Conductivity is expressed in µS/cm and the other are in mg/l; S/GNC – Standard/Guideline Non-Compliance; dark orange cells: values failing water quality standards used; light orange cells: values below the detection limits.

In water streams draining to the swamp, none of the samples show good results for drinking purposes (ZS and WHO) and they do not respect the minimum environmental quality of European standards. Samples from the north part of the swamp fail due to metal concentrations. Samples from the south fail due to metals and nitrates. Two of these samples (15S and 6S) were collected very close to springs and even those show low patterns of water quality.

3.6.3.1. Assessment of contamination

In general, quality of surface water is a function of both natural influences and human activities. Without human influences, water quality would be determined by: 1) weathering of bedrock minerals; 2) atmospheric processes; 3) natural leaching of organic matter and nutrients from soil, 4) hydrological factors that lead to runoff; 5) biological processes within the aquatic environment that can alter the physical and chemical composition of water (UNEP, 2006).

However, water quality is also affected by human induced factors like soil erosion from agriculture and mining activities, lack of wastewater treatment facilities, application of pesticides and fertilizers, and so forth.

A) Nitrates

The Lukanga Swamp Area is enriched in nitrates. Concentrations show the following trend: Streams draining into the swamp (>30 mg/l) > Near shore water (>10 mg/l) > Swamp inner water (>1.5 mg/l). Considering the land use in the study area, this trend indicates agriculture and/or domestic effluents as the source for nitrates in surface water. However, the values and distribution patterns of BOD and COD (below) indicate that the origin of nitrates is agriculture, and this conclusion is in accordance to groundwater data (above).

B) Organic contamination

In the Copperbelt area COD tends to increase in the Kafue River while crossing main cities (Chingola and Kitwe), which implies sources of organic matter from industrial and household sources.

In the Lukanga Swamp area, concentrations show the following trend: Swamp inner water (15 - 121 mg/l) > Near shore water (4 - 85 mg/l) > Streams draining into the swamp (<4 - 17 mg/l). In the swamp area the origin for the organic material is not wastewater but rather natural decomposition of vegetation inside the swamp. Relatively similar results are obtained for BOD with higher values inside the swamp.

There is no sign of enrichment of organic compounds such as PAH, HCB or HCH.

C) Trace metals

In the Lukanga, except for Cr and Co, which show relatively low concentrations in surface water, concentrations of dissolved metals (Cu, Zn, Pb, Cd, Ni) vary considerably throughout the whole system.

Sources for these metals in the area go from the use of fertilizers rich in Zn and Cd to dust fallout coming from smelters in Kabwe, particularly enriched in Pb and Zn. Tembo *et al*. (2006) and Kribek *et al*. (2018) conclude that around Kabwe topsoil has been contaminated with metals by dust fallout from smelters operating in the city. Given the prevailing wind direction to the West and Northwest the study area is in fact in the path of this dust.

Rock formations of the Lukanga area also show local enrichments in metals [e.g. pyrite and pyrrhotite are common accessory minerals in lower Kundelungu marble; aggregates of pyrite occur scattered throughout quartz veins – Vrana (1974)].

In the Copperbelt, typical waste rocks and tailings contain pyrite and have high metal concentrations, in particular of Cu and Co. Due to high carbonate content, resulting in a high buffering capacity, sulphide oxidation does not result in a major production of acid drainage (Pettersson, 2002).

During the rainy season, it is likely that washout of secondarily retained weathering products from mining waste is the main source for Cu and other metals in the Kafue

River. During the low discharge season, point sources such as the Konkola mine (Muchichima stream) and the Muntimpa dam have a major influence on the water quality of the river. However, data here presented also indicate that the Uchi and Wusakili streams may have been releasing acid water into the Kafue River during the period of the field visits (October 2019).

According to Pettersson (2002), during this season water from the Konkola mine may contribute about 40% of the total discharge of the river. The mine water has high concentration of Ca and S from pyrite oxidation and carbonate buffering and a relatively high Cu concentration, and therefore has a strong influence on the water quality of the river. These observations are also visible from our data in the Kafue River, and in October 2019 the streams coming from the referred dam and mine have the highest conductivity value recorded and the highest concentration of Co, Zn, Cu and Ni, and other parameters.

3.6.4. Sediment

Chemical and physical analyses were performed to the 21 sediment samples collected in the Lukanga Swamp area and the upper Kafue River. Grain-size results, and concentrations of metals, metalloids, organic compounds, and total organic carbon are shown in more detail in the complete assessment (Appendix 2).

3.6.4.1. Grain-size analysis

Grain-size analysis shows that “sand” and “loamy sand” dominate sediment analysed. However, sediment samples span from a classification of clay (maximum value of 50% in sample 6) to sand (maximum value of 94% in sample 15).

Table 10 – Specific weight and grain-size classification of sediment samples collected in the Lukanga Swamp Area and Upper Kafue River Basin

Sta./Param.	Specific weight (g/l)	Grain-size (%)				Classification*
		< 2 µm	2 - 63 µm	63 µm - 2 mm	> 2 mm	
1	2179	43	27	26	4	Clay
2	2565	5.8	15.2	76	3	Loamy Sand
3	2190	<1	15	73	11	Loamy Sand
4	2556	<1	3.8	93.2	2	Sand
5	2716	2.8	59.2	25	13	Silt Loam
6	2147	50	15	24	11	Clay
7	2338	29	7	45	19	Sandy Clay Loam
8	2419	8	55	11	26	Silt Loam
9	2570	<1	12	80	7	Sand
10	2141	49	19	21	11	Clay
11	2546	<1	5.5	90.5	3	Sand
12	2071	14	26	16	44	Sandy Loam
13	2487	15	21	64	0	Sandy Loam
14	2514	1.9	3.8	92.3	2	Sand
15	2514	<1	4.2	93.8	1	Sand
16	2256	34	42	14	10	Clay Loam
17	2505	8.5	19.5	67	5	Sandy Loam
18	2432	24	22	46	8	Sandy Clay Loam
19	2300	30	21	38	11	Sandy Clay Loam
26	1821	26	10	17	47	Sandy Clay Loam
27	2114	11	14	39	36	Sandy Loam

*Classification according to Figure 29

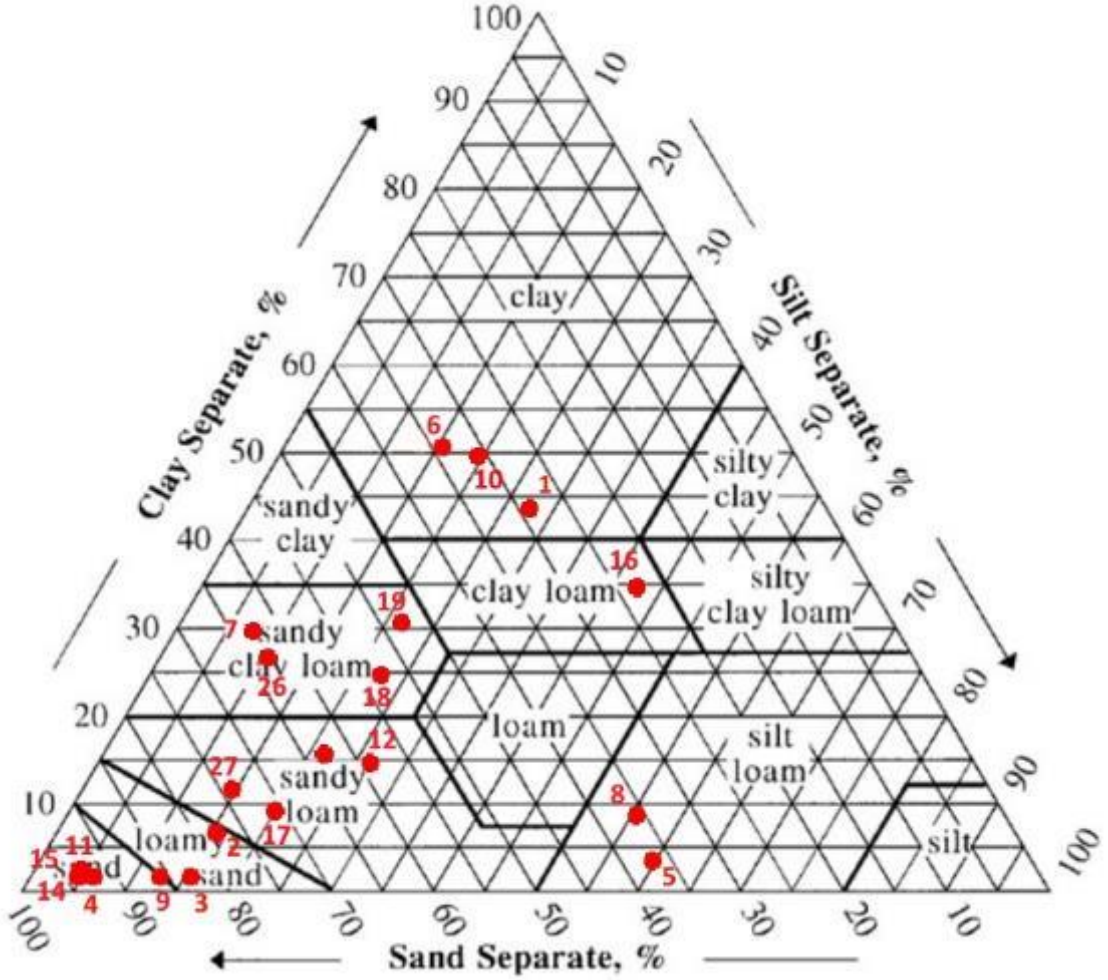


Figure 29 – Sediment texture classification triangle plot for sediment samples collected in the Lukanga Swamp area and Upper Kafue River Basin

3.6.4.2. Chemical analyses

Major elements Al and Fe show average low concentrations of 1.8% (range from 0.1% to 4.5%) and 1.9% (0.2% - 8.5%), respectively. In accordance, concentration of clay-sized particles is also relatively low (average = 17%, range = <1% - 50%).

These sediments have low contents of aluminosilicates and are probably enriched in other types of minerals such as quartz, carbonates or even sulphides. In accordance, Vrana (1974) for the area south of the Lukanga Swamp states that most of the area is covered by eluvial soils of the Plateau type, which are fine- to medium-grained sandy soils, with low content of clay at the surface.

Copper is the trace metal with the highest concentrations (average of 888 mg/kg), followed by Co (average of 91 mg/kg), Cr (average of 34 mg/kg) and Zn (average of 30 mg/kg).

Metal concentrations are in fact higher in the Copperbelt area in comparison to the Lukanga Swamp, respectively (average values):

- Cu – 2247 vs. 44 mg/kg;
- Co – 222 vs. 10 mg/kg;
- Zn – 59 vs. 13 mg/kg*;
- Cr – 47 vs. 34 mg/kg;
- Ni – 19 vs. 14 mg/kg;
- Pb – 14 vs. 7 mg/kg*;
- Fe – 2.5 vs. 1.7%;
- Al – 2.0 vs. 1.8%.

* More than half of the samples have concentrations below the detection limits so these average values must be looked at with caution.

Except for sample 16 (Copperbelt), Cd and Hg concentrations are consistently below detection limits.

Sediments collected in the Lukanga Swamp area are characterised by high contents of organic carbon (organic matter) with average value of 2.9% (<0.1% - 5.7%). On the other hand, sediments collected in the Copperbelt area show low contents of organic matter (average TOC of 0.8%; range between <0.1% and 3.3%). Regarding metals, TOC only correlates significantly with Al (Table 11). This correlation is higher if samples from the Lukanga and Copperbelt areas are analysed separately (not shown).

Table 11 – Spearman correlations between metals and organic carbon and grain-size parameters

Metals	TOC	% clay	% fine-grained fraction
Al	0.56, p 0.03	0.79, p 2E-05	0.78, p 3E-05
As	-	0.01, p 0.98	0.06, p 0.89
Co	-0.35, p 0.21	0.02, p 0.93	0.26, p 0.25
Cu	-0.21, p 0.46	0.02, p 0.94	0.24, p 0.29
Cr	-0.03, p 0.91	0.39, p 0.08	0.36, p 0.11
Fe	-0.44, p 0.10	0.11, p 0.64	0.27, p 0.23
Pb	-	0.48, p 0.27	0.42, p 0.34
Ni	0.48, p 0.07	0.51, p 0.02	0.53, p 0.01
Zn	-	0.51, p 0.19	0.71, p 0.05

3.6.4.3. Comparison with quality guidelines

The sediment quality guideline (SQG) of the National Oceanic Atmospheric Administration (NOAA), developed to assess biological effects of metal contamination, classifies different levels of metal concentration as “Effects Range-Low” (ERL) and “Effects Range-Medium” (ERM). These ERL and ERM represent, respectively, the 10th and 50th percentiles of the available dataset for different trace metal components (Long *et al*., 1995). The ERMs are supposed to represent concentrations above which adverse biological effects are expected to be common (between 17% and 95%, depending on the parameter), whereas ERLs represent concentrations below which effects are expected to be rare. Between these values effects are expected to happen occasionally. Obviously, this classification is rather arbitrary since it is merely based on the statistics of the available data, and chemical concentrations do not directly correspond to sediment toxicity (O’Connor & Paul, 2000).

Table 12 summarises the comparison between concentrations of different parameters and NOAA’s sediment quality guidelines. According to the results there are higher probabilities of having toxicity for all metals in sediments from those places sampled in the Copperbelt Province. Total concentrations of PAH are always below ERL in both areas.

Copper is the element with highest number of samples above ERL, and the only one with concentrations above ERM, which occur in the Copperbelt Province. For this specific element and threshold, adverse biological effects are expected in 83.7% of the cases.

Nickel is the following metal with the highest number of samples above ERL in both areas. Arsenic and Cr are the following ones with samples above ERL in both areas. On the other hand, Pb and Zn only have samples above ERL in the Copperbelt Province (Table 12).

Table 12 – Percentage of sediment samples above the ERL and ERM

Parameters	Lukanga (13 samples)		Copperbelt (8 samples)	
	ERL (%)	EML (%)	ERL (%)	EML (%)
As	7.7	0	12.5	0
Cr	7.7	0	12.5	0
Cu	46.2	0	12.5	87.5
Pb	0	0	12.5	0
Ni	15.4	0	37.5	0
Zn	0	0	12.5	0
PAH	0	0	0	0

Looking into the Lukanga Swamp Area, sample 4 (located near Chitanda) has higher concentrations than ERL for four elements (As, Cr, Cu and Ni), and sample 12 (near Shishimo) for two elements (Cu and Ni). The other 4 samples have higher concentrations than ERL values only for Cu.

3.6.4.4. Assessment of contamination

The assessment of sediment contamination included analysis of metals (Al, As, Cd, Cu, Cr, Co, Fe, Hg, Ni, Pb, Zn).

Results show that Hg and Cd are not contaminants in the sediment analysed as they show concentrations almost consistently below detection limits.

To study the enrichment of trace metals in sediments different approaches will be used according to the metal. For Co, Cu, Cr, As and Ni enrichment factors will be used because these elements show positive correlations with conservative common element (Al and Fe). Given the correlations found between metals (Appendix 2), Fe was used as normaliser for Co, Cu, Cr, As, and Al for Ni. Enrichment factors will not be calculated for Pb and Zn because they do not show a significant positive correlation with any of the above normalisers.

A) Concentrations of Pb and Zn

Most of the collected sediment samples show low concentrations of Pb (<10 mg/kg) and Zn (<50 mg/kg). The only exception is a sample collected downstream from Kitwe in the Kafue River which has 60 mg/kg of Pb and 250 mg/kg of Zn.

The relatively low inputs of Pb and Zn in the Kafue River along the industrial Copperbelt area is also shown in Kribek *et al*. (2011). These authors show that Pb concentrations go from 4 -13 mg/kg to 15 - 34 mg/kg and from 45 – 80 mg/kg to 38 – 73 mg/kg for Zn, from upstream to downstream of the industrial Copperbelt area, respectively.

In the Lukanga Swamp, Pb concentrations are consistently lower than 15 mg/kg. These values are in accordance with concentrations found in non-contaminated areas:

- 4 – 13 mg/kg in sediments from the Kafue River (upstream from industrial Copperbelt area) (Kribek *et al.*, 2011);
- 9.0 – 9.7 mg/kg in topsoil samples from 20 km to the north and east of Kabwe mine (Tembo *et al*., 2006).

Concentrations of Zn are lower than 27 mg/kg, and as referred above these values are even lower than those found in non-contaminated areas of the Kafue River.

B) Enrichment factors

To calculate enrichment factors (EF), trace metal contents were normalised using a conservative common element.

To calculate EF ideally one should use local background concentrations. However, these are not always available. For this reason, mean concentrations of metals at Chimfunshi published in M'kandawire *et al.* (2017) were used. This is an upstream preindustrial site located in the Kafue River. So, in this report when one says sediment is enriched in a given metal it is in relation to this area.

From the highest number of samples with EF > 1.5 to the lowest results show the following succession: As (75%) > Cu (48%) > Co (38%) ~ Ni (38%) > Cr (5%) (Table 13).

The relatively high percentage of samples enrichment in As occurs because most of the samples analysed have concentrations below the detection limit (< 4 mg/kg) and so EF were not calculated in these.

In the Lukanda Swamp and water streams draining into it (excluding the Kafue River samples 1 and 14) Cu, Cr and Co show no signs of enrichment in comparison to Chimfunshi. Regarding Ni, only sample 4 (Chiyuni River, near Chitanda) shows enrichment. For As, enrichment could only be determined in some samples (4, 18, 19), and all of them show enrichment; besides the Chiyuni River, sample 18 was collected in the Mundu River and 19 in the Waya channel.

Table 13 – Summary of results for the sediment enrichment factors

Element	Lukanga		Copperbelt	
	Number Samples above 1.5	Average EF value	Number Samples above 1.5	Average EF value
As	3 (out of 3)	3.3	3 (out of 5)	1.7
Cr	1 (out of 13)	0.8	0 (out of 8)	0.6
Co	1 (out of 13)	0.7	7 (out of 8)	6.5
Cu	2 (out of 13)	0.9	8 (out of 8)	18.1
Ni	3 (out of 13)	1.5	5 (out of 8)	1.8

It is not surprising that these rivers and channel show some As and Ni enrichments as:

- Some garbage was observed there during the field surveys; and
- There is high sediment turbation. Sediment turbation occurs in these rivers because it is common to see cattle there; for the Waya channel, resuspension occurs due to frequent boat transit propelled by sticks in them. In addition, children were observed bathing in these water streams.



a – Chiyuni River



b – Muundu River



C – Waya Channel

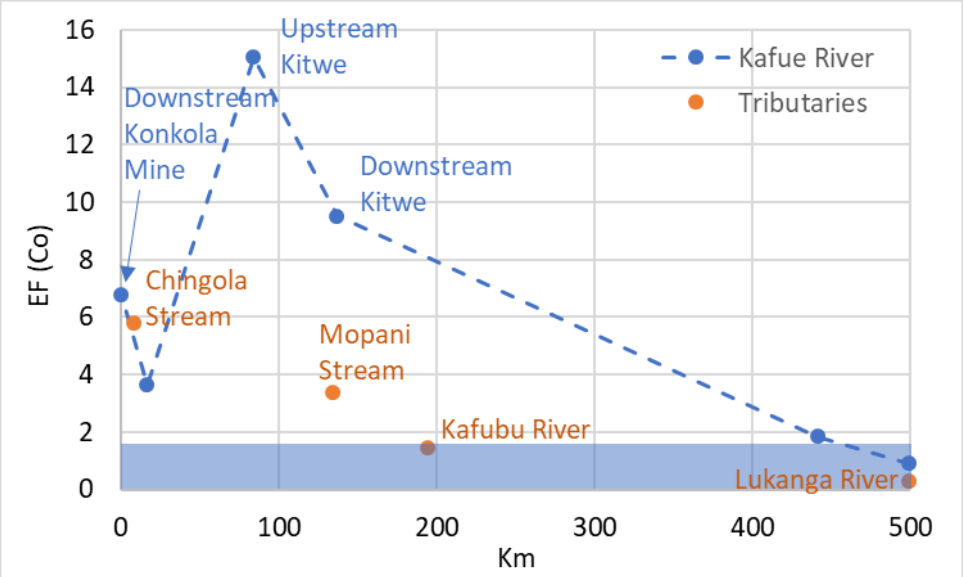
Figure 30 – Sediment sampling stations 4 (a), 18 (b) and 19 (c)

Arsenic may also be of natural origin in these sediments.

As expected, the highest EF values were found for Cu and Co in the Copperbelt Province. The distribution of EF(Co) along the Upper Kafue River Basin (Figure 31) show that:

- Cobalt is enriched in the Kafue River until around its junction with the Lukanga River;

- Chingola and Mopani streams are also enriched in Co;
- The highest enrichment of Co was found upstream from Kitwe and downstream from the junction of the river with the Chingola stream. The source for this Co is certainly from upstream Kitwe and it may be accumulating in this area for reasons related to hydrodynamics of the river.
- The Kafubu River shows no sign of Co enrichment, however a sediment sample collected in the Luanshya River (upstream tributary of the Kafubu River) shows EF of 6. These results suggest that the amount of unenriched sediment from the Kafubu River is enough to dilute the enriched contributions of the Luanshya River.
- There are no signs of Co entering in the Lukanga Swamp coming from the Kafue River.



Note: Blue bar highlights values below 1.5

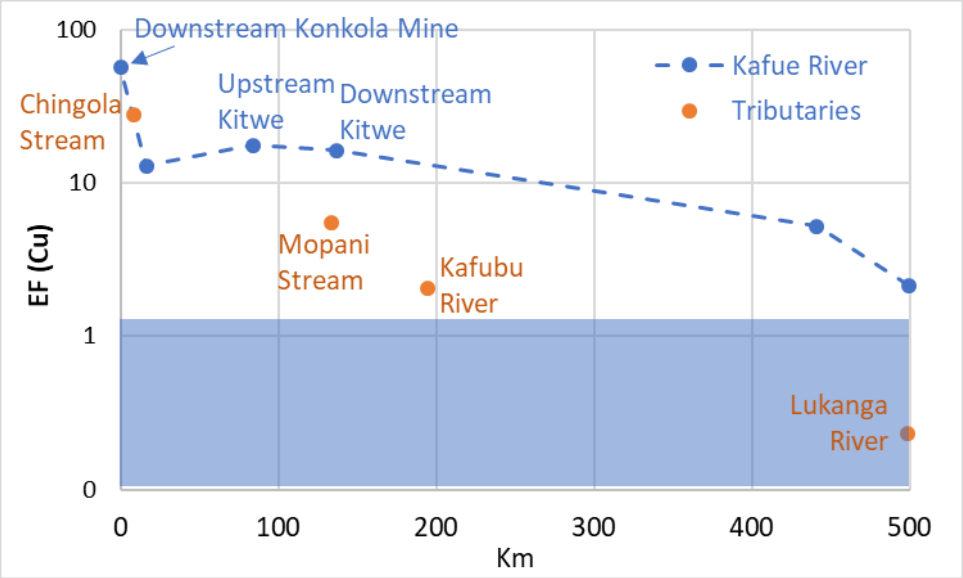
Figure 31 – EF(Co) in sediments collected in the Kafue River and selected tributaries

The distribution of EF(Cu) along the Upper Kafue River Basin (Figure 32) shows that:

- Copper is enriched in the Upper Kafue River, including the area of the junction with the Lukanga Swamp.
- Chingola, Mopani and Kafubu streams are also enriched in Cu.
- The highest enrichment of Cu was found downstream Konkola mine, but values continue high in the Kafue river even downstream Kitwe.
- The Kafubu River shows EF(Cu) of 2, and the sediment sample collected in the Luanshya River (upstream tributary of the Kafubu River) shows EF of 6.

These results are in accordance with the above idea of dilution along the Kafubu River.

- Despite existing sediments enriched in the downstream part of the Upper Kafue River, there are no evidence that this metal enters into the Lukanga Swamp.



Note: Blue bar highlights values below 1.5

Figure 32 – EF(Cu) in sediments collected in the Kafue River and selected tributaries

3.6.5. Leaves

Bulk concentrations of metals in the analysed leaves follow the pattern: [Zn] > [Cu] > [Cr] ~ [Co] ~ [Ni] > [Pb] ~ [As] > [Hg] ~ [Cd]. Results from analyses performed in leaves are summarised in Table 14.

Table 14 – Elemental concentration in composite leaf samples (in mg/kg)

Sta./Param.	As	Cd	Co	Cu	Cr	Pb	Hg	Ni	Zn
28 – Luk	0.0089	0.0034	0.024	1.5	0.40	0.170	0.0032	0.23	**30**
29 – Luk	0.036	0.0010	0.18	6.6	**1.10**	0.098	0.0045	0.65	26
27 – Luk	0.120	0.0017	0.023	3.9	0.40	0.290	0.0035	0.36	16
25 – Luk	0.110	0.0013	0.013	1.0	0.13	0.049	0.0040	0.10	21
26 – Luk	0.031	0.0020	0.022	3.6	0.24	**0.300**	0.0028	0.18	15
16 – CoBelt	**0.330**	**0.0036**	0.46	12	**1.10**	0.160	0.0036	0.47	7.9
2 – CoBelt	0.011	0.0009	0.049	5.4	**1.10**	0.028	0.0026	**1.00**	11
11 – CoBelt	0.140	0.0022	**1.10**	**19**	**1.10**	0.063	0.0030	0.87	7.5
15 – CoBelt	0.084	0.0030	0.41	12	0.75	0.100	**0.0049**	0.44	11
17 – CoBelt	0.048	0.0021	0.99	11	0.58	0.072	0.0043	0.34	14
AVG – Luk	*0.061*	*0.002*	*0.052*	*3.320*	*0.454*	*0.181*	*0.004*	*0.304*	*21.60*
AVG – CoBelt	*0.123*	*0.002*	*0.602*	*11.880*	*0.926*	*0.085*	*0.004*	*0.624*	*10.28*

Notes: Stat. – Station; Param. – Parameters; Luk – Samples collected in the Lukanga Swamp area; CoBelt – Samples collected in the Copperbelt Province.
Underlined concentrations are minimums and **bold concentrations** are maximums for that specific element.

In the same way as it happens for sediments, there is a predominance of maximum concentrations in the Copperbelt Province and of minimum concentrations in the Lukanga Swamp area (Table 14). In fact, only Pb and Zn behave the other way around.

The comparison between both areas becomes easier when analysing them through box plots for the different elements (Appendix 2). Through these it becomes clear that distributions of Zn, Cu and Co are indeed different in the two areas. Sampled leaves from the Lukanga Swamp area have higher concentrations of Zn, while sampled leaves from the Copperbelt Province have higher concentrations of Cu and Co.

Mean concentrations of As, Cr, Ni, Cd and Hg are also higher in the Copperbelt Province but both distributions intercept greatly, so the distinction is less clear (Appendix 1). On the other hand, Pb seems also to be higher in the Lukanga Swamp area.

3.6.5.1. Comparison with reference values; assessment of contamination

In order to assess the presence of excess or toxic amounts of metals (or metalloids in the case of As) in leaves, the concentrations found are compared to reference values summarised in Kabata-Pendias (2011). These are a range of concentrations of trace elements in mature leaf tissue generalised for various species.

The comparison shows that all but one concentration are below excessive or toxic concentrations. The one sample with concentrations very close (< 2 mg/kg) to excessive or toxic concentrations refers to sample 11 collected in the Copperbelt Province (sampling location is presented in Appendix 2).

In Vymazal *et al.* (2007) metal concentrations from different portions of *Phragmites australis* and *Phalaris arundinacea* are analysed and compared with concentrations found in both natural and constructed wetlands around the world.

Metal concentrations found in leaves here analysed are only comparable to those referred in Vymazal *et al.* (2007) for Cu and Zn. The other metals that are indicated in the referred study (Cd, Cr, Pb, Ni) have concentrations similar to the lowest concentrations found in these studies (Table 15).

Table 15 – Comparison of average concentrations found in leaves with those from leaves of *Phragmites* spp. in natural and constructed wetlands around the world

Stat./Param.	As	Cd	Co	Cu	Cr	Pb	Hg	Ni	Zn
AVG (range) leaves Vymazal *et al.* (2007)	-	2.3 (0.03 – 9.7)	-	7.3 (1.5 – 72)	4.1 (0.39 – 15)	16.9 (0.1 – 264)	-	4.9 (0.64 – 20.7)	22.1 (10 – 277)
AVG – Luk	*0.061*	*0.002*	*0.052*	*3.3*	*0.45*	*0.18*	*0.004*	*0.30*	*21.6*
AVG – CoBelt	*0.123*	*0.002*	*0.602*	*11.9*	*0.93*	*0.09*	*0.004*	*0.62*	*10.3*

Stat. – statistics; Param. – parameters; AVG – average; Luk – Lukanga Swamp Area; CoBelt – Copperbelt Province

According to the above information, elemental concentrations found in leaves from the Lukanga Swamp and the Copperbelt Province are well below the range of excessive or toxic concentrations found in literature. If there is a relative enrichment of metals in the analysed leaves it would be of Cu in the Copperbelt Province and Zn in the Lukanga Swamp.

However, the above information does confirm that other media (sediment / soil / water) surrounding the plants' environment is contaminated. First, the mobility and bioavailability of metals in environment is largely controlled by their adsorbent substrates (Wang & Jia, 2009). In addition, according to the experiments done by these same authors, contamination of heavy metals in sediments both as adsorbents and adsorbates were mostly immobilized by *Phragmites australis* in roots with little translocation to aboveground parts due to root bioaccumulation and plaques adsorption.

Concentrations of Pb and Zn are clearly higher in the Lukanga Swamp area compared to those found in the Copperbelt area. It is expected that soil from the Lukanga area is enriched in these two metals because of dust fallout from smelters operating in the past in Kabwe. This was not seen in the sediment samples, but this may be because sediments were collected in aquatic environments and in this context these metals pass to the dissolved phase. In fact, surface water (and even groundwater) shows high contents of these metals and others (Cd and Cu).

3.6.6. Discussion

3.6.6.1. Upper Kafue River Basin

Mining of Cu and Co has taken place in the Zambian Copperbelt since the early 1920s and during this period the area has developed into a highly urbanised region. For this reason, concentrations of metals can be quite high in water and sediment. Concentrations of metals found in leaves of *Phragmites* sp. are not extraordinarily high, probably because most of the metals are trapped in the roots. However, concentrations of As, Cr, Cu, Co and Ni in leaves collected in the Copperbelt Province are consistently higher than those collected in the Lukanga Swamp.

Sulphide oxidation in mining areas often induces the production of important acid drainage which then causes other kinds of problems on ecosystems downstream. In the

Kafue River, this does not happen because of high carbonate content on waste rocks and tailings, and even in the riverbed of the Kafue River.

However, metals do accumulate in the riverbed adsorbed to hydroxides and/or in the dissolved phase in pore water of sediment and are gradually transported downstream in the particulate phase. Several reports (local people during field visits and stakeholders during interviews) indicate that cattle sometimes die after drinking water from the river.

There is also evidence that surface water from streams in the Copperbelt area is contaminated with organic material. For example, COD tends to increase in the Kafue River while crossing main cities (Chingola and Kitwe), which implies sources of organic matter from industrial and household sources.

Agriculture activities do not seem to affect the Kafue River in the Copperbelt area very much. However, this statement is made considering only concentrations of nitrates and results from one campaign during the dry season.

3.6.6.2. Lukanga Swamp

A) Main water quality problems of the Lukanga Swamp

In terms of water quality, the Lukanga wetland system seems rather complex because parameters and budgets of water may change drastically.

People living around the Lukanga Swamp use groundwater for their everyday needs, including drinking. All analysed wells fail guideline values (ZS and/or WHO) for this use, and this was because of metal concentrations in all cases[1], because of pH values (6 out of 14) and concentrations of nitrates (3 out of 14). While high concentrations of nitrates are clearly explained by human activities, pH and metal concentrations may or may not be partially explained by them. The fact that most (if not all) of the wells are affected by high concentrations of metals, even in remote areas, indicates that probably there is a natural component to these concentrations. In addition, some metals may be coming from the fertilizers used.

[1] There are two cases where detection limit is higher than guideline value.

Except for Co and Cr, these relatively high concentrations of metals continue to exist (or they even increase in the case of Cu) in streams and outer parts of the swamp. However, in the inner part of the swamp concentrations for all metals decrease drastically.

In fact, surface water in the wetland (swamp and streams) shows significant variations in the parameters analysed. For instance, pH increases gradually and consistently from groundwater (minimum values of 6) to streams (minimum values of 7) and towards inside the swamp (minimum values of 8). The same consistent increase may be observed for conductivity and COD, and DO to a certain extent.

All this information is in accordance with what was observed in other wetlands around the world (e.g., Reid & Mosley, 2015). The density of vegetation in the swamp is quite high and removal of CO_2 during photosynthesis typically causes the pH to increase during the daytime, and CO_2 production from respiration causes the pH to decrease during the night-time. Carbon dioxide is the preferred source of inorganic carbon for plants but under alkaline conditions, free CO_2 becomes limiting for photosynthesis (Reid & Mosley, 2015). If CO_2 is not replaced by diffusion from the surface, then increasing pH should result unless other compensatory reactions occur (e.g., precipitation of Ca and Mg carbonates). However, if divalent metals are limiting, photosynthesis may result in pH increases up to 12.6 (Baas Becking *et al*., 1960). In the Lukanga Swamp divalent metals (e.g., Ca and Mg but also Zn, Cu, Pb, Cd, Ni) are not limiting as seen by the high concentrations of metals in streams and groundwater from the area and because pH was not recorded to be higher than 9. Note that the Lukanga Swamp watershed is partially occupied by carbonate rocks from the Katanga System (e.g., Vrana, 1974).

In accordance, leaves of *Phragmites* sp. collected in the Lukanga Swamp show higher concentrations of Pb and Zn (and similar of Cd and Hg) than those from leaves collected in the Copperbelt Area in areas clearly enriched in metals. As observed in other wetlands, the Lukanga Swamp seems to work as a filter for dissolved metals reaching the swamp. In fact, in Hunink *et al*. (2017) the Lukanga Swamp ecosystem service of improving water quality by trapping sediment and absorbing nutrients is highlighted.

B) Hydrodynamics of the Lukanga Swamp inferred from water characteristics

The parameters analysed also seem to reflect the hydrodynamics of the swamp. The amount of surface water reaching the swamp is clearly higher in the north from the Lukanga and Mufukushi rivers and in the southwest from the Muundu and Mufuwa rivers. To the East and Southwest, the width of the watershed is smaller and consequently there is not major stream. In accordance, field observations between September and October 2019 reveal that there was no stream with surface runoff in this area of the swamp, while the above-mentioned rivers had. The average annual water yield in the Lukanga watershed (Figure 19) determined in Hunink *et al*. (2017) also shows these differences.

These observations imply that water in the East (Waya) and particularly in the Southeast (Kaswende) parts of the swamp has higher residence time. This would imply higher salinity of water due to evapo-concentration and so water in this area of the swamp tends to have higher conductivities, higher contents of nutrients (phosphorus) and lower oxygen contents.

Apparently, this higher residence time and salinity in the southeast of the swamp is not reflected in different types of habitats present and/or in the degradation state of these. However, fishermen drink water from the swamp while fishing and undoubtedly swamp water near Kaswende and Waya shows lower quality for this purpose.

C) Effects of the mining activities from the Copperbelt Province

According to Hunink *et al.* (2017), most of the surplus water that the swamp receives during wet years comes from the Lukanga watershed itself, and not overflow from the Kafue River. The overflow was estimated to be at maximum 6% of the surface water in the Kafue River. These authors also state that excess loads from upstream in the Kafue River Basin, as well as pollutant loads from the mining industry are likely filtered to some extent in the floodplain of the Kafue River itself. But when the Lukanga Swamp connects with the floodplain it also receives part of the nutrient and pollutant loads. The swamp likely filters these, contributing to cleaner water for downstream users.

Cu and Co are transported downstream, particularly during high water discharge periods, adsorbed by Fe-rich oxyhydroxides (for Cu) and by Mn-rich particles (for Co) (Pettersson, 2002) (this is shown in the correlation analysis as well – Appendix 2). This author continues with saying that impacts from the mining activities can be traced in the Kafue

River downstream of the Copperbelt mining area in the dissolved and suspended phase and in the deposited sediment.

Downstream, in less hydrodynamic areas such as the Kafue floodplain and later in the Lukanga Swamp, these particles may rest in the river/swamp bed. However, after deposition, secondary oxyhydroxides dissolve when reaching reducing conditions in the sediment.

In accordance, sediments in streams and near the shore of the Lukanga Swamp show few signs about this transfer of metal pollutants coming from upstream (EF of Cu and Co are higher in the Kafue River compared to near shore sediments of the Lukanga Swamp). Curiously, from near shore sediments of the Lukanga Swamp sample 12 (near Shishimo), located in an area where overflow enters the Lukanga Swamp has the highest concentrations of Cu, Co and Ni.

Besides de above, the main indication that this transport may be happening is the extremely high concentration of dissolved metals near the shore of the swamp. However, these metals also seem to be coming from the swamp's watershed. Moreover, leaves from the East of the swamp show higher concentrations of Cu and if this metal was mainly coming from the West during overflow, it would have higher concentrations also in the West.

Given the above, it might be said there is transport of particles from the Kafue River to the West and Northwest parts of the swamp, but probably this does not significantly affect other parts of the swamp. Note that according to Hunink *et al*. (2017), most of the surplus water that the swamp receives during wet years comes from the Lukanga watershed itself.

3.6.6.3. Conclusion

Sampling of surface water, groundwater, sediment and leaves and physical-chemical analyses were performed covering the Lukanga Swamp and the Kafue basin upstream from the swamp. This effort included 87 sampling stations, distributed along the plan areas to properly characterise the upper and middle Kafue and the connections with Lukanga Swamp and its catchment.

The assessment shows surface water characteristics can greatly vary from the Copperbelt Province to the Lukanga Swamp Area. Conductivity, COD and BOD show higher values in the Copperbelt Province, while nitrates, Cr, Pb and Zn are clearly higher in the Lukanga Swamp Area. Contents of dissolved oxygen lower than 50% occur essentially in some areas of the Lukanga Swamp. Both areas show high concentrations of Cu (>0.1 mg/l) in specific sectors (Chingola and Southwest zone, in the Copperbelt and Lukanga Swamp catchment, respectively).

Groundwater samples were only collected in villages around the Lukanga Swamp. The comparison between the concentrations found and guideline concentrations for water for drinking purposes (ZABS, WHO) show that none of the 14 wells studied satisfies the guidelines for this kind of use. The main problem of the quality of groundwater is related with concentrations of metals, particularly of Cd and Pb. High concentrations of nitrates also occur in some groundwater samples.

Grain-size analysis done in sediments shows that “sand” and “loamy sand” are the main type of sediment. Metal concentrations are higher in the Copperbelt Area in comparison to the Lukanga Swamp, respectively (average values): Cu – 2247 vs. 44 mg/kg; Co – 222 vs. 10 mg/kg; Zn – 59 vs. 13 mg/kg, to give some examples.

Bulk concentrations of metals in the analysed leaves follow the pattern: [Zn] > [Cu] > [Cr] ~ [Co] ~ [Ni] > [Pb] ~ [As] > [Hg] ~ [Cd]. In the same way as it happens for sediments, there is a predominance of maximum concentrations in the Copperbelt Province and of minimum concentrations in the Lukanga Swamp Area. However, Pb and Zn behave the other way around.

3.7. Ecology

3.7.1. Introduction; scope and methodology

This section establishes the ecological character of the Conservation Plan areas, composed of the Upper Kafue River Basin, the Lukanga Swamp Catchment, and the swamp itself. The objective of this baseline is to enable the identification of the area's values and their state, directing the analysis towards the aspects deemed more relevant to the conservation plan and to the assessment of ecosystem services.

The swamp and surrounding area benefited from a more in-depth ecological characterisation, including a description of vegetation cover from secondary information and the production of habitats cartography, validated on-site through field work.

Field visits were conducted in September and October 2019 (Figure 33), at the end of the dry season, and included the following general tasks:

- Identification of main vegetation communities;
- Assessment of preliminary mapping of land use, main existing macro-habitats and related conservation status (identification of pressures, etc.);
- Informal register of faunal species sighted during site walk-overs.

During these field surveys, a total of 56 sites were assessed and classified (see Appendix 3 for detailed mehodologies) (Figure 33).

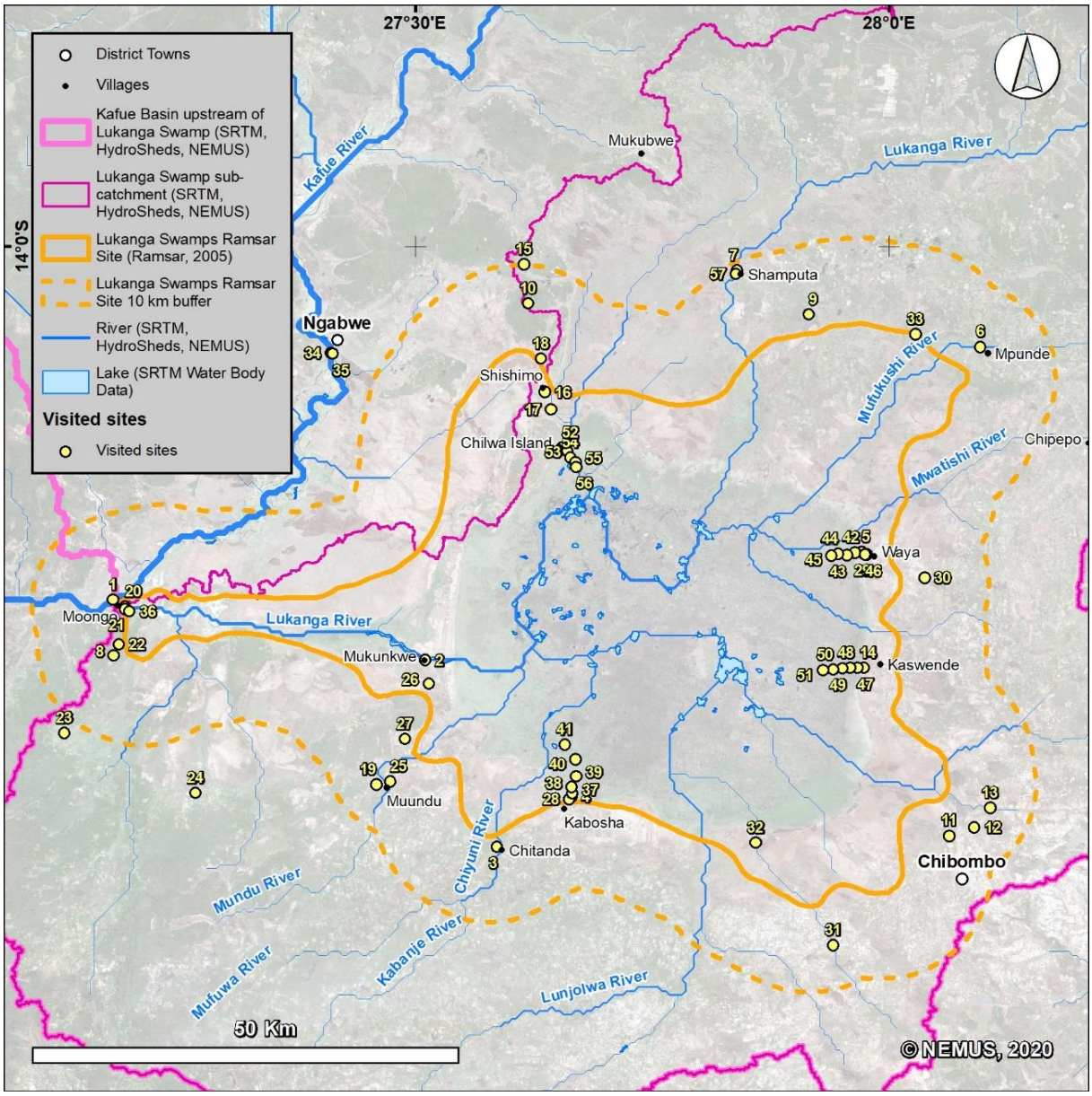


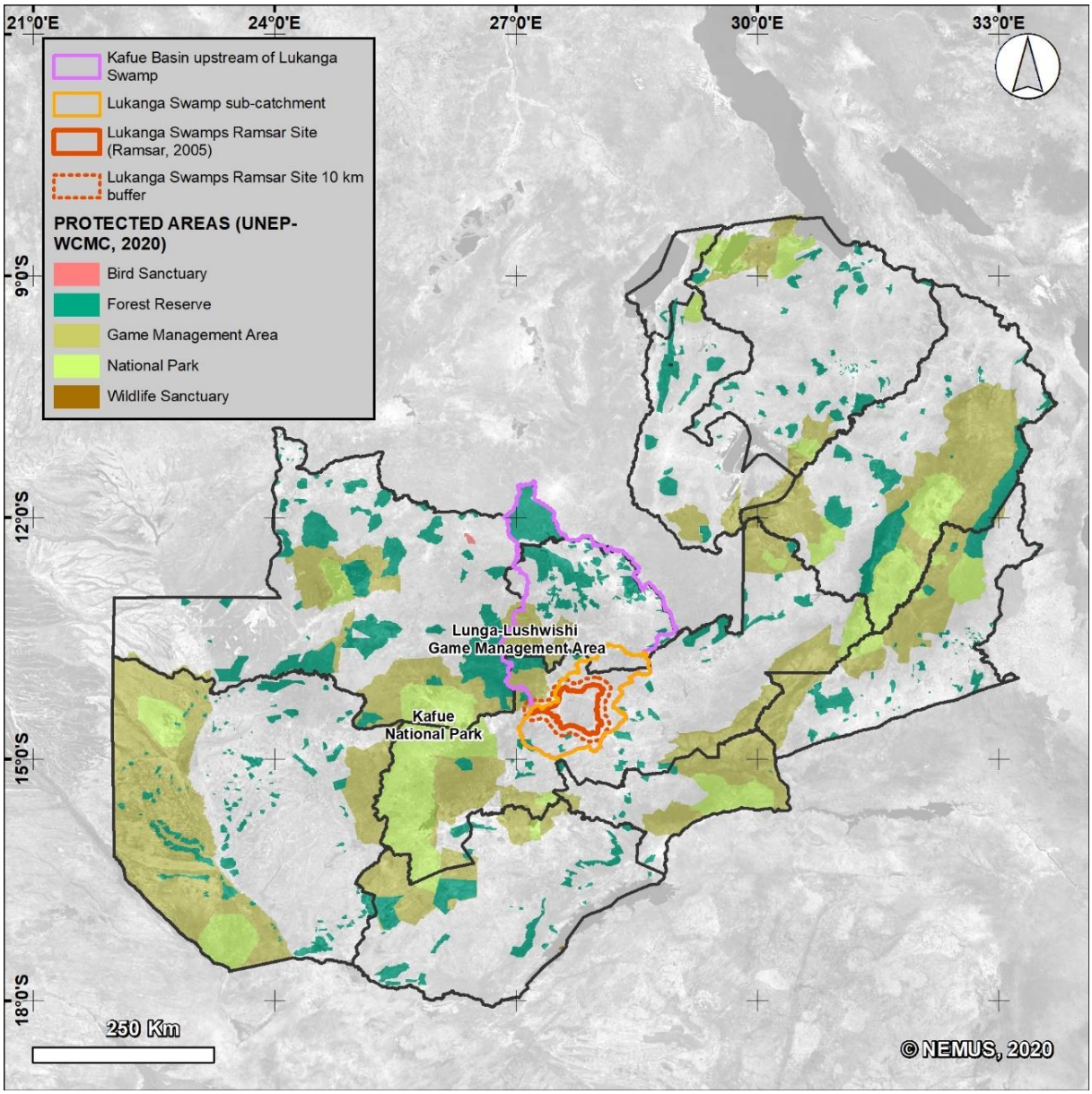
Figure 33 – Sites visited in September and October 2019 for ground truthing of cartographic units

The ecology baseline is structured around the following sections:

- Designated areas for the protection of biodiversity (section 3.7.2);
- Land cover (section 3.7.3);
- Lukanga swamp; habitats, flora and fauna (section 3.7.4).

3.7.2. Designated areas for the protection of biodiversity

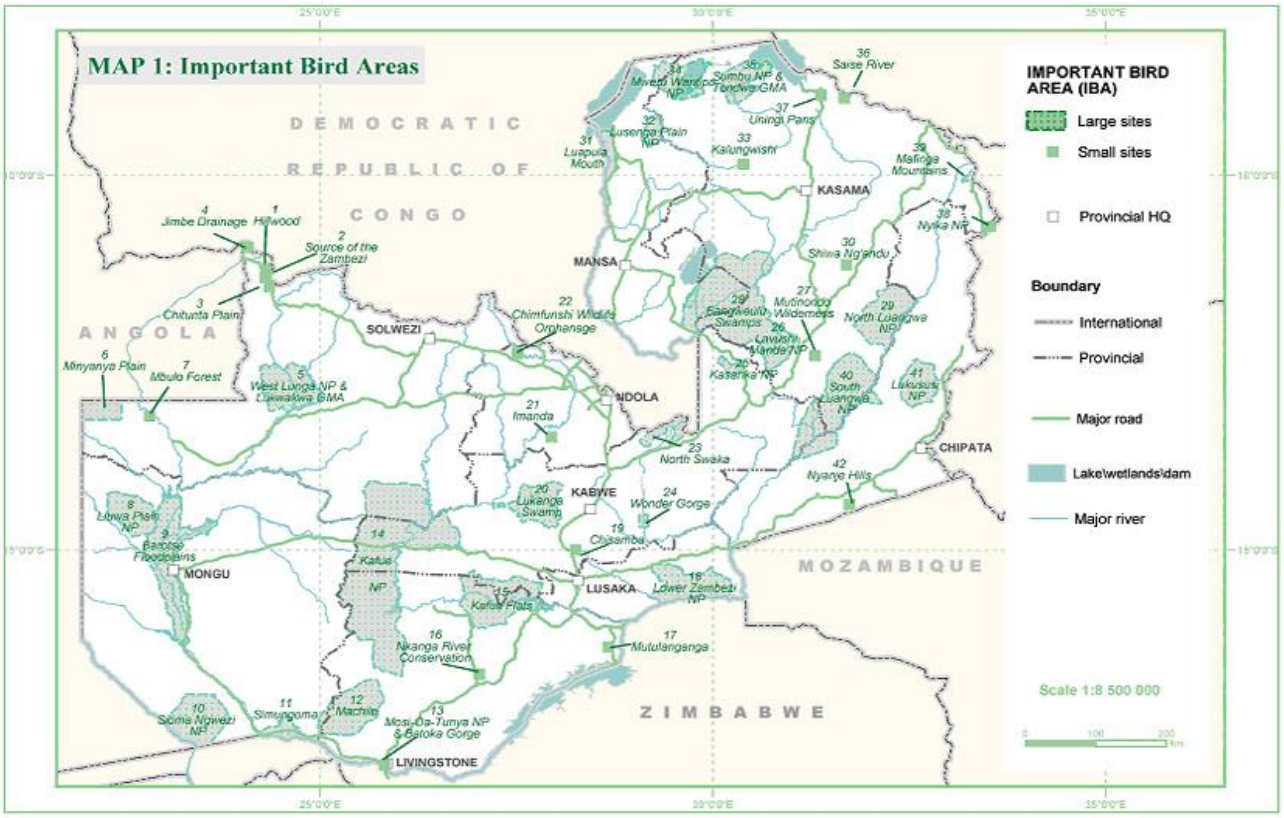
The ecological relevance of the Lukanga swamp and its regional setting is demonstrated by the existence of two different typologies of protected areas specifically designated for the Lukanga's wetland ecosystems, and at least three more types of national designations in the upper Kafue basin and the swamp's sub-catchment (Figure 34).



Source: adapted from UNEP-WCMC and IUCN (2020).

Figure 34 – Contextualization of the Lukanga Swamp in Zambia's national network of protected areas

In addition to the nationally classified areas, three additional categories occur in Zambia, of international significance, including eight (8) Ramsar Site designations, 42 Important Bird Area (IBA) designations (Figure 35) and one (1) World Heritage Site (UNEP-WCMC and IUCN, 2020).



Source: Birdwatch Zambia (2019).

Figure 35 – Important Bird Areas of Zambia

Hence, the Lukanga Conservation Plan areas intersect several nationally and internationally classified areas (UNEP-WCMC and IUCN, 2020), namely:

- Important Bird Areas:
  - Lukanga Swamp (ZM020);
  - Chimfunshi Wildlife Orphanage (ZM022) (upper Kafue);
  - Imanda (ZM021) (upper Kafue);
- Ramsar sites:
  - Lukanga Swamp Ramsar Site;
- Game Management Areas:
  - Lunga-Luswishi (upper Kafue);
  - Machiya Fungulwe (upper Kafue);

- Forest Reserves:
  - In the upper Kafue basin, there are three large national reserves, the Kafue head waters National Forest, the East Lunga National Forest and the Lamba Headwaters National Forest, together with several other smaller National forests, such as Kabwima, Misaka, Monkey Fountain, and Luano, as well as local forests, such as Luena;
  - In the Lukanga's sub-catchment, there are mainly smaller local reserves, such as the Mumbwa Local Forest, the Mushingashi Local Forest, the Kalulu Local Forest or the Lukulaisho Local Forest;
- Bird sanctuaries:
  - Chembe Bird Sanctuary (upper Kafue).

3.7.3. Land-cover

The upper Kafue basin is set in the Great African Plateau, touching on the ecoregions of the Central Zambezian Miombo Woodland to the north, and both Kalahari Acacia Woodland and Southern Miombo Woodland ecoregions to the south (Burgess *et al*., 2006).

Typical woodland habitats of the Zambezian region dominate the terrestrial landscape, which is interrupted by Zambezian seasonally flooded grasslands, permanent swamps and rivers, of the Kafue Freshwater and Zambezian Headwaters Ecoregions.

The major vegetation type of the Zambezian region is the **woodland**, consisting of open stands of trees of at least 8 m height, with a canopy cover of 40% or more, but never with inter-locking crowns and usually with a field layer of heliophilous grasses. While it is generally interpreted as the climatic climax vegetation, some of the historical distribution is thought to be secondary, deriving from the replacement of dry forest by historical disturbance, and an increasing proportion of current woodland is secondary, having been altered by anthropogenic activities such as cultivation and fire (Phiri, Morgenroth and Xu, 2019; White, 1983; Forestry Department, 2016).

The main woodland type in the upper Kafue basin is the miombo, an open woodland dominated by three genera on the canopy, *Brachystegia*, *Julbernardia* or *Isoberlinia*, with a field layer of herbaceous species, usually sparse. Being largely secondary, the miombo of this region typically presents reduced floristic and structural complexities. Other

woodland types are referenced as occurring in the region, such as the Chipya, Munga and Baikiaea, according to White (1983).

Grasslands (structurally simple formations dominated by an herbaceous field layer) are usually present as the edaphic climax vegetation of seasonally and permanently waterlogged soils, such as in river floodplains and depressions with increased water retention ability. Secondary grassland also occurs, but is maintained by fire and usually contains trees (White, 1983).

The majority of the upper Kafue river basin is located in agro-ecological zone IV, the northern and north-western high rainfall zone (between 1,000 and 1,500 mm annual rainfall), with low pH leached soils and of “moderate potential for agriculture” (Mukosha & Siambale, 2008).

The upper Kafue basin is predominantely covered by forest, grassland, wetland and cropland (Figure 36). Hotspots of higher cropland density can be observed south of the Lukanga and around the urban centers of the Copperbelt Province (Ndola, Kitwe and Chingola), while intensive cultivation projects are mainly located in the middle region. Extensive forested areas occupy the north and central western portion of the basin.

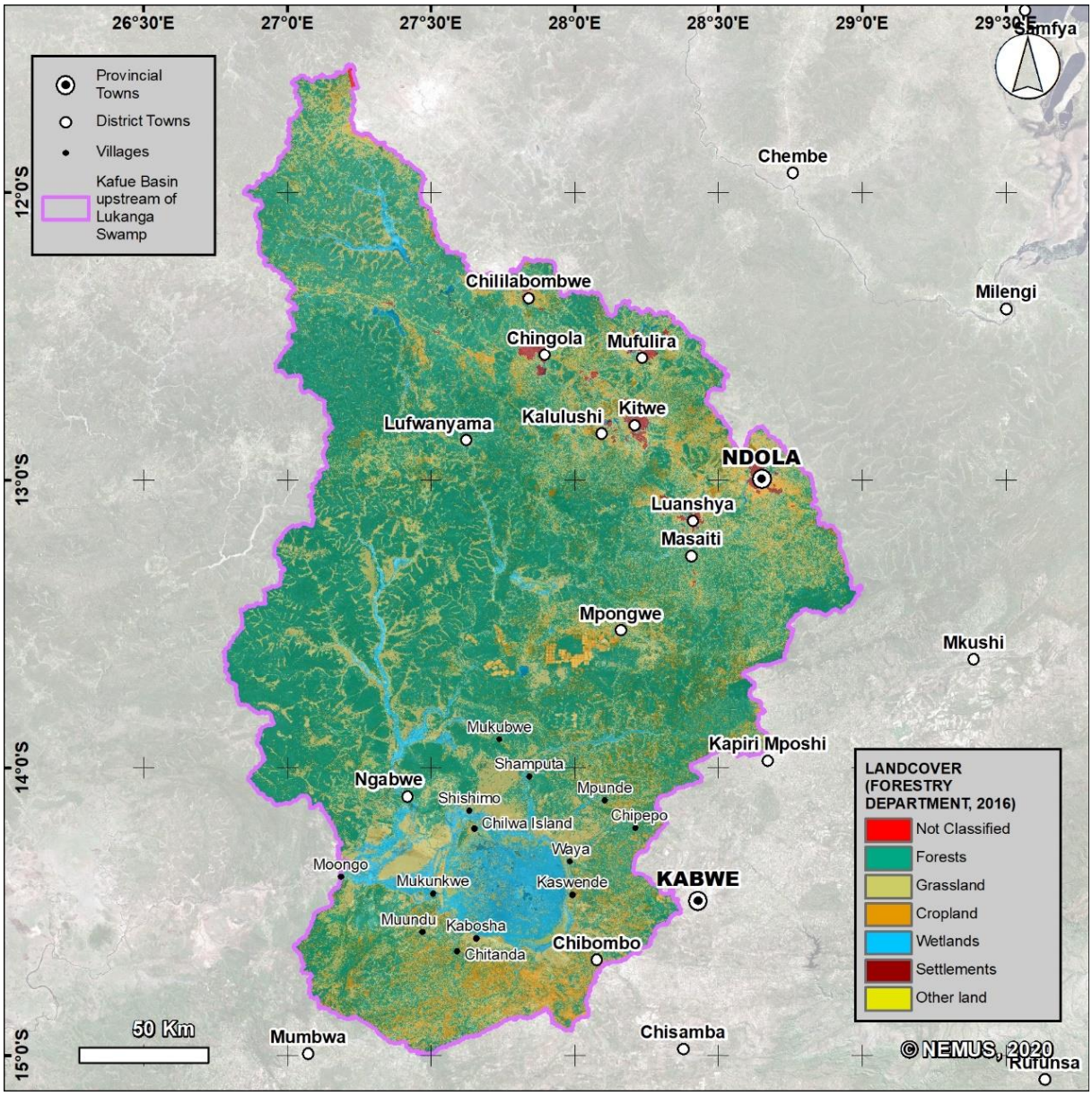


Figure 36 – Upper Kafue basin and Lukanga subcatchment land cover

Regarding the Lukanga's sub-catchment, in addition to miombo woodland, chipya and edaphic grassland, this region includes the potential distribution area of the North Zambezian undifferentiated woodland (also known as munga or *Acacia-combretum*, according to dominant species). Being an open savanna formation without the miombo's canopy dominants, this vegetation holds a high floristic variability overall and between different sites/stands (Kindt *et al*., 2011).

The sub-catchment of the Lukanga stands right at the southern edge of the wetter miombo potential distribution, after which it is replaced by drier miombo. It is at the

transition between these two rainfall-defined regions and the actual vegetation should reflect this.

The swamp's sub-catchment, in contrast to the upper Kafue, is located in agro-ecological zone IIb (annual rainfall between 800 and 1,000 mm on Kalahari Sand soils), with moderately leached clayey to loamy soils, and of "high agricultural potential" (Mukosha & Siambale, 2008). Correspondingly, and as mentioned above, the sub-catchment is a cropland hotspot.

Regarding the swamp itself, it is predominantly covered by agro-ecological zone IIb, but also reaches into zone III (higher rainfall) in the north. The wetland land-cover dominates, with grassland and cropland following (Figure 37).

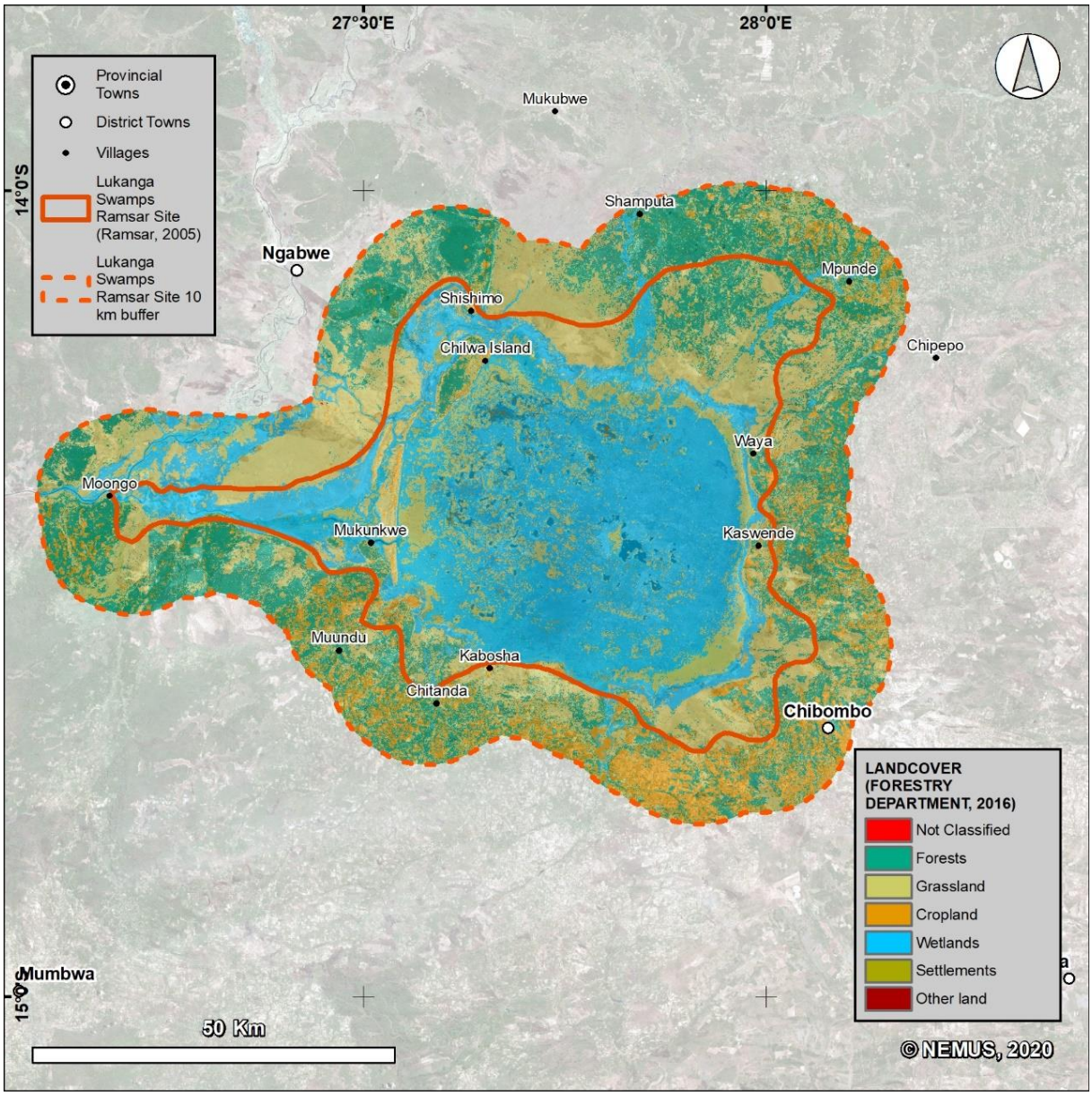


Figure 37 – Lukanga swamp land cover

3.7.4. Lukanga Swamp

3.7.4.1. Habitats mosaic

A habitat is defined as a territory unit which, given physical conditions, supports the development of a specific biological community (Alves *et al.*, 1998; Potschin-Young *et al.*, 2018). The development of vegetation (plant communities) into structural units of known composition serves as an indicator of the abiotic conditions of a particular area, as well as of its potential use by fauna and by human communities (Timberlake, 2000), thus providing an appropriate proxy for habitat classification.

Habitats can be divided between three main typologies of land-use, defined by the degree of distance or approximation to pristine vegetation characteristics:

- **Natural**; areas that maintain original conditions, and therefore vegetation types (referring to composition, structure and abundance) and associated faunal resources represent in majority or totality, the original values. In and around the Lukanga, “natural areas” have actually been shaped by a long history of sustainable human uses such as cattle grazing or resource harvesting;
- **Semi-natural**; areas characterized by vegetation composed of different species than those that composed the original assemblages; there is a predominance of introduced vegetation, as these are managed by humans; these include managed land, such as cultivated and fallow areas, small to large-scale, and tree plantations;
- **Artificial/humanized;** areas that display a profound degree of alteration; natural conditions and faunal values are totally distant from original ones, and vegetation, when present, is anthropic and mainly opportunistic; in these areas, the degree of soil impermeabilization is usually high, and land use is associated with human presence.

The central portion of the plan areas, composed of the wetland system, is dominated by natural land cover and sustainable land uses. The disc-shaped centre is surrounded to the south and east by a patchwork of semi-natural cropland and fallow land, natural woodland, and scattered artificial human settlements. To the north and west, natural land dominates again, mainly composed of the flooding-prone Termitaria and upland woodland vegetation.

As expected, inside the boundaries of the Ramsar Site, natural land use dominates, although some encroachment can be observed along the edges, to the south and west, in the form of cropland and rural settlements (c.f., Habitats Map, Appendix 3A).

The local **macro-habitat pattern** is caused by topographic discontinuities of the territory which impose local hydrological regimes where azonal vegetation forms, interrupting the Great African Plateau's typical woodland landscape.

As such, there is a clear evolution of the macro-habitats' structural and compositional complexity from the central depression pan outwards, along the environmental gradients of edaphic water content and depth. The central permanent swamp vegetation is replaced by seasonally flooded grasslands, that turn into a transition belt of grassland permeated by woodland and shrub vegetation on islands of higher ground (the termitaria), before actual woodland habitats develop on the upland. Both wetland and terrestrial habitats are further shaped by current and historical human activity. A patchwork of small-scale agricultural landscape disrupts the woodland throughout virtually the whole area, which is advancing inward, increasingly encroaching the seasonally flooded grasslands to make use of the available water.

The following natural macro-habitats can be distinguished, in addition to semi-natural and artificial typologies (cultivated and managed land, and rural built-up areas):

- Aquatic and semi-aquatic, including permanently and seasonally wet areas:
  - Permanent swamp;
  - Edaphic grassland;
  - Lakes;
  - Rivers and streams;
  - Termitaria;
- Terrestrial:
  - Forest land (woodland [Miombo, Baikiaea, Chipya and Munga]).

Table 16 presents the extent of each of these classes' coverage in the site.

Table 16 – Macro-habitats of the Lukanga Ramsar site and surrounding area

Macro-habitat		Ramsar		Total (Ramsar + buffer)	
		(ha)	(%)	(ha)	(%)
Forest land	Miombo	10,617.88	3.2	47,433.56	7.07
	Baikiaea	-	-	1,190.12	0.18
	Lake basin Chipya	4,471.84	1.35	5,184.30	0.77
	Munga or Miombo	87.29	0.03	12,587.33	1.88
Total		**15,177.02**	**4.589**	**66,395.31**	**9.9**
Wooded grassland	Termitaria	44,869.19	13,54	154,619.44	23.05
Total		**44,869.19**	**13,54**	**154,619.44**	**23.05**
Grassland	Edaphic grassland	78,436.29	23.67	112,951.26	16.83
	Permanent swamp	169,235.99	51.06	169,655.34	25.29
	Rivers and stream-associated wetland vegetation	958.80	0.29	3,035.99	0.45
Total		**248,631.09**	**75,02**	**285,642.59**	**42,57**
Inland water	Lakes	4,887.72	1.47	4,887.72	0.73
	Rivers and streams	550.87	0.17	1,581.33	0.23
Total		**5,438.59**	**1.64**	**6469,05**	**0.96**
Anthropic landscapes	Cultivated and managed land	16,912.63	5.1	156,658.19	23.35
	Rural built-up land	398.29	0.12	1,149.95	0.17
Total		**17,310.92**	**5.22**	**157808,13**	**23.52**
Total		**331,426.81**	**100**	**670,934.52**	**100**

The detailed characterisation of the area's macro-habitats can be consulted in the Appendix 3, and focuses on the main natural values that compose them – deemed relevant in terms of conservation planning –, on the description of their ecological functions, and available faunal niches, and. A summary is given below.

A) Permanent swamp

The permanent swamp forms part of the palustrine wetland, and consists of the vegetated and permanently flooded disc-shaped pan at the centre of the area. This is a zone of slow-flowing or stagnant water, flooded to varying depths, and colonized by hydrophytes with physical and physiological characteristics that confer them a range of tolerance to flooding.

The swamp is composed of dense stands of emergent vegetation rooted to the substrate, cut out by channels and pools that serve as refuge to submerged and floating-leaved macrophytes (Denny, 1985; Figure 38).

Among the swamp's ecological processes, functions and services, the following are highlighted:

- **Water reservoir**; compared to open water bodies, reed swamps have reduced levels of evapotranspiration; dense reed stands reduce light penetration into the water, generally down to below 10%, reduce temperature, as much as 3ºC, and reduce wind velocity down to 18% (several studies in Howard-Williams and Gaudet, 1985);
- **Habitat for wildlife**; the system of channels and pools that cuts out reed stands, in offering interface areas with higher horizontal mixing, reduces stagnation and increases dissolved oxygen concentrations; submerged macrophyte communities develop here, increasing surface area and habitat complexity below water, therefore increasing the habitat's potential as breeding and refuge for fish, habitat for invertebrates, and increasing food-supply for grazers and predators alike (Bird, Day and Malan, 2014);
- **High primary productivity**; the majority of the production can be attributed to the dominant emergent species, *Phragmites australis* and *Typha capensis*, with floating-leaved and submerged macrophytes contributing significantly less (Howard-Williams and Gaudet, 1985);
- **Carbon sinks** or **sources**; atmospheric carbon is sequestered and stored as plant biomass through primary production (i.e., fixation through photosynthesis), and is then deposited in the swamp's substrate as detrital matter, which can be oxidized back to the atmosphere, reduced to CH_4 by microbial action, or be buried and preserved long-term; the rates of these different pathways depend on acting biogeochemical processes;

- **Filtering of nutrients and waste off the water** (Howard-Williams and Gaudet, 1985); throughflow water is filtered out of organic compunds, suspended solids, pathogens, metals, pesticides, nutrients, etc., its gas and nutrient dissolution is changed, and its clarity increases downstream (Howard-Williams and Gaudet, 1985; García-Ávila *et al*., 2019);
- **Nutrient pumping** (Howard-Williams and Gaudet, 1985); the accumulation of nutrient rich detritus in the sediment forms what is called the sludge, which can be washed out of the swamp to downstream environments, representing an important source of nutrients;
- **Raw material and food** for local communities; emergent macrophytes such as *Phragmites australis*, *Typha capensis* and *Cyperus papyrus* are sources of raw material, or fibre; while the swamp's fisheries are an important source of protein and income (field observation, 2019; McCartney *et al*., 2011).

Regarding faunal communities, several obligate wetland dwellers can colonize perennial swamps (Howard-Williams and Thompson, 1985), such as:

- **Aquatic invertebrates**; macroinvertebrtates (insects, annelids, crustaceans, molluscs, acarine and turbellarians), for instance, prefer submerged vegetation in comparison to emergent communities (Bird, Day and Malan, 2014);
- **Ichthyofauna**, mainly in the channels and shallow pools, where most fish breed and take refuge (especially fry);
- **Avifauna**; the swamp is an important habitat for this group, in particular waterfowl, as reiterated by its Ramsar and IBA designations (3.7.2 – Designated areas for the protection of biodiversity);
- **Mammals**; few large herbivores still colonize the permanent swamp; small mammals (bats, insectivores and rodents) not dependent on swamps but which can exploit them, and semi-aquatic carnivores such as otters, mongooses and civets, are more abundant (Cotterill, 2000a and b; Pacini and Harper, 2008).



Source: Nemus (2019).

Figure 38 – Permanent swamp macro-habitat: A. floating aquatic macrophytes; B. emergent macrophytes

B) Edaphic grassland

This macro-habitat consists of herbaceous wetlands that are only seasonally waterlogged, and encompasses a plethora of areas with different flooding regimes, such as dambos[2], riverine floodplains and seasonal swamps (Thompson, 1985; Ellenbroek, 1987), occurring around the central pan and along the existing rivers. It occupies the landward end of the wetland vegetation continuum, and is composed of species adapted to periodic saturation.

By definition, the grassland is a physiognomically or structurally simple habitat, as the herbaceous layer constitutes the main aspect of the landscape (Figure 39), and woody species may occur only at low densities, their presence being precluded by the high water table and poor drainage.

Among the grassland's ecological processes, functions and services, the following are highlighted:

- **Nutrient cycling**;
- **Habitat for wildlife**;
- **Carbon sequestration**; These grasslands' high primary production means an equally high rate of carbon sequestration from the atmosphere, which is predominantly stored as below-ground biomass (Gibson, 2009); grasslands can rapidly turn into carbon sources, however, as opposed to sinks, through the unmanaged intensification/increased frequency of dry season fires and grazing pressure;
- **Food and breeding habitat for fish**, which in turn is an important food source for bird and human populations;

[2] A *dambo* can defined as a "broad valley […] that is waterlogged for some months during the wet season" (Timberlake, 2000).



Source: Nemus (2019).

Figure 39 – Edaphic grassland habitat at the end of the dry season

Regarding faunal communities, because this habitat is subjected to periodic flooding, there are at least two distinct instances of colonization by fauna:

- **Wet season**: flooded grasslands provide important habitat for African inland freshwater fish; fish migrations occur to and from floodplains; several bird species use the flooded grassland for breeding, refuge and feeding;
- **Dry season**: as water recedes, fish populations return to permanent waterbodies and wild herbivores and cattle recolonize the floodplain grassland; some bird species remain in the dried-up grassland; as floodwater recedes, bird flocks concentrate in the littoral zone, in the dry grassland near flooded channels and shallow ponds (Ellenbroek, 1987); floodplains fringing permanent swamps are important forage habitats for large and medium-sized mammal herbivores; insectivores and rodents are abundant in these habitats (Gibson, 2009; Namukonde et al., 2017), and remain the predominant wildlife of the area (Chabwela et al., 2010).

C) Termitaria

The termitaria grasslands occur in seasonally flooded areas or where the water table is permanently high. What distinguishes this macro-habitat from the edaphic grassland is the existence of well-drained islands of higher ground, formed by termites, which allow the colonization by less flood-tolerant and woody species whose development is inhibited in the rest of the area (Chabwela, Chomba and Thole, 2017).

This habitat forms after the zone of low-flood (Chabwela *et al*., 2010), and dominates the north western region, including in the Itundu Plain up to the Kafue river, i.e., occupying the area between wetland and woodland habitats, as observed in the Kafue flats (Ellenbroek, 1987).

Structurally, this is a complex habitat where the basal layer is composed of edaphically-determined grassland as described earlier (c.f. section B) – Edaphic grassland), and the canopy presents as clusters of different woody plant communities, from shrubs to trees, forming a wooded grassland, or savanna-type environment (White, 1983; Shakachite *et al.*, 2016).



Source: Nemus (2019).

Figure 40 – Termitaria macro-habitat; here, the extensive plain north of the Lukanga river and downstream of the swamp

Among the Termitaria's ecological processes, functions and services, the following are highlighted:

- **Habitat**; the mounds introduce additional levels of structure complexity and associated functionality, compared to the grassland matrix; during inundation, these are dry islands where animal species such as small mammals and birds can take refuge (Ellenbroek, 1987; Pullan, 1974); the surrounding flooded grassland is a rich feeding habitat at this point (c.f. section B) – Edaphic grassland);
- **Soil formation**; termites are important soil engineers as they can alter the soil's physical, chemical and microbiological properties.

The main faunal groups occupying the termitaria macro-habitat are terrestrial invertebrates, avifauna and mammals. During the dry season, these habitats are generally abandoned, being used mostly by small animals seeking for shelter. During the inundation period, termite mounds represent dry islands thought to provide refuge for mammal and bird species alike. These are used, in the Kafue Flats, by waterfowl and lechwe, which feed from the surrounding grassland (Ellenbroek, 1987).

D) Rivers and streams

The rivers and streams encompass both open water and vegetated permanent streams. Structurally, permanently inundated streams and rivers include two major configurations, open water and emergent vegetation (i.e., inland waters and grassland) (Figure 41).



Source: Nemus (2019).

Figure 41 – On top, the Lukanga river upstream from the swamp, flowing through Mpunde; on the bottom, the same river, downstream from the swamp, flowing towards the confluence with the Kafue

The banks are usually colonized by a fringe of emergent macrophytes, which can overgrow the entire stream if it is sufficiently shallow and slow-flowing. Inward from the banks, towards deeper water, there is a turnover from emergents into different communities dominated by floating-leaved and submerged macrophytes, along depth, flow, and turbidity gradients.

Submerged macrophyte vegetation provides important habitat (for breeding and shelter) and food for fish, while emergent vegetation provides a number of products to local communities. Local communities harvest the *Cyperus papyrus* sedge for the construction of mats, and consider it to be more adequate to such uses than *Phragmites australis*, which currently dominates the swamp's emergent cover (field observation, 2019; key informant interviews, 2019). The common reed *P. australis* is widespread and more abundant, and so it is also commonly harvested.

Regarding faunal assemblages, cyprinid and cichlid species are particularly important (Winemiller *et al.*, 2008). According to Chabwela *et al.* (2010), inflowing streams to the swamp are important breeding areas for fish species.

Resident and migrant waterfowls use the rivers and streams, however, given the higher degree of human disturbance, and the availability of better habitat in the proximity, most are expected to prefer the swamp and the Lukanga Rivers outflow.

Semi-aquatic mammals include hippopotamuses, otters, mongooses, civets, etc., and other terrestrial groups are closely dependent on water courses.

E) Lakes

Several large bodies of open water are scattered throughout the permanent swamp area, their area varying seasonally according to flood levels and resulting growth of emergent vegetation (Chabwela *et al.*, 2010; Hunink *et al.*, 2017) (Figure 42).



Source: Nemus (2019).

Figure 42 – Lake habitat; here, the lake off the village of Kabosha

Lakes are colonized by aquatic macrophytes along the depth gradient. These are fringed by emergent reed stands, with shallower edges being occupied by floating-leaved and submerged macrophytes. Because the lakes within the swamp vary considerably in size and depth, they can showcase a variety of vegetation patterns.

While some lakes are deep enough to exclude the development of macrophytes altogether (Figure 42), others include large areas of deep enough water as to exclude the swamp's emergent and floating-leaved vegetation, but shallow enough to allow the development of extensive submerged meadows (Figure 43). The two biggest lakes, Suye and Chiposya surpass 10 ha, and depth varies at least between around 0.5 and 4 m according to available records (Mwambazi, 1998, in Chabwela *et al.*, 2010; Hunink *et al.*, 2017).

Because of the relatively milder conditions of lakes compared to the vegetated swamp, these provide breeding, feeding and refuge for fish, and, subsequently, for the bird populations that predate on them. Large, shallower and vegetated lakes in particular, such as Lake Suye, are important fish breeding areas.

Deep open water does not support significant bird populations, whereas shallower open lakes are used by *Phalacrocorax* spp., *Pelecanus* spp. and *Chlidonias* spp. (Leonard, 2001). The Grey-headed Gull, *Larus cirrocephalus* (LC), prefers open water bodies with swampy or grassy islands of vegetation for breeding, for instance, and was observed in Lake Suye in October 2019.



Source: Nemus (2019).

Figure 43 – Submerged macrophyte *Najas* sp. in Lake Suye, off Chilwa island

F) Forest land

Forest land is the typical dry land vegetation of the region, occupying the upland areas in relation to the Lukanga swamp, and therefore supporting the development of more structurally and species complex woody vegetation (Beilfuss *et al.*, 2001). Inside the swamp and seasonally flooded areas, two islands exist, Chilwa and Chiposha, of Kalahari sand (Chabwela *et al.*, 2010), that support upland vegetation.

Forest land as defined by FAO encompasses from closed and multi-storeyed forest vegetation down to open stands of trees with a field layer of heliophilous grasses only (FAO, 2000; White, 1983). The woodland, is widespread in the African continent and the major vegetation type of the Zambezian region, making up the wooded vegetation surrounding the wetland. According to available bibliography, four distinct types occur in the area: miombo, munga, chipyia and baikiaea.

Structure wise, it typically presents as an open stand of trees without interlocking crowns, of varying heights, and a field layer of herbaceous species with scattered shrubs (White, 1983; Chidumayo, 1987a) (Figure 44).



Source: Nemus (2019).

Figure 44 – General aspects of the forest land macro-habitat

Around the Lukanga Swamp, the **miombo** - open woodland (or light closed-canopy) readily distinguished by its canopy composition dominated by three genera, Brachystegia, Julbernardia or Isoberlinia - is the most widespread type of forest vegetation, and occurs throughout the northern and southwestern parts (c.f., Habitats Map). Chabwela, Chomba and Thole (2017) describes two different communities, namely:

- East of Waya harbour, woodlands are dominated by Pseudolachnostylis maprouneifolia, Julbernardia paniculata, Albizia adianthifolia, Diplorhynchus

condylocarpon and Craterosipjon quarrei, and display the typical indicator species Uapaca nitida, Combretum ghasalense, Lannea discolor, and Brachystegia boehmii;

- In Maunde Forest, the vegetation is dominated by Isoberlinia angolensis and Julbernardia globiflora, with typical Albizia adianthifolia, Brachystegia boehmi, B. taxifolia, Diplorhynchus condylocarpon, and Parinari curatellifolia.

The munga woodland, also designated as North Zambezian undifferentiated woodland and wooded grassland (White, 1983), is a savanna-type open woodland, described by White as characteristically lacking the miombo and mopane dominants (*Colosphospermum mopane* in the latter)- It occurs mainly in the north western part, between the swamp and the Kafue river, and to the south and southwest, in river-associated soils along streams (c.f. Habitats Map, Appendix 1; Edmonds, 1976, in Chabwela, Chomba and Thole, 2017; Chabwela *et al.*, 2010).

Other woodland types are referenced as occurring in the region, such as the chipya [formations of trees lacking the miombo dominants, mixed in well-developed grass (White, 1983]), a fire- or agriculture-induced (i.e., man-derived and degraded) type of savanna woodland, whereby fire-tolerant tree species are maintained through seasonal

Forested habitats such as the Baikiaea, a subtype of the Zambezian dry deciduous forest and scrub forest distinguished by its almost pure canopy of *Baikiaea plurijuga* (Kindt *et al.*, 2011), are the potential climatic vegetation of the region, typically occurring in areas that experience a long season of low atmospheric humidity. These are referenced as occurring only in small patches in the region of the Lukanga Swamp (c.f., Habitats Map, Appendix 1; Edmonds, 1976, in Chabwela, Chomba and Thole, 2017), having been replaced by other woodland vegetation due to human influence.

Among the forest's ecological processes, functions and services, the following are highlighted:

- **Climate regulation**; forested lands are important sinks for atmospheric carbon; however, the characteristic disturbance regime of tropical open woodlands such as the miombo reduces its ability to effectively and lastingly store it (Williams *et al.*, 2007); conversion for agriculture and frequent burning will release the stored carbon and reduce the patch's ability to sequester more, so that effective management (e.g., through sustainable

timber harvesting, reduced frequency of fire, etc.) and requalification can enhance both sequestration and storage (Williams *et al.*, 2007).

- **Provision of consumption goods**; wild fruit from miombo species such as *Parinari curatellifolia*, *Uapaca nitida*, *Uapaca kirkiana*; roots, leaves and bark as traditional medicinew, from species such as *Brachystegia boehmii*, *Swartzia madagascariens* (syn. *Bobgunia madagascariensis*), *Pseudolachnostylis maprouneifolia* and *Pterocarpus angolensis*; edible mushrooms (*Amanita zambiana*, *Cantharellus* spp. and *Boletos* spp.) produced from ectomycorrhizal associations with the miombo's dominant species, such as *Brachystegia* spp., *Julbernardia* spp., *Isoberlinia* spp., *Marquesia* spp. and *Uapaca* spp. (Frost, 1996);
- **Provision of raw material**; tree species resistant to wood-eating insects and wood-decaying fungi are sources of construction materials, including the construction of dugout canoes and fish drying structures; Miombo trees such as *Brachystegia boehmii* are also widely cut for the production of charcoal and firewood.

The miombo typically displays a low faunal density and biomass, the most important groups being birds, small mammals, dung beetles and lepidoptera (Frost, 1996).

The following miombo endemics should be mentioned as possibly occurring in the surrounding healthy woodlands: Miombo Grey Tit, *Melaniparus griseiventris*, Miombo Rock Thrush, *Monticola angolensis*, Shelley's Sunbird, *Cinnyris shelleyi*, and Stierling's Woodpecker, *Dendropicos stierlingi* (all classified as LC).

Large herbivores specific to the miombo include the sable antelope, *Hippotragus niger*, roan antelope, *H. equinus*, and Lichtenstein's hartebeest, *Alcephalus buselaphus* subsp. *lichtensteinii* (Frost, 1996). These are specialist grazers of the grass layer, and tend to move about looking for higher quality forage, which includes recently burnt patches (Frost, 1996).

However, because the more undisturbed woodland stands are fragmented and are still subjected to human presence (c.f. Habitats Map, Appendix 1), large mammal fauna is expected to be low or even locally extinct (personal communication, February 2020). In addition, the existence of GMAs, Forest Reserves and the Kafue NP in the proximity provide better conditions for fauna, which implies the possibility that animal populations have migrated towards these refugia. This has inclusively been suggested by local communities (key informant interviews, 2019).

G) Cultivated and managed land

These areas include cultivated land, both annual and perennial crops, and fallow. Here, the vegetation is largely anthropogenic, as human intervention/management is needed for its maintenance.

Cultivated land is structurally and floristically simpler than the original woodland vegetation, typically presenting as a mosaic of cultivated plots with scattered tree cover, woodland regrowth and secondary grassland (Beilfuss *et al.*, 2001; Figure 45).



Source: Nemus (2019).

Figure 45 – Anthropic landscapes surrounding the Lukanga Swamp

Cropland consists of the anthropic replacement of the regional woodland and wooded grassland vegetation (miombo, munga, chipya and termitaria grassland) with less diverse vegetation composed of species of nutritional interest. The main crops grown in the area are maize, cassava, soya beans, cotton, groundnuts, and vegetables such as pumpkins, tomato and cabbage (key informant interviews, 2019; McCartney *et al.*, 2011; Kachali *et al*., 2008). Maize is grown during the wet season, while vegetables are grown in the dry season.

In the wetland, there are mainly low-input and low-yield small-holder farms, explored for household consumption, with surplus being commercialized locally or used as barter for fish (key Informant Interviews, 2019). The main farming systems employed are: shifting cultivation, semi-permanent hoe farming and semi-permanent hoe and ox plough (Saasa, 2003).

Crops are not irrigated, with the exception of garden crops on seasonally flooded areas, where shallow ponds are dug nearby for this purpose (key informant interviews, 2019). Medium-scale explorations for commercialization (mainly cotton, in the south) exist as well, with improved seed and fertilizer inputs (key informant interviews, 2019). Cotton is grown under an out-grower scheme, and is sold to a cotton ginning plant in Mumbwa (key informant interviews, 2019). Fertilizers such as top dressing / D compound and urea are added to the maize fields. Pesticides are mainly added to cotton crops.

Land covered by this semi-natural macro-habitat no longer holds the original floristic values, and as a result, is devoid of the original (or pristine) faunal values to some extent. Their value is no longer ecological, but economic.

In addition to domesticated animals such as cattle and goats, cultivated and managed land is more likely to be used by generalist species, capable of benefiting from a wide range of conditions, and anthropic species, particularly suited to take advantage of human presence.

3.7.4.2. Flora

In this section, an overview of the area's phytoplankton and vascular flora is given, aiming at the identification of natural values with ecological or socio-economic value, as well as those in need of management or conservation action.

A) Phytoplankton

Phytoplankton organisms, i.e. microalgae that colonize the water column, constitute basal elements of aquatic ecosystems' trophic webs, and respond rapidly to environmental change, hence the group's utility in the assessment of ecosystem condition.

Records of phytoplankton species in the Lukanga Swamp, however, are only available for the wet season of the year 2019, and the list presented in Appendix (Appendix 3B – Flora species list) was sourced from this study entirely (BWZ & Dof MFL, 2019). As it is qualitative and derives from one sampling region and period only – four sites off Waya – it does not reflect the spatial or inter and intra-annual variability of phytoplankton population dynamics, and does not allow for in-depth conclusions to be drawn concerning the site's conditions.

The list includes eight (8) species and six (6) taxa only identified to the genus level (a total of 14 taxa), belonging to 11 families (Appendix 3B – Flora species list). Six (6) phylla are represented, including the three major freshwater wetland clades, Bacillariophyta (diatoms), Cyanobacteria (blue green algae) and Chlorophyta (green algae), as well as Charophyta (green algae), Euglenophyta and Ochrophyta.

The list includes potentially toxic and bloom-forming cyanobacteria genera, Microcystis and Anabaena (Pearl, Otten and Kudela, 2018), which tend to be favoured by nutrient enrichment.

B) Vascular flora

The Lukanga Swamp is located within the region classified by White (1983) as the Zambezian regional centre of endemism, the second largest phytochorion in Africa. This center has one of the richest floras of the African continent, including 8,500 species, 54% of which endemic (White, 1983). It constitutes the center of variation of the *Brachystegia* genus, and includes the woody endemic genera *Colophospermum*, *Diplorhynchus*, and *Pseudolachnostylis* (cf., 5.5 – Natural and semi-natural macro-habitats) (White, 1983).

The flora list compiled for the Lukanga swamp and its surroundings (Ramsar Site/Intervention Area + 10 km buffer) includes a total of 214 species and 20 genera belonging to 55 families (c.f., Appendix 3B – Flora Species List; see Appendix 3 for methodologies).

Of the 55 families, *Fabaceae* and *Poacea* are the most represented ones, at 65 and 43 taxa respectively, followed by *Combretaceae* and *Malvaceae* both with nine (9), and *Cyperaceae* and *Phyllanthaceae* both with seven (7). 26 families are only represented by one (1) taxon, 14 by two (2), and the remaining 13 are represented by six (6), five (5), four (4) or three (3) taxa.

Regarding conservation statuses, of the 214 listed species, 114 are classified as Least Concern (LC) in IUCN's Red List of Threatened Species, two are classified as Near Threatened (NT) and the remaining 98 are not listed (IUCN, 2020). The NT species are the Mukusyi, or Zambezi Teak, *Baikiaea plurijuga* Harms (of probable occurrence in Baikieae vegetation) and the African Blackwood, *Dalbergia melanoxylon* Guill. & Perr. (of probable occurrence in Munga and Termitaria), both of which are additionally classified as "Vulnerable" in Zambia's Red List (Bingham & Smith, 2002).

One species is classified as "Lower Risk" in Zambia, *Dalbergiella nyassae* Baker f. (Bingham & Smith, 2002), and two are further classified as "locally threatened" due to over-harvesting for timber, the Mupaap, or Pod Mahogany, *Afzelia quanzensis* Welw. and the Mulonbe, or Mulonbwa, *Pterocarpus angolensis* DC. (Forestry Department, 2016).

Two species are classified as introduced on the Flora of Zambia (Bingham *et al*., 2020), *Mimosa pigra* L., and *Salvinia molesta* D. Mitch, both also classified elsewhere as invasive (CABI, 2020).

3.7.4.3. Fauna

In this section, an overview of the area's animal assemblages is given, aiming at the identification of natural values with ecological or socio-economic value, as well as those in need of management or conservation action.

The next sections provide brief accounts of the following faunal groups:

- Invertebrates;
- Ichthyofauna;
- Herpetofauna;
- Avifauna;
- Mamofauna.

A) Invertebrates

According to Zambia's NBSAP-2 (Professor Keith Mbata, *in* MLNREP, 2014), national invertebrate diversity is estimated at 6,135 species, 69 of which endemic.

The major invertebrate phyla associated to wetlands include Mollusca (snails and clams), Arthropoda (insects, mites, crustaceans, etc.), Nematoda (roundworms), Annelida (segmented worms and leeches), Platyhelminthes (flat worms), Rotifera and Gastrotricha (Batzer & Boix, 2016).

Terrestrial invertebrate assemblages are predominantly composed of Arthropoda, typically including myriapods (e.g., millipedes and centipedes), arachnids (e.g., spiders and mites), and insects (e.g., termites and beetles).

Given data limitations, the following groups were considered in the present assessment:

- Zooplankton – microinvertebrates colonizing the water column (pelagic), mainly planktivores and detritivores;

- Phyllum Mollusca – macroinvertebrates colonizing the bottom (benthic), mainly herbivores, detritivores and filter feeders.

Regarding zooplankton, a total of 14 taxa (12 species and two [2] genera) were found in the 2019 wet season survey, belonging to the two (2) typical phyla Rotifera and Arthropoda (subphylum Crustacea) (cf. Appendix 3C – Fauna species list). Rotifers

dominate the list, with 10 species and one (1) genus, belonging to one class (Euratatoria), one (1) order (Ploima) and five (5) families (Lepadellidae, Brachionidae, Trichocercidae, Asplanchnidae and Lecanidae).

Copepod and cladoceran microcrustaceans make up the remaining three (3) species and one (1) genus. These represent two (2) classes (Branchiopoda and Hexanauplia), two (2) orders (Anomopoda and Cyclopoida) and three (3) families (Chydoridae, Cyclopidae and Daphniidae).

Regarding molluscs, a list of 19 species was compiled (for methodologies consult Appendix 3), consisting of 14 gastropods belonging to six (6) orders and six (6) families, and five (5) bivalves belonging to one (1) order and three (3) families (cf. Appendix 3C – Fauna species list).

Of the 19 species, two (2) are classified as Data Deficient, and one (1), *Lobogenes michaelis* Pilsbry & Bequart, 1927, is Endangered (IUCN, 2020). All others are considered of Least Concern (IUCN, 2020).

Finally, species of the gastropod genera *Biomphalaria* and *Bulinus* (possibly occurring in the area) can be intermediate hosts to *Schistosoma haematobium* or *S. mansoni*, parasitic platyhelminths that cause Schistosomiasis, or Billharzia, in humans (Kalinda *et al*., 2018). In terms of disease prevalence, the area is currently classified as “Low Risk” (≥1% and <10%) (Kalinda *et al*., 2018).

B) Ichthyofauna

Zambia holds a rich fish biodiversity with up to 201 species recorded for its water bodies with commercial or subsistence fisheries, excluding the 289 species endemic to Lake Tanganyika (MLNREP, 2014).

A total of 16 species was listed for the swamp (for methodologies consult Appendix 3), belonging to five (5) orders (Perciformes, Cypriniformes, Characiformes, Siluriformes and Osteoglossiformes) and six (6) families (*Cichlidae, Cyprinidae, Alestidae, Clariidae, Anabantidae* and *Mormyridae*) (cf. Appendix 3C – Fauna species list). The list is dominated by Perciformes (perch-like fishes), followed by Siluriformes (cat fishes). Within Perciformes, Cichlidae is the most represented family, as expected. The 2014 Frame Survey of the Lukanga Swmap (DoF, 2014) references three other families as

recurrently occurring in the swamp, *Characidae* (Characiformes), *Mochokidae* (catfishes) and *Schilbeidae* (catfishes).

Of the 16 listed species, 13 are classified as Least Concern (LC), two (2) are classified as Vulnerable (VU), the greenhead Tilapia (*Oreochromis macrochir* [Boulenger, 1912]) and the many spined climbing perch (*Ctenopoma multispine* Peters, 1844). One (1) species is classified as Critically Endangered (CR), the yellow-belly bream (*Serranochromis robustus* [Gunther, 1864]).

The yellow-belly bream was caught only in the 2015 survey, and was therefore classified as "probably" occurring in the swamp. This is a non-migrant piscivore cichlid who prefers vegetated rivers over lakes, lagoons or swamps. It breeds in summer and is an oviparous mouthbrooder.

One species, the Nile tilapia (*Oreochromis niloticus* [Linnaeus, 1758]), has been introduced in Zambian waters and can become invasive (CABI, 2020). This species was not caught in the 2019 survey.

C) Herpetofauna

Zambian herpetofauna is also still poorly documented, with estimates of 74 amphibian species and 156 reptile species evenly distributed across the country (MLNREP, 2014).

A total of 42 amphibian species belonging to one (1) order (Anura) and 12 families was listed as possibly occurring in Lukanga Swamp (cf. Appendix 3C – Fauna species list, and Appendix 3 for methodologies). The most represented family is Ptychadenidae (11, or 27%), also known as grassland frogs, followed by Hyperoliidae (7, or 17%), sedge or bush frogs. These consist mainly of common species with broad geographical distributions and favorable conservation status (Least Concern, LC), which probably results from the lack of localized surveys and from the compilation method, which might have biased the list towards abundant and widespread species. Amphibians are carnivorous, predominantly consuming invertebrates such as insects and molluscs.

A total of 21 reptile species belonging to three (3) orders (Squamata, Testudines and Crocodylia) and 14 families was listed, 13 of which possibly occurring and one (1) historically occurring, but known to not occur anymore (cf. Appendix 3C – Fauna species

list). Of these, 11 are classified as LC, and the other nine (9) are Not Evaluated (NE). Colubridae (snakes) is the most represented family, with 4 species (20%).

D) Avifauna

The Lukanga wetland is a particularly relevant habitat for avifauna, as demonstrated by its Important Bird Area (IBA) designation back in 2015. The site's Ramsar designation also targets waterfowl (among other, under criterion 2, which refers to the hosting of several endangered species) and calls for the inclusion of its conservation in management decisions.

A total of 356 species belonging to 24 orders and 79 families constitutes the avifauna inventory for the Lukanga swamp and its surroundings (for the methodology consult Appendix 3).

Of the 356 species listed, 119 are water birds (associated exclusively with wetland habitats: permanent swamp, edaphic grassland, lakes, rivers and streams), 12 of which are exclusive to the swamp. Phenology wise, 47 species are Palearctic migrants (i.e., wintering in the area), 42 are afro-tropical migrants (i.e., breeding in the area), 89 are partial or possible migrants, and 178 are resident species (i.e., both wintering and breeding in the area).

Diet wise, 48.7% of species belong to predominantly omnivorous orders, 45.5% belong to predominantly carnivorous orders (mainly insectivores, piscivores and generalist invertebrate eaters), and 4.8% to predominantly herbivore orders (granivores and frugivores).

Regarding conservation statuses, of the 356 species listed, 343 are classified as Least Concern (LC), five (5) as Near Threatened (NT), five (5) as Vulnerable (VU), one (1) as Endangered (EN) and two (2) as Critically Endangered (CR), in IUCN's Red List of Threatened Species (IUCN, 2020). One (1) species is introduced, the house sparrow (*Passer domesticus* [Linnaeus, 1758]), nine (9) are "of global conservation concern", and other nine (9) are of "regional conservation concern" according to Willems & Leonard (2019). Eight (8) species have distributions with restricted ranges.

E) Mamofauna

While Zambian mamofauna is relatively well documented in terms of charismatic megafauna, particularly within protected areas, small mammals and faunal assemblages outside of designated areas are comparatively understudied (Namukonde, 2017).

The list of possibly/potentially occurring mammal fauna consists of 122 species belonging to 11 orders and 34 families (cf. Appendix 3C – Fauna species list; see Appendix 3 for methodologies). Local mammal assemblages are mainly composed of small insectivores, herbivores and omnivores well-adapted to the exploitation of herbaceous wetland vegetation and associated invertebrate diversity. Chiroptera (bats), Carnivora (felines, mustelids, etc.), Cetartiodactyla (ungulates) and Rodentia (rodents) are the most represented orders in number of taxa. *Vespertilionidae* (insectivorous bats) and *Bovidae* (ungulates such as antelopes and buffalos) are the most represented families in terms of number of taxa, as expected given their ecological preferences.

Of the 122 taxa, 113 are classified as Least Concern (LC), while two (2) are Vulnerable (VU) and seven (7) are Near Threatened (NT) (IUCN, 2020).

According to comments from local communities from September and October 2019, large mammals are likely to occur towards the Itundu Plain and Lunga-Luwishi GMA rather than the rest of the swamp and grassland areas.

In general, large ungulate populations have been driven into protected area networks (including buffer areas such as GMAs) through the encroachment by rural communities and land-use change, as is illustrated by the negative relation of ungulate biomass and diversity to human settlements within NPs, GMAs and game ranches found by Lindsey *et al*. (2014).

Similarly, carnivores such as hyaenas (*Crocuta crocuta* [Erxleben, 1777]), caracals (*Caracal caracal* [Schreber, 1776]) servals (*Leptailurus serval* [Schreber, 1776]), and jackals (*Canis adustus* Sundevall, 1847), were listed given their historical distribution and hypothetically suitable habitat, but are unlikely to still occur or visit. Most of the listed large carnivore species occur in the KNP and are expected to occur in surrounding GMAs, down to the Kafue River boundary (Purchase, Mateke and Purchase, 2007).

3.8. Socioeconomics

In this section the characterisation of Lukanga Swamp and Upper Kafue Basin socioeconomic background is complemented with data on the evolution of the population from 1969 to 2010 with projections to 2020 and 2035.

The plan areas cross five districts of the Central Province (Chibombo, Kabwe, Kapiri Mposhi, Mumbwa and Ngabwe) and all the ten districts of the Copperbelt Province (Chililabombwe, Chingola, Kalulushi, Kitwe, Luanshya, Lufwanyama, Masaiti, Mpongwe, Mufulira and Ndola). Therefore, the analysis is focused primarily at the district level and, more broadly, at the province level. Nevertheless, it also includes a comparison with the whole country.

The information presented below is based on the 2000 and 2010 Census of Population and Housing (CSO, 2004a and b, 2012, 2013a and b, 2014a).

However, Ngabwe only became a district after the 2010 Census. In fact, Ngabwe was only declared a district in 2013; until that time, it was part of Kapiri Mposhi district, corresponding to Ngabwe and Mukubwe Wards (Lusaka Voice, 2013). Therefore, when the existing data is not available at the ward level, Ngabwe's information is not displayed.

3.8.1. Population and demography (1969-2035)

From 2000 to 2010, Zambia's population grew at an average rate of 2.8 percent per year, reaching 13,092,666 persons (CSO, 2012). In 2010, 60 percent of the country's total population was residing in rural areas.

The total population for the districts under analysis in 2010 was about 23 percent of the whole Zambia's population, according to the 2010 Census of Population and Housing (CSO, 2013a and 2014a) and considering the part of the Kapiri Mposhi district that became Ngabwe District[3].

Between 2000 and 2010, there was a population increase in all the districts under analysis. In Central Province the population grew at an average rate of 2.6 percent per year, while in Copperbelt Province the annual growth rate was approximately 2.2 percent.

Table 17 and Table 18 present the evolution of the population in Central and Copperbelt Provinces, between 1969 and 2010, as well as the annual growth rate between 2000 and 2010 and the population density.

[3] Ngabwe and Mukubwe Wards.

Table 17 – Population for Central Province districts crossed by the plan areas (1969-2010)

Province District	Population					Annual Growth Rate (2000-2010)	Density (2010) (pop/km^2)
	1969	1980	1990	2000	2010		
Central Province	358,655	511,905	771,818	1,012,257	1,307,111	2.6%	11.8
Chibombo District*	n.a.	n.a.	158,382	241,612	303,519	2.3%	37.1
Kabwe District	65,974	136,033	169,026	176,758	202,360	1.4%	130.8
Kabwe Rural District	122,570	146,295	n.a.	n.a.	n.a.	n.a.	n.a.
Kapiri Mposhi District*	n.a.	n.a.	110,762	194,752	253,786	2.7%	24.1
Mumbwa District	60,138	83,907	148,927	158,861	226,171	3.6%	11.4
Ngabwe District	n.a.	n.a.	n.a.	n.a.	21,238	n.a.	3.3

Legend: n.a. = data not available, it refers to either new or non-existent districts. (*) new districts which were formerly part of Kabwe Rural.
Source: Adapted from Zambia 2000 and 2010 Census of Population and Housing (CSO, 2004a, 2012 and 2013a).

Table 18 – Population for Copperbelt Province districts crossed by the plan areas (1969-2010)

Province District	Population					Annual Growth Rate (2000-2010)	Density (2010) (pop/km^2)
	1969	1980	1990	2000	2010		
Copperbelt Province	816,309	1,251,178	1,458,459	1,581,221	1,972,317	2.2%	63.0
Chililabombwe District	44,862	62,131	65,218	67,533	91,833	3.1%	92.1
Chingola District	103,292	145,993	168,999	172,026	216,626	2.3%	125.5
Kalulushi District	32,272	59,267	69,597	75,806	100,381	2.8%	97.4
Kitwe District	199,798	32,032	347,024	376,124	517,543	3.2%	640.5
Luanshya District	96,282	129,589	144,815	147,908	156,059	0.5%	166.4
Lufwanyama District	n.a.	n.a.	51,745	63,185	78,503	2.2%	6.9
Masaiti District	n.a.	n.a.	84,831	95,581	103,857	0.8%	29.1
Mpongwe District	n.a.	n.a.	37,718	64,371	93,380	3.8%	10.9
Mufulira District	107,802	150,069	152,735	14,393	162,889	1.2%	130.2
Ndola District	159,786	281,315	334,777	374,757	451,246	1.9%	467.6
Ndola Rural District	72,215	102,494	n.a.	n.a.	n.a.	n.a.	n.a.

Legend: n.a. = data not available, it refers to either new or non-existent districts.
Source: Adapted from Zambia 2000 and 2010 Census of Population and Housing (CSO, 2004b and 2014).

During the period of analysis, the districts' organisation in Zambia suffered a lot of changes. Therefore, data is not always available because it refers to either new or non-existing districts. Nevertheless, it is possible to conclude that in both Central and Copperbelt Provinces the population has significantly increased between 1969 and 2010.

In Central Province, between 1969 and 2010 the population more than tripled, reaching 1.3 million persons. In average, the population in this province increased 3.2 per cent per year during this period. In Copperbelt Province, in turn, the population increased at

an average rate of 2.2 per cent per year between 1969 and 2010, reaching almost 2 million persons.

The country is sparsely populated with a density of 17.4 persons per square kilometre (CSO, 2012). The density for Central Province is even lower, with 11.8 persons per square kilometre. On the opposite way, Copperbelt Province has a density of 63 persons per square kilometre. Kitwe and Ndola Districts are among the most densely populated, with approximately 641 and 468 persons per square kilometre, respectively.

Table 19 and Table 20 show the Central Statistical Office's (CSO) population and demographic projections regarding the Central and Copperbelt Provinces' districts, for the period between 2011 and 2035 (CSO, 2013b). According to these estimates, Central and Copperbelt Provinces will have approximately 2,565,450 and 3,823,642 inhabitants in 2035, respectively.

The population in the Central Province districts near Lukanga Swamp will increase 82.8% between 2011 and 2035, reaching 926,994 persons (CSO, 2013b). Despite population increase, the projections for the annual population growth rate indicate that, from 2020, the growing trend will be at a slower pace in some of the districts under analysis, such as Chibombo, Kabwe and Kapiri Mposhi (see Table 19).

Table 19 – Total population projections for Central Province districts crossed by the plan areas (2011-2035) (Medium Variant projection)

Province District	Population			Projected Annual Population Growth Rate	
	2011	2020	2035	2011-2020	2020-2035
Central Province	1,355,775	1,734,601	2,565,450	2.5%	2.5%
Chibombo District	156,708	194,778	271,991	2.2%	2.1%
Kabwe District	101,599	113,993	133,547	1.3%	1.0%
Kapiri Mposhi District	131,088	167,744	245,952	2.5%	2.4%
Mumbwa District	117,658	163,870	275,504	3.3%	3.3%
Ngabwe District	n.a.	n.a.	n.a.	n.a.	n.a.

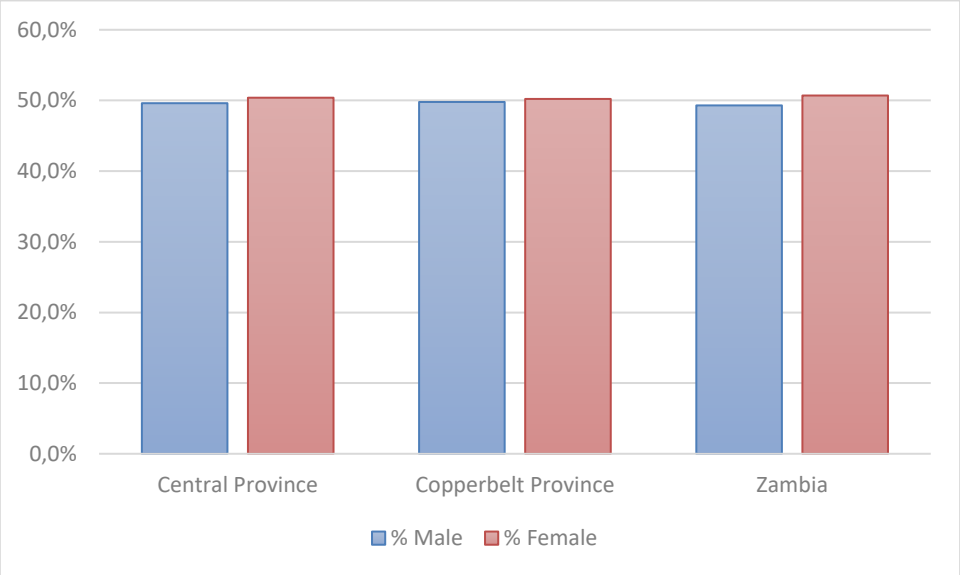
Source: Adapted from Zambia Population and Demographic Projections 2011-2035 (CSO, 2013b).

Table 20 – Total population projections for Copperbelt Province districts crossed by the plan areas (2011-2035) (Medium Variant projection)

Province District	Population			Projected Annual Population Growth Rate	
	2011	2020	2035	2011-2020	2020-2035
Copperbelt Province	2,143,413	2,669,635	3,823,642	2,2%	2,3%
Chililabombwe District	100,395	134,272	213,929	3,0%	3,0%
Chingola District	235,519	293,959	417,590	2,2%	2,2%
Kalulushi District	109,524	143,032	219,084	2,7%	2,7%
Kitwe District	566,131	762,950	1,223,870	3,0%	3,0%
Luanshya District	167,533	177,934	192,474	0,6%	0,5%
Lufwanyama District	85,268	105,156	146,443	2,1%	2,1%
Masaiti District	111,738	122,024	138,536	0,9%	0,8%
Mpongwe District	102,543	145,239	254,133	3,5%	3,6%
Mufulira District	175,753	199,095	240,307	1,3%	1,2%
Ndola District	489,009	585,974	777,276	1,8%	1,8%

Source: Adapted from Zambia Population and Demographic Projections 2011-2035 (CSO, 2013b).

In what concerns gender distribution, the territories under analysis have a similar profile. Although there is a slight difference between the number of male and female individuals, the population was almost equally distributed, as Figure 46 shows. In 2010, women represented 50.4 percent and 50.2 percent of total population in Central and Copperbelt provinces, respectively. At the district level the distribution was very similar. In Kabwe, the district where the population was more unequally distributed, women represented 51.2 percent of total population.



Source: Adapted from Zambia 2010 Census of Population and Housing (CSO, 2012, 2013a and 2014).

Figure 46 – Percent distribution of the population (*De jure*) by gender for Central Province, Copperbelt Province and Zambia (2010)

The percent distribution of the population by age group is presented in Table 21.

Table 21 – Percent distribution of the population (*De jure*) by age group for Central Province, Copperbelt Province and Zambia (2010)

Age group	Zambia	Central Province	Copperbelt Province
0 - 4	17.2%	17.5%	14.7%
5 - 9	14.6%	15.0%	12.8%
10 - 14	13.6%	14.1%	13.4%
15 - 19	11.7%	12.0%	12.9%
20 - 24	9.1%	8.9%	9.8%
25 - 29	8.1%	7.4%	8.7%
30 - 34	6.4%	6.0%	6.9%
35 - 39	5.2%	0.5%	5.6%
40 - 44	3.6%	3.5%	3.9%
45 - 49	2.9%	2.8%	3.2%
50 - 54	2.2%	2.2%	2.5%
55 - 59	1.5%	1.5%	1.8%
60 - 64	1.3%	1.3%	1.4%
65+	2.6%	2.8%	2.3%

Source: Adapted from Zambia 2010 Census of Population and Housing (CSO, 2012 and 2014a).

Table 21 shows that Zambia has a young population, with 45.4 percent of persons aged bellow 15 years, in 2010. The median age, in 2010, was 16.9 years, higher in urban areas (18.7 years) than in rural areas (15.6 years) (CSO, 2012).

The proportion of the population aged bellow 15 years was higher in the Central Province (46.6 percent). Also, the median age in Central Province was lower than that of the country as a whole (16.3 years in 2010). As in Zambia, the median age in urban areas was higher when compared to rural ones (18.3 years against 15.6 years, in 2010) (CSO, 2014a).

In Copperbelt Province, in turn, the proportion of the population aged below 15 years was 40.9 percent, lower than that for Zambia. This may be due to the fact that Copperbelt is essentially urban. In this province, the median age was also higher in urban areas than in rural ones (18.8 years against 16.6 years, in 2010).

3.8.2. Economic activities

It is estimated that about 60,000 people live in, or close to, the Lukanga wetland and that products, derived from fishing, hunting, and agriculture, support a hinterland population of some 6.1 million people (Ramsar Sites Information Service, 2005 in McCartney *et al*., 2011).

Indeed, the main economic activities in the communities living in and around Lukanga Swamp are:

- Farming – the most common livelihood strategy in the Lukanga catchment (Kachali *et al*., 2008);
- Charcoal production – charcoal burning or wood sales, which are pressuring the use of unsustainable practices, such as deforestation (Kachali, 2007 and Chabwela *et al*., 2010);
- Livestock rearing – common coping mechanism in periods of drought and natural disasters (Kachali *et al*., 2008); it is estimated that approximately 60 000 herds of cattle use the Lukanga swamp area at one time of the year (Chabwela *et al*., 2010);
- Fishing – main basis of the region's economy, with nearly every inhabitant being a fisherman and fish being the major diet of Lukanga swamp communities (Chabwela *et al*., 2010).

In this section the socio-economic characterisation of Lukanga Swamp is complemented with inputs from the Focus Groups Discussions (FGDs) held in local communities during the development of the plan.

The FGDs conducted in Chiyuni area allowed to detail the main economic activities performed by those residing in Kabosha and Muchoko fishing camps, detailed by gender. Table 22 and Table 23 summarise these results. They confirm that the Lukanga provides a variety of services, being a major source of income through fishing, as well as other secondary businesses. Additionally, it is also relevant to note that most of the activities are now performed both by men and women, as opposed to what the social norms and practices of the Lenje people established in the past (see section 3.9).

Table 22 – Economic activities performed by those living in Kabosha, by gender

Description of business	Who are the majority in the type of business	
	Male	Female
Fish trading	X	X
Trading in groceries	X	X
Barter system – exchange maize meal and fish		X
Banana plantation	X	X
Poultry	X	X
Buying and selling firewood	X	X
Trading in beer	X	X
Trading in tobacco	X	X
Trading in second hand clothes	X	X
Renting out canoes and small boats to fishermen and traders wanting to go to the island	X	X

Source: Nemus (FGDs held in Chiyuni area from the 18th to the 22nd December), 2019.

Table 23 – Economic activities performed by those living in Muchoko, by gender

Description of business	Who are the majority in the type of business	
	Male	Female
Brewing local beers for sale to fishermen at the swamps	X	X
Brewing local sweet drinks	X	X
Buying firewood from upper lands and Selling to fishermen who use that to process fish	X	X
Buying fish from fishermen and sell to people in the upper land	X	X
Farming – livestock and crops	X	X
Selling of maize meal to fishermen	X	X
Exchange of commodities through non-cash systems	X	X
Buying vegetables from other places for sell to fishermen	X	X
Buying milk from cattle keepers and reselling at the swamps and upper land	X	X
Renting out boats to fishermen and/or traders	X	X

Source: Nemus (FGDs held in Chiyuni area from the 18th to the 22nd December), 2019.

Finally, the main economic activity(ies) performed by each tribe is presented in Table 24. As it can be seen, most of the traditional communities are involved in fishing and farming.

Table 24 – Main economic activity(ies) performed by some specific social groupings

Tribe	Main economic activity in the tribe
Tonga	Farming
Bemba	Fishing
Lozi	Farming/fishing
Lenje	Farming/fishing
Namwanga	Trading/intermediary business
Ngoni	Farming/fishing
Kaonde	Farming/fishing
Kalunda	Farming/fishing
Luvale	Farming/fishing

Source: Nemus (FGDs held in Chiyuni area from the 18th to the 22nd December), 2019.

3.9. Governance

As stated by McCartney *et al*. (2011) Lukanga Swamp is managed following the National Wetlands Policy. The National Policy on Wetlands (2018) aims to promote "a coordinated approach to management and conservation of wetland ecosystems in Zambia" in order to address its degradation.

The Ministry responsible for Natural Resources is in charge of supervising the implementation of this Policy, as well as leading the inter-agency coordination on the management of wetlands in the country. In fact, the implementation and management of wetlands involve several institutions and stakeholders. Besides the presence of Zambian government, through its ministries and agencies, there is also a group of non-governmental organizations working in Lukanga, such as the World Wide Fund for Nature (WWF), the International Water Management Institute (IMWI), Development Aid from People to People (DAPP) and BirdLife International (Kachali *et al*., 2008 and Mapedza *et al*., 2012).

The fact that natural resource management, and particularly in this case wetland management, is fragmented in several government institutions and different regulations is often pointed out as contributing to natural resource degradation (Kachali *et al.*, 2008 and DSI, 2008). Furthermore, government authorities are often absent from the territory and therefore local communities are the actual managers of the wetlands (McCartney *et al.*, 2011).

Indeed, as most of the land in Zambia that is controlled under customary rights, the Lukanga Swamp and its catchment are under the traditional land system (Chabwela *et al*., 2010). This means that chiefs are very important stakeholders, not only being responsible for allocation of land but also in interpreting government policy and mobilizing the population for development programs (Chabwela *et al*., 2010). Traditional leaders thus remain very influential, being also responsible for giving permission to cultivate land, access to water and collect plants from the wetland and its surrounding areas (Mapedza *et al*., 2011 and McCartney *et al*., 2011).

There are five chiefs in the Lukanga – namely Ngabwe, Mukubwe, Chipepo, Liteta and Chitanda –, who preside over the predominantly Lenje speaking people (MCDSS-SWD, written communication, December 2019).

The group activities with headmen confirmed that chiefs are very important stakeholders and that local communities play a key role in wetland management.

Nevertheless, the headmen from Muchoko and Kabosha as well as his royal highness Chief Chitanda underlined the importance of having government support. The participants in the FGDs mentioned that with the closing of the Fisheries and Forestry Departments' offices in Chiyuni, they feel powerless to enforce environmental conservation and management practices. This is in line with a statement from the Social Welfare Department of the Ministry of Community Development and Social Services (written communication, December 2019), that "become nearly impossible to (…) police the fish ban due to inadequate manpower from the department of fisheries". Furthermore, the participants also revealed that, in the past, the presence of government soldiers and policemen helped to maintain peace and order in their chiefdoms. However, this does not happen anymore, which in the participants' opinion is creating more governance challenges.

In what concerns communities' characterisation there are three main tribal groups living in and around Lukanga Swamps (the Lenje, the Tonga and the Bemba), with the Lenje and Tonga people representing 25% of the total population in the area (Kachali *et al*., 2008 and Chabwela *et al*., 2010).

During the FGDs, the perception on the magnitude and diversity of the population at Muchoko and Kabosha were assessed through a participatory process of scoring using stones. The results presented in Table 25 and Table 26 confirm that the Lenje, the Tonga and the Bemba are the main tribal groups in Muchoko and Bemba is the largest group in Kabosha. Nevertheless, many other groups were mentioned, illustrating the diversity increase among Lukanga population.

Table 25 – Perception on the population of different tribes in Muchoko

Tribe	Score	Tribe	Score
Lenje	27	Luvale	4
Tonga	22	Kaonde	2
Bemba	5	Ngoni	2
Lozi	5	Namwanga	1
Kalunda	2	Others	1

Source: Nemus (FGDs held in Chiyuni area from the 18th to the 22nd December), 2019.

Table 26 – Perception on the population of different tribes in Kabosha

Tribe	Score	Tribe	Score
Lenje	8	Chokwe	3
Kalubale	64	Shona	2
Lozi	40	Namwanga	1
Bemba	800	Nsenga	2
Kaonde	3	Mwachusa	2
Mbunda	2	Tonga	2
Nkhoya	4	Lunda	8
Kasai	1	Ngoni	7
Luba	5	Lamba	1
Mambwe	1	Chawa/ Yao	1

Source: Nemus (FGDs held in Chiyuni area from the 18th to the 22nd December), 2019.

Another aspect that was underlined refers to the socio-cultural norms and practices adopted by the locals.

The Lenje people are the oldest tribal group in Lukanga and claim to be the "local residents" (Mapedza *et al*., 2012). Therefore, their beliefs and values had a great influence in management practices and rules that prevail nowadays in the wetland.

The FGDs confirm that for Lenje people the Lukanga is regarded as a sacred shrine, being a home for their ancestral spirits. Some participants shared stories about seeing ghosts and hearing invisible people singing, for example. These beliefs led them to adopt socio-cultural norms and practices in respect of their ancestral spirits, such as the prohibition to draw water from the Lukanga using a pot that was darkened as a result of being used on firewood, the ban of radios, alcohol and shops in the fishing camps or the fact that women, widows/widowers and sick people were not allowed to enter Lukanga.

In the traditional leaders' opinion, these social norms together with other conservation and management practices (the prohibition to catch small fishes, the fishing ban – from October to March – or the existence of just one official entry and exit point in the swamp) allowed to preserve the integrity of Lukanga ecosystem.

However, after the 1960s, the population in the Lukanga Swamp increased exponentially and became more diverse, because of the opening up of the Lukanga to people from

other tribal groups (see Table 25 and Table 26). The locals' perception on population growth is, in fact, supported by the results of the Census displayed in Table 17 and Table 18. From the social point of view, the disturbance of the social and traditional values and ecosystem degradation is associated with immigration from different tribal groupings.

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4. Evaluation

Evaluation is the process of identifying important features, ecosystem processes and services provided by a wetland. The purpose is to understand why the wetland is important not only to the local people, but also at wider scales. The process of evaluation helps to describe the “values” associated with the wetland and identifies the reasons for its conservation (Chatterjee, Philips and Stroud, 2008).

4.1. Diagnostic – assessment of wetland values

4.1.1. Hydrological and biogeochemical values

Considering all the information summarized in the baseline, the main hydrological and biogeochemical values of the Lukanga Swamp area and its catchment are:

- Surface water quality (biogeochemical and hydrological value);
- Surface water quantity (hydrological value);
- Groundwater quality (biogeochemical and hydrological value);
- Groundwater quantity (hydrological value);
- Soil quality (biogeochemical value).

The identified values were qualified according to an ecological value scale (in four classes, low to very high), based on their relevance and state. Table 3 and Table 4 show the parameters used for this classification.

Table 27 – Ecological relevance of hydrological and biogeochemical values

Ecological relevance	Considers the significance of the value for wildlife and local communities, and for the functions and services provided by the area in general.	
	Very high	Performs essential ecological functions; has a high economic value due to the species it supports and functions it performs; all members of local communities and flora and fauna are affected by its decrease
	High	Performs important ecological functions; has an economic value due to the species it supports and functions it performs; most of the members of local communities, and flora and fauna are affected by its decrease

	Moderate	Performs important ecological functions; selected members of local communities and more sensitive flora and fauna species are affected by its decrease
	Low	Performs some important ecological functions, but local communities and most flora and fauna can thrive without it
	(non-existent)	Does not support relevant ecological functions

Table 28 – Ecological state of hydrological and biogeochemical values

Ecological state	Takes into account observed indicators of degradation; criteria are different for the different values considered: chemical concentrations, long term trends, management practices, and opinion of stakeholders	
	Favourable	Water quality: no signs of contamination Water quantity: no long-term trends Soil quality: adequate agriculture practices, no signs of erosion and degradation, no signs of contamination
	Medium	Water quality: crossing of some thresholds Water quantity: decreasing long-term trends Soil quality: unsustainable agriculture practices, signs of erosion and degradation, signs of contamination
	Unfavourable	Water quality: crossing of several thresholds Water quantity: decreasing long-term trends Soil quality: unsustainable agriculture practices, signs of erosion and degradation, signs of contamination

Taking into account the aforementioned relevance and state scales, Table 29 shows the classification of each value, and the resulting final classification of its ecological value.

At the same time, the recognition of the above hydrological and biogeochemical values allows the identification of some of the ecosystem services indicated in the following section.

Table 29 – Classification of hydrological and biogeochemical values from the Lukanga Swamp and its catchment

Value	Ecological relevance		Ecological state		Ecological value
	Descriptive	**Classific.**	**Descriptive**	**Classific.**	
Surface water quantity	It is particularly because of the surface water quantity and dynamic water levels, that this area gains most of its biological features. Suffice to say that the body of water created is responsible for maintaining all its aquatic fauna and flora.	**Very High**	To our best knowledge, there are no evidences of a decrease of surface water quantity in the swamp, at least between 1959 and 1988 and between 2002 and 2016 (Section 3.2.3.3). During the first period there was a variation of 4 m in Twenty Village and 2,5 m in Chilwa Island. During the second period there was a global average variation of around 3 m. This indicates that probably there are no differences also between both periods. However, local people refer that water levels of the swamp have been decreasing throughout the past years. This may be because there are high internannual variations of the water levels in the swamp and cycles of variation of 5 years or more, and so the recent memory of people may lead them to wrong impressions. Overall, there is no sufficient data to be certain about the long-term trend.	**Medium**	**High**

Table 29 – Classification of hydrological and biogeochemical values from the Lukanga Swamp and its catchment (cont.)

Value	Ecological relevance		Ecological state		Ecological value
	Descriptive	Classific.	Descriptive	Classific.	
Groundwater quantity	Quantity of groundwater is an important value because not only it is the main source of water for all the human communities living in the catchment, but also because it is an important source of water to the streams draining into the swamp and also directly into the swamp. These contributions are particularly important during the dry season.	**High**	To our best knowledge, there is no monitoring of the water depth of wells or boreholes in the catchment. Local people refer that water levels have been decreasing throughout the past years. Once again this could be related with the high internannual variations and cycles of variation of 5 years or more, and so the recent memory of people may lead them to wrong impressions.	**Medium**	**Moderate**
Surface water quality	The quality of surface water allows maintaing aquatic life and the most basic uses of water, as drinking, especially to wild animals and cattle, but fisherman also drink from the swamp while fishing.	**Very High**	Quality of surface water in the whole Lukanga Swamp and catchment varies greatly (Chapter 3.6 and Appendix 2). Water streams and water from the outer part of the swamp shows high concentrations of trace metals and in some cases nitrates. In the inner part of the swamp the quality with regards to these parameters clearly increase.	**Medium**	**High**
Groundwater quality	The quality of groundwater allows local people to have a source of water for drinking and all household uses in general. Groundwater quality will also interfere with quality of surface water of streams and swamp.	**High**	Problems on groundwater seems generalized in the catchment. The main problems seem related with concentrations of metals, particularly of Cd and Pb, but also with high concentrations of nitrates and low pH (Chapter 3.6 and Appendix 2).	**Unfavourable**	**Low-Moderate**

Table 29 – Classification of hydrological and biogeochemical values from the Lukanga Swamp and its catchment (cont.)

Value	Ecological relevance		Ecological state		Ecological value
	Descriptive	Classific.	Descriptive	Classific.	
Soil quality	The maintenance or improvement of soil resources in the Lukanga area so that they can provide sufficient food, fibre, and fresh water, maintain biodiversity, and deliver overall environmental protection and ecosystem services is key.	**Very High**	Local people report lack of fertilite of soil and its degradation. Given the soil management practices used in the area, soil degragadtion comes from loss of soil biodiversity, reduction of organic matter, contamination of soil, nutrient inbalance and soil erosion. To our knowledge, the state of soil quality is undifferentiated throughout the catchment.	**Unfavourable**	**Moderate**

4.1.1.1. Threats

Below the main threats to the hydrological and biogeochemical values in the Lukanga swamp and its catchment will be quickly analysed. However, these main threats, particularly those that are associated with the drivers of change will be further developed in the next chapter.

A) Surface water and groundwater quantity

The amount of surface water and groundwater in the swamp and catchment is threatened by changes in land use in the catchment of the Lukanga Swamp, by water abstractions in the Upper Kafue River Basin and by climate change.

B) Surface water and groundwater quality

The decrease of water quality in general is in one hand due to human activities (be it the increase of population without the development of infrastructures that allow the maintenance of the balance of natural systems or the wrong agriculture practices), but on the other hand the high amount of trace metals can also be associated with the geology of the area.

C) Soil quality

Mainstream agriculture practices (tillage-based crop production, simplified crop rotations, monocultures, improper application of fertilizers, etc.), extensive grazing and burning of rangelands are the main threats to the value “soil quality”. The combination of these practices leads to soil degradation in general which may combine loss of soil biodiversity, reduction of organic matter, contamination of soil, nutriente inbalance and soil erosion.

4.1.2. Ecological values

Based on the descriptive work done so far, the current chapter identifies and prioritizes wetland ecological values - habitats, flora and fauna – in order to direct the definition of the conservation plan's objectives, strategies and action plan (Chatterjee, Philips and Stroud, 2008).

The diagnosis will also serve as the basis for the revision of the LSCMP, in particular in what relates to the zonation for the Multiple Use Conservation Area. Areas with higher ecological value support relevant biodiversity and functions, and are candidates for protection. Those with low ecological value can be candidates for management action.

4.1.2.1. Habitats

For this, the Ramsar site and surrounding area's key ecological features were qualified according to an ecological value scale (in four classes, low to very high), based on the classification of two other parameters, relevance and state (Table 30 and Table 31).

Table 30 – Ecological relevance

Ecological relevance	Takes into account the significance for wildlife (in particular, waterfowl), natural values (eg., "rarity or uniqueness of the associated biodiversity" according to national and international classifications, such as the IUCN Red List of Threatened Species), functions and services, as well as national and international classifications regarding its relevance	
	Very high	Habitat with high primary productivity and very relevant biodiversity; it performs essential ecological functions (biodiversity refuge; nursery; feeding; breeding/nidification) and others (such as protection/buffering of other habitats); has a high economic value due to the species it supports and functions it performs
	High	Habitat with a relevant biodiversity; performs important ecological functions (biodiversity refuge, nursery, feeding and nidification), as well as other functions (buffering of other habitats); has an economic value attached to the species and functions is supports
	Moderate	Performs important ecological functions (refuge, nursery, feeding and nidification) and eventually other functions (such as protection of other habitats); the associated biodiversity is not relevant

	Low	Performs some important functions, but its associated flora and fauna is generally not relevant
	(non-existent)	Negligible biodiversity; does not support relevant ecological functions

Table 31 – Ecological state

Ecological state	Takes into account the presence of an ecological continuum (degree of "continuity and connectivity" of and between natural habitats), the risk of fragmentation (considering observed pressures) and the conservation status defined as the degree of human presence (naturalness/integrity, ie., the distance to original/pristine conditions based on literature accounts and field observations: degree of human presence, observed indicators of degradation, water quality, among others)	
	Favourable	The ecological continuum is evident/apparent, without any visible fragmentation; the risk of fragmentation is variable, depending of existing pressures; the conservation status of the vegetation is good to very good.
	Medium	The ecological continuum is interrupted to a higher or lesser degree; further fragmentation risk present; conservation status of the vegetation low to medium.
	Unfavourable	The ecological continuum is visibly interrupted; there is a risk of the fragmentation worsening; the conservation status of the vegetation is low.

Taking into account the aforementioned relevance and state scales, Table 32 presents the classification of each habitat, and the resulting final classification of its ecological value. The table summarizes the elements that were considered in the evaluation, according to the diferent criteria, but does not substitute the baseline description developed earlier and presented in detail in Appendix (Appendix 3).

Table 32 – Classification of the Lukanga site's habitats

Habitat	Ecological relevance		Ecological state		Ecological value
	Descriptive	**Classific.**	**Descriptive**	**Classific.**	
Forested land	Buffering/protection of wetland habitats and water bodies; refuge, breeding or feeding habitat for species of conservation priority; great economic value (provision of food, medicine and raw material for construction and energy)	**High**	Visibly interrupted ecological continuum (greater in the east), with a great risk of further fragmentation; threatened by resource use/harvesting, and land conversion; low (south and northeast) to medium (northwest) conservation status	**Unfavourable**	**High to moderate**
Termitaria grasslands	Refuge for small mammals and avifauna; breeding and feeding habitat for large herbivores; some economic value (grazing grounds)	**Moderate**	Intact ecological continuum; further fragmentation risk is present, given observed pressures: grazing, dry season fires and reclamation for agriculture as upland cultivation expands; conservation status is low to medium (worsening towards the east)	**Medium**	**Moderate**
Edaphic grasslands	Seasonally high productivity; breding habitat for fish; breeding and feeding habitat for waterfowl; breeding and feeding habitat for large herbivores; nutrient cycling; some economic value (grazing grounds)	**Very high**	Intact to interrupted ecological continuum (worsening towards east of the swamp); further fragmentation risk is present, given observed pressures: grazing, dry season fires and reclamation for agriculture as upland cultivation expands; also threatened by increasingly severe droughts; good to medium conservation status (worsening in the east and south) (field observations; Chabwela, Chomba and Thole, 2017)	**Medium to favourable**	**High to very high**

Table 32 – Classification of the Lukanga site's habitats (cont.)

Habitat	Ecological relevance		Ecological state		Ecological value
	Descriptive	**Classific.**	**Descriptive**	**Classific.**	
Permanent swamp	High productivity; nursery habitat for fish; refuge, breeding and feeding habitat for waterfowl; refuge, breding and feeding habitat for wetland obligate mammals; nurient sink and source; water filtering and storage; great economic value (fisheries and raw material)	**Very high**	Intact ecological continuum (worsening towards east, as encroachment advances); fragmentation risk is present but reduced; threatened by resource use/ harvesting, land conversion (settlement of fishing camps), pollution and invasive species; medium conservation status, mainly derived from the presence of exotic species *Salvinia molesta* (Chabwela, Chomba and Thole, 2017; BWZ,2020a)	**Medium**	**Very high**
Riparian vegetation	Breeding and feeding habitat for wetland obligate carnivores; protection/buffering of wetland and open water habitats (eg., sediment retention); maintenance /fixation of river margins; economic value (raw material)	**Very high**	Visibly interrupted ecological continuum; further fragmentation risk is high; threatened by resource use/harvesting; low conservation status	**Unfavourable**	**High**
Open rivers and streams	Habitat for species of conservation priority; economic value (fisheries)	**Moderate**	Intact ecological continuum; threatened by pollution, sedimentation, invasion by alien species and increasingly severe droughts; low conservation status	**Medium**	**Moderate**
Lakes	Habitat for species of conservation priority; introduces complexity to the swamp; of economic value (fisheries)	**High**	Intact ecological continuum; fragmentation risk is present; threatened by resource use, pollution, invasive species and increasingly severe droughts; good conservation status	**Favourable**	**High**

Table 32 – Classification of the Lukanga site's habitats (cont.)

Habitat	Ecological relevance		Ecological state		Ecological value
	Descriptive	Classific.	Descriptive	Classific.	
Cultivated land	---	**Low**	---	**---**	**Low**
Artifical areas (rural settlements, etc.)	---	**(null)**	---	**---**	**(null)**

Habitats that warrant prioritization in planning or managing are, in general, those of significance for waterfowl, wild ungulates and fish populations, that also support a range of important ecosystem services.

The habitats of highest value were found to be the permanent swamp and the edaphic grassland, particularly towards the west, followed by forested land (where it is less degraded), riparian vegetation and lakes.

Overall, the current state of natural habitats descreases in quality eastward and southward, which is in accordance with the encroachment by human settlements and associated intensification of human activities in that zone.

4.1.2.2. Biodiversity

In addition to the classification of habitats, certain flora and fauna species or communities are also values warranting prioritization in planning or managing, given either their unfavourable conservation status, or their role in the system's food-webs or in particular ecological functions and services (Table 33).

Table 33 – Prioritization of flora and fauna

Species/community	Relevance	State	Occurrence	Value
Flora				
Phytoplankton and phytobenthos	Maintenance of food-webs	Insufficient data	Permanent swamp; lakes; rivers and streams	**VERY HIGH**
Aquatic macrophytes	Habitat for species of conservation priority; maintenance of populations	Insufficient data	Permanent swamp; lakes; rivers and streams	

Species/community	Relevance	State	Occurrence	Value
Fauna				
Zooplankton	Maintenance of food-webs; maintenance of swamp biodiversity	Insufficient data	Permanent swamp	**VERY HIGH**
Swamp macroinvertebrates	Maintenance of food-webs; maintenance of fish populations	Insufficient data	Permanent swamp	
Fish assemblages	Maintenance of food-webs; feeding for waterfowl; fisheries	Suspected unfavourable, in recovery (BirdWatch Zambia & DoF, 2019), but data is not sufficient	Permanent swamp; rivers and streams	
Wild ungulates	Maintenance of the grassland ecosystem; carrion for endangered species; potential for future trouristic revenue	Suspected unfavourable, but data is not sufficient	Edaphic grassland; termitaria; permanent swamp; higher suitability in the west and northwest (confluence of the Kafue and Lukanga Rivers; Itundu Plain)	
Waterbirds	Critera for Ramsar and IBA designation; several species classified as vulnerable; potential for future trouristic revenue	Insufficient data	Permanent swamp; edaphic grassland; termitaria; rivers and streams higher suitability in the west and northwest (confluence of the Kafue and Lukanga Rivers; Itundu Plain)	

Species/community	Relevance	State	Occurrence	Value
Serranochromis robustus Gunther, 1864 (yellow-belly bream)	Critically endangered (IUCN, 2020)	Insufficient data	Rivers and streams; lakes	HIGH
Gyps africanus Salvadori, 1865 (white-backed vulture)	Critically endangered (IUCN, 2020)	Insufficient data	Termitaria; Forested land; prefers *Acacia-combretum*/ munga; sensible to human presence	
Trigonoceps occipitalis (Burchell, 1824) (white-headed vulture)	Critically endangered (IUCN, 2020)	Insufficient data	Forested land; prefers Acacia trees for nesting, but is sensible to human presence	
Lobogenes michaelis Pilsbry & Bequart, 1927	Endangered (IUCN, 2020)	Insufficient data	Permanent swamp	
Aquila nipalensis Hodgson, 1833 (steppe eagle)	Endangered (IUCN, 2020)	Insufficient data	Termitaria; higher suitability in the west and northwest	

Sources: IUCN, 2020; Beilfuss *et al*., 2002

In addition to these, several other species are classified as near threatened or vulnerable, and, while not being prioritary for management at this momemnt, the proposed actions and measures will take them into consideration. Since most are associated with the swamp, management/conservation actions for this habitat and other, similar, biodiversity values will cover for the conservation of these. These include, but are not limited to:

- *Oreochromis macrochir* (Boulenger, 1912) (greenheaded tilapia) (insufficient information);
- *Ctenopoma multispine* Peters, 1844 (many spined climbing perch) (insufficient information);
- *Bugeranus carunculatus* (Gmelin, 1789) (wattled crane) (unfavourable, based on Beilfuss *et al*., 2001);
- *Balaeniceps rex* Gould, 1850 (shoebill) (insufficient information);
- *Egretta vinaceigula* (Sharpe, 1895) (slaty egret) (insufficient information);
- *Polemaetus bellicosus* (Daudin, 1800) (martial eagle) (insufficient information);

- *Smutsia temminckii* (Smuts, 1832) (ground pangolin) (insufficient information);
- *Hippopotamus amphibius* Linnaeus, 1758 (hippopotamus) (unfavourable, based on Beilfuss et al., 2002 and informant interviews);
- *Afzelia quanzensis* Welw. (pod mahogany) (locally threatened) (insufficient data);
- *Pterocarpus angolensis* DC. (mulonbe) (locally threatened) (insufficient data).

4.1.2.3. Threats

Table 34 lists the threats to the healthy functioning and conservation of these values, as observed during the site visits and identified in focus groups and available literature.

Table 34 – Main threats affecting the conservation of the site's values

Very high value	
Permanent swamp	• pollution from diverse sources with impacts on the chemical condition of aquatic habitats (eg., from agricultural land uses, from fishing camps within the swamp, etc.) • invasive weed introduction and propagation, with impacts on the biodiversity and the conditions of aquatic habitats • reduction of water and flood levels, with impacts on the vegetation and on the chemical conditions of aquatic habitats • degradation of terrestrial habitats with protective functions in the catchment (eg. deforestation leading to increased run off and siltation) • overfishing or harvesting leading to biodiversity loss, with impacts on the system's resilience to external pressures • eutrophication from increased nutrient input, with impacts on the biodiversity and the chemical conditions of aquatic habitats
Phytoplankton and benthic microalgae	• idem
Aquatic macrophytes	• idem

Edaphic grasslands	• unsustainable fire regime • unsustainable grazing pressure • reduction of water and flood levels (either from climate change or water development projects upstream), causing a shrinkage of the habitat with encroachment from terrestrial vegetation • loss of coverage due to land reclamation for anthropic uses
Zooplankton	• deterioration of ecological conditions of aquatic habitats
Swamp macroinvertebrates	• deterioration of ecological conditions of aquatic habitats
Fish assemblages	• insufficient identification/delimitation and communication of breeding and nursery areas where fishing is prohibited • insufficient enforcement of fishing bans and gear restrictions • overfishing due to the above, and intensified by increased human population and inexistence of alternative means of subsistence • deterioration of the ecological conditions of aquatic habitats • competition with *Oreochromis niloticus*
Wild ungulates	• poaching • habitat degradation
Waterbirds	• habitat loss or degradation from pollution, fires, weed invasion and modification of the hydrological regime • hunting of adults and eggs for consumption or illegal trade • depletion of food resources from overfishing and biodiversity loss in aquatic habitats • human disturbance • mortality from cattle trampling the nests

High value	
Forested land	• conversion; mainly for agriculture • degradation from: – unsustainable harvesting/ logging for charcoal, firewood and construction (canoes, fish-drying and smoking structures, etc.) – unsustainable incidence of fires (e.g., increased frequency of late dry season fires) – unsustainable harvesting of plants for medicinal use – unsustainable harvesting of fruits and mushrooms for consumption • overall, insufficient regulation, enforcement and/or incentives for the wise use of forest products
Riparian vegetation	• unsustainable harvesting for construction (thatching, matts, baskets, etc.)
Open lakes	• reduced area of coverage from the reduction of water levels leading to reed overgrowth (from climate change or upstream water development projects) • pollution from diverse sources with impacts on the chemical condition of aquatic habitats (eg., from agricultural land uses, from fishing camps within the swamp, etc.) • eutrophication from increased nutrient input, with impacts on the biodiversity and the chemical conditions of aquatic habitats • overfishing; with impacts on the biodiversity
Serranochromis robustus Gunther, 1864 (yellow-belly bream)	• overfishing (see threats for fish assemblages in general)
Gyps africanus Salvadori, 1865 (white-backed vulture)	• pesticide poisoning • reduction of food resources (carrion) from the reduction in ungulate populations
Trigonoceps occipitalis (Burchell, 1824) (white-headed vulture)	• idem

Lobogenes michaelis Pilsbry & Bequart, 1927	• pollution and eutrophication, causing the deterioration of ecological conditions in the aquatic habitat • water development projects upstream, altering the hydrological regime of the wetland
Aquila nipalensis Hodgson, 1833 (steppe eagle)	• reduction in suitable habitat through land conversion for agriculture or settlements • pesticide poisoning
Moderate value	
Rivers and streams	• water development projects upstream, altering the hydrological regime of the wetland • pollution and eutrophication
Termitaria	• degradation from: – unsustainable harvesting/ logging for charcoal, firewood and construction (canoes, fish-drying and smoking structures, etc.) – increased incidence of fires – unsustainable harvesting of plants for medicinal use – unsustainable harvesting of fruits and mushrooms for consumption
Forested land	• *idem* to the forested land of high value

Sources: Appleton, Curtis and Kristensen, 2010;

Table 34 compiles the indirect and direct threats that drive change in the wetland and surrounding ecosystems, jeopardizing the conservation of biodiversity and the good functioning of the system, which in turn translates into impacts on human well-being. These main direct threats can be categorised as such:

- changes in land use and cover: deforestation, fire regime, grazing regime, harvesting, among others; in the catchment, these threats act as percursors/intensifiers of pollution and nutrient input into the system, while also contributing to the removal of species and habitats on site;
- species removal and/or introduction: invasion by alien species; overfishing; poaching; etc.; the introduction or removal (local extinction) of a species or groups of species can disrupt food-webs, reducing the system's capacity to assimilate external pressures, and possibly amplifying other negative impacts;
- pollution and eutrophication: from agricultural runoff and poor sanitation;

- changes of the hydrological regime: from hydraulic projects, water abstraction and climate change.

Acting on these are a number of indirect and basal threats, of a more general nature, but which need to be considered if effective management is to be achieved:

- population growth (demographics);
- poverty and inexistence of alternative income sources (economic) at the individual level; the economic situation of the population means people are generally unable to make ecologically sustainable decisions in everyday life;
- limited knowledge of the system's functioning (research and education); there is still a lack of quantitative baseline data on the biological diversity and ecological processes of the site; in addition, the flawed and unsuficient dissemination of data further limits the capacity for accurate and sustained management decisions to be made;
- limited institutional resources, legislation and policy; financial and human resources are scarce and largely insufficient (MFL, 2020);
- insufficient public awareness of the benefits and services of natural systems; while there is an understanding of the overall importance of natural systems among local polulations, an opportunity remains to clearly explain the interactions between different drivers of change and their impacts on the harvested/perceived benefits, together with promoting sustainable use of wetland and forest resources, prioritizing traditional knowledge and practices, this way capacitating local people to make better-informed decisions.

Further details on some of these threats are given in a later chapter (cf., Drivers of change and impacts).

Finally, for the development of conservation measures and actions, the risk of new biological introductions and fulffillment of their invasive potential, as it is happening with the Kariba weed, must be addressed. Prevention is the most important phase in the management of invasive species, since the cost of controlling an established invasion is much higher.

Accordingly, Table 35 lists the species that have been detected in the swamp or are in higher risk of introduction, and thus warrant mentioning and eventually management to minimize risks.

Table 35 – Invasive alien species

Flora	
Salvinia molesta D. Mitch (Kariba weed)	• aquatic free-floating fern from the family *Salviniaceae*; it invades water bodies, preferring slow flowing or standing waters • reproduces asexually though fragmentation of the rhizome • introduced around 2009 in the swamp • currently under management by BirdWatch Zambia in a biocontrol project where a specialized feeder weevil was introduced • typically introduced in the gear of fishermen when they travel between different systems • may significantly alter the swamp's conditons, leading to biodiversity loss (affecting commercially important fish species); can also form thick mats that clogg water channels, preventing the movement of canoes; it is also a breeding habitat for vectors of malaria and bilharzia • the invasion is facilitated in sheltered areas (from strong winds and currents), with continued nutrient input, and in the absence of competitors or grazers
Eichhornia crassipes (Mart.) Solms (water hyacinth)	• aquatic free-floating perennial Angiosperm from the family *Pontederiaceae* • similar in invasiveness, impacts and introduction paths to *S. molesta* • according to existing records and the field visits in 2019, it is not present; preventive management is key
Mimosa pigra L. (giant sensitive plant)	• small perennial shrub from the family *Fabaceae*; it invades floodplains and other open wet grasslands • seed propagating

	• referenced in Chabwela *et al.* 2010 as occurring in “riverine wetland/floodplain” and in “swamp and flood plain”; not detected inside the area during the field work conducted in 2019, and nor referenced either in Chabwela, Chomba and Thole (2017) • forms large monospecific stands, impeding movement of people and livestock, and obstructing access to water resources; alters local biodiversity • can be introduced on cattle as it is transported, or in transport equipment; spreads naturally by floating along river systems • *the current status of the invasion in the Lukanga must be confirmed and monitored*
Fauna	
Oreochromis niloticus (Linnaeus, 1758) (Nile tilapia)	• freshwater to brackish water fish species of the family *Cichlidae*; introduced in Zambian waters, with the capacity to become invasive • caught in the swamp in 2015 but not in 2019 • as main impacts, can cause native biodiversity loss or degradation, trophic level changes and subsequentely altered ecosystems • the main path of spread is through the intentional introduction for aquaculture and subsequent inadvertent escape into natural systems • the current status of the invasion in the Lukanga must be confirmed and monitored, especially given the occurrence of *O. macrochir* in the system
Cherax quadricarinatus (von Martens, 1868) (redclaw crayfish)	• Aquatic crayfish from the family *Parastacidae*; occurs in slow to fast flowing freshwater and brackish water • abundant in the Kafue river downstream of Itezhi-tezhi, and present in the Mushingashi Conservancy, which is just downstream of the swamp and upstream of the KNP • introduced into fish farms on the Kafue Flats and Lake Kariba, from which it is believed to have escaped; may have been deliberately released as well

	• can spread parasites to native crustaceans and affect artisanal fisheries; food source for species of conservation interest; no nutritional value • the current status of a possible invasion in the Lukanga must be confirmed and monitored

References: Kafue River Trust, 2020; CAB International, 2020

4.2. Ecosystem services assessment

This section approaches the Lukanga Swamp through the lens of its ecosystems and associated services, establishing the connection between the baseline and diagnostic of the wetland and the economic valuation, describing the services or benefits provided by the biophysical elements of the region (De Groot *et al.*, 2006).

4.2.1. Selection of ecosystem services

Ecosystem components (biological, chemical and physical) interact in complex processes that perform several ecological functions (De Groot *et al.*, 2006). The latter are the means through which the ecosystem delivers goods and services, and the health/condition of these components and processes determines the system's ability to function and deliver accordingly.

Ecosystem services and goods (ES) were identified through literature review, and from field visits – where field sampling and observation, key informant interviews and focus group discussions were conducted – and are listed in Table 36.

The classification of services and goods follows that of the Common International Classification of Ecosystem Services (CICES) V5.1 (Haines-Young & Potschin, 2018). The CICES classification groups services into three sections, relating to how each function/contribution of an ecosystem supports (1) the provision of material and energy needs; (2) the regulation and maintenance of the environment for humans; and (3) the cultural/non-material characteristics that affect physical and mental states of people (EEA, 2020).

Table 36 – Ecosystem services and goods identified in the Lukanga Swamp and its catchment, following the CICES v5.1 classification

Section	Code	Class	Descriptor	Examples of relevant ecosystems
Provisioning (Biotic)	1.1.1.1	Cultivated terrestrial plants grown for nutritional purpose	Crops and fruits grown for food	Cultivated and managed land
	1.1.3.1	Animals reared for nutritional purposes	Livestock raised and grazed outdoors	Grassland
				Termitaria
	1.1.5.1	Wild plants for nutrition	Food from wild plants and fungi	Forest and woodland
	1.1.5.2	Wild plant fibres and other materials for direct use or processing	Materials from wild plants	Swamp
				Rivers and streams
				Forest and woodland
	1.1.5.3	Wild plants used as a source of energy	Materials from wild plants, used for energy	Forest and woodland
	1.1.6.1	Wild animals for nutrition	Food from wild animals	Swamp
				Grassland
				Lakes
				Rivers and streams
				Termitaria
				Forest and woodland

Table 36 – Ecosystem services and goods identified in the Lukanga Swamp and its catchment, following the CICES v5.1 classification (cont.)

Section	Code	Class	Descriptor	Examples of relevant ecosystems
Regulation and maintenance (Biotic)	2.2.1.1	Control of erosion rates	Controlling of preventing soil loss	Swamp
				Grassland
				Forest and woodland
	2.2.1.3	Hydrological cycle and water flow regulation	Regulating the flows of water in our environment	Swamp
				Grassland
	2.2.2.1	Pollination	Pollinating our fruit trees and other plants	Forest land
	2.2.2.3	Maintaining nursery populations and habitats	Providing habitats for wild plants and animals that can be useful to us	Swamp
				Grassland
				Lakes
				Rivers and streams
	2.2.3.1	Pest control	Controlling pests and invasive species	Swamp
				Grassland
	2.2.4.1	Decomposition and fixing processes and their effect on soil quality	Ensuring the organic matter in our soils is maintained	Swamp
				Grassland
				Termitaria
				Forest and woodland
	2.2.5.1	Regulation of the chemical condition of freshwater by living organisms	Controlling the chemical quality of freshwater	Swamp
				Grassland
	2.2.6.1	Regulation of the chemical composition of the atmosphere	Regulating our global climate	Swamp
				Grassland
				Termitaria
				Forest and woodland

Table 36 – Ecosystem services and goods identified in the Lukanga Swamp and its catchment, following the CICES v5.1 classification (cont.)

Section	Code	Class	Descriptor	Examples of relevant ecosystems
Cultural (Biotic)	3.1.2.1	Characteristics of living systems that enable scientific investigation or the creation of traditional ecological knowledge	Researching nature	Swamp
Provisioning (Abiotic)	4.2.1.1	Surface water for drinking	Drinking water from sources at the ground surface	Swamp
	4.2.2.1	Ground (or subsurface) water for drinking	Drinking water from below the ground	Aquifer
Regulation and maintenance (Abiotic)	5.2.1.1	Mass flows	Physical barriers to landslides	Swamp
	5.2.1.2	Liquid flows	Physical barriers to flows	Swamp

Source: Adapted from EEA, 2020.

Table 37 shows the equivalence of the services identified through the CICES system with the Millennium Ecosystem Assessment (MA) and The Economics of Ecosystems and Biodiversity (TEEB) frameworks.

Table 37 – Equivalence of the selected ecosystem services and goods to the MA and TEEB ecosystem services classification and assessment frameworks

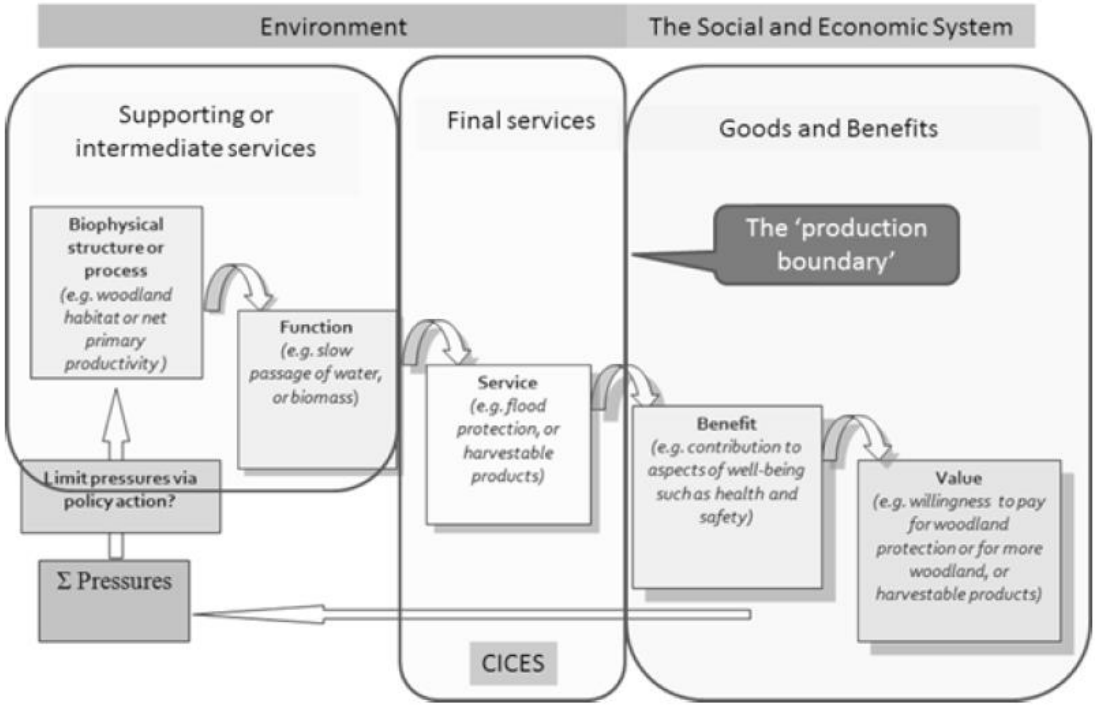
Code	Class	MA	TEEB
1.1.1.1	Cultivated terrestrial plants grown for nutritional purpose	Food	Food
1.1.3.1	Animals reared for nutritional purposes	Food	Food
1.1.5.1	Wild plants for nutrition	Food	Food
1.1.5.2	Wild plant fibres and other materials for direct use or processing	Fibre	Raw materials, medicinal resources
1.1.5.3	Wild plants used as a source of energy	Biochemical	Raw materials, medicinal resources
1.1.6.1	Wild animals for nutrition	Food	Food
2.2.1.1	Control of erosion rates	Erosion regulation	Erosion prevention
2.2.1.3	Hydrological cycle and water flow regulation	Water regulation	Regulation of water flows, regulation of extreme events
2.2.2.1	Pollination	Pollination	Pollination
2.2.2.3	Maintaining nursery populations and habitats	n.e.	Biological control
2.2.3.1	Pest control	Pest regulation	Biocontrol
2.2.4.1	Decomposition and fixing processes and their effect on soil quality	Soil formation	Maintenance of soil fertility
2.2.5.1	Regulation of the chemical condition of freshwater by living organisms	Water regulation	Water
2.2.6.1	Regulation of the chemical composition of the atmosphere	Atmospheric regulation	Climate regulation
3.1.2.1	Characteristics of living systems that enable scientific investigation or the creation of traditional ecological knowledge	Knowledge system and educational values	Information and cognitive development
4.2.1.1	Surface water for drinking	Water	Water

Code	Class	MA	TEEB
4.2.2.1	Ground (and subsurface) water for drinking	Water	Water
5.2.1.1	Mass flows	n.e.	n.e.
5.2.1.2	Liquid flows	n.e.	n.e.

Notes: MA – Millennium Ecosystem Assessment; TEEB – The Economics of Ecosystems and Biodiversity.
Source: Adapted from EEA, 2020; n.e.: no equivalent.

4.2.2. Economic valuation

As mentioned previously, natural ecosystems deliver services and goods which are accessed by society as benefits in a number of different ways, under the different ES categories (provisioning, regulation and maintenance, and cultural/non-material). Employing the CICES conceptual framework (Figure 47), it is possible to perceive how the system's biophysical structures and processes and its functions result in outputs ("final services") that give rise to the goods and services that will be harvested by the socio-economic dimension (the "production boundary").



Source: Haines-Young & Potschin (2018).

Figure 47 – The setting of CICES in the cascade model

In environmental economics, the economic value of these benefits is frequently defined in terms of the Total Economic Value (TEV), an approach often used in the context of ecosystem services assessment as it takes into account the whole set of benefits society derives from a particular system, from direct commercial values to non-market values.

Ecosystem services that are traded in markets – for example, raw materials and food – and that consequently have a market value are limited in number. In fact, most ecosystem services do not have an explicit monetary price (Farber *et al*., 2002; de Groot *et al*., 2012) and therefore their contributions to human well-being are often not considered in decision making processes regarding territorial and environmental

management. Additionally, through TEV, decision-making processes have additional tools at their disposal that allow them to have indicative monetary values of some ecosystem services and consider and compare them with other services that may also contribute to human well-being, in a more transparent way (Turner *et al*., 2003).

These comparisons should be cautious, since the monetary values of ecosystem services that are obtained are merely indicative and can be greatly underestimated, many ecosystem services may still be out of the analysis and the ecosystems have intrinsic, ecological and sociocultural values that are not expressed in monetary terms and that may also be considered in decision-making processes.

Succinctly, the TEV categorizes benefits/costs according to use values. In addition to the indirect and direct use values traditionally attached to environmental goods, the TEV framework acknowledges option values and non-use values, so that it allows the integration of services for which market-derived data is not available, allowing a more comprehensive analysis (Mavsar *et al*., 2014). TEV integrates the issue of irreversibility and the patrimonial dimension of the environment in the analysis (Plottu and Plottu, 2007).

Using the TEV approach, the economic functions/benefits of wetlands can be categorized as follows:

- Use values:
  - **Direct use** values: derived from the uses made of wetland, grassland and forest resources and services such as fish, raw material, timber and hunting (consumptive) or recreation and education (non-consumptive);
  - **Indirect use**: indirect services derived from wetland, grassland and forest functions, such as water purification, water regulation, carbon sequestration and soil conservation;
  - **Option value**: value of preserving the option of using a service which is not currently in use, given future uncertainty, directly and indirectly, such as biodiversity and habitat preservation;
- Non-use: preferences for preserving an environmental asset for maintaining others' accessibility to it (altruistic value), or for future generations (bequest value), or solely for the knowledge of their existence (existence value), such as enhancing altruistic opportunities for others, preserving habitats and protecting endangered species.

The ecosystem services and goods (ES) were identified through literature review and field work (field sampling and direct observation, key informant interviews and focus group discussions), following the CICES v5.1, MA and TEEB classifications (cf. Table 37). In the following table (Table 38), the benefits of the Lukanga Swamp's ecosystems to be considered in the valuation of ecosystem services are presented, categorized according to their value types.

Table 38 – General ecosystem services identified as they relate to the TEV value types

Use values		
Direct use value	**Indirect use value**	**Option value**
- Food production (1.1.1.1; 1.1.3.1; 1.1.5.1; 1.1.6.1) - Raw material (1.1.5.2; 1.1.5.3) - Educational and research activities (3.1.2.1) - Water for drinking (4.2.1.1; 4.2.2.1)	- Carbon sequestration and storage (2.2.6.1) - Disturbance regulation (5.2.1.1; 5.2.1.2) - Hydrological regulation (2.2.1.3) - Pollination (2.2.2.1) - Pest regulation (2.2.3.1) - Soil retention (2.2.1.1) - Soil formation (2.2.4.1) - Water purification (2.2.5.1)	- Biodiversity protection (2.2.2.3) (for any potential future uses, direct or indirect)

Note: under parenthesis, the CICES v5.1 code, for reference.
Source: Adapted from Table 5.1 in Mavsar *et al*. (2014).

The list presented in Table 38 includes the general benefits derived from all the ecosystems in and around the Lukanga Swamp. The comprehensive ecosystem services identified in Lukanga Swamp and its catchment are presented in Table 39.

Table 39 – Comprehensive ecosystem services identified as they relate to the TEV value types of use

Benefit	Ecosystem services identified in the Lukanga Swamp and its catchment (CICES v5.1 classification)	Value type
Food production	1.1.1.1 Cultivated terrestrial plants grown for nutritional purpose	Direct use
	1.1.3.1 Animals reared for nutritional purposes	
	1.1.5.1 Wild plants for nutrition	
	1.1.6.1 Wild animals for nutrition	
Raw material	1.1.5.2 Wild plant fibres and other materials for direct use or processing	
	1.1.5.3 Wild plants used as a source of energy	
Education and research activities	3.1.2.1 Characteristics of living systems that enable scientific investigation or the creation of traditional ecological knowledge	
Water	4.2.1.1 Surface water for drinking	
	4.2.2.1 Ground (or subsurface) water for drinking	
Soil formation	2.2.4.1 Decomposition and fixing processes and their effect on soil quality	Indirect
Soil retention	2.2.1.1 Control of erosion rates	
Hydrological regulation	2.2.1.3 Hydrological cycle and water flow regulation	
Water purification	2.2.5.1 Regulation of the chemical condition of freshwater by living organisms	
Carbon sequestration	2.2.6.1 Regulation of the chemical composition of the atmosphere	
Disturbance regulation	5.2.1.1 Mass flows	
	5.2.1.2 Liquid flows	
Pollination	2.2.2.1 Pollination	
Pest regulation	2.2.3.1 Pest control	
Biodiversity protection	2.2.2.3 Maintaining nursery populations and habitats	Option

5. Objectives

5.1. Conservation objectives

In this section, objectives are defined so as to guide the development of conservation strategies and actions. Indeed, specific “ecological state” objectives must be defined for prioritary ecological values (4 – Evaluation) in order to guide decision-making throughout the management cycle. Once objectives are set, operational limits and indicators are established to guide the implementation of specific actions or measures, that can then be updated in response to monitoring results (Chatterjee, Philips and Stroud, 2008).

As previously stated, (4.1.2.3 – Threats), however, the current unavailability of quantitative baseline data on the biological diversity and ecological processes of the site greatly limits the establishment of these targets.

Management must ensure sustainable levels of resource use are maintained, guided by the precautionary principle and based on available data in the literature, while planning for the continued data collection to inform future decision-making cycles.

As a designated Ramsar site, and under Article 3.1 of the Convention, one of the main objectives of planning around the Lukanga swamp should be its wise use, that is, one that safeguards the “maintenance of [its] ecological character, achieved through the implementation of ecosystem approaches, within the context of sustainable developement” (Ramsar, 2007). Or, in other words, the “maintenance of ecosystem benefits/services to ensure long term maintenance of biodiversity as well as human well-being and poverty alleviation” (Ramsar Handbook 1, 4th Edition).

As such, the two primary management objectives for the site, in what relates exclusively to its ecology, should be to

- maintain or achieve a favourable conservation status of habitats and associated biodiversity, prioritizing those values which play significant roles in the conservation of biological diversity and ecosystem benefits/services; and
- establish, through surveying, the current state of those values deemed prioritary and for which information is lacking.

Coupled with the decision-making framework (see chapter 6), the information gathered through monitoring in the scope of these objectives will ensure trade-offs are

appropriately considered and that the system is managed through an integrated, adaptive and ecosystems-based approach.

Table 40 lists the specific objectives, targets and indicators for the ecological components deemed of “very high” and “high” value (chapter 4 – Evaluation). Although not subject to particular objectives and targets, the remaining ecological components (moderate value habitats, and vulnerable and near threatened species) will be considered and targeted when conservation actions and recommendations are developed in a later phase.

Table 40 – Conservation objectives and targets for prioritary ecological values

Very high value	
Permanent swamp	
Current state	medium
Objectives and targets	**to achieve a favourable conservation status, defined ad hoc as** • visible ecological continuum, with encroachment kept below current levels (currently at around 60% of the swamp perimeter, if we consider as “encroaching”, the area within the 10 km buffer – grassland, termitaria and woodland - predominantely covered by anthropic land uses), and a reduced risk of further fragmentation (i.e., threats/pressures/drivers are under control) • the species list (including, for instance the monitoring of the spread and relative ominance of S. molesta, as is done by BirdWatch Zambia) and physiognomy (strata, height and cover) of the habitat align with or are close to the expected based on litterature accounts of the same habitat; degradation signs (litter, cut vegetation, burnt vegetation, trampled vegetation, etc.) are reduced or negligible **to maintain the current extent of permanently flooded swamp vegetation** **to achieve sustainable resource harvesting from the reedstand of the Lukanga, while ensuring food security and human well-being**

Indicators	• *ecological continuum* - degree of continuity and connectivity of and between natural habitats, assessed qualitatively • *risk of fragmentation* – risk of further deterioration of the ecological continuum based on the observed pressures (advancing anthropic land uses, etc.), assessed qualitatively • *conservation status* - distance to original/pristine conditions, based on field observations/measurements of the following parameters: species list, presence/absence and relative dominance of native, ruderal and exotic species (determined through transect surveys as in BWZ, 2020a, which is to be considered the reference); presence/absence of degradation indicators; water quality (to articulate with responsible entities, avoiding redundant efforts) • *extent* of the habitat
Grasslands	
Current state	medium to favourable
Objectives and targets	**to achieve a favourable conservation status, defined *ad hoc* as** • visible ecological continuum among grasslands (purely edaphic + termitaria), with encroachment kept below current levels (currently estimated to be above 60% of the total perimeter, if we consider as "encroaching", the upland area within the 10 km buffer – i.e., where woodland is the original cover - predominantely covered by anthropic land uses), and a reduced risk of further fragmentation (e.g., grazing and burning regimes are regulated and restrictions are enforced) • the species list and physiognomy (strata, height and cover) of the habitat align completely or are close to the expected based on litterature accounts of the same habitat; degradation signs (litter, cut vegetation, burnt vegetation, trampled vegetation, etc.) are reduced or negligible • this should further allow to: – confirm the presence/absence of *M. pigra*, and monitor its evolution, if present **to maintain the current area of grassland and termitaria grassland habitats**

Indicators	• *ecological continuum* - degree of continuity and connectivity of and between natural habitats, assessed qualitatively • *risk of fragmentation* – risk of further deterioration of the ecological continuum based on the observed pressures (advancing anthropic land uses, etc.) and current management, assessed qualitatively • *conservation status* - distance to original/pristine conditions, based on field observations/measurements of the following parameters: species list, presence/absence and relative dominance of native, ruderal and exotic species (determined through transect surveys as in Chabwela, Chomba and Thole, 2017, which is to be considered the reference); presence/absence of degradation indicators • *extent* of the grassland and termitaria grassland habitats
Benthic macroinvertebrates	
Current state	unknown/ insufficient data
Objectives and targets	**to characterize the current community structure** • given current knowledge gaps concerning benthic communities, and their responsiveness to fluctuations of ecological conditions, the data from this monitoring effort can build the knowledge on LS's biodiversity and help inform if the thresholds for the system's capacity to assimilate external pollution inputs are being reached • confirm the presence or absence of *Lobogenes michaelis* Pilsbry & Bequart, 1927 (endangered), of gastropod genera *Biomphalaria* and *Bulinus*, and of *C. quadricarinatus* **to maintain or achieve a favourable conservation status** • target values for this objective need to be established after baseline conditions are known
Indicators	• *community structure* (richness, abundance, diversity) obtained from surveying

Phytoplankton and zooplankton	
Current state	unknown/ insufficient data
Objectives and targets	**to characterize the current community structure** • microalgae and zooplanktonic community compositions are often monitored as a bio-indicator for water quality assessments, a process which requires long-term, seasonal and spatially representative monitoring efforts for the establishment of reference values, which is not the case currently, even though some surveying has been done • ideally, this would also include benthic microalgae **to maintain or achieve a favourable conservation status** • target values for this objective need to be established after baseline conditions are known
Indicators	• *community structure* (relative abundances) and *biomass*, obtained from surveying
Fish assemblages	
Current state	suspected unfavourable, in recovery, but data is not sufficient
Objectives and targets	**to characterize the current community structure** • fish community structure can also inform on the ecological status of a waterbody or wetland; given the benefit derived from this particular group by local people, a major goal of management must be to follow community dynamics consistently throught time and space; • this should further allow to: – confirm the role of the swamp as breeding habitat and identify the areas that are more important, and – confirm the the presence and status of *Serranochromis robustus* (Gunther, 1864) (**critically endangered**) and *Oreochromis niloticus* (Linnaeus, 1758) (**exotic and potentially invasive**) **to maintain or achieve a favourable conservation status** • target values for this objective need to be established after baseline conditions are accurately known

Indicator	• species composition • abundance • population structure (based on age or length classes) • evolution of capture fisheries production these can be obtained from routine catch assessment, gill net and frame surveys meant to be conducted by the Department of Fisheries (MFL, 2020)
Aquatic macrophytes	
Current state	unknown/ insufficient data
Objectives and targets	**to characterize the current community structure** • given the importance of this group to the maintenance of fish populations, as well as its value as a bioindicator of environmental change, a clearer understanding of their current condition is needed • this will further allow to – monitor the status of the *S. molesta* invasion – monitor for a potential introduction of *E. crassipes* **to maintain or achieve a favourable conservation status** • target values for this objective need to be established after baseline conditions are known
Indicators	to characterize macrophyte community in a meaningful way, the following parameters can be obtained through field surveying: • number of taxa, or diversity • macrophyte cover • macrophyte biomass
Waterbirds and other avifauna	
Current state	unknown
Objectives and targets	**to characterize the current community structure** • BirdWatch Zambia already conducts yearly bird counts inside the swamp, so that these datasets should be used • surveys in other habitats such as grassland, termitaria and Miombo could also be introduced, to confirm the presence/absence and state of critically endangered and endangered species such as the white-backed vulture, the white-headed vulture and the steppe eagle **to assess the conditions available for promotion of birdwatching-based tourism**
Indicators	• number of taxa, or diversity • relative abundances

Wild ungulates	
Current state	unfavourable/ insufficient data
Objectives and targets	**to characterize the current status of populations** • this is particularly important given (i) the importance of this group to the regulation of grassland habitats, (ii) the maintenance of carrion-dependent bird species, and (iii) the number of potentially occurring species that are near threatened (see Appendix 3, Ecological Assessment), and may have been eliminated due to human-wildlife conflicts (Table 34) **to properly assess the option to reintroduce large herbivores into the system** • once the current state of wild ungulate populations is known, and social and ecological impacts of a repopulation effort are assessed (management costs; revenue opportunities; worsening of human-wildlife conflicts; destabilisation or maintenance of grassland ecosystems), an informed decision can be taken regarding this option
Indicators	• number of taxa, or diversity • population estimates
High value	
Forested land	
Current state	unfavourable
Objectives and targets	• **to halt deforestation completely in the Ramsar site and the 10 km buffer** • **to reduce deforestation by 25% in the subcatchment** • **to achieve sustainable resource harvesting from the woodlands around the Lukanga, while ensuring food security and human well-being** • **to define an afforestation programme in the area surrounding the swamp in order to increase the forested area and the ecological continuum**
Indicators	• extent of forest cover • deforestation rate • fragmentation levels

Riparian vegetation	
Current state	unfavourable
Objectives and targets	• **to increase the cover of riparian vegetation in the Lukanga and Mushingashi rivers upstream of the swamp**
Indicators	• extent of riparian cover • species number, or diversity

5.2. Historical trends and drivers of change

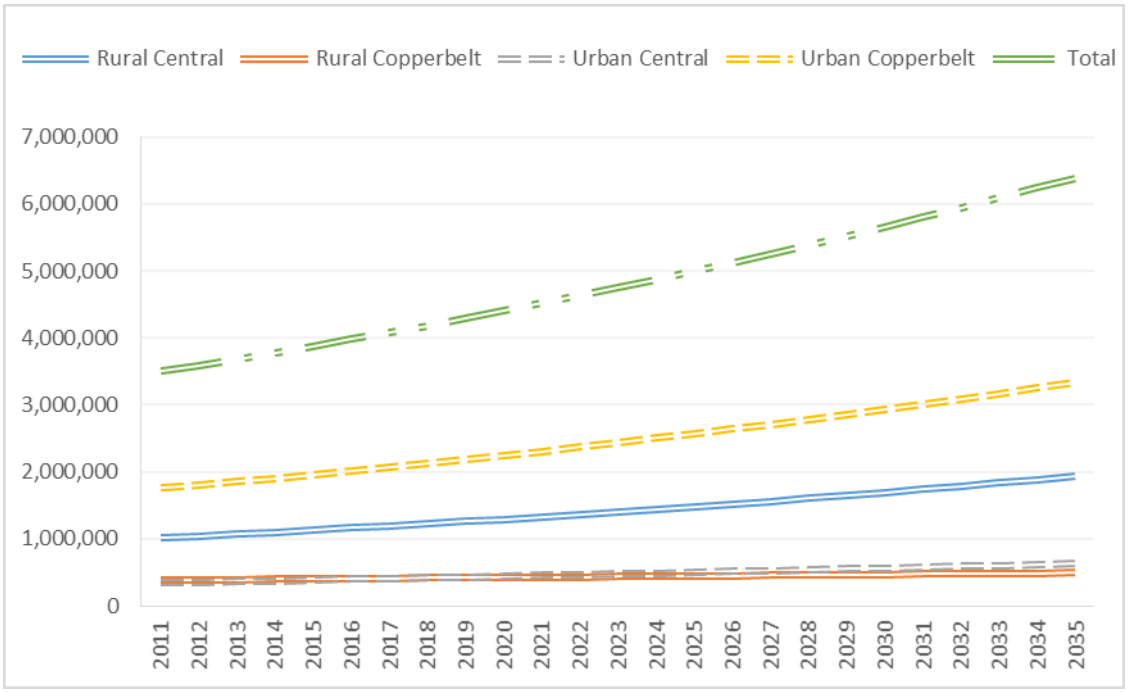
5.2.1. Past trends

5.2.1.1. Socioeconomic environment

Regarding the socioeconomic environment, the following trends were identified in the Lukanga Swamp and Upper Kafue Basin.

A) Population growth

Total population in Central and Copperbelt provinces in Zambia is expected to reach six million in 2033 according to Central Statistical Office's projections (see Figure 48), almost doubling the 2010's figures (around 3.3 million). However, this significant population growth shows a dichotomy between the two provinces under study: population growth in Copperbelt is essentially urban, with expected population growth in rural areas being relatively lower (2.7%/ year vs 1.0%/ year); population growth in Central province occurs significantly both in rural and urban areas (2.7%/ year and 2.5%/ year).



Source: CSO (2013b).

Figure 48 – Rural, urban and total population projections (2011-2035)

This dichotomy is clearly seen in Figure 48, with rural population in Central province expected to reach almost two million in 2035; and urban population totalling 3,3 million in the Copperbelt province in 2035.

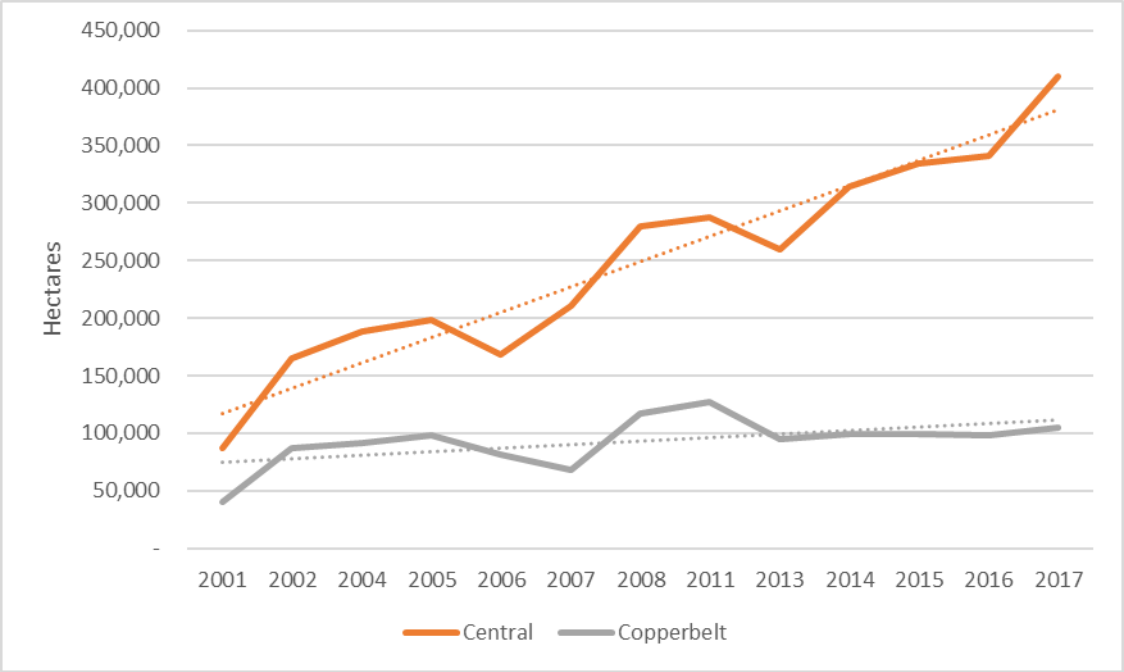
B) Growth of agricultural area

Agricultural activities are of key importance for populations in Central and Copperbelt provinces. As can be seen in Table 41, almost 70% of households in Central province practice some type of agriculture activity (43% in Copperbelt). Crop production and livestock raising are the most common agricultural activities in both provinces. Because rural population is a majority in Central province, this greater preponderance of agricultural activities in this province is an anticipated reality. Moreover, as stated in last section, the expected significant growth of rural population in Central province anticipates a rather significant growth of households producing crops or raising livestock in the next decades. As shown in Figure 49 and Figure 50, historical trends reflect a significant growth both in the area used for the production of agricultural crops and in the total number of cattle in Central province. Consequently, this trend is expected to continue and intensify in the coming years in Central province.

Table 41 – Distribution of agricultural households by type of activity (2018)

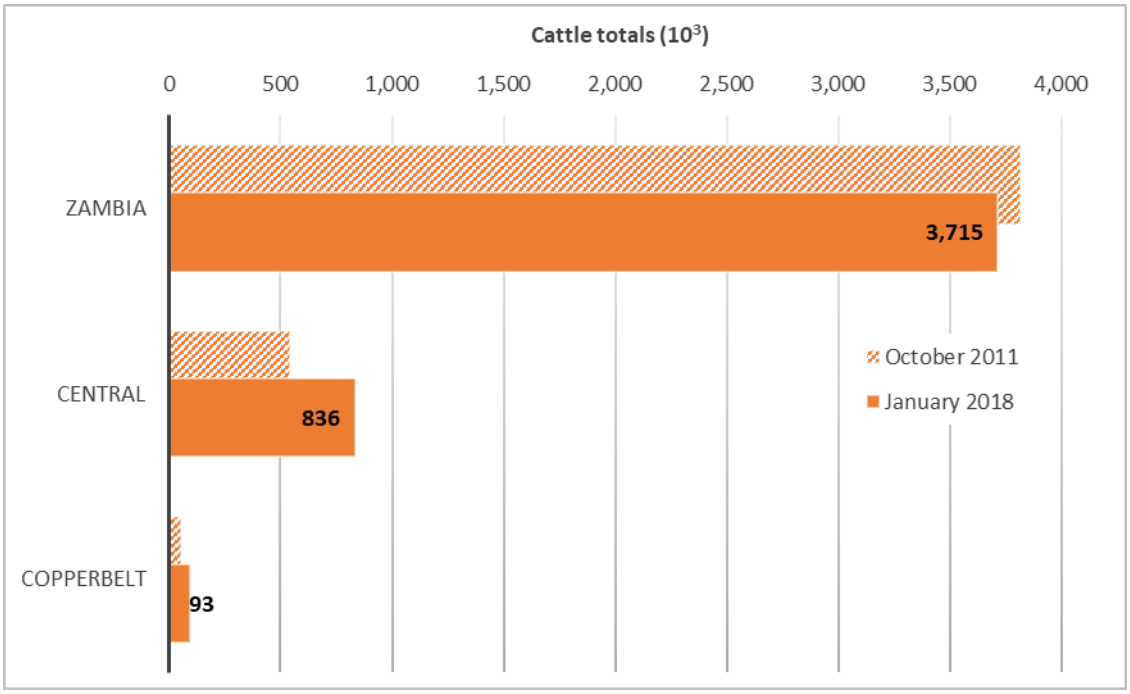
Province	Central		Copperbelt	
	Number	%	Number	%
Total of households	365,330	-	535,701	-
Total agricultural households	252,716	69.2%	230,443	43.0%
Households participating in:				
Crop/ fodder production	227,892	62.4%	181,362	33.9%
Livestock raising	196,729	53.8%	143,002	26.7%
Bee keeping	4,782	1.3%	2,760	0.5%
Fish farming	463	0.1%	902	0.2%

Source: Ministry of Fisheries and Livestock (2019).



Note: Area planted of maize, sorghum, rice, millet, sun flower, ground nuts, soya beans, mixed beans and sweet potato.
Source: Crop forecast surveys (CSO, 2020).

Figure 49 – Trend of agricultural area planted in Central and Copperbelt provinces

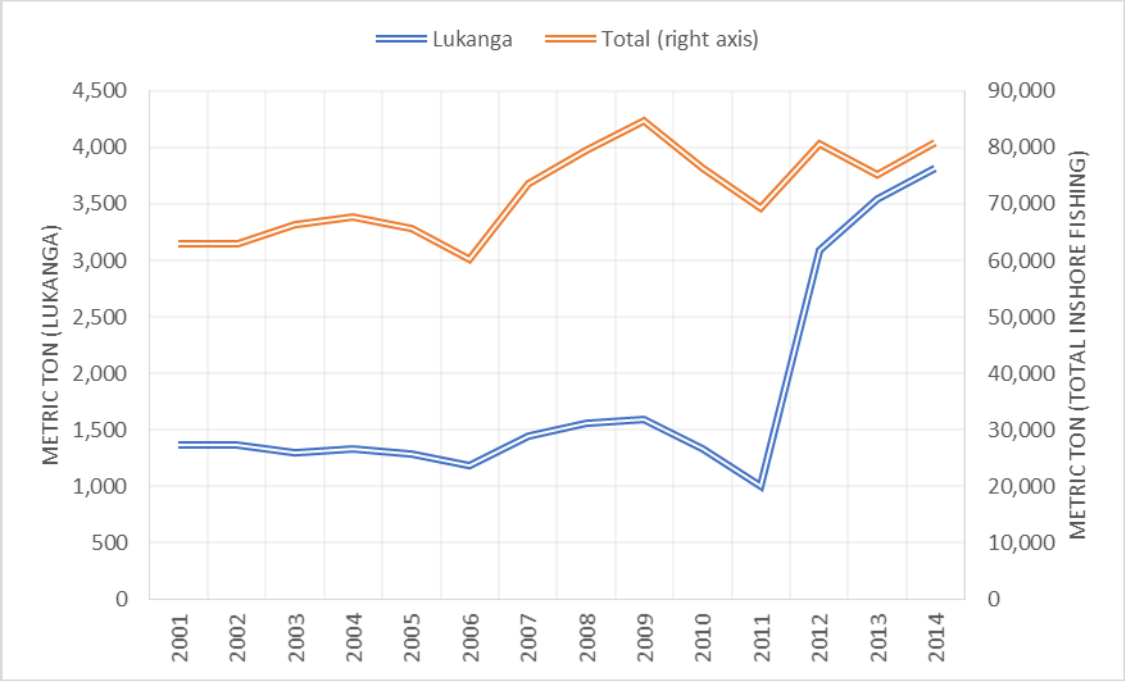


Source: (CSO, 2014b; 2019).

Figure 50 – Total cattle raised in Central and Copperbelt provinces and Zambia (2011; 2018)

C) Growth of inshore fishing

As stated in the last section regarding agricultural areas, inshore fishing also increased significantly in the last decades in Lukanga, as in the country (see Figure 51). The importance of this activity for local communities in the surroundings of Lukanga Swamp is referenced in section 3.8.2. Taking into account the context of population growth, it is expected that this activity will intensify in the coming decades in the plan areas.

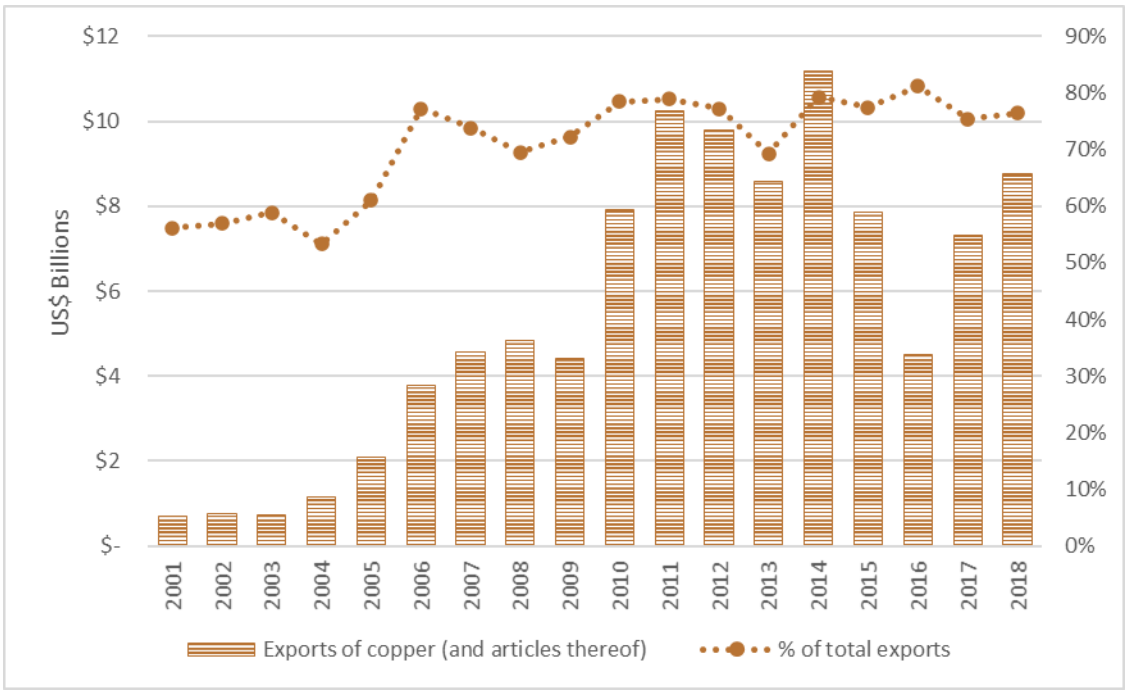


Source: DoF (2015).

Figure 51 – Inshore fish catch in Lukanga and total in Zambia (2001-2014)

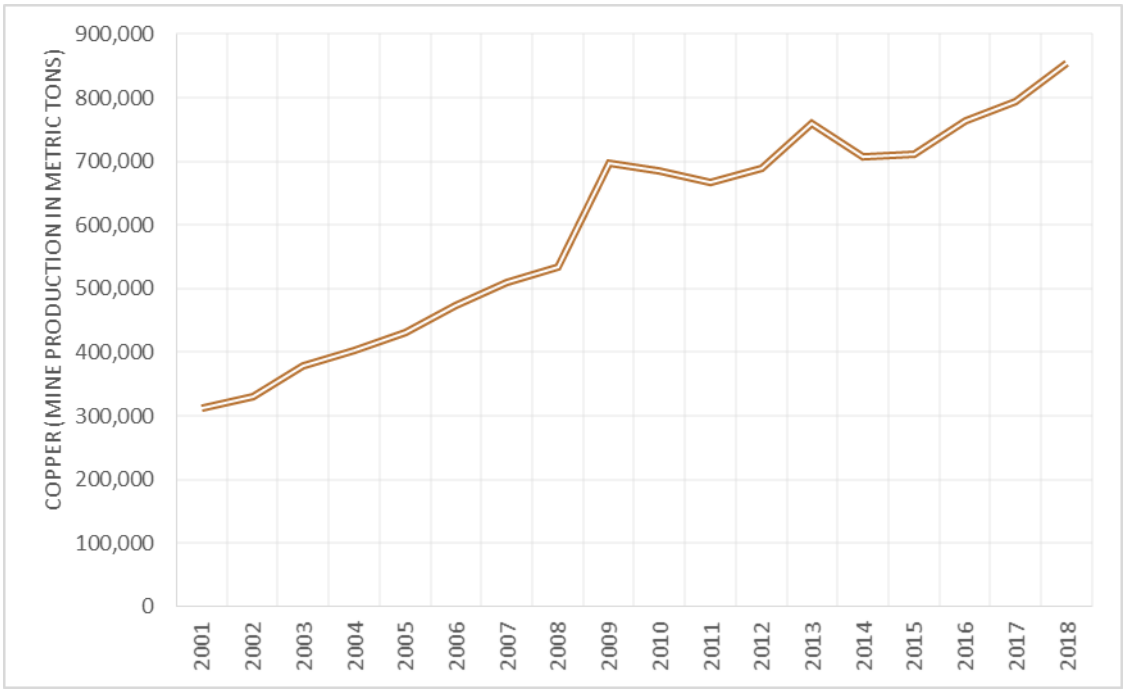
D) Intensification of mining activities

Copper production is undoubtedly one of the most important economic activities in Zambia, considering the GDP data and exports. As can be seen in Figure 52, exports of copper and copper related products represent around 77% of total exports in the 2010 decade. The importance of copper in the economy of Zambia has increased since the beginning of the century, which parallels a production growth (see Figure 53) and the commodity super-cycle of the 2000s and early 2010s. Copperbelt province in Zambia has important reserves of copper, and its production has increased in the last years, as can be seen in Table 42.



Source: MIT (2020).

Figure 52 – Exports of copper in Zambia (2001-2018)



Source: NMIC (2020).

Figure 53 – Production of copper in Zambia (2001-2018)

Table 42 – Production of copper in Zambia per mine and province (2016-2018)

Province / Mine	2016	2017	2018	Growth 2016-2018
Copperbelt	242,698	235,541	276,010	13.7%
Chibuluma	10,841	10,195	11,259	3.9%
Konkola	105,345	84,436	93,165	-11.6%
Luanshya (CNMC)	34,286	43,206	50,363	46.9%
Lubambe	19,031	18,037	22,075	16.0%
Mopani	41,109	44,860	62,191	51.3%
NFCA	26,871	27,706	27,644	2.9%
Sino Metals	5,215	7,100	9,313	3.9%
North-Western	519,818	557,888	575,077	10.6%
Total (except small scale)	762,516	793,428	851,087	11.6%

Source: ZCM (2019).

5.2.1.2. Biophysical environment

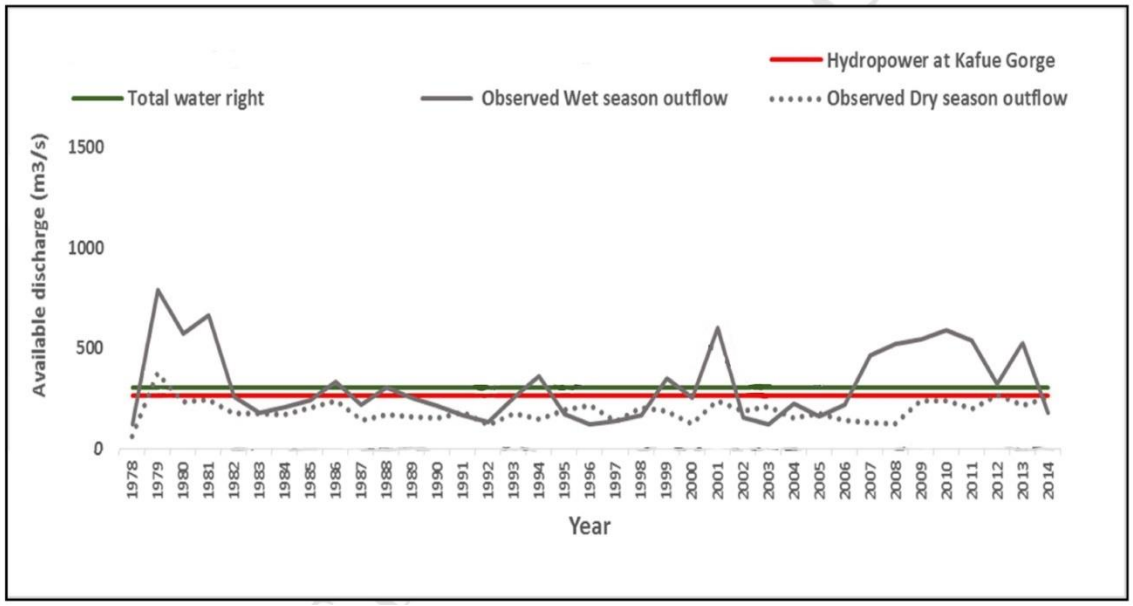
This section identifies past trends for different biophysical components of the plan areas, from secondary sources of information.

The main trends detected in the area were:

- Changes in the hydrological regime and hydrodynamics of Lukanga Swamp and its catchment;
- Water and sediment/soil quality degradation;
- Land cover change;
- Biodiversity loss;
- Deterioration of conditions;
- Climate change.

A) Changes in the hydrological regime and hydrodynamics of Lukanga Swamp and its catchment

The main development of the Kafue has involved the construction of the Kafue Gorge dam and power plant completed in 1971 and the subsequent construction of the regulation dam at Itezhi-Tezhi which was completed in 1978. The Upper Kafue River from the source to Itezhi-Tezhi Dam is largely unregulated. The hydrological regime upstream from this dam would only have changed due to climate change or changes in the land use of the basin or because of abstractions. By looking at Figure 54 one may arguably state that there are no long-term trends in the available discharges after the completion of the Itezhi-Tezhi dam.



Adapted from Kalumbaa and Nyirenda (2017)[4]

Figure 54 – Available discharge at Itezhi-Tezhi hydropower facility between 1978 and 2014

[4] KALUMBA, M., NYIRENDA, E. (2017). *River flow availability for environmental flow allocation downstream of hydropower facilities in the Kafue Basin of Zambia*. Physics and Chemistry of the Earth, doi: 10.1016/j.pce.2017.07.003.

B) Water and sediment/soil quality degradation

The economic development of the basin commenced in the 19th century. The establishment of mining activities and line of rail in the Copperbelt occurred between 1890 and 1930. According to Lindahl (2014), copper production in Zambia peaked in the early 1970s. After 1975 the copper production declined, and the industry faced a number of challenges due to the lack of investment, over-staffing, poor technology and falling copper prices. In the year 2000, the mines were privatized and ZCCM's assets were divided and sold to various investors. During the privatization process, the government made a deal with the new owners that none of the historic environmental legacies and the impacts resulting from them would fall under the responsibility of the new owners. Instead it was decided that the state through ZCCM-IH should take care of remediation actions and monitoring of the historical sites.

There is no systematic monitoring of water and sediment quality of the Upper Kafue river, so it is impossible to build a trend of water and sediment/soil quality degradation in the river over the past decades. However, environmental problems related to mining activities in Zambia are frequently referred to in official reports and documents and scientific papers. The following paragraphs were taken from Lindahl (2014) and give a synthesis of the problem.

Environmental problems directly linked to historical mining operations in the Copperbelt are largely related to geotechnical integrity of waste dumps. There are at least 21 waste rock dumps covering more than 388 hectares, 9 slag dumps covering 279 hectares and finally more than 45 tailing dams covering an area of around 9125 hectares (Environmental Council of Zambia, 2008). In total, more than 10 000 hectares in the Copperbelt is covered with mineral waste and thus represent a "loss of opportunity" for the local population in terms of other land use such as agriculture, forestry, housing, ranching etc (SGAB *et al.*, 2005).

Since 2001, most of the previously state-owned and unprofitable copper mines have been revived through extensive investments by new owners. As the mining operations are scaling up production to make profits on the invested capital, the concern for the environment is prone to be overlooked.

Several studies have shown that concentrations of many dissolved elements (i.e. ions) are clearly elevated in the Kafue and its tributaries within the Copperbelt. The dissolved copper content has shown to be considerably higher than standards for protecting

aquatic life in more or less all monitoring stations within the Copperbelt region (SGAB *et al.*, 2005). The most significant contributors to metal pollution are the Nchanga, Nkana and Konkola mining operations (SGAB *et al.*, 2005). Downstream the mining operations, the concentrations of mining-related contaminants are quickly lowered mainly due to the formation of secondary particles that rapidly settles on the riverbed. Since the severe pollution from mines mainly is concentrated to hotspots, the water companies around the Copperbelt manages with producing potable water. However, there are exceptions and especially the Mulonga and Nkana water and sewerage companies often struggle with water quality (National Water Supply and Sanitation Council, 2010). Additionally, accidents do happen from time to time. In media there have been reports of complete water supply failure in Chingola in 2006 due to a spill from Konkola's leaching plant, and in 2008, at least 13 people in Mufulira were admitted to hospital after a similar spill from Mufulira's leaching plant. Even though high concentrations from the mining areas are mostly local, elevated concentrations of dissolved sulphur can be traced all the way down to the confluence with the Zambezi River (Pettersson, 2002). When the water discharge in Kafue is increased during the rainy season, secondary particles are re-suspended and transported downstream in the river system.

Mining activities in the Copperbelt also severely affects the waterways through extensive siltation. Concentrations of suspended elements (i.e. small particles) are naturally very low in the Kafue River but because of pollution from the mining industry suspended concentrations of copper and cobalt can be seen down to the junction with the Zambezi River (Pettersson, 2002). The siltation problem is partially a result of erosion from existing tailing dams and waste dumps (contribution of 9 000 tons/year), but the really large impact comes from ongoing mining operations. For example, dewatering of Konkola mine contributes with 15 000 tons/year and the Nchanga mining area alone contributes with 91 000 tons/year by for example discharging tailings directly to the river (SGAB *et al.*, 2005). Due to extensive siltation caused by mining activities there is a continuous build up in the river channel and the bed sediment in many places is totally dominated by tailing material with high metal concentration.

It is safe to say that from 2000's onwards the water and sediment/soil interannual quality oscillation in the Upper Kafue river hasn't probably been significantly changed. However, water quality of the river changes seasonally, with lower quality during the wet season.

C) Land cover change

By land cover change (LCC) is understood the modification or loss of vegetation cover, resulting from environmental causes or from changes of land use. The latter includes, for instance, the change from natural non-use, non-disturbed cover to degraded or non-existing cover through resource harvesting, agriculture or rural development.

Zambia suffers nationally from a high rate of natural land cover loss, especially primary forest, through the expansion of agriculture, and rural and urban land-uses (Shakachite *et al*., 2016; Phiri, Morgenroth and Xu, 2019).

The Lukanga Swamp is directly above a deforestation hotspot, where over 40% of the primary forest cover has been lost (MLNREP, 2014). As pointed out by Mwakikagile (2010, in ZEMA *et al*., 2012), changes in forest cover between 1991 and 2011 south of the swamp have been “drastic”. This is readily apparent when directly comparing aerial images of a portion of the Lukanga swamp taken 31 years apart (Figure 55).



Source: Google Earth (2020).

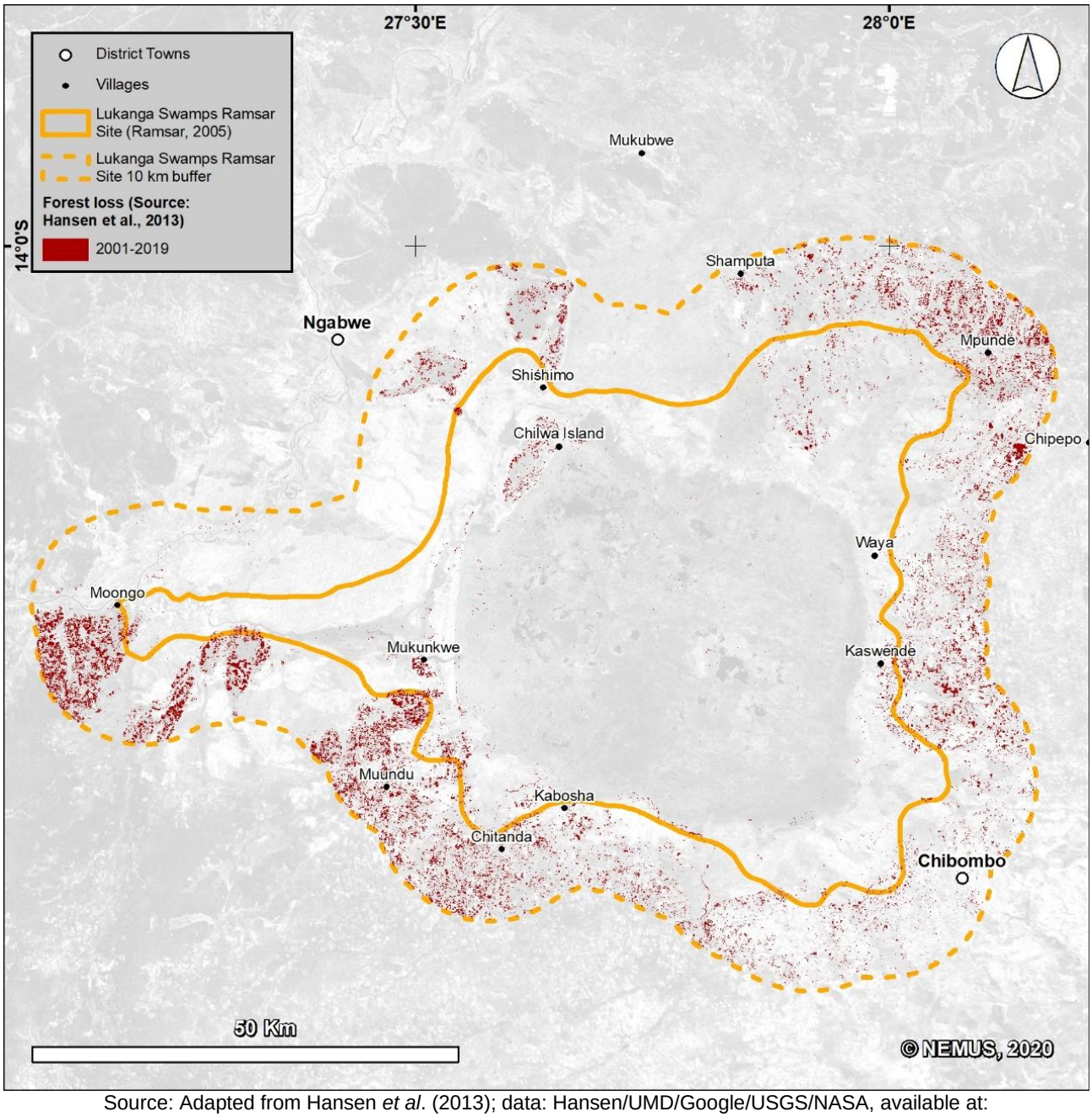
Figure 55 – Satellite images from 1984 (left) and 2015 (right) demonstrating the evolution of anthropogenic landscapes across the southwest quadrant of the swamp (LS: Lukanga swamp)

In the images above, the agricultural landscape can be observed advancing along human movement routes into pristine areas and expanding outwards into the natural vegetation, ultimately replacing it and encroaching the wetland ecosystems.

Phiri, Morgenroth and Xu (2019) conducted a detailed spatial and multi-temporal analysis of land cover spanning the entire country in the period between 1972 and 2016 and established that almost two thirds of Zambia's primary forest cover had been lost, from a total of $36{,}335.52 \times 10^3$ ha to $12{,}433.89 \times 10^3$ ha. They determined the annual rate of decline of primary forest cover at -2.48% y^{-1}, while cropland and settlement covers showed a rate of annual increment of 1.50% y^{-1}, and secondary forest cover grew at a rate of 2.01% y^{-1}(Phiri, Morgenroth and Xu, 2019). Primary forest was lost mainly to secondary forest, grassland and cropland, while secondary forest – despite showing a net increase over the study period - was mainly lost to cropland and settlements (Phiri, Morgenroth and Xu, 2019). The overall deforestation rate (conversion from all forest types, primary, secondary and plantation) for the 40-year period ranged between **-0.54 and -3.05% y^{-1}** (83,000 to 453,000 ha y^{-1}) (Phiri, Morgenroth and Xu, 2019).

Sakachite *et al*. (2016) considered secondary and primary forest together in their assessment and determined the annual rate of deforestation in Zambia for a fourteen-year period (2000 – 2014) at 0.17% y^{-1}, or 79,345 ha y^{-1}, increasing to 0.5% y^{-1}, or 30.142 ha y^{-1} in the Central Province alone, the province with the highest annual rate of deforestation countrywide. Both forest and grassland covers were lost mainly to encroachment by **agriculture** or **settlement expansion** in this period (Shakachite *et al*., 2016).

Hansen *et al*.'s (2013) global forest change data was used to assess the extent of deforestation around the Ramsar site for the period between 2001 and 2019 (Figure 56).

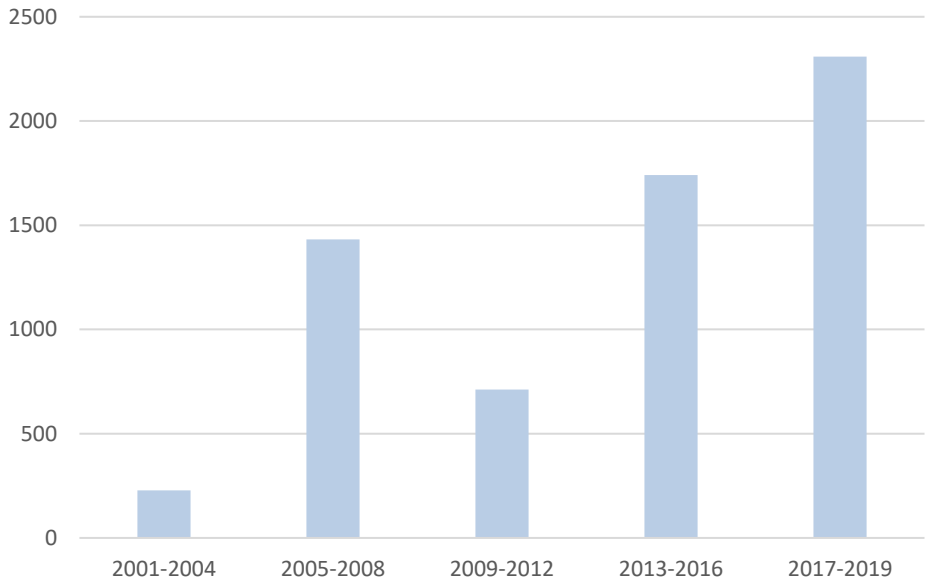


Source: Adapted from Hansen *et al*. (2013); data: Hansen/UMD/Google/USGS/NASA, available at: http://earthenginepartners.appspot.com/science-2013-global-forest/download_v1.7.html)

Figure 56 – Area of forest loss between 2001 and 2019

A total of **23,382.56 ha** was lost in the 19-year period, for an average annual loss of **1,230.66 ha** (±947.12).

Over 60% (61.78%) of the loss occurred in the last nine (9) years (2011-2019), and close to 30% (29.62%) in the last three years alone (2017-2019). It appears that the rate of deforestation accelerated over the 19 years (Figure 57).



Source: adapted from Hansen *et al*. (2013).

Figure 57 – Area of forest loss in four-year periods between 2001 and 2019

The seasonally flooded grassland vegetation is also vulnerable to agriculture reclamation because of its higher fertility. According to Sakachite *et al*. (2016), conversion to cropland accounted for 5.47% of total grassland losses between 2000 and 2014, i.e., at an annual loss rate of **-0.001% y^{-1}**.

Regarding **swamp vegetation**, according to Hunink *et al*. (2017), while vegetation cover has remained high and stable in the period between 2001 and 2015, there is variability between years. Intra-annually, vegetation cover is highest during the dry season (April to November), which is possibly attributed to algal growth and the increased propagation of surface floating aquatic weeds, which are favoured by slow-flowing water and higher nutrient concentrations (cf. chapter 4; Hunink *et al.*, 2017).

The comparison of multiyear detection of open water surface from spectral data revealed a declining trend in the area of open lakes within the swamp between 2005 and 2009. The shrinking of lakes is also reported in Chabwela *et al*. (2010) for the period between 1986 and 1995, and is mainly attributed to the advancement of emergent vegetation into previously open water areas during periods of intense drought and exceptionally low water levels. It is safe to assume that the decrease in precipitation, runoff and increase in drought indicators in the future (5.2.2.2 – Climate change) could put additional pressure on shallower lakes, which can eventually be lost to emergent vegetation entirely.

Finally, one of the prominent trends in wetlands globally is the **growing invasion by aquatic weeds**. This is the case of the palustrine and riverine areas of the Lukanga wetland, where the Kariba weed *Salvinia molesta* is said to have been introduced on fishing nets from fishermen from the Kafue River around 2009.

The invasion grew at least until 2018, when BirdWatch Zambia introduced the Javani beetle *Cyrtobagus salviniae* as a biological control measure (BWZ, 2020b).

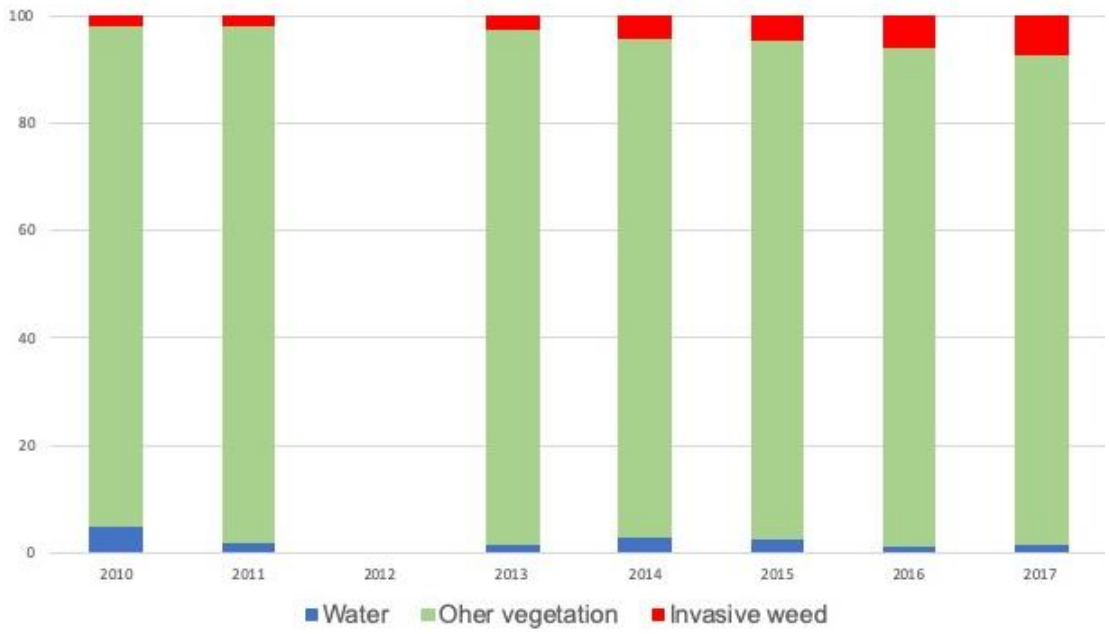
The following table and chart show the weed invasion increasing fourfold in the seven years between the detection and the initiation of biocontrol measures, as mapped by MEDEEM Zambia and BirdWatch Zambia (Table 43, Figure 58).

Table 43 – Results from the satellite image analysis undertaken by MEDEEM Zambia in the scope of the weed control project

Year	Land cover	Area (hectares)	%
2017	Water	4,510.8	1.37
	Other vegetation	300,721.86	91.4
	Invasive weed	23,800.41	7.23
2016	Water	3,616.38	1.2
	Other vegetation	304,955.37	92.68
	Invasive weed	20,461.23	6.22
2015	Water	7,635.78	2.32
	Other vegetation	305,679.42	92.9
	Invasive weed	15,717.87	4.78
2014	Water	9,518.58	2.89
	Other vegetation	305,549.82	92.86
	Invasive weed	13,964.67	4.24
2013	Water	4,803.21	1.46
	Other vegetation	315,529.74	95.9
	Invasive weed	8,700.12	2.64
2011	Water	5,385.78	1.64
	Other vegetation	316,993.51	96.34
	Invasive weed	6,659.91	2.02

Year	Land cover	Area (hectares)	%
2010	Water	16,049.79	4.88
	Other vegetation	306,993.51	93.3
	Invasive weed	5,989.68	1.82

Source: BWZ & MEDEEM Zambia (2018).



Source: adapted from BWZ & MEDEEM Zambia (2018).

Figure 58 – Evolution of the area of different land covers in the swamp

During the field work in September and October 2019, this species was detected in 46.7% of the spot assessments conducted in the wetland's flooded habitats (i.e., permanent swamp, lakes and rivers) (Figure 59).

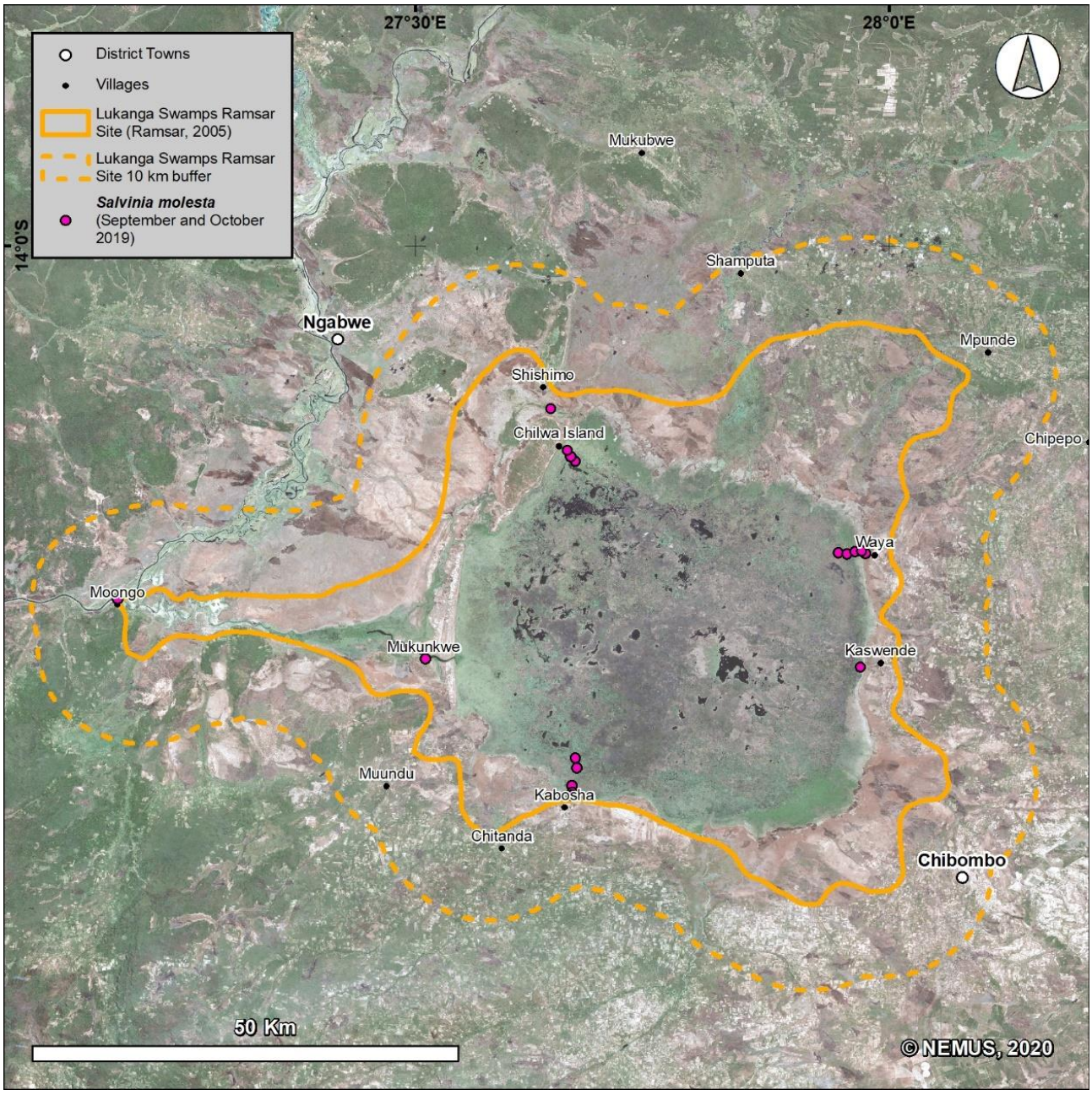


Figure 59 – Field observations of the aquatic weed Salvinia molesta, in September and October 2019

D) Biodiversity loss

Biodiversity refers to the variability of and between living organisms, including genes, species and ecosystems. High dominant species and functional group diversities introduce compensatory mechanisms to the ecosystem (through redundancy and complementarity) that confer resilience against increasingly volatile or unstable environmental conditions, promoting its long-term sustainability.

Regarding **terrestrial ecosystems**, as pointed out earlier (C) – Land cover change), the miombo and munga woodlands that dominate the landscape around the Lukanga have been, to an extent, degraded and finally lost to agricultural land-use throughout the southern and eastern regions.

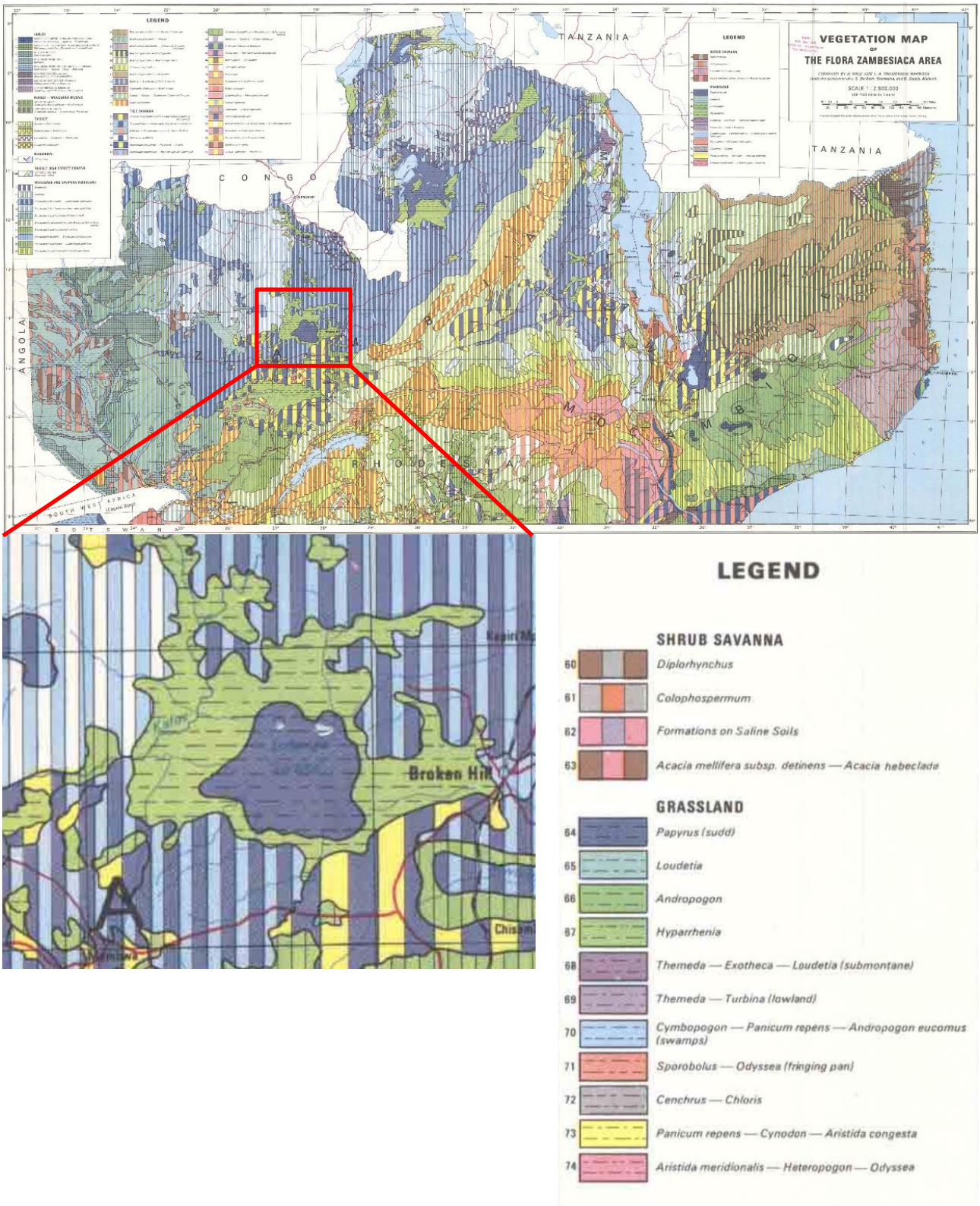
This loss of forest or woodland cover represents a significant reduction in biodiversity, both of the composing flora and of the inhabiting fauna, but also of regional ecosystem variability.

Kalaba, Quinn and Dougill (2013) showed that secondary forest patches derived from charcoal and slash and burn fallows held a significantly lower tree species richness than mature stands. Original biodiversity levels were only recovered after 20 years undisturbed, with some of the original species not being recovered at all.

Furthermore, according to Zambia's Second National Biodiversity Strategy and Action Plan (NBSAP – 2) (sourced from NBSAP Stocktaking and Assessment Report, 2015), the swamp falls within the middle region of variation in species richness of flowering plants in Zambia, with an estimated 48 to 89 species per ha.

Finally, the loss of Miombo woodland cover represents a loss to the *Brachystegi*a genus itself, since this is its centre of diversity (White, 1983).

Regarding **wetland vegetation**, according to key informant interviews conducted in October 2019, the swamp used to be dominated by a different species, "harder", which has now been completely replaced by the common reed. The Lukanga's permanent swamp community was originally dominated by *Cyperus papyrus*, as represented in the "Vegetation Map of the Flora Zambesiaca Area", compiled by Wild and Barbosa in 1967 (Figure 60), which classifies the central main swamp area as *Papyrus* grassland.



Source: Wild & Barbosa (1967).

Figure 60 – Vegetation map of the Flora Zambesiaca area (north sheet)

Clarke, 1975 (*in* Howard-Williams & Thompson, 1985), also described the Lukanga as a *Papyrus* swamp supporting an important fishery. The first report of the common reed appears in Kamweneshe and Beilfuss, 2002, who characterised the emergent vegetation as “visually dominant” *Papyrus* and *Phragmites* swamps.

Thirty years after Clarke, in 2005, the Ramsar Information Sheet for the wetland already refers a complete shift in vegetation communities, from *Papyrus* dominated to *Vossia cuspidata*, *Typha* and *Phragmites*, depending on the location (Ramsar, 2005). This may be attributed to seasonal or occasional extreme fluctuations of water levels (as happened throughout the 1990s), to which *C. papyrus* is ill-adapted compared to the common reed, as was the case of the fringing communities in Lake Chad (Thompson, 1985). The propagation of *Phragmites australis* was mentioned by local users in reference to the theme of invasive weeds and its overgrowth was said to slow down the movement of canoes along channels (key informant interviews, October 2019). During the 2019 field work, stands of *Cyperus papyrus* were only detected in the banks of the Lukanga river, near the villages of Moongo and Mukunkwe, downstream of the swamp.

Regarding past trends of **faunal populations**, data are scarce throughout the different groups, including for avifauna, the most charismatic.

The last Wattled crane (*Bugeranus carunculatus*) aerial survey in the Lukanga dates to 2001, when the population was estimated at around 50 individuals, out of 25 individuals observed (Kamweneshe & Beilfuss, 2002). The estimated size of the Wattled crane population in Zambia has been declining since 1985, from 11,000 to 7,000 or 8,000 in 1994 and finally to <4,500 in 2004, when the last estimate was obtained from extensive aerial surveys in the major wetlands (Beilfuss *et al*., 2001). Disturbance by human activity (including nest-destruction by fire and trampling, nest-robbing and hunting), is appointed as the most significant threat (Leonard, 2001; Kamweneshe & Beilfuss, 2002).

According to available sources and interviewees, **large mammal populations** have also decreased considerably (Kamweneshe & Beilfuss, 2002). A common discourse in the region is that there are no more large animals in and around the Lukanga swamp (Informal conversation with tourism operator, Kabwe, 2019; key informant interviews, 2019). The majority of animal wildlife is thought to have migrated out of the swamp, towards the Lunga-Lushwishi GMA and Kafue NP, in response to the exceptional droughts of the 1990s (Focus groups discussions, 2019; Kamweneshe & Beilfuss, 2002; Personal communication, 2020).

Extreme hydrological events throughout the years are believed to have facilitated poacher's access to mammal species in two distinct ways. During exceptional droughts, the water's retreat allows poachers to enter deeper into the previously inundated wetland vegetation and target swamp dwelling species such as the **Sitatunga** (*Tragelaphus spekii*). During higher flooding years, on the other hand, animal species that settle along the flood line are driven closer to human settlements, hence becoming more vulnerable to opportunistic poaching (Kamweneshe & Beilfuss, 2002).

In the 2001 aerial survey, Kamweneshe & Beilfuss (2002) only observed three species, all in low numbers: the Red lechwe, the Oribi and the Sitatunga. The population of **Red Lechwe**, *Kobus leche leche* showed a declining trend between the 1960s and 2001, reducing from 800 individuals (Hanks, 1969, *in* Kamweneshe & Beilfuss, 2002) to an estimated fewer than 100 individuals (Kamweneshe & Beilfuss, 2002). The **Oribi**, *Ourebia ouribi*, was also recorded as having decreased significantly up to 2001, to an estimated number of more than 60 individuals. The **Sitatunga**, *Tragelaphus spekii*, population was estimated at under 100 individuals.

This is in accordance both with Zambia's NBSAP-2, which reports higher mammal populations within protected areas (MLNREP, 2014), and with past trends in other Zambezian wetlands, such as in the Barotse floodplains, Okavango Delta and Bangweulu Flats, where ungulate populations have declined due to increased human pressure, in opposition to the Busanga Flats (northern Kafue National Park), a protected area where populations increased between 1948 and 1985 (Cotterill, 2000a).

E) Deterioration of ecological conditions

Several trends indicate a deterioration of ecological conditions across the wetland, which can eventually translate into impacts on uses, goods or benefits harvested by human communities.

During the field visits in September and October 2019, a total of 57 spot surveys was conducted to assess vegetation cover, land uses and degradation levels in and around the Lukanga Swamp. In order to evaluate degradation levels, stressors (sources of pressure) acting on the habitats were identified, related to resource harvesting, resource use, land conversion, pollution and invasion by exotic species (Table 44).

Table 44 – Degradation indicators observed in the wetland in September and October 2019

Sources of pressure and degradation	Indicators	Affected habitats
Resource use and harvesting	Cut grasses, reeds or sedges	Swamp; river; grassland; woodland
	Logged trees	Cultivated land
	Fishing activity	Swamp; lake; river banks
	Animals grazing or grazed vegetation	River; grassland; forest land; termitaria; swamp edges
	Trampled vegetation	Grassland
	Soil disturbance	Grassland; river banks; termitaria; swamp edges
	Active fire	Swamp
	Recent fire	Swamp; grassland; forest land; termitaria; river banks
Land conversion	Cultivation	Cultivated and managed land
	Infrastructure (bridges)	Rivers
	Infrastructure (unpaved roads)	Rivers; forest land; termitaria; grassland; swamp
	Infrastructure (settlements)	Rivers
	Infrastructure (stream crossings with flow obstruction)	Grassland; rivers
	Landfills	Grassland
Pollution	Excessive sediment	Rivers
	Presence of litter/debris	Swamp
	Clothes washing	Rivers
Invasive species	Presence of *Salvinia molesta*	Swamp; river, lake

The primary degradation indicator in the wetland habitats is the invasion by the aquatic weed *Salvinia molesta*, whose coverage increased until 2018 (C) - Land cover change). This species was detected in 46.7% of the spot assessments in the wetland's flooded habitats (i.e., permanent swamp, lakes and rivers) in September and October 2019, and has significant impacts on existing ecosystems' functions, including biodiversity loss, decreasing fish yields, hampered movement, among others (cf. chapter 4; BWZ, 2020b).

Regarding the **fishery**, all the interview and focus group respondents reported that fish yields have been declining. Some have argued that the fish is plenty, but is now in ponds far inside the swamp, in inaccessible areas.

Local communities claim that catches have been decreasing since the 1990s at least (Kapungwe, 2000, *in* Kamweneshe & Beilfuss, 2002; Kachali *et al*., 2008; Key informant interviews, 2019; Focus group discussions, 2019). BirdWatch Zambia (2020a) reports a reduction of the catch per effort from close to 35 kg hr^{-1} to >20 kg hr^{-1}.

In addition, according to the Focus group discussions held in December 2019 around the swamp (in Kabosha, Chiyuni and Mushiko), prior to the intensification of the Lukanga fisheries' exploitation, breams were "very big and would be caught using 4.5 to 5 inches nets", and caught species have significantly reduced in size, as far as forcing them to use nets with smaller mesh sizes.

The reduction of fish sizes could be indicative of an over-exploited system, in which the increased fishing effort causes a reduction in the abundance of larger species and individuals until only smaller ones remain, at which point the fishery has become fished-down (Tweddle *et al*., 2015; Welcomme *et al*., 2010). This is a negative feedback loop, since fishermen are driven into using smaller and smaller mesh-sized nets in order to reach smaller, low-value fish, further depleting the fishery (Kachali *et al*., 2008; Tweddle *et al*., 2015; Dof MFL & BWZ, 2019).

The gillnet surveys undertaken in the region of Waya in July 2015 and December 2019 aimed at conducting fish stock assessments and establishing the impact of the Kariba weed control attempt (Dof MFL & BWZ, 2019). A total of 370 specimens was caught in 2019, compared to eight (8) in 2015, which suggests a rebound of fish populations. The study attributes the increase to two main factors: the recently made suitable habitat due to the weed control efforts; and the low water levels due to recent droughts, which concentrate fish in the surveyed sites. The interpretation must be cautious, however, given the differences between the two surveys.

Overall, it appears that individual catches, as stated by key informants, have been suffering a decrease for some time due to increased fishermen numbers, which was further intensified with the invasion by *S. molesta*. Current control attempts are having positive impacts on the weed's levels and, consequently, on the habitats' conditions, allowing fish populations and other biodiversity to recover (Dof MFL & BWZ, 2019; BWZ, 2020a).

An additional trend indicating the deterioration of the wetland's conditions are the frequent outbreaks of waterborne diseases such as cholera and dysentery in the end of the dry season, and which are attributed to increasingly low water levels (Focus group discussions, 2019; Murebwa-Chirambo *et al*., 2017). Outbreaks concentrate around fishing camps without sanitary conditions, since fishermen use the water body for drinking and sanitation purposes, and the Lukanga is one of Zambia's hotspots for the disease (Kapina *et al*., 2018).

Regarding **terrestrial ecosystems**, in addition to land conversion for agriculture, these are mainly impacted by infrastructure development, fire, tree cutting and felling, and grazing (Table 44).

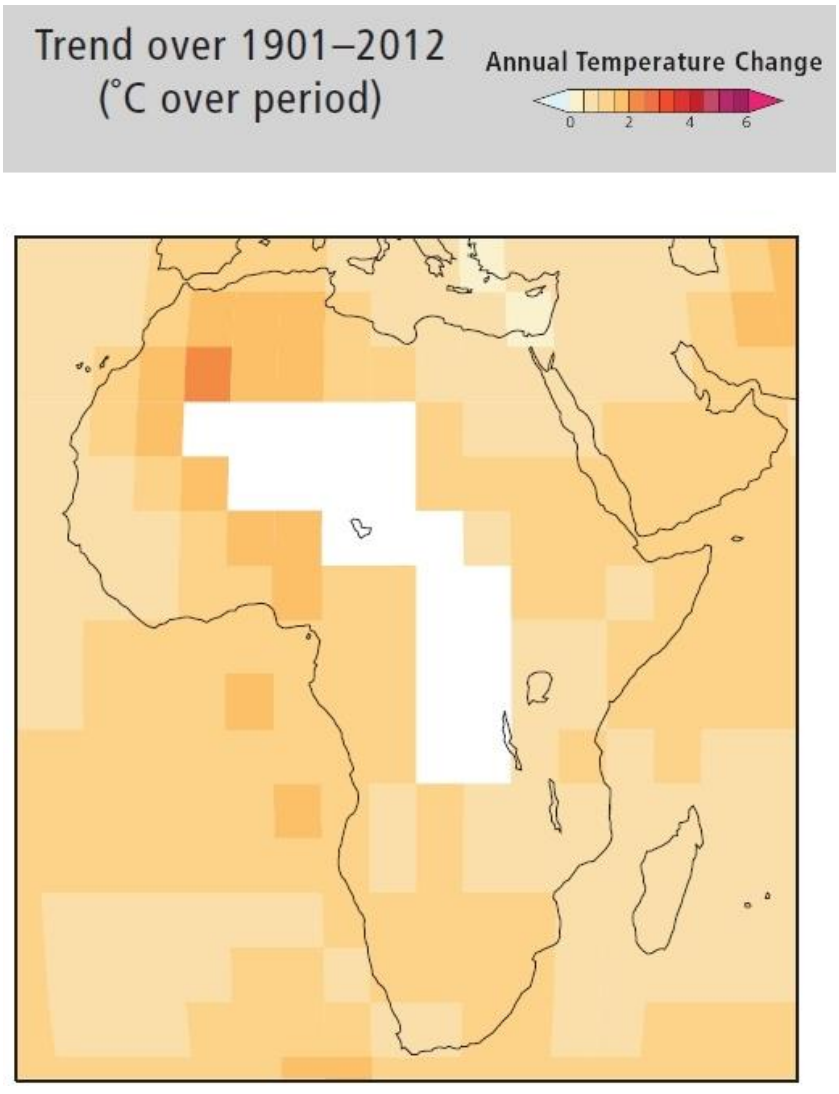
Chabwela *et al*. (2017) reported differences between the structure of Miombo in the protected forest and in Chilwa and east of Waya, namely, a dominance of understorey species in the latter, and attributed it to "excessive tree removal". It appears that current forest cover around the wetland is predominantly secondary, having replaced primary forest cover in response to human disturbance, mainly dry season fire, chitemene and over-harvesting, in line with Zambia's national trend (Phiri, Morgenroth and Xu, 2019). Between 1972 and 2016, forest degradation (i.e., conversion from primary forest to secondary forest) occurred at a rate of -2.23% y^{-1} nation-wide (Phiri, Morgenroth and Xu, 2019). Connectivity between primary forests dropped significantly during the 40-year period (from 79% to 13%), and grew between secondary forests until 2000 (from 16% to 65%), after which it started dropping until 2016 (to 54%). Overall, connectivity dropped by 22% between all forest types, which, coupled with an increase in number of forest patches and distance between them (Phiri, Morgenroth and Xu, 2019) suggests a growing fragmentation of forested area across the territory.

In line with these forest degradation trends, the ILUA Project's Phase II reports an overall increase in the time and distance necessary to travel to wood and non-wood forest product collection sites (Shakachite *et al*., 2016). This is supported by key informants, who reported that species harvested for traditional medicine are declining due to overharvesting and vegetation clearing for agriculture, so that locating these when needed is harder and takes longer than before (Key informant interviews, 2019). The quantity of wild food is also reported to be declining in the Chilwa island, mainly owing to the growing population

F) Climate change

Temperatures

Evidence of warming over land regions across Africa, consistent with anthropogenic climate change, has increased (since IR4 of IPCC). Decadal analyses of temperatures strongly point to an increased warming trend across the continent over the last 50 to 100 years (Niang *et al.*, 2014) (Figure 61).



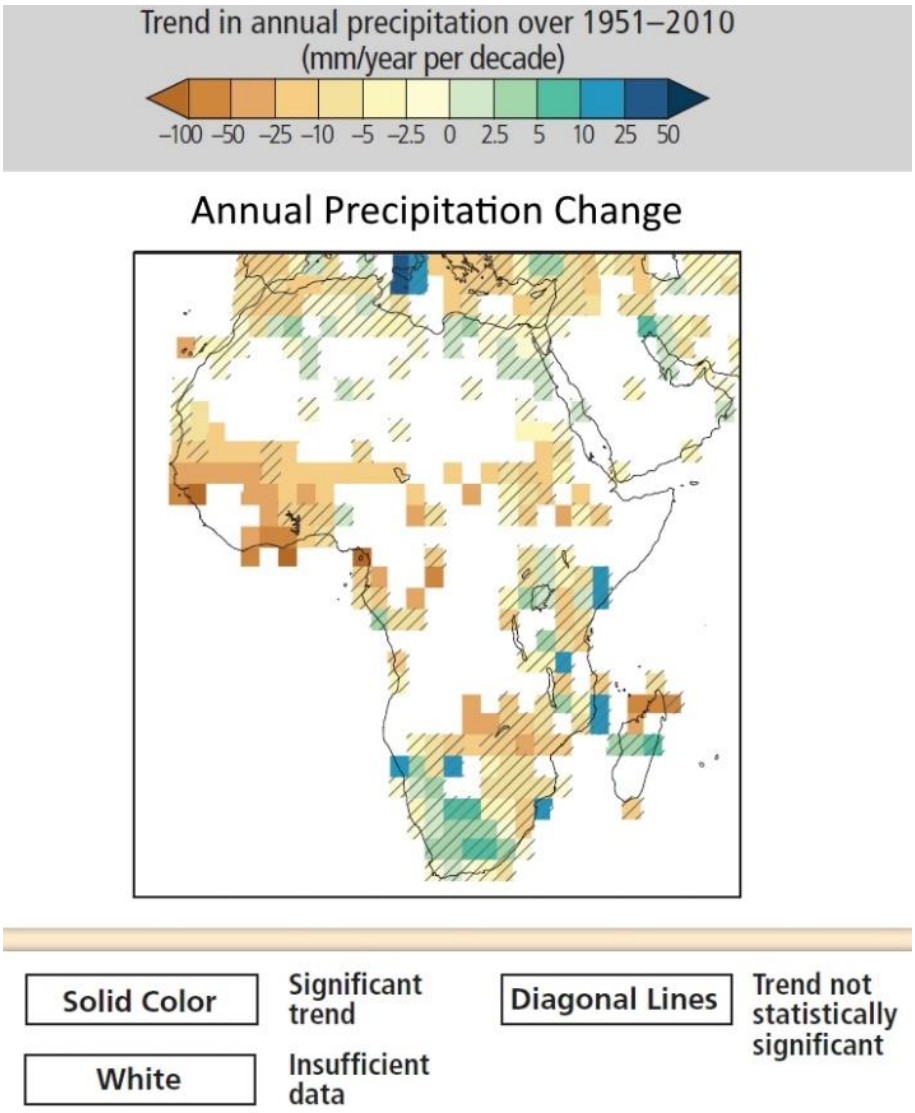
Source: Niang *et al.* (2014).

Figure 61 – Observed changes in annual average temperature from 1901–2012, derived from a linear trend

In recent decades, most of southern Africa has also experienced upward trends in annual mean, maximum, and minimum temperature over large extents of the sub-region during the last half of the 20th century, with the most significant warming occurring during the last 2 decades (e.g. Zhou *et al*., 2010 *in* Niang *et al*., 2014). Minimum temperatures have increased more rapidly relative to maximum temperatures over inland southern Africa (New *et al*., 2006 *in* Niang *et al*., 2014).

Precipitation

Most areas of the African continent lack sufficient observational data to draw conclusions about trends in annual precipitation over the past century (Figure 62). In addition, in many regions of the continent discrepancies exist between different observed precipitation data sets (e.g., Kim *et al*., 2013).



Source: Niang *et al*. (2014).

Figure 62 – Observed changes in annual average precipitation from 1951–2010, derived from a linear trend

Areas where there are sufficient data include very likely decreases in annual precipitation over the past century over parts of the western and eastern Sahel region in northern Africa, along with very likely increases over parts of eastern and southern Africa. It is worth mentioning that most of the data shows trends not statistically significant.

According to Niang *et al.* (2014), over southern Africa a reduction in late austral summer precipitation has been reported over its western parts, extending from Namibia, through Angola, and toward the Congo during the second half of the 20th century (New *et al.*, 2006). Modest downward trends in rainfall are found in Botswana, Zimbabwe, and

western South Africa. Apart from changes in total or mean summer rainfall, certain intra-seasonal characteristics of seasonal rainfall such as onset, duration, dry spell frequencies, and rainfall intensity as well as delay of rainfall onset have changed (e.g. Tadross *et al*., 2009). An increasing frequency of dry spells is accompanied by an increasing trend in daily rainfall intensity, which has implications for run-off characteristics (New *et al*., 2006).

5.2.2. Drivers of change and related impacts

The following factors are directly **driving change** in Lukanga Swamp, being responsible for the main expected impacts in the future:

- **Population growth** –
  - Land conversion;
  - Overharvesting/exploitation;
  - Introduction of exotic species;
- **Climate change**.

5.2.2.1. Population growth

Population growth is the main driver of ecosystem change worldwide, posing significant pressures in the natural environment through the intensification of anthropogenic land uses such as resource use, agriculture and rural or urban development.

Within the Ramsar site and surrounding area, the following impact categories are expected to intensify in response to population growth:

- Land conversion -
  - Land conversion refers to any modification of the original cover of an area be it in composition or condition.
  - Depending on the nature of this change, an ecosystem's functioning can be impacted to different extents, from simply decreasing its yield of food products, to completely inverting its role as carbon sink into carbon source, for instance.
  - Factors directly causing land conversion include all the human activities which alter the vegetation cover of an area: expansion of cultivated land, livestock herding, seasonal burning and resource harvesting, including tree felling.
  - When this exploitation or repurposing of land-cover is uncontrolled and indiscriminate, it may become unsustainable, with adverse effects locally and in downstream water systems.
  - In the conversion of natural forest cover to cultivated land, as well as in the felling of trees in forest areas for charcoal production, biodiversity is lost through direct removal of canopy cover, and

indirectly through the loss of suitable habitat for threatened flora and fauna species.

- The elimination of the original canopy cover will eliminate the products provided by tree species such as fruit and roots, as well as products derived from their symbiotic or commensal species such as mushrooms and caterpillars.
- Locally, the removal of wooded cover/biomass facilitates nutrient leaching, soil erosion, and decreases organic matter input, reducing soil fertility; regionally, the resulting increased runoff causes agrochemical inputs from upstream agricultural land and sediments from upstream eroded deforested land to end up in the wetland, increasing eutrophication, siltation and pollution.

- Overharvesting/ exploitation –
  - Several naturally occurring resources are directly harvested from the ecosystems in and around the Lukanga, potentially directly impacting existing ecosystems.
  - These include fish, reeds, grasses, mushrooms, leaves, fruit, bark, roots, timber, firewood, wild birds and small wild mammals.
  - While sustainable resource use/harvesting levels are possible to maintain, growing population, unemployment, decreasing land fertility, and decreasing fish yields will indirectly drive the intensification of subsistence activities such as these, which in turn drives the degradation of the different macro-habitats, their resilience in the face of environmental uncertainty and their provision of ecosystem services and goods.

- Introduction of exotic species –
  - Migration into the Lukanga area of people seeking to complement their income represents a heightened risk of new introductions of both terrestrial and aquatic exotic species with the potential to become invasive and further pressure ecosystem stability.

These impacts are directly caused by the following activities or land uses:

- Seasonal burning;
- Cultivation;
- Livestock herding;
- Fishing;
- Plant product harvesting;
- Hunting.

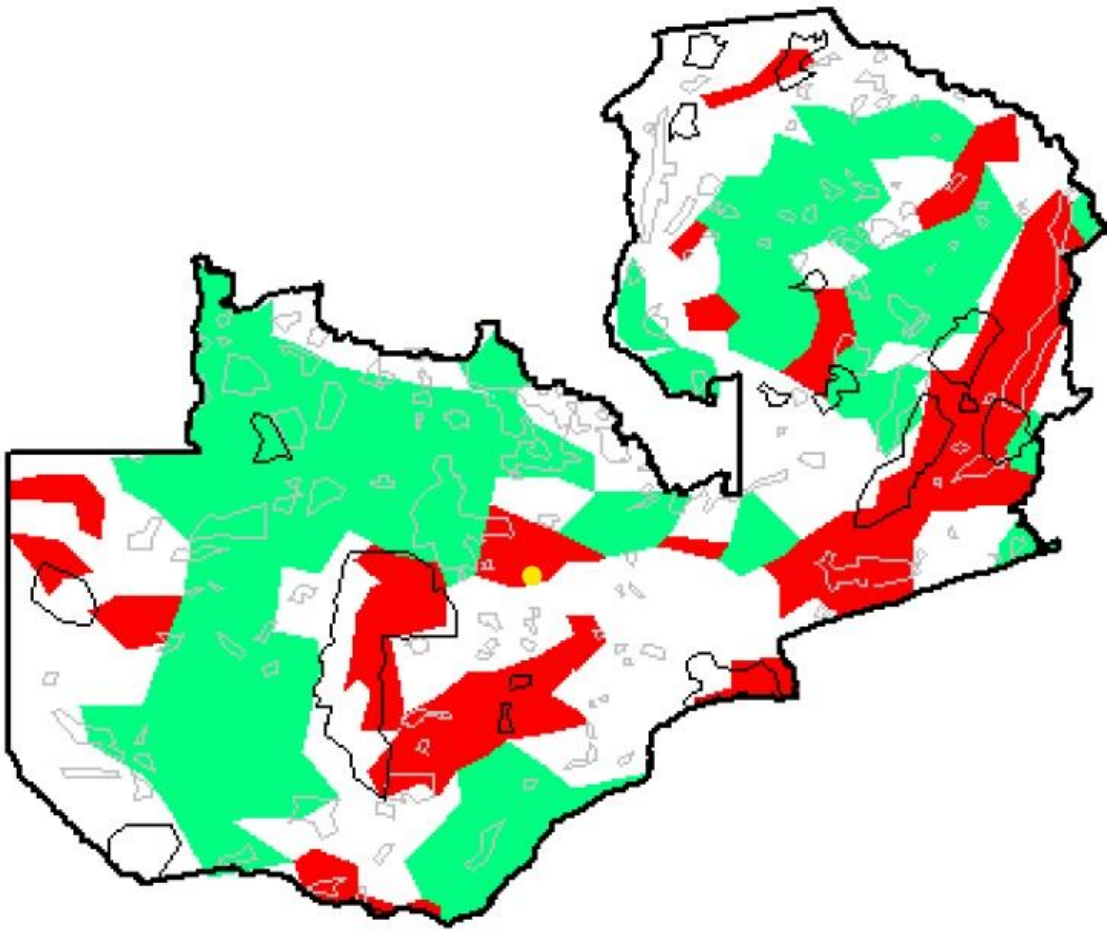
A characterisation of these elements is given in the following sections. Despite not consisting of a human activity or land use, the introduction of exotic species is also developed in this chapter (c.f., G) - Invasive species), considering its role as a modifier of the natural environment.

A) Seasonal burning

Fire has been used as a management tool across Zambezian ecosystems for centuries (Eriksen, 2007). Whether originated accidentally or deliberately, dry-season fires in particular are an inherent element of these landscapes.

According to Chidumayo (1995, in Campbell, 1996), mean fire-return interval for central Zambia was of **1.6 years** in the 90s, although other analyses found lower frequencies, with intervals of **3 years** (Campbell, 1996).

Based on data from the period between 1981 and 1991, the former Ministry of Land, Natural Resources and Environmental Protection (MLNREP, 2014) reports an **annual** fire frequency for the northernmost half of the swamp area, and of **every two (2) to three (3) years** in the southernmost half (Figure 63).

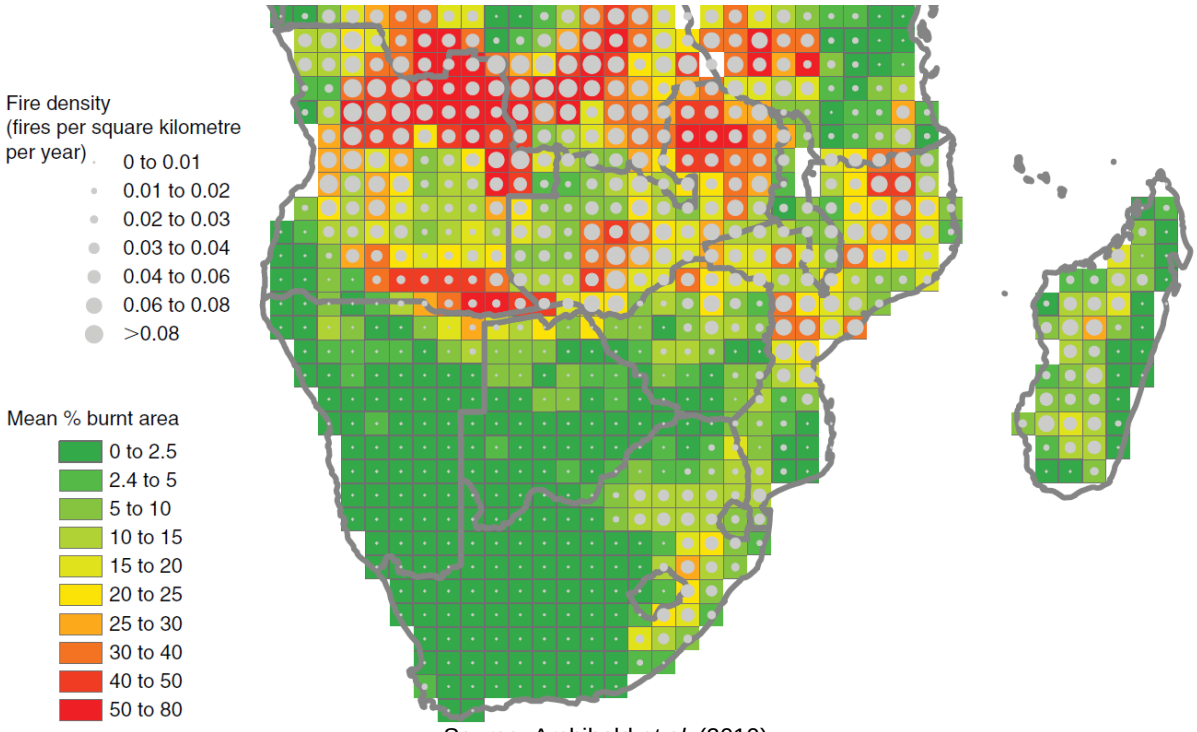


Source: MLNREP (2014).

Figure 63 – Distribution pattern of fire frequency in Zamia; based on Barbosa, Stroppiana, and Grégoire (1999); Red for areas burnt annually, white for areas that burn once in 2-3 years, and green for areas that burn in 3-4 years; the location of the Lukanga swamp is marked in yellow

Based on Barbosa, Stroppiana and Grégoire (1999)'s country-specific annual burned area values, a mean 161,500.00 km^2 burned annually across Zambia for the eight-year period between 1981 and 1991 (data for 1984-85 was discarded), which equates to 21.46% of the territory each year. Of the total area burned in the African continent, wetter Miombo woodland fires accounted for 8.06%, fires in North Zambezian undifferentiated woodland accounted for 18.71%, and fires in mosaics of edaphic grassland and semiaquatic vegetation for 1.26% (vegetation types according to White's UNESCO Vegetation Map of Africa). This represents an estimated 6,015% of these vegetation types together burned annually in the country, which would yield an annually burned area of 40,355.35 km^2 for the Ramsar site and surrounding area alone, assuming White's cover classification.

Archibald *et al.* (2010) conducted a similar study of southern African fire regimes for the period between 2001 and 2008, yielding similar results to the ones found for the 80s (Figure 64; Table 45).



Source: Archibald *et al*. (2010).

Figure 64 – "Fig.6. Density of fires per square kilometer [per year], plotted over the mean % burnt area for Southern Africa. […] Fire density and burned area seem to be related"

Table 45 – Fire statistics of different vegetation types and land-use categories (for the 8-year period 2001-2008, for Zambia)

Vegetation	Land use	Km^2 (x10^3)	% burnt	CI	*MEI* all	CI	*MEI* burnt	CI	Peak month	Seasonality
Forest	Protected Areas	6	7	(7-8)	12	(7.7-17)	2.4	(2-3)	Jun	0.8
Forest	Uncultivated	31	8	(7-9)	26	(12-56)	3.8	(2.8-5.1)	Aug	0.8
Grassland	Protected areas	46	31	(30-35)	3.8	(3.1-4.5)	1.7	(1.5-1.9)	Aug	0.8
Grassland	*Uncultivated*	*39*	*26*	*(34-26)*	*4*	*(3.3-4.8)*	*1.8*	*(1.6-2)*	*Aug*	*0.8*
Grassland	*Cultivated*	*6*	*53*	*(51-55)*	*1.7*	*(1.5-1.8)*	*1.2*	*(1.1-1.3)*	*Aug*	*0.8*
Savanna-woodland	Protected areas	143	33	(32-34)	2.6	(2.3-3)	1.8	(1.6-2.1)	Aug	0.8
Savanna-woodland	*Uncultivated*	*408*	*22*	*(21-23)*	*7*	*(5.2-9.3)*	*2.2*	*(1.9-2.7)*	*Aug*	*0.8*
Savanna-woodland	*Cultivated*	*43*	*20*	*(18-21)*	*5.5*	*(4.4-7)*	*2.1*	*(1.8-2.4)*	*Aug*	*0.8*
Savanna-woodland	Settlements	1	0	(0-1)	~	~	~	~	Aug	0.7
Thicket	Protected areas	4	37	(33-44)	2.3	(2-2.6)	1.8	(1.6-2)	Jun	0.8
Thicket	Uncultivated	1	44	(43-57)	1.5	(1.4-1.6)	1.3	(1.2-1.4)	Aug	0.9

Source: Adapted from Archibald *et al*. (2010).

Columns represent: the total area evaluated, median % burnt area ('% burnt'); 25% confidence intervals (CI); the median fire-return interval (*MEI*) calculated (CI, 25%) for all pixels ('MEI all') and only burnt pixels ('MEI burnt'); the month of peak fire; and the seasonality of fire (ranging from 0, fire all year round; to 1, all fire occurred in 1 month). The tilde (~) indicates the Wiebull parametrisation did not converge, so median fire return could not be calculated.

In *italic*, the vegetation and land use categories found in the swamp area. In their reclassification of White's vegetation classes, Archibald *et al*. (2010) included edaphic grassland mosaics in the "grassland" category and woodlands (i.e., wetter Miombo and North Zambezian Undifferentiated woodland) in the "savanna-woodland" category.

During the 8-year period studied: 36% (confidence interval, CI 34-26) of **uncultivated grassland** area burned, for a fire-return interval of 1.8 years (CI 1.6-2) (calculated for burnt pixels only); 53% (CI 51-55) of **cultivated grassland** area burned, for a fire-return interval of 1.2 years (CI 1.1-1.3); 22% (CI 21-23) of **uncultivated woodland-savanna** area burned, for a fire-return interval of 2.2 years (CI 1.9-2.7); and 20% (CI 18-21) of **cultivated woodland-savanna** area burned, for a fire-return interval of 2.1 years (CI 1.8-2.4).

Fires in July, August, September and October (dry seasons) account for over 80% of the total area burnt countrywide (Archibald *et al*., 2010, *Fig. 4*), which is further demonstrated by seasonality values (between 0.7 and 0.8, c.f. Table 45). The month of peak fire activity was August for all vegetation/land use types, except forest and thicket vegetation in protected areas, for which it was July (Table 45).

Finally, central Zambia (which includes the main plan areas), is characterized by a high density of small fires throughout the year (>0.06 fires per square kilometer per year, with the largest fires ranging between 5 and 30 km^2) but that burn between 30 and 50% of the area (Archibald *et al*., 2010, *Fig. 6*).

The act of seasonally burning the vegetation is practiced around the Lukanga with the purposes of promoting the growth of fresh herbs for cattle, to prepare the land for cultivation, and to eliminate original cover for the conversion of natural land to cultivated land (Key informant interviews, 2019) (Figure 65).

Within the permanent swamp, controlled areas are burnt towards the end of the dry season in order to open up patches of decreased cover and increased nutrients, purposefully increasing reproductive and feeding habitat availability for fish, which can be harvested later on (Personal communication, 2019) (Figure 65).



Source: Nemus (2019).

Figure 65 – Late dry season fires and burnt vegetation in the swamp (top), floodplain (bottom left), and woodland (bottom right)

In the floodplain, dry season fires consume the standing mature plant biomass of poor forage quality, and induce the growth of fresh, more palatable herbs for cattle, through the volatilization of nutrients back into the soil (Marchand, 1987; Gibson, 2009). The effects of fire on grassland vegetation are scale- and pattern-dependent (Gibson, 2009). Periodic, low frequency, small-scale fire regimes generate and maintain the spatial heterogeneity of the vegetation structure across the regional landscape (Gibson, 2009; SANBI, 2013). In contrast, uncontrolled, large and frequent fires will decrease diversity and heterogeneity, thus decreasing ecosystem resilience (Gibson, 2009).

In the swamp, controlled burning of aerial shoots and leaves in the end of the dry season has been shown to promote new vegetative growth, remobilize nutrients and decrease shade, promoting the growth of periphyton and hence providing the conditions for fish grazers and bird predators to increase as well.

Controlled burning of the ground cover in forested and cultivated areas is undertaken towards the end of the dry season for the same purposes of preparing the land for cultivation (clearing and fertilizing arable land) and promoting the growth of fresh grass to be grazed (Key informant interviews, 2019; Eriksen, 2007).

In general, fire results in (Gibson, 2009):

- Release of carbon stocks – the burning of forested land – an important carbon sink – releases the greenhouse gas back into the atmosphere, eliminating the forest's role in the regulation of regional climate;
- Reduced above-ground plant biomass, through its consumption as fuel;
- Species composition is altered through continuous burning, favouring annuals and species adapted to seasonal burning;
- Lower soil albedo (reflectivity), through the deposition of ash;
- Higher soil temperature, through the increased absorption of solar radiation as a result of the lower soil albedo;
- Volatilization and release of nutrients;
- Higher susceptibility to wind and water erosion.

B) Cultivation

Land conversion in Zambia is mostly due to loss of primary or secondary forest cover to cultivation or settlements, an important trend nationally and around the Ramsar site alike (c.f., 5.2.1.2.C) - Land cover change).

Main types of cultivation practiced around the Lukanga swamp consist of small-scale subsistence farming, with crop surplus being commercialized locally or regionally (e.g., Mumbwa and Kabwe). This is undertaken both in the upland and in the seasonally flooded grassland, therefore constituting a driver of land conversion in terrestrial and seasonally flooded ecosystems (Key informant interviews, 2019; Kachali *et al*., 2008).

Cash crops include sunflowers and cotton, and **food crops** include maize, beans, cassava, sweet potato, tomato, soyabeans, pumpkin, bush yam, groundnuts and cabbage (c.f., 3.7.4.2 - Flora).

Recession crop farming is practiced in the floodplain and termitaria grassland during the dry season as water recedes, mainly for maize, cotton, groundnut and sunflower

(Mapedza *et al*., 2012). Cultivation directly impacts floodplain vegetation through the removal of the original cover, modification of soil characteristics through ploughing, and modification of nutrient status through the application of fertilizers (SANBI, 2013).

In the upland, semi-permanent and shifting farming systems are the predominant forms, mainly through hand or ox-plough and slash and burn methods (Kapekele, 2006; Saasa *et al*, 2003). The Lukanga is situated within Zambia's Agro-ecological zone IIb (annual rainfall between 800 and 1,000 mm on Kalahari Sand soils) for the major part, and partially in Zone III to the north (annual rainfall between 1,000 to 1,500 mm).

The impacts of cultivation include:

- Release of carbon stocks into the atmosphere from the initial clearing of vegetation through burning;
- Reduced C-assimilation capacity - growing of crops with lower - the replacement of the original vegetation with permanent crops significantly reduces carbon sequestration (in Hauser & Norgrove, 2013); the recovery of carbon uptake during the fallow period is also hindered, as the slash-and-burn, which includes the use of hand hoes, disturbs soil structure (Kalaba, Quinn and Dougill, 2013); carbon stocks from cleared Miombo vegetation are recovered after 20 years (Kalaba, Quinn and Dougill, 2013).
- Increased water runoff and erosion - potentially negatively affecting the neighboring wetland's condition;
- Pollution and eutrophication of water bodies – excess loading of phosphorus, nitrogen and other pollutants from the use of agro-chemicals coupled with increased runoff can cause the eutrophication of water bodies, deteriorating their functioning;
- Biodiversity loss - since cultivated land results from the substitution of natural vegetation with structurally and floristically simpler formations, these semi-natural habitats no longer hold the original floristic values, and as a result, are also devoid of the original (or pristine) faunal values to some extent; their value is no longer ecological, but economic; values lost to slash and burn practices, for instance, can recover over a long period undisturbed, but species composition remains different from the original even after over 50 years (Kalaba, Quinn and Dougill, 2013).

Currently, the growth of human population is reducing the area available for farming in rural communities, implicating a reduction of fallow periods and/or a complete shift towards semi-permanent to permanent cultivation systems instead (Chidumayo, 1987b), and an increase of the area travelled to for charcoal production, with impacts on the landscape and its ecology.

C) Livestock herding

Communities around the Lukanga engage in a subtropical grassland-based livestock system, where cattle and goats are reared in a communal manner in natural grazing areas, mainly free range, and under the traditional migration pattern of transhumance (Ng'uni, 2013; Marchand, 1987).

During the wet season, when the grassland is flooded, livestock is herded in the upland (Marchand, 1987; Key informant interviews, 2019). As water recedes during the dry season, herds recolonize the floodplain grassland (Figure 66). During this period, remnants of the flooded vegetation are burned, enabling the growth of fresh herbs for forage (Marchand, 1987; Key informant interviews, 2019).

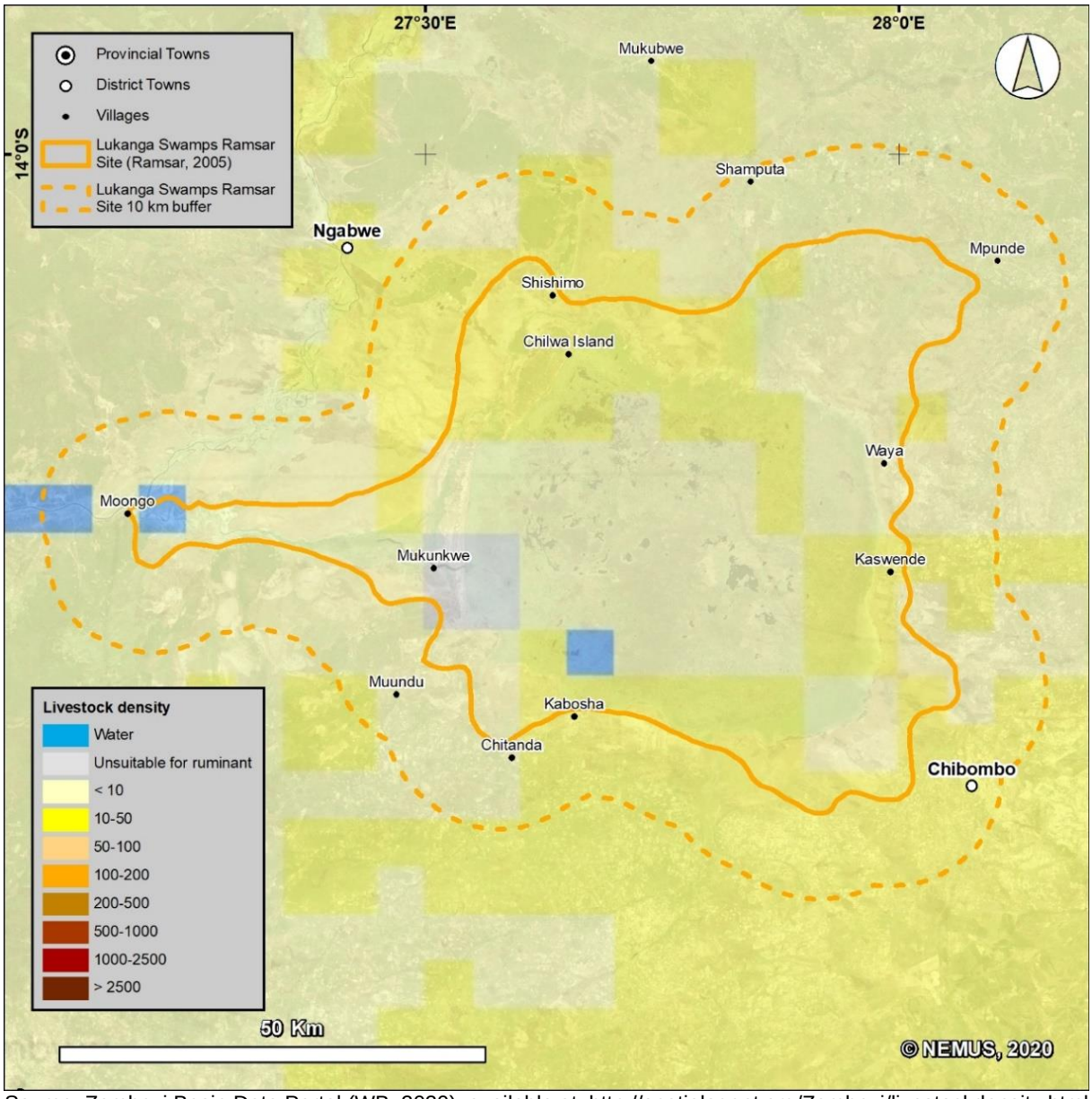


Source: Nemus (2019).

Figure 66 – Livestock grazing and drinking on the swamp's edges and floodplain grassland, upstream (top) and downstream (bottom) of the swamp, during the dry season

Upland residents own significant numbers of cattle, while residents of the fishing villages and migrants normally raise only a few animals as investment, to finance household needs such as school fees, marriage ceremonies and land preparations (Key informant interviews, 2019).

According to data compiled in the Zambezi Basin Data Portal (WBG, 2020), the south-eastern and north-eastern quadrants of the swamp's surroundings hold a livestock density of 10 to 50 heads per 25 km^2, while the remaining area support less than 10 (Figure 67).



Source: Zambezi Basin Data Portal (WB, 2020), available at: http://spatialagent.org/Zambezi/livestockdensity.html

Figure 67 – Livestock density in the plan area

As explained earlier, grazing, as an agent of disturbance, is an essential driver and element of African landscapes, and of grasslands in particular (c.f., 3.7.4.1.B) - Edaphic grassland), accelerating the nutrient cycle and defining to an extent the composition of the vegetation. When appropriate levels of grazing are enforced, biomass production is stimulated, habitat heterogeneity is increased through localized/patchy disturbance, and nutrients are redistributed through consumption and waste (SANBI, 2013).

However, indiscriminate and uncontrolled grazing can surpass the system's carrying capacity, and incur in significant pressures which hinder the system's long-term health

and provision of services. When inappropriate, grazing pressure may drive the vegetation to become dominated by unpalatable species, facilitate the invasion by exotic species, and increase soil erosion (SANBI, 2013).

According to Marchand (1987), during the non-flood period, floodplain grasslands have a productivity of 8 to 10 t ha^{-1} y^{-1}, which enables a carrying capacity of 1 to 2 heads per ha.

D) Fishing

Fishing is practiced by resident and migrant communities in the permanent swamp, open lakes and riverine system, as well as in the lagoons and floodplains formed in the wet season (DoF, 2014).

This a typical low-cost, low-tech and multi-species small-scale artisanal fishery (SSF), as many other inland African fisheries, where the majority of the fish is sold locally or regionally, while a minor proportion is bartered for items such as mealie-meal, clothes, groceries, etc., or consumed directly (DoF, 2014).

When not sold fresh, fish is smoked in drums or mud made kilns, using firewood from neighbouring woodlands ("fast and easy"), with tree species such as the Mutondo, or *Isoberlinia angolensis* (Welw. Ex Benth.) Hoyle & Brenan (Key informant interviews, 2019; DoF, 2014). During the dry season, fish can also be arranged on structures made of wood or other materials to dry in the sun, although less commonly (Figure 68; Key informant interviews, 2019; DoF, 2014).

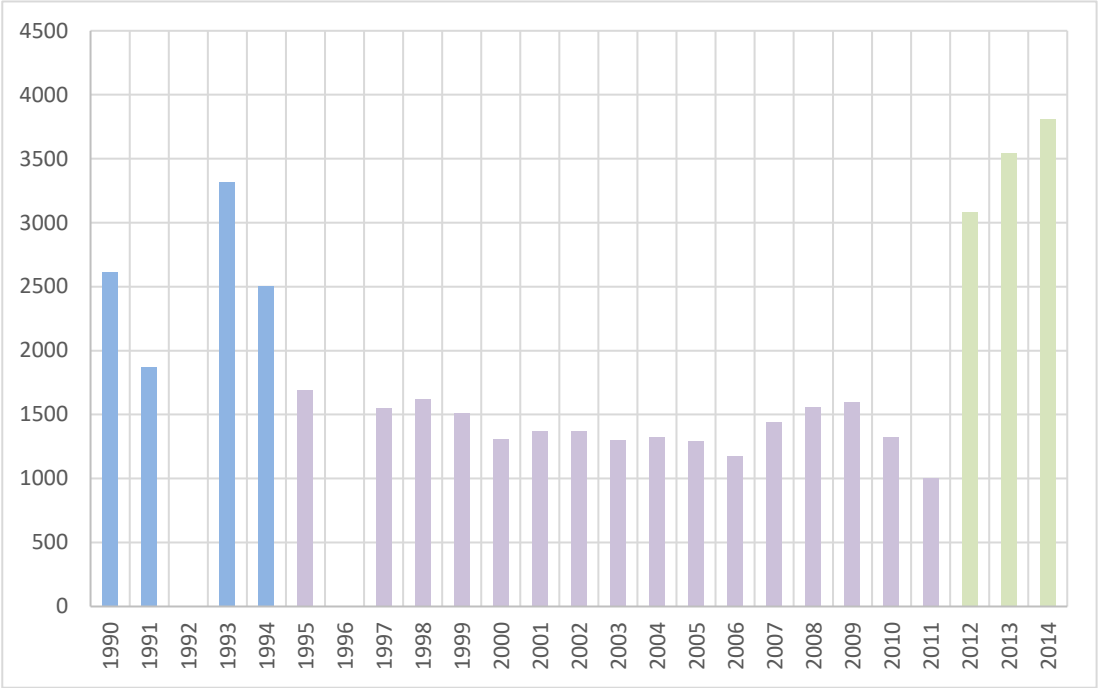


Source: Nemus (2019).

Figure 68 – Different methods for adding value to the fish product prior to its commercialization: on the left, firewood for smoking fish in Kabosha; on the right, sun drying in Moongo

Catch data between 1990 and 2014, covering the whole area, averages at **1,878.39 MT** (±809.54) caught yearly (FSIMU, 2015), with a median of 1,554 MT, a maximum of 3,811 MT in 2014 (most recent available data) and a minimum of 1,007 MT in 2011. This indicates an average annual production for the Lukanga Swamp fishery of **7.22 kg ha^{-1}** (±3.11).

Three distinct epochs can be observed for this period: prior to 1994, between 1994 and 2011, and between 2012 and 2014 (Figure 69).



Source: FSIMU (2015).

Figure 69 – Historical catches on the Lukanga swamp between 1990 and 2014. Data for the year of 1992 is missing due to a cholera outbreak, and 1996 for unknown reasons

The fishery produced on average **2,577.25 MT** of fish per year between 1990 and 1994, fell to an average of **1,403.25 MT** per year between 1995 and 2011, before rising again to an average of **3,480.67** MT between 2012 and 2014.

Annual fish landings obtained by the Department of Fisheries from designated harbours around the Swamp between 2017 and 2019 are given in Table 46.

Table 46 – Fish landings from the capture Fishery on the Lukanga Swamps

District	Annual fish landings (MT)				Species of economic importance
	2017	2018	2019	2020 (Q1)	
Chibombo	106.4	113.9	54.4	-	*Clarias* sp., tilapiines
Kapiri Mposhi	36.2	172.0	86.6	11.6	*Clarias* sp., tilapiines
Ngabwe	-	-	-	-	No data
TOTAL	142.6	285.9	141.0	11.6+	-

Source: MLF (2020).

Values up to 2014 and those between 2017 and 2019 show great discrepancies, and the latter should be considered with caution, given the collection of catch data did not cover

the entire area and has been hampered by short staffing, the inaccessibility and dimension of the fishery (MLF, 2020).

In 2014, the DoF reported 24 permanent villages around the swamp, and 13 temporary villages, or camps, within it (DoF, 2014), while the Ministry of Fisheries in Livestock (2020) recently reported only 22 and 11, respectively.

Temporary camps are set in floating islands inside the permanent swamp (Figure 70), where fishers can move to for two (2) to three (3) weeks to pursue the fishing activity, before returning to their permanent residencies (DoF, 2014).



Source: Nemus (2019).

Figure 70 – Fishing camp in the region of Waya (14°19'43.3200"S, 027°56'09.1680"E)

The swamp's fishery began being regularly exploited towards the end of the 1960s, around the time people from other Zambian tribes and surrounding countries arrived in the area (Kachali *et al*., 2008; Focus group discussions, 2019). Prior to this, local residents from the Lenje tribe turned to fishing more as a function of proximity to the swamp, relying primarily on other livelihood strategies (Kachali *et al.*, 2008; Focus group discussions, 2019).

Fishing efforts significantly rose in the 1960s after the first wave of inward Bemba migration (Kachali *et al.*, 2008), and recently rose again very significantly, as a response to the abundance of fish.

Active fishermen numbers are currently at **3,936** (2014), all of which unlicensed (DoF, 2014). This number increased from **759** in 1997 to **901** in 2005 (+142, or 18.71%, in eight [8] years), and then reached **3,936** in 2014 (+3,035, or 336.85%, in nine [9] years) (CSO, 2018; Chitembore, 1998, in Kamweneshe & Beilfuss, 2002).

According to the DoF (2014), 16 tribes are currently represented in the fishermen population, the most representative being the Lumba, Bemba, Lenje, Lozi and Kaonde tribes, and including also members from the Bisa, Lala, Namwanga, Hgoni, Nsenga, Swaka, Unga, Nkoya, Lunda, Nyanja and Tonga tribes.

Seasonal migration into the swamp to fish is still increasing, predominantly of people from the Bemba and Lamba tribes, the former being traditionally associated to fishing activities in Zambia. Nonetheless, the influx of migrants to some of the villages – Moongo and Kaswende, for instance – has recently slowed, owing to a decrease in fish yields.

Regarding months spent fishing yearly, 5% of active fishermen reported to do it for less than 3 months, 40% for 3 to 5 months, 51% for 6 to 9 months and 4% reported to fish between 10 and 12 months of the year, thus not observing the 3-month fishing ban (introduced by the Fisheries Regulations of 2012, under the Fisheries Act Nº22 of 2011) from December to February (DoF, 2014).

The number of boats is reported as "steadily increasing" from **1,054** in 2006 to **1,672** in 2014, +618 (58,63%) over an eight [8] year period (DoF, 2014), including dugout canoes (dominant) and fibre or plunk boats (DoF, 2014) (Figure 71).



Source: Nemus (2019).

Figure 71 – Dugout canoes in Waya

Most of the fishing is done with passive gears deployed in the water and hauled the following day, but seine and long line methods are also employed (DoF, 2014).

The number of gillnets has increased from **18,268** in 2006 to **31,855** in 2014, +13,587 (74.38%), over the same eight [8] year period (CSO, 2018; DoF, 2014). Other gears are used, such as seine nets and longlines, at lower rates.

Fishing gears have last been inventoried at a total of **462,687** (2014), including gillnets (dominant), seine nets and long lines (DoF, 2014). Gillnet mesh sizes vary between **13 and 152 mm** (0.5 and 6.5 inches, respectively), and are dominated by the size 63 mm (31.87%) (DoF, 2014). The 2012 Fisheries Regulations (under the Fisheries Act Nº22 of 2011) prohibit the use of gillnets with mesh sizes under 9 mm, the use of any draw or seine net, and of monofilament nets with mesh sizes under 127 mm, in the Lukanga fishery.

Finally, the most recent **CPUE** estimate, of **20.58**, dates to 2013 (prior to the 2014 data), and was determined for a total of 51 days of activity per year out of 270 open fishing days (activity rate of 0.19) (FSIMU, 2015). This value is widely contested as being too high, as it has been extrapolated from catch assessment surveys for other Zambian

fisheries (Personal Communication, 2020). Recent efforts to update this value were not conclusive (DoF MFL & BWZ, 2019).

As mentioned earlier (c.f., 5.2.1.2.E) - Deterioration of ecological conditions), riparian communities have been reporting decreasing fish yields and sizes for a while (Kachali *et al.*, 2008; Key informant interviews, 2019; Focus group discussions, 2019), indications of an **overfished fishery**.

Overfishing is caused by high fishing efforts and the use of unsustainable methods, which are both exacerbated by enforcement limitations, in turn driven by population growth and unemployment.

The increasing trend of active fishermen numbers (having risen by 336.85%, in nine [9] years) is attributed to high unemployment in the area, to the inexistence of alternative livelihood strategies, to the general hardship of the region, and to growing demand for fish protein from fast human growth (Key informant interviews, 2019; Tweddle *et al*., 2015).

Unemployment rates among younger generations, in particular, are appointed as a significant driver. On the other end, pensioners were also said to migrate towards this fishery as a result of delayed government benefits, to increase their income through the fish trading activity (Key informant interviews, 2019).

Depleting fisheries around the country have also been driving fishermen into the Lukanga. Active fishermen numbers tend to increase when fish yield increases, as migrant fishers abandon less profitable fisheries to maximise profit (Kolding & van Zwieten, 2011). Residents from local riparian communities – who depend on local fisheries for food security and economic gains - are less motile and remain exploiting local fisheries even after they have been depleted (Tweddle *et al*., 2015). In line with this, there seems to be a slowing trend of the influx of migrants to Moongo and Kaswende, following steady decreases in fish yields (Key informant interviews, 2019).

All the focus groups and key informants appointed nets with small mesh sizes as a driver of the decline. However, the necessity to get sustenance forces them to continue using these methods, because if they do not, “nothing is caught” (Key informant interviews, 2019; Focus group discussions, 2019). Fishermen have had to improve the competitiveness of their gear – reducing mesh sizes (Figure 72), resorting to illegal

methods such as the Kutumpula[5] and even fishing year-round, not observing the fishing ban – to improve their yields in response to decreasing catches and growing fishermen numbers (DoF, 2014; Key informant interviews, 2019).



Source: Nemus (2019).

Figure 72 – Mosquito net being used by local fishermen

This is similar to what happens in other Zambian fisheries, such as those of the Kafue Flats and the Barotse Floodplains, where fishermen use nets below permissible size and mosquito seine nets, despite them being aware this is problematic (Tweddle *et al.*, 2015).

Local communities also insist that before the opening up of the Lukanga, minimum mesh sizes were established (4.5 to 5 inches), and use was monitored and enforced by

[5] The *kutumpula* is a variant of gill netting where nets with small mesh sizes are deployed around vegetation in shallower reaches of rivers and fishermen then thump on the water with poles to drive the fish out. Nets are pulled more frequently and relaunched at a faster pace.

fishermen themselves – local people were responsible for policing and reporting others to the traditional leaders (Focus group discussions, 2019).

Although key informants claimed that local fishermen abide by the annual nation-wide fishing ban (from December 1st to the end of February), and that this is enforced by the Fisheries Department through swamp patrols, conflicting data is reported in MLF (2020) and DoF (2014), as well in the information shared in the focus groups discussions.

These claimed that the swamp's fishery is actually never interrupted, and that this arises from an inefficient enforcement by the government, which has been reported elsewhere (Kamweneshe & Beilfuss, 2002; DoF, 2014; Dof MFL & BWZ, 2019).

The enforcement of the annual closed season (December 1st to the end of February) between 2016 and the first quarter of 2020 totalled 14 arrests, 880 kg of fresh fish confiscated, and 1,615 kg of dried fish confiscated (Table 47; MLF, 2020).

Table 47 – Closed fishing season reports

Season	Station	Number of arrests	Fresh fish confiscated (kg)	Dried fish confiscated (kg)
2019-2020	Kapiri Mposhi	1	155	-
	Ngabwe	-	20	100
	Total	*1*	*175*	*100*
2018-2019	Kapiri Mposhi	-	600	-
	Ngabwe	-	-	565
	Chibombo	10*	105	200
	Total	*10*	*705*	*765*
2017-2018	-	-	-	-
2016-2017	Kapiri Mposhi	-	-	150
	Ngabwe	3*	-	-
	Chibombo	-	-	600
	Total	*3*	*-*	*750*
TOTAL		***14***	***880***	***1,615***

Adapted from: MLF, 2020
Notes: (*) all were pardoned by court.

However, these values (arrests and interceptions) are described as “fairly low” by the DoF, and as **underrepresenting** the levels of non-compliance by local fishers and traders for the seasons in study.

This is the period when fishing can have a more detrimental impact on the maintenance of populations, as swamps and floodplains provide breeding habitat, refuge and food for adult and juvenile fish who migrate horizontally from the Kafue river system as the water levels rise (Welcomme, 1975).

Finally, local communities mentioned repeatedly that growing fishermen numbers are negative for the fisheries because of difficulties in regulating the activity and enforcing the regulations.

Entry to the swamp used to be controlled (there were fewer official entry and exit points) and headmen were capable of enforcing technical and socio-cultural conservation and management practices as well as supervise the fishermen (Focus group discussions, 2019).

Traditional leaders claim they are currently not able to enforce the ban since the Department of Fisheries' local offices were closed due to lack of funding (Focus group discussions, 2019). Lenje residents said that prior to the sudden rise in migration, the fishing ban was successfully enforced, and in those months, fishermen would shift to farming the plateau.

According to the MLF (2020), the enforcement of fishery regulations (e.g., fishing ban, fishing methods and mesh sizes), are hindered by the following issues:

- Absence of stationed Zambia Police Service;
- Lean departmental workforce;
- Vast catchment area;
- Inadequate equipment (boats, engines, etc.);
- Low disbursements of operational funds towards enforcement officers;
- Lack of an enforcement wing within the department;
- Weak co-management structures.

The collection of reliable data is also hindered by the low staffing and the dimension and complexity of the wetland.

The impacts of fishing include:

- Reduction of the abundance of desired fish species - these are typically fish predators and crucial components of wetland food-webs (Kolding & van Zwieten, 2011); the shift of the fish community structure represents a disruption of the wetland ecosystem, since it can have rippling effects in other levels of the food-chain, such as epiphyton, macrophytes, invertebrates and bird assemblages;
- Maintenance of the network of channels and pools / control of reed overgrowth – this happens through the movement of fishermen inside the permanent swamp, and their habit of burning of patches of reed stands during the late dry season to create ponds in which to fish later in the wet season (c.f., A) - Seasonal burning); these actions alter vegetation structure and composition, maintaining the pools and channels' network crucial for maintaining biodiversity, particularly of fish, invertebrate and submerged macrophyte species.

E) Wild plant products

Plant products directly harvested from the natural environment (excluding cultivated land) include:

- Reed, grasses and sedges;
- Wood forest products: firewood, charcoal;
- Non-wood forest products: fruit, fungi, nuts, roots, leaves, bark and seeds.

Local communities harvest the *Cyperus papyrus* sedge as a source of fibre, for instance for the construction of mats, considering it to be more adequate to such uses than *Phragmites australis*, which currently dominates the swamp's emergent cover (*Pers. observation*, 2019; Key Informant interviews, 2019) (Figure 73).



Source: Nemus (2019).

Figure 73 – Traditional harvesting of *Cyperus papyrus* culms and stems as raw material for the fabrication of matts, in the banks of the Lukanga River, just before the confluence between this and Kafue river, near the settlement of Moongo

The common reed *P. australis* is widespread, more abundant, and is also commonly harvested.

According to the Global Environment Facility (2000, in Sentinel Vision Team, 2019), 60% of interviewed people from communities near the swamps said to harvest reeds and grasses.

Local communities engage in tree cutting and felling for firewood and for the production of charcoal in the wooded upland that surrounds the swamp, as is commonly practiced throughout Zambia (Chidumayo, 1986).

Charcoal is predominantly produced with the earth kiln technology, whereby trees are clear-felled at knee height and cut into logs which are first left to dry and are then piled (into a clamp) and covered with earth, forming the kiln (Chidumayo, 1986; Chidumayo, 2019). The kiln is lit from a small opening which is then covered, and the wood is left burning until it carbonizes. Miombo species – *Brachystegia* spp., *Isoberlinia* spp. and *Julbernardia* spp., together with *Pterocarpus angolensis* and *Afzelia* spp.- are the preferred sources of wood for the production of charcoal. According to Chidumayo (1986), one hectare of miombo woodland (from which the majority of charcoal wood production originates) in the region of the Lukanga yields an estimated total of 200 to 250 m^3 of charcoal.

Sakachite *et al*. (2016) estimated an average of 0.73 ha of forest were cleared per household in 2015 nationally, decreasing to 0.52 ha in the Central Province. The province with the highest proportion of households engaged in forest clearing was Central, at 23.6%, while 18.2% engage in selective cutting, and the remaining 58.2% do not engage in tree cutting at all.

In the Central Province, 48.6% of forest land is used for fuelwood collection, while 3.1% is used for charcoal (Sakachite *et al*., 2016).

According to the assessments conducted for ILUA Project's second phase (Shakachite *et al*., 2016), 54.4% of households in the Central Province collect fuelwood from primary forest, 44.3% from secondary forest, 1% from cultivated land and 0.1 from villages and built-up areas. For charcoal production, 76.6% of households go to primary forests, 16.7% to secondary forest and 6.7% to cultivated land (Shakachite *et al*., 2016).

Throughout Zambia and for some time, tree harvesting for fuelwood and charcoal production, coupled with shorter fallow periods driven by growing population, have been degrading forest habitats (Chidumayo, 1987c).

Wood collection for charcoal production significantly decreases species richness (i.e., biodiversity) of miombo woodlands, and lost carbon storage levels are only recovered after 20 years (Kalaba, Quinn and Dougill, 2013). Species composition remains different from the original one, which can negatively impact the provision of forest goods (such as

mushrooms, the development of which is tree-specific), and other regulating or supporting services maintained by the original composition (Kalaba, Quinn and Dougill, 2013).

The collection of non-wood forest products as wild food and traditional medicine – fruits, roots, tuber, bulbs, other herbaceous plants, and mushrooms - is a significant activity for rural communities, and is practiced not only in forest land (i.e., miombo, munga, chipyia and Baikiae) but also in other wooded land classes (i.e., termitaria) (Sakachite *et al*., 2016) (Figure 74).



Source: Nemus (2019).

Figure 74 – Roots sold for medicinal uses on a roadside market

In the Central Province, 63.8% of forest area is used for the collection of fruits, nuts and berries, 9.5% for mushrooms, and 6.5% for medicinal plants (Sakachite *et al*., 2016).

The **consumption of mushrooms** is an important nutritional complement of local communities' diet in the rainy season throughout Zambia (Bourdeaux *et al*., 2003). Edible fungi include ectomycorrhizal (ECM), sarophytic and termite-grown species. The former are the dominant forms and are developed in a root symbiotic association mainly with Miombo dominants (*Brachystegia*, *Julbernardia* and *Isoberlinia* species).

Bourdeaux *et al.* (2003) conducted an inventory in the Copperbelt Province, predominantly occupied by Miombo woodlands, and found 32 edible ECM fungi species, developing sequentially from October to April according to each species phenology.

Degreef *et al*. (2020) tried to quantify the natural production of these resources by the miombo ecosystem and obtained a mean annual productivity of edible mushrooms of 36.46 (±17.86) and 241.04 (±81.88) kg of fresh biomass (FB) ha^{-1} yr^{-1} according to the type of Miombo.

Regarding the **collection of indigenous wild fruits**, this is also an important complement to rural people's diets of Zambia in the rainy season, the "hunger" months (Kalaba, 2007). These are collected from indigenous fruits trees (IFT) which also provide local communities with other plant parts for medicinal uses, such as the roots, leaves and bark.

Common IFT collected by rural populations in the Copperbelt Province (in the area of Mwekera) and listed for the habitats of the swamp and surrounding area are presented in Table 48.

Table 48 – Indigenous fruit trees and their uses

Species	Common name	Uses	Occurrence
Adansonia digitata L.	Baobab; Muuyu	FF	Ps in forest land
***Anisophyllea boehmii* Engl.**	Mufungu	FF; IRB; DRB	Ps in forest land
Diospyros mespiliformis Hochst. Ex A. DC.	-	FF	Prb in termitaria and grassland
Landolphia kirki Dyer	Kirk's Landolphia	FP	Ps in forest land and termitaria
***Parinari curatelifolia* Planch. Ex Benth.**	Mupundu	FF; SO	Prb in forest land
Strychnos cocculoides Baker	Kasongole	FF; DR	Ps in forest land
Strychnos innocua L.	Mulumgi	FF; SO	Ps in forest land
Strychnos pungens Soler.	-	FP	Probable in forest land (chipya)
Syzygium guineense (Willd.) DC.	-	FF	Prb in forest land
Trichilia emetica Vahl.	-	FF; SO	Prb in forest land
***Uapaca kirkiana* Mull. Arg.**	Masuku	FF; ILB	Prb in forest land and termitaria

Source: Adapted from Kalaba, 2007.
Legend:
In bold: preferred species.
Uses: FF – fruit eaten fresh; FP – fruit eaten in a pulp; SO – oil extracted from seeds; IRB - infusion from roots and barks; DRB – decoction of roots and bark; ILB – infusion of leaves and bark; DR – decoction of roots.
Occurrence: Ps – possible; Prb- probable.

F) Hunting

Local communities are also known to hunt for wildlife as a source of food – e.g., mammals (antelopes, hares and mice) and birds - across the different macro-habitats, forest land, permanent swamp, termitaria and edaphic grassland (Kachali *et al*., 2008; Key informant interviews, 2019).

Little information is available regarding this practice. Sakachite *et al*. (2016) reported that 2% of forest area in the Central Province is used for this purpose.

According to the Global Environment Facility (2000, in Sentinel Vision Team, 2019), 4% of interviewed people from communities near the swamps said to hunt wildlife, although this is believed to be greatly underestimated.

G) Invasive species

One of the major pressures acting in natural environments globally, and in African wetlands in particular, is the invasion by exotic species.

The first record of the Kariba or Javana weed, *Salvinia molesta* (also known as Giant Salvinia), on the Lukanga Swamp dates to 2009 (Kafue River Trust, 2013). According to Focus Group Discussions (2019), the weed was inadvertently introduced into the Lukanga wetland on the nets of fishermen from the Kafue River.

Concerted efforts by Birdwatch Zambia to control the invasion started in 2013 through manual removal of the weed using rakes, pitchforks and sickles, with limited success (Phiri, Nanja and Kihumba, 2020).

A biocontrol-based project is currently underway also by Birdwatch Zambia, in partnership with the Ministry of Livestock and Fisheries, Zambia Agriculture Research Institute (ZARI), Zambia Environmental Management Agency (ZEMA) and the Centre for Agriculture and Bioscience International (CABI) (Phiri, Nanja and Kihumba, 2020).

This project consists of the introduction of the Javani beetle, or weevil, *Cyrtobagous salviniae*, a specialist grazer of this weed. From an initial total of 2,000 beetles, 1,900 individuals were introduced in October 2018 in 10 sites from the Waya, Kabosha and Chilwa entry points (Pers. Comm., 2020). The remaining 100 beetles were used for rearing, which allowed a second release. Weevils have now been introduced to 33 sites, 11 of which currently merged. Rearing has been up scaled and there are 13 mass rearing avenues with the objective of increasing weevil mass for its release in additional points of the swamp.

Extensive awareness raising and site monitoring activities are on-going for the assessment of the measure's impact. The monitoring of the extent of weevil spread shows an average distance of approximately 35 m covered monthly, and the most distance covered from the initial releasing site in October 2019 is of 2,400 m (BWZ,

2020b). Approximately 662 km^2, or 20% of the infested area, have already been occupied by weevils (BWZ, 2020b).

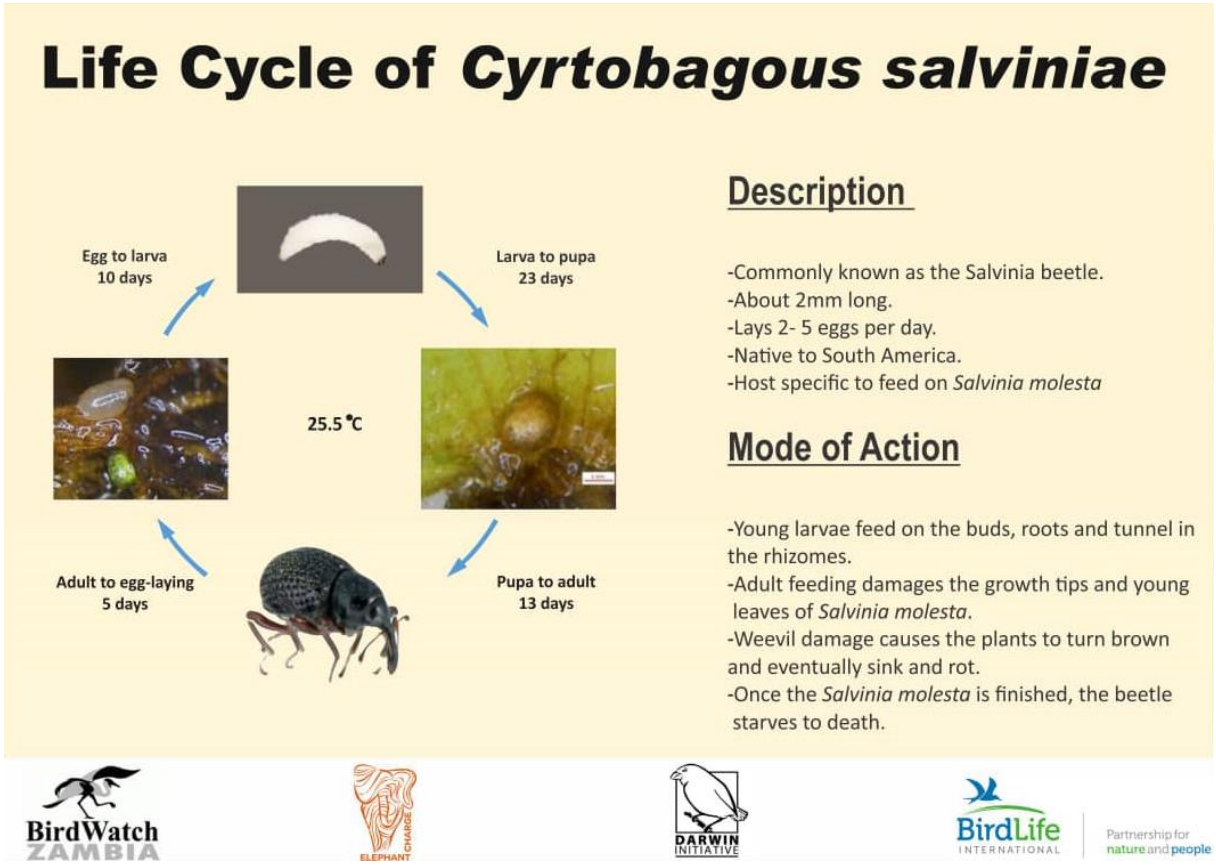
Awareness raising actions have reached a total of 3,104 individuals so far, 1,799 males (58%) and 1,305 females (42%) (BWZ, 2020b). These focus on the purpose of the project, the weevil mechanisms and the dos and don'ts in rearing them (BWZ, 2020b) (Figure 75).

Because this is a surface floating macrophyte, its capacity to disperse is increased in areas where emergent vegetation cover is lower. In addition, it is an aquatic annual fern that reproduces asexually though fragmentation of the rhizome (McFarland *et al*., 2004), and thrives in low flowing or standing waters. This is the case of the Lukanga during the weed's growing season, and, since it has no natural grazers in the area, it can multiply rapidly and form extensive and dense monotypic mats up to 1 m thick, which affect human movement and the whole swamp system and its organisms.

The rate of biomass doubling is around 8.1 days in the wild, midsummer in Lake Kariba (Mitchell & Tur, 1975). The weed's optimal temperature ranges between 15ºC and 30ºC, and its growth is mainly hindered by plant density, having an estimated maximum biomass of 500 g dry weight/ m^{-2} (Henry-Silva *et al*., 2008). The growth of *Salvinia molesta* is not hindered by either nutrient loading or limitation, hence its ability to invade oligotrophic environments (Henry-Silva *et al*., 2008).

Since it is not attached to the substrate, it occurs either in mats or just drifting in open water, being particularly difficult to map. Mapping of the weed's distribution through remote sensing was done in 2017 for the BirdWatch Zambia project currently attempting to control the invasion, and, according to this project, the coverage of the swamp's surface area has increased from 1.82% in 2010 to 7.23% in 2017 (BWZ & MEDEEM Zambia (2018).





Source: BWZ (2020a).

Figure 75 – Awareness raising material

Surface-floating overgrowth by invasive weeds has the following impacts on swamp environments (BWZ, 2020b; Key informant interviews, 2019; Mitchell, 1985a; Mitchell 1985b):

- Increased shade – the reduction of light penetration impedes primary production, negatively affecting the condition of submerged macrophytes, epiphytes and phytoplankton;
- Reduced flow – thick *S. molesta* mats interfere with water flow, slowing it down and potentially leading to stagnation;
- Increased vegetative surface area provides habitat for invertebrates; however, coupled with water stagnation, this provides ideal breeding ground for vectors of human diseases such as Malaria (i.e., *Anopheles* spp. mosquitoes), and Schistosomatosis (i.e., *Bulinus* spp. and *Biomphalaria* spp. gastropods);
- Decreased dissolved oxygen content, increased carbon dioxide, and reduced pH – as decaying vegetative matter accumulates and both photosynthesis and water flow are impaired as a result of weed over-growth, anaerobic and acidic conditions develop, representing a degradation of water quality and a reduction of the system's potential as fish, invertebrate and macrophyte habitat;
- Clogging of water channels and pools – the development of *S. molesta* mats decreases mobility inside the swamp, interfering with water-based transport and the activities that rely on it, such as fishing, reed harvesting, recreation and scientific research (Figure 76);
- Increased water loss through evapotranspiration – the rate of water loss from emergent plant tissues can be higher than the loss through evaporation in open water conditions;
- Reduced or altered biodiversity – the weed-catalysed modification of the swamp's habitats may alter its ability to support original biodiversity levels; in extreme cases, it can lead to shifts in community composition and structure across the different groups (macrophyte, phytoplankton, invertebrates, fish, birds, etc.); fish breeding may be inhibited, waterbirds may be affected by the reduction of prey availability, and benthic fauna has also been shown to decrease (in CABI, 2013);
- Reduced aesthetic value – reduces the potential for recreation and the associated economic activities.



Source: Nemus (2019).

Figure 76 – *S. molesta* infestation in a channel off Kabosha (left) and Chilwa (right) in late 2019, showcasing the impacts on light penetration and navigation

In sum, this is a plant species that, although not posing significant threats in low/controlled levels, rapidly spirals out of control becoming a nuisance for biodiversity and human communities, with serious socio-economic consequences. The effects are most significant (with longer-lasting effects) when mats are well-established.

Factors contributing to the growth of *S. molesta* include continued nutrient input (from cultivation and livestock herding), sheltering from strong winds, wave and currents, absence of established and diverse macrophyte communities, and absence of animal grazers (Mitchell, 1985b).

The risk of new introductions is also present, as fishermen migration remains high and preventing measures are not implemented.

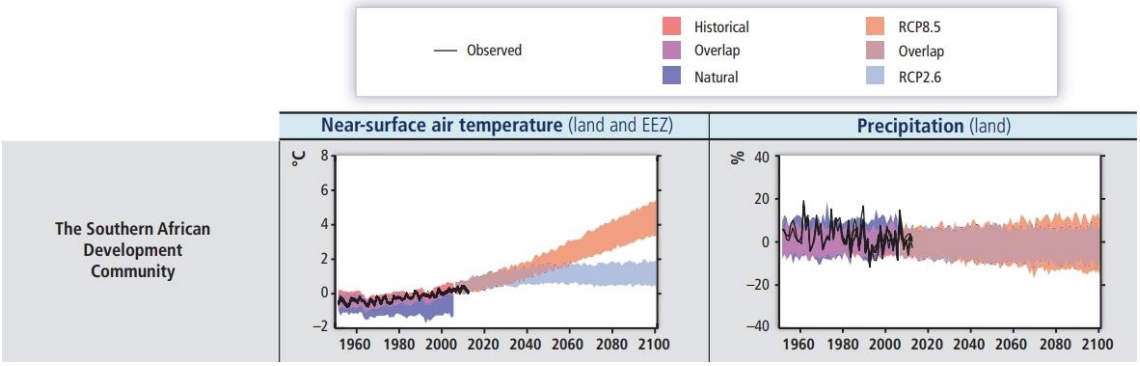
5.2.2.2. Climate change

A) Projected climate trends for Southern Africa

Mean land surface warming in Southern Africa is likely to exceed the global mean land surface temperature increase in all seasons (e.g., James and Washington, 2013). Furthermore, towards the end of the 21st century the projected warming of between 3.4ºC and 4.2ºC above the 1981–2000 average under the A2 scenario[6] far exceeds natural climate variability (Moise and Hudson, 2008). High warming rates are projected over the semi-arid southwestern parts of the sub-region covering northwestern South Africa, Botswana, and Namibia (e.g., Watterson, 2009). Observed and simulated variations in past and projected future annual average temperature over SADC is captured in Figure 1, which indicates the projected temperature rise is very likely to exceed the 1986–2005 baseline by between 3°C and 6°C across these regions by the end of the 21st century under RCP8.5[7].

According to Niang *et al.* (2014) over southern Africa CMIP3 GCM projections show a drying signal in the annual mean over the climatologically dry southwest, extending north-eastward from the desert areas in Namibia and Botswana (e.g. James and Washington, 2013). This pattern is replicated by CMIP5 GCMs. During the austral summer months, dry conditions are projected in the southwest while downscaled projections indicate wetter conditions in the southeast of South Africa and the Drakensberg mountain range (e.g., Engelbrecht *et al*., 2009). Consistent with the AR4, drier winters are projected over a large area in southern Africa by the end of the century as a result of the poleward displacement of mid-latitude storm tracks (e.g., Engelbrecht *et al*., 2009; James and Washington, 2013). Rainfall decreases are also projected during austral spring months, implying a delay in the onset of seasonal rains over a large part of the summer rainfall region of southern Africa (e.g., Seth *et al*., 2011).

[6] The A2 scenario describes a very heterogeneous world. The underlying theme is self-reliance and preservation of local identities. Fertility patterns across regions converge very slowly, which results in continuously increasing global population. Economic development is primarily regionally oriented and per capita economic growth and technological change are more fragmented and slower than in other storylines.
[7] This high-emissions scenario is frequently referred to as “business as usual”.



Notes: **Black lines** show various estimates from observational measurements. **Shading** denotes the 5th to 95th percentile range of climate model simulations driven with "historical" changes in anthropogenic and natural drivers (63 simulations), historical changes in "natural" drivers only (34), the RCP2.6 emissions scenario[8] (63), and RCP8.5 (63)
Source: Niang *et al*. (2014).

Figure 77 – Observed and simulated variations in past and projected future annual average temperature over Southern African Development Community (SADC)

B) Impacts for Southern Africa

Ecosystems

It is recognized that interactions between different drivers of ecosystem structure, composition, and function are complex, which makes the prediction of the impacts of climate change more difficult. In AR4, the chapter on Africa indicated that extensive pressure is exerted on different ecosystems by human activities (deforestation, forest degradation, biomass utilization for energy) as well as processes inducing changes such as fires or desertification. Even if the trend is toward better preservation of ecosystems and a decrease in degradation (such as deforestation), pressures linked, for example, to agriculture and food security, energy demand, and urbanization are increasing, putting these ecosystems at risk.

There is high agreement that continuing changes in precipitation, temperature, and carbon dioxide (CO_2) associated with climate change are very likely to drive important future changes in terrestrial ecosystems throughout Africa. However, substantial

[8] The RCP2.6 emission and concentration pathway is representative of the literature on mitigation scenarios aiming to limit the increase of global mean temperature to 2°C.

uncertainties are inherent in projections because vegetation across much of the continent is not deterministically driven by climate alone.

Freshwater ecosystems in Africa are at risk from anthropogenic land use change, over-extraction of water and diversions from rivers and lakes, and increased pollution and sedimentation loading in water bodies (Darwall *et al*., 2011).

Climate change is also beginning to affect freshwater ecosystems as evident by elevated water temperatures reported in surface waters of Lakes Kariba, Kivu, Tanganyika, Victoria, and Malawi (e.g. Ndebele-Murisa *et al*., 2012).

Water Resources

Several studies from Africa point to a future decrease in water abundance due to a range of drivers and stresses, including climate change in southern and northern Africa (medium confidence). For example, all countries within the Zambezi River Basin could contend with increasing water shortages (A2 scenario) although non-climate drivers (e.g., population and economic growth, expansion of irrigated agriculture, and water transfers) are expected to have a strong influence on future water availability in this basin (Beck and Bernauer, 2011).

The overall impact of climate change on groundwater resources in Africa is expected to be relatively small in comparison with impacts from nonclimatic drivers such as population growth, urbanization, increased reliance on irrigation to meet food demand, and land use change (e.g. Taylor *et al*., 2009).

Groundwater recharge may also not be significantly affected by climate change in areas that receive more than 500 mm per year, where sufficient recharge would remain even if rainfall diminished, assuming current groundwater extraction rates (Barthel *et al.*, 2009). The Upper Kafue River has more than 800 mm/year (USAID, 2016).

C) Projected climate trends and impacts for Zambia

The analysis of climate change and impacts specifically for Zambia was retrieved from USAID (2016).

Projected changes on climate obtained by using the Coupled Model Intercomparison Project, Phase 5 (CMIP5) models can be summarised as follows:

- Mean annual temperatures increasing 1.2–3.4˚C by 2060, with warming occurring more rapidly in the south and west.
- Substantial increase in frequency of hot days and nights; decrease in cold days and nights.
- Decrease in Sept–Oct rainfall; increase in Dec–Feb rainfall, particularly in the northeast.
- Proportion of rain falling in heavy events expected to increase annually.

The impacts in Zambia for different sectors are listed in Table 49. It is worth mentioning that these impacts are not applicable to all Zambian territory. For instance, decrease productivity seems to be the net results for the country but there are certain crop types and certain areas that will experience an increase in the productivity.

Table 49 – Risks and potential impacts for different sectors in Zambia

Sectors	Risks and potential impacts
Agriculture production	Less predictable growing seasons Increased pests, weeds and pathogens affecting crops and livestock Increased soil erosion Limited field operations due to waterlogging Decreased productivity and crop failure Reduced water and feed resources for livestock Increased incidence of mortality and heat stress in livestock
Water resources	Reduced recharge rates and lowered water tables, leading to drying of boreholes Flooding, causing siltation and sedimentation of rivers Contaminated water sources and reduced access to clean drinking water
Human health	Reduced water quality, exacerbating health and sanitation problems Spread of waterborne diseases such as cholera (urban areas), diarrhea (urban and southern provinces), and dysentery (southern provinces) Changing distribution of vector-borne diseases (e.g. malaria) Decreased crop and livestock productivity, leading to increased malnutrition and undernutrition
Ecosystems	Reduced fodder and water availability, leading to loss of wildlife or wildlife migration, causing increased potential for human/wildlife conflict Higher incidence of forest fires Reduced capacity for growth and regeneration of forests Changes to wildlife and vegetation diversity and composition Lower nutrient levels in rivers, reducing fish stocks and impacting aquatic ecosystems Increased number and diversity of pests and pathogens
Energy and infrastructure	Reduced hydropower generation capacity Increased vulnerability of energy and physical infrastructure to extreme rainfall events (i.e., damage to bridges, railways and roads) Available forest biomass for energy generation at risk of reduction from increased incidence of wildfires and drought

5.3. Indicators and Environmental Cost-Benefit Analysis (ECBA)

Economic valuation of ecosystem services is one of the means by which decision-makers can assess the impact of different local management strategies in terms of profitability or economic efficiency, justify conservation planning or action, and assess the social and economic impact of upstream development projects (Springate-Baginski *et al*., 2009). Indeed, through the identification and monetary valuation of wetland values under different scenarios, these can be adequately factored into decision-making.

So, once the wetland's values are determined, an environmental cost-benefit analysis (ECBA) is one of the most commonly used decision tools for the social evaluation of investment projects or policies that involve significant environmental impacts. An *ex ante* cost-benefit analysis is usually conducted before any project, plan or policy is implemented to find the optimal alternative.

The ECBA is a multi-stage effort conducted through the steps below (Kuosmanen & Kortelainen, 2007; Mavsar *et al*., 2014), which are described in the sections that follow:

- Problem definition (what are the objectives, what are the alternatives / management solutions and over what time period);
- Identification of relevant impacts;
- Physical quantification of relevant impacts;
- Monetary valuation of relevant impacts;
- Discounting costs and benefit flows;
- Sensitivity analysis.

Co$ting Nature (version 3), a tool/model developed by King's College London and AmbioTEK CIC, is a sophisticated, data-based phenomenological model for ecosystem services, that has functionality for economic valuation of ecosystem services developed in collaboration with the International Institute for Environment and Development (IIED; Mulligan, 2018). This multi-service model was thus selected to support the ECBA and decision-making under the Conservation Plan for Lukanga Swamp and Upper Kafue Basin and is further described in chapter 6 (section 6.6 – Conclusion and decision-making framework).

5.3.1. Problem definition

The ECBA aimed at comparing different future scenarios for the ecosystems in and around the Lukanga Swamp. The recognition of the economic value of nature and the services it provides to humanity has become increasingly essential in the context of wetlands management. Therefore, the ECBA intended to provide data (including economic valuation of benefits and costs) to bolster decision support systems. Following studies such as Swetnam *et al.* (2010) and Luisetti *et al.* (2011), the objective of this ECBA was to transform into monetary values potential future scenarios for the evolution of the Lukanga Swamp's ecosystem services, in order to anticipate possible major changes, to incorporate climate change projections, historical trends and socioeconomic tendencies to guide decision-making.

Therefore, the objective was not to compare two or three future scenarios based on different project options, as usual in project appraisal cost benefit analysis. The objective was thus more comprehensive, to incorporate different variables (projections; historical trends; socioeconomic tendencies; non-linearities; threshold effects; uncertainties) and investments (particular conservation actions; management plan's options) in a modelling tool, i.e., a decision-making framework.

Taking into account the above, a first Baseline scenario was constructed, considering current resource exploitation/land uses. It consists of a scenario in which there is no significant change in the variables identified as key, whether it be population growth, deforestation, among others. Therefore, the baseline scenario is not the most likely scenario to occur.

In addition to the Baseline Scenario, a decision-making framework was constructed, based on the ECBA methodology and considering different outcomes for the different considered variables (projections; historical trends; socioeconomic tendencies; non-linearities; threshold effects; uncertainties; particular conservation actions; management plan's options). These different outcomes for each variable affect differently and cumulatively each ecosystem service (and benefit) and therefore will produce different scenarios.

The decision-making framework aims to help support decisions in line with the policy question(s) that the model is to answer, such as the ones typified below:

- How will a given ecosystem service behave, with the implementation of a particular conservation action?

- Of the generated benefits and impacts, which stakeholders will benefit, and which stakeholders will be impaired?
- What is the best action to minimise impacts on a given ecosystem service while ensuring an equitable sharing of the benefits amongst stakeholders?
- Which actions are most cost effective to benefit a given ecosystem service?

In order to be comparable, each scenario considers costs (for different interventions and management options) and respective benefits of the area comprising the Lukanga's swamp catchment's ecosystems (see section 3.7.1). Regarding the time period, the ECBA considers a reference period of **30 years** (2020-2050), as is recommended internationally for projects with long-term benefits (EC, 2014).

5.3.2. Identification of relevant impacts

At this stage, the impact of the scenarios under evaluation on the wetland's values must be identified.

Positive impacts signify an increase of the quality or quantity of goods and services derived from ecosystems, or a decrease in their price. These include marketable goods as well as externalities, such as increased cropland area, increased carbon sequestration, increased biodiversity, increased air quality, introduction of recreation access, among others.

Negative impacts signify a decrease in quality or quantity of goods and services, or a decrease in their price.

Furthermore, each particular conservation action and management plan's option will be valued in order to assess the cost-benefit ratio between different options.

The relevant impacts are listed in the section below.

5.3.3. Physical quantification of relevant impacts

This stage involves determining the physical amounts of cost and benefit flows for each scenario and identifying when in time they will occur. For example, if considering the benefits and costs of improved forest management, which would result in increased wood production. Table 50 presents a comprehensive list of indicators used per ecosystem service in order to complete the environmental cost-benefit analysis.

Table 50 – Comprehensive ecosystem services identified in Lukanga Swamp and its catchment and indicators of physical quantification

Ecosystem services identified in Lukanga Swamp and its catchment (CICES v5.1 classification)	Indicators
1.1.1.1 Cultivated terrestrial plants grown for nutritional purpose	• Yields of food crops (planted area; harvested area; expected production; prices)
1.1.3.1 Animals reared for nutritional purposes	• Livestock data (livestock units /area)
1.1.5.1 Wild plants for nutrition	• Mean income from non-wood forest products per collector (data from focus groups)
1.1.6.1 Wild animals for nutrition	• Average annual fish catch (ton /year)
1.1.5.2 Wild plant fibres and other materials for direct use or processing	• Above ground carbon stock map accessible to the population (timber)
1.1.5.3 Wild plants used as a source of energy	• Above ground carbon stock map accessible to the population (fuelwood)
2.2.1.1 Control of erosion rates	• Forest cover (ha)
2.2.2.1 Pollination	• Non-cropland area (ha) • Cropland area (ha)
2.2.1.3 Hydrological cycle and water flow regulation	• Available water (m^3)
2.2.3.1 Pest control	• Non-cropland area (ha) • Cropland area (ha)
2.2.4.1 Decomposition and fixing processes and their effect on soil quality	• Area occupied by forests (ha) and grassland (ha)
2.2.2.3 Maintaining nursery populations and habitats	• Average annual fish catch (ton /year)
2.2.5.1 Regulation of the chemical condition of freshwater by living organisms	• Surface of wetlands (ha) • Water supply (m^3)

Ecosystem services identified in Lukanga Swamp and its catchment (CICES v5.1 classification)	Indicators
2.2.6.1 Regulation of the chemical composition of the atmosphere	• Dry matter productivity (ton biomass /ha /year) • Above ground carbon stock
3.1.2.1 Characteristics of living systems that enable scientific investigation or the creation of traditional ecological knowledge	• Citations of scientific papers with the topics of "Lukanga" and "Kafue"
4.2.1.1 Surface water for drinking	• Total supply of water (m^3) • Population and per capita water consumption
4.2.2.1 Ground (or subsurface) water for drinking	• Population and per capita water consumption
5.2.1.1 Mass flows	• Area occupied by forests (ha)
5.2.1.2 Liquid flows	• Surface of wetlands (ha) and other water bodies (ha)

The calculations for determining the physical quantity of each of these ecosystem services are detailed below.

5.3.3.1. Cultivated terrestrial plants grown for nutritional purpose

The value of total agricultural output (for each scenario) was estimated using the Crop Forecast Survey for 2017 and 2018 data (CSO, 2020). Crop data (area planted; area harvested and expected production) for Central and Copperbelt provinces was compiled. Total production for the area under study (Lukanga Swamp and Lukanga Swamp Sub-Catchment) was assumed proportional in regard to the cropland area (data from FORESTRY DEPARTMENT, 2016).

5.3.3.2. Animals reared for nutritional purposes

Livestock data (for each scenario) was estimated using the 2017/18 Livestock and Aquaculture Census Report (Ministry of Fisheries and Livestock, 2019). Livestock data (cattle, goats, sheep, and pigs) for Central and Copperbelt provinces was compiled. Total livestock for the area under study (Lukanga Swamp and Lukanga Swamp Sub-Catchment) was assumed proportional in regard to the grassland area (data from FORESTRY DEPARTMENT, 2016).

5.3.3.3. Wild plants for nutrition

For the physical quantification of this ecosystem service, the Co$ting Nature tool (version 3), provided by King's College London and AmbioTEK CIC (Mulligan, 2018) was used. In the Co$ting Nature tool (version 3), this ecosystem service (wild plants for nutrition) corresponds to “non-wood forest products” service.

Non-wood forest products are a wide range of forest fruits, nuts, fungi, animals, and plants sourced from forests (excludes timber and fuelwood). The potential service is calculated as the fractional tree cover (di Miceli et al., 2011) for rural areas (Schneider et al., 2009) only (urban trees are considered not to be usable for NWFPs) on the basis that all forests can potentially provide NWFPs. The realised service is the product of the potential service and the normalised population considered poor (Elvidge et al., 2006) on the basis that NWFPs increase in use and importance with poverty.

5.3.3.4. Wild animals for nutrition and maintaining nursery populations and habitats

The wild animal for nutrition physical quantification (for each scenario) was estimated using the inshore fish catch data for Lukanga (see Figure 69). The fish catch data for Lukanga (2000-2014) was next used to create a growth forecast for 2050 based on a logarithmic function. The service maintaining nursery populations and habitats is also physical quantified by this method.

5.3.3.5. Wild plant fibres and other materials for direct use or processing

For the physical quantification of this ecosystem service, the Co$ting Nature tool (version 3), provided by King's College London and AmbioTEK CIC (Mulligan, 2018) was used. In the Co$ting Nature tool (version 3), this ecosystem service (wild plant fibres and other materials for direct use or processing) corresponds to “timber” services.

Timber is separated into commercial timber and domestic timber. The spatial distribution of hardwood and softwood is calculated according to the work of Box and Fujiwara (2005) in which mean annual temperature and a cold index are calculated from mean monthly temperature (Hijmans et al., 2005). The cold index is the sum of temperature for months where temperatures are less than 5 degrees. Hardwood distributions are calculated as those with a mean annual temperature >20C and a cold index >-10C. Softwood areas are calculated as all other areas.

For commercial timber, the potential mass of timber (the potential service) is estimated from the above ground carbon stock map (Ruesch et al., 2008; Saatchi et al., 2011). The proportion of carbon coming from trees in a pixel is calculated as the product of carbon stock and fractional tree cover (di Miceli et al., 2011) for rural areas (Schneider et al., 2009) only (urban trees are considered not to be usable for timber). The sustainable harvest is considered to be the reciprocal of the number of years taken to develop the stock at the annual sequestration rate, according to the dry matter productivity data of Mulligan (2009) based on a 10 year climatology of SPOT VGT data. The realised service (the timber accessible) is calculated as potential timber within 6 hours travel time of a population centre of >50K people (Uchida and Nelson, 2009) and on slope gradients <31.5 degrees (70%) (Lehner et al., 2008) considered to be workable for logging (Greulich et al., 1999).

For domestic timber, the realised domestic timber service is thus the domestic timber demand (assuming one tonne dry weight person per year) (where demand<supply) and the supply (if demand >supply), with unmet demand then supplied via markets.

5.3.3.6. Wild plants used as a source of energy

For the physical quantification of this ecosystem service, the Co$ting Nature tool (version 3), provided by King's College London and AmbioTEK CIC (Mulligan, 2018) was used. In the Co$ting Nature tool (version 3), this ecosystem service (wild plant used as a source of energy) corresponds to “fuelwood” service.

As with timber the potential mass of timber (the potential service) is estimated from the above ground carbon stock map (Ruesch et al., 2008; Saatchi et al., 2011). The proportion of carbon coming from trees in a pixel is calculated as the product of carbon stock and fractional tree cover (di Miceli et al., 2011) for rural areas (Schneider et al., 2009) only (urban trees are considered not to be usable for timber). The sustainable harvest is considered to be the reciprocal of the number of years taken to develop the stock at the annual sequestration rate, according to the dry matter productivity data of Mulligan (2009) based on a 10 year climatology of SPOT VGT data.

Fuelwood demand is considered to scale with rural population (Landscan, 2007) and per-capita use of 3.65 tonnes/person/year (OECD, 2006) but also with slope gradient using a linear decrease in fuelwood demand (from baseline demand to zero) as slope increases from 0 to 90 degrees. The realised fuelwood service (tonnes) is thus equal to the fuelwood demand (where supply >= demand) or is constrained to the supply where (supply < demand). Fuelwood can overlap spatially with domestic and commercial timber use, given domestic and commercial timber only consumes the main trunks, whereas fuelwood will consume branches and wastage.

5.3.3.7. Control of erosion rates, hydrological cycle and water flow regulation, mass and liquid flows

For the physical quantification of these ecosystem services, the Co$ting Nature tool (version 3; Mulligan, 2018) was used. In the Co$ting Nature tool (version 3), these ecosystem services correspond to the “hazard mitigation” service. In the tool, the hazard mitigation services consider flood storage/mitigation, flow regulation, in addition to landslide/erosion control.

The landslide/erosion control service is assumed to scale with the proportion of upstream land that is tree-covered (di Miceli et al., 2011) or protected (WDPA, 2016). The potential cyclone hazard is calculated as the relative cyclone hazard frequency of Dilley et al.

(2005). Potential flood hazard is calculated as proportional to the available water in each pixel (downstream cumulated rainfall minus actual evapotranspiration).

Socio-economic exposure to hazards is considered to scale with the relative human population (Landscan, 2007); relative infrastructure including dams (Mulligan et. al., 2011), mines (Mulligan, 2010a), oil and gas (Mulligan, 2010b), urban (Schneider et al., 2009), roads (UN FAO GIEWS, 2010); relative agriculture (Fritz et al, 2015 and Ramankutty et al., 2008) and relative GDP (Ghosh et al., 2010) indices.

5.3.3.8. Pollination and pest control

For the physical quantification of these ecosystem services, the Co$ting Nature tool (version 3; Mulligan, 2018) was used. In the Co$ting Nature tool (version 3), the ecosystem service pollination corresponds to "wildlife services". In the tool, the wildlife services also consider pest control by wildlife.

Potential wildlife services are calculated (for non-urban areas only) as the product of the fraction of non-cropland and its relative productivity (Mulligan, 2009) on the basis that natural lands of higher productivity will produce more birds, small mammals and other pollinators and insectivores that could provide wildlife services to cropland. Note that wildlife services to croplands can also be produced by pasture lands in this metric. For this service to be realised, there needs to be non-cropland to produce it and cropland nearby to make use of it. Thus, the realised service is zero for pixels in which there is no non-cropland to provide the service and scales from the potential service value to zero as the distance to the nearest cropland increases.

5.3.3.9. Decomposition and fixing processes and their effect on soil quality

The decomposition and fixing processes and their effect on soil quality service provided in the area under study was valued according to a prior study by Costanza et al. (1997) and using the same methodology as Lal et al. (2017). Therefore, a unit value per area of forest and grassland (ha) was used to estimate the value of this ecosystem service (using land cover data from FORESTRY DEPARTMENT, 2016). The total value per scenario changes according to the land cover changes expected.

5.3.3.10. Regulation of the chemical condition of freshwater by living organisms

For the physical quantification of this ecosystem service, it was used the average annual water supply provided by the Lukanga swamp. Total avoided cost was then divided by the wetland surface area (ha) to calculate the per area indicator.

5.3.3.11. Regulation of the chemical composition of the atmosphere

For the physical quantification of this ecosystem service, the Co$ting Nature tool (version 3; Mulligan, 2018) was used. In the Co$ting Nature tool (version 3), this ecosystem service (regulation of the chemical composition of the atmosphere) corresponds to “carbon” service.

The total carbon service is thus the combination of carbon stocks and carbon sequestration and the balance between the two clearly depends on the time period over which sequestration is calculated. Carbon sequestration is calculated here from the dry matter productivity (DMP) analysis of Mulligan (2009). DMP (t biomass/ha/yr) is multiplied by 0.42 to convert to units of tC/ha/yr. Above-ground carbon stock is calculated from Saatchi et al (2011) for the areas in which data are available and Ruesch and Gibbs (2004) elsewhere. This is combined with soil carbon calculated from the map of Scharlemann et al. (2009) to produce total above- and below-ground carbon stocks. The realised carbon service is thus the mean of normalised carbon sequestration, normalised above-ground carbon stocks and normalised below-ground carbon stocks.

5.3.3.12. Characteristics of living systems that enable scientific investigation or the creation of traditional ecological knowledge

The physical quantification of this service is considered proportional to the number of citations of scientific papers with the topics of "Lukanga" and "Kafue" in Zambia. This data was retrieved from the Web of Science database for the period 2000-2019. Afterwards, the citations data (2000-2019) was used to create a growth forecast for 2050 based on a polynomial function.

5.3.3.13. Water for drinking (surface and ground)

For the physical quantification of these ecosystem services, the Co$ting Nature tool (version 3; Mulligan, 2018) was used. In the Co$ting Nature tool (version 3), these ecosystem services (surface water for drinking; ground water for drinking) corresponds to “water” services.

The water provisioning services is an index of the volume of clean (not human impacted) water available to downstream beneficiaries. Water quantity is calculated as the water balance (rainfall minus actual evapotranspiration) cumulated downstream. Potential water provisioning services for each cell are first calculated as the volume of clean water available from upstream. The realised water services depend on the intensity of downstream use measured as the normalised area of irrigation, number of people and number of dams.

5.3.4. Monetary valuation of relevant impacts

In this step, each benefit and cost must be assigned a monetary value. Here, the methodology for valuing each benefit/cost is detailed, so that indicators can be appropriately selected and measured.

Several authors have been developing methodologies that try to estimate the economic value of ecosystem services that are not traded in markets. These estimates try to make clear, in economic terms, that not only economic goods and services are relevant to human well-being. Accordingly, different economic valuation methods exist for the different types of use considered in the TEV approach, namely (De Groot *et al*., 2006; Springate-Baginski *et al*., 2009):

- **Revealed preference** – methods based on observing people's actual behaviour, such as:
  - Market pricing valuation (for the direct and indirect use values) – assigns value equal to the total market revenue of goods/services;
  - Replacement cost valuation assigns a value to the cost of replacing the function with an alternative technology – e.g., for the benefits of water regulation and carbon sequestration;
  - Avoided cost valuation assigns a value to the cost of repairing damages resulting from the absence of a given service – e.g., the regulation of mass flows (sediments or water) by the swamp avoids downstream flooding or siltation and the associated damage to infrastructure or agriculture;
  - Mitigation cost methods assign a value to a service according to the expenditures of having to mitigate or restore a wetland upon the loss or deterioration of the said service – e.g., the loss of the mass flow regulatory function of the swamp may impose the need to desilt downstream reservoirs; or, the loss of water purification functions impose the construction of water purification facilities to ensure its safety to downstream users;
  - Income factor methods, or production function methods, assign a value to a service according to its contribution to the income generated through the production of other services – e.g., valuation of the effect of water purification through its effect on fish production;

- **Stated preference** – survey-based methods based on obtaining people's responses to hypothetical scenarios, such as:
  - Contingent valuation methods, used for non-use values, to infer the value placed on services by communities, for instance, through their willingness to pay (WTP) for services, or their willingness to accept compensation (WTA) for their loss;
  - Participatory, or group, valuation – contingent valuation of a service through group deliberation and consensus building; this is particularly relevant for subsistence economies, where cash exchange is not so relevant;
- **Benefit transfer** – this method uses available information from studies already completed in another location and/or context, when there are significant resource constraints for the implementation of other methods.

The valuation method for each ecosystem service is presented in Table 51. A detailed description is also provided in the following pages.

Table 51 – Selected valuation techniques for Lukanga Swamp's benefits

Ecosystem service	Value type	Valuation method
Cultivated terrestrial plants grown for nutritional purpose	Direct use	Market prices
Animals reared for nutritional purposes	Direct use	Market prices (participatory valuation)
Wild plants for nutrition (non-wood forest products)	Direct use	Market prices (participatory valuation)
Wild animals for nutrition/ maintaining nursery populations and habitats	Direct use	Market prices (participatory valuation)
Wild plant fibres and other materials for direct use or processing (timber)	Direct use	Market prices (participatory valuation)
Wild plants used as a source of energy (fuelwood)	Direct use	Market prices (participatory valuation)
Control of erosion rates, hydrological cycle and water flow regulation, mass, and liquid flows (hazard mitigation)	Indirect use	Replacement cost
Pollination and pest control	Indirect use	Avoided cost (participatory valuation)

Ecosystem service	Value type	Valuation method
Decomposition and fixing processes and their effect on soil quality	Indirect use	Benefit transfer
Regulation of the chemical condition of freshwater by living organisms	Indirect use	Avoided cost
Regulation of the chemical composition of the atmosphere (carbon)	Indirect use	Market prices
Characteristics of living systems that enable scientific investigation or the creation of traditional ecological knowledge	Indirect use	Benefit transfer
Surface and ground water for drinking (water services)	Direct use	Market prices

After benefits and costs are identified and expressed in monetary terms, the final steps of the ECBA can be undertaken, namely: discounting costs and benefit flows; the sensitivity analysis.

5.3.4.1. Cultivated terrestrial plants grown for nutritional purpose

Market prices for each crop used were sourced from the following: for the majority of crops, producer prices (USD) from FAO (2020); tobacco prices from Goma et al. (2019); and remaining crop prices from Selina Wamucii (2020).

5.3.4.2. Animals reared for nutritional purposes

Market prices for each animal were sourced from focus groups discussions (FGDs) held with local communities in 2020 (October).

5.3.4.3. Wild plants for nutrition

Mean income from non-wood forest products per household were sourced from focus groups discussions (FGDs) held with local communities in 2020 (October). Using the Co$ting Nature tool (version 3), the realised economic value is calculated simply from the biophysical value as the product of the number of families with access to NWFPs (assuming one collector per family) and the mean income per collector per year.

5.3.4.4. Wild animals for nutrition and maintaining nursery populations and habitats

Average market prices for fish products in the Lukanga swamp area were sourced from focus groups discussions (FGDs) held with local communities in 2020 (October).

5.3.4.5. Wild plant fibres and other materials for direct use or processing

Average market prices for timber products (per tonne) were sourced from focus groups discussions (FGDs) held with local communities in 2020 (October). Using the Co$ting Nature tool (version 3), the realised economic value is calculated simply from the biophysical value as the product of the per pixel hardwood and softwood timber annual use (tonnes) and the per tonne timber price.

5.3.4.6. Wild plants used as a source of energy

Average market prices for fuelwood (per ton) were sourced from focus groups discussions (FGDs) held with local communities in 2020 (October). Using the Co$ting Nature tool (version 3), the realised economic value is calculated simply from the biophysical value as the product of the per pixel fuelwood annual use (tonnes) and the per tonne fuelwood price.

5.3.4.7. Control of erosion rates, hydrological cycle and water flow regulation, mass and liquid flows

This metric maps directly on to the economic value GDP protection or replacement cost per year per USD at risk. Using the Co$ting Nature tool (version 3), GDP per grid cell is calculated as a metric of income and the product of GDP and the potential or realised hazard mitigation services index is used as surrogates for the potential and realised income loss mitigated. The product of this income risk mitigated in a cell and the user-specified protection or replacement cost per USD income at risk provides the value of the potential or realised hazard mitigation service by pixel.

5.3.4.8. Pollination and pest control

Using the Co$ting Nature tool (version 3), the wildlife service maps the areas benefiting from pollination and pest control. The valuation is derived from the pesticide cost avoided by local farmers. Average pesticide cost avoided (per area) was sourced from focus groups discussions (FGDs) held with local communities in 2020 (October).

The realised economic value is calculated simply from the biophysical value as the product of the normalised extent of benefit in a pixel and the value per unit area per year when benefitting

5.3.4.9. Decomposition and fixing processes and their effect on soil quality

The decomposition and fixing processes and their effect on soil quality service provided in the area under study were valued according to a prior study by Costanza et al. (1997) and using the same methodology as Lal et al. (2017). Therefore, unit values per area of forest (18 USD /ha) and grassland (1.8 USD /ha) were used to estimate the value of this ecosystem service. These unit values correspond to the updated value for 2020 of those presented in Costanza et al. (1997) for the same ecosystem service.

5.3.4.10. Regulation of the chemical condition of freshwater by living organisms

According to Mierzwa *et al*. (2008), water treatment alone costs around 0.2 USD/m^3. Consequently, the regulation of the chemical condition of freshwater by living organisms in the wetlands was evaluated according to the cost of replacing these functions with an alternative technology (in this case, water treatment), considering the average annual water supply provided by the Lukanga swamp.

5.3.4.11. Regulation of the chemical composition of the atmosphere

Average market price for a carbon tonne (27.4 USD) was sourced from market data of the EU Emissions Trading System (for the first ten months of 2020). The economic value is calculated simply from the biophysical value as the product of the per pixel carbon sequestration (tonnes) and the per-tonne price.

5.3.4.12. Characteristics of living systems that enable scientific investigation or the creation of traditional ecological knowledge

The value of a scientific paper citation was sourced from Diamond (1986) and updated to the present taking into account the inflation of the last decades (unit value of 1,111 USD). The economic value is calculated simply from the bibliographic data (scientific paper citations per year) and the unit price.

5.3.4.13. Water for drinking (surface and ground)

Using the Co$ting Nature tool (version 3), the realised service is calculated as the product of the rural population weighted natural footprint on water quality and the per-capita willingness to pay for this service. The per-capita willingness to pay was estimated based on the Lukanga WSC approved tariff for 2020 (5.75 K/ m^3 for households until 6m^3), and the per capita average annual consumption of 28m^3 (based on average value for Lukanga WSC for 2010/11) (NWASCO, 2011, 2019).

5.3.5. Discounting costs and benefit flows

At this stage, costs and benefits will need to be converted into their present value (PV), a common metric which accounts for time preferences between consumption periods, allowing for the comparison between different scenarios.

ECBA performance indicators are also calculated at this point, depending on the project nature, such as the net present value (NPV). The NPV is an indicator of the better performing alternative out of the scenarios being assessed (i.e., the one with the greater NPV value).

The net present value (NPV) and present value (PV) of each benefit/ cost are calculated using the following formulas, where X is the present value of costs (C) or benefits (B) at time (t) at the discount rate (r):

a) $PV\ (X) = X_t\ (1 + r)^{-t}$;

b) $NPV = \sum B_t\ (1 + r)^{-t} - \sum C_t\ (1 + r)^{-t}$.

5.3.6. Sensitivity analysis

Finally, a sensitivity analysis is done to the results of the cost-benefit analysis, to analyse how the ECBA changes in response to variation of assumptions, inputs, etc., such as the discount rate or the lifespan of the scenario (Mavsar *et al*., 2015).

For instance, benefits and costs are largely dependent on a discount rate, which fluctuates in accordance to economic growth, inflation and other macroeconomic variables. For this, the net present value was calculated for different discount rates (3%; and 10%), as is normally used in similar international studies (Tuan and Tinh, 2013).

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6. Assessment – Future scenarios and decision-making framework

6.1. Baseline scenario

The **baseline scenario** considers current resource exploitation and land uses, and not the most probable trend projections, *i.e.*, it consists of a scenario in which there is no significant change in the variables identified as key, whether it be population growth, deforestation, among others. Therefore, the baseline scenario is not the most likely scenario to occur**.**

Taking into account the above, the economic valuation of the baseline scenario for Lukanga Swamp Sub-catchment's ecosystem services (considering the methodology explained in the previous section), for the 3% discount rate, is presented in Table 52. Thus, the present economic value of the considered ecosystem services in the Lukanga Swamp Sub-catchment is estimated at around USD 500 million (with a 3% discount rate) for 2050. This value decreases to around USD 50 million if a 10% discount rate is applied.

In both cases, **commercial and domestic timber** is considered the most valuable ecosystem service, at around USD 287 million with a 3% discount rate, or USD 16 million with a 10% discount rate (in 2050). The distribution of this service (timber) in the Lukanga Swamp Sub-catchment can be seen in Figure 78.

Fuelwood can also be considered a significant ecosystem service provided in the Lukanga Swamp Sub-catchment, as can be seen in Figure 79. With an identical economic value, at around USD 21 million with a 3% discount, wildlife services (pollination, pest control) distribution in the Lukanga Swamp Sub-catchment can be seen in Figure 80.

Water services (water for drinking) are estimated at around USD 2.2 million with a 3% discount rate (in 2050). The distribution of this service in the Lukanga Swamp Sub-catchment can be seen in Figure 81. Finally, hazard mitigation services are estimated at almost USD 6 million with a 3% discount, with most of the service being provided in areas near Chinombo and Kapiri Mposhi (see Figure 82).

Table 52 – Baseline scenario valuation – 10^3 USD/ year (2050)

Ecosystem service	Discount rate = 3%
Cultivated terrestrial plants grown for nutritional purpose	$9,829
Animals reared for nutritional purposes	$16,010
Non-wood forest products provided to the local beneficiaries	$761
Commercial and domestic timber provided	$287,261
Fuelwood provided to local beneficiaries	$22,993
Inland fisheries catch	$2,882
Water for drinking	$2,164
Hazard mitigation services	$5,991
Wildlife services (pollination, pest control)	$21,085
Decomposition and fixing processes and their effect on soil quality	$4,599
Regulation of the chemical condition of freshwater by living organisms	$127,828
Regulation of the chemical composition of the atmosphere	$18
Characteristics of living systems that enable scientific investigation/ traditional knowledge	$1,115
Total	$502,535

Source: Nemus' calculations based on Mulligan (2018).

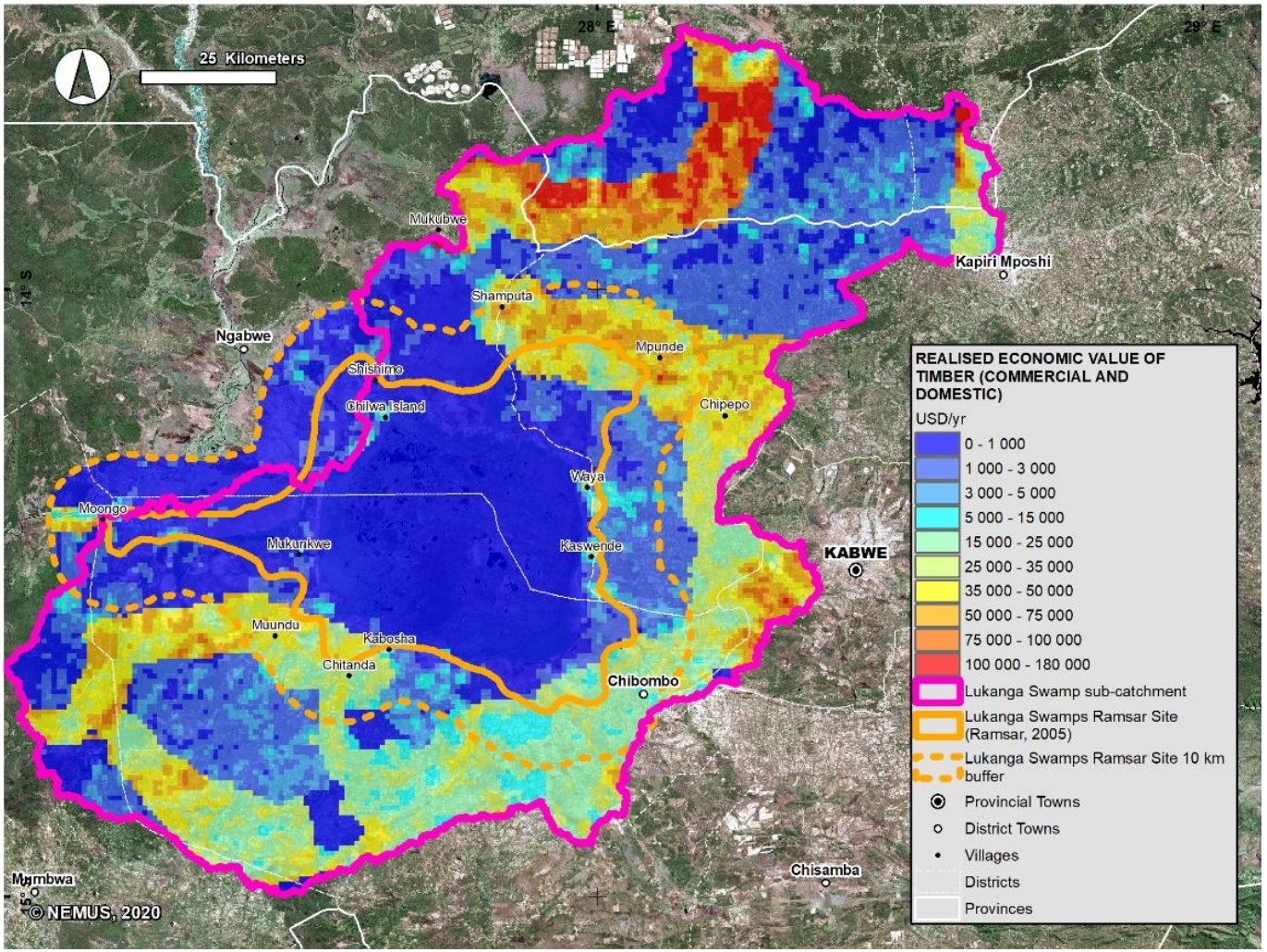


Figure 78 – Economic value of timber in Lukanga Swamp Sub-catchment (baseline scenario, 3% discount rate, USD/ year – 2050)

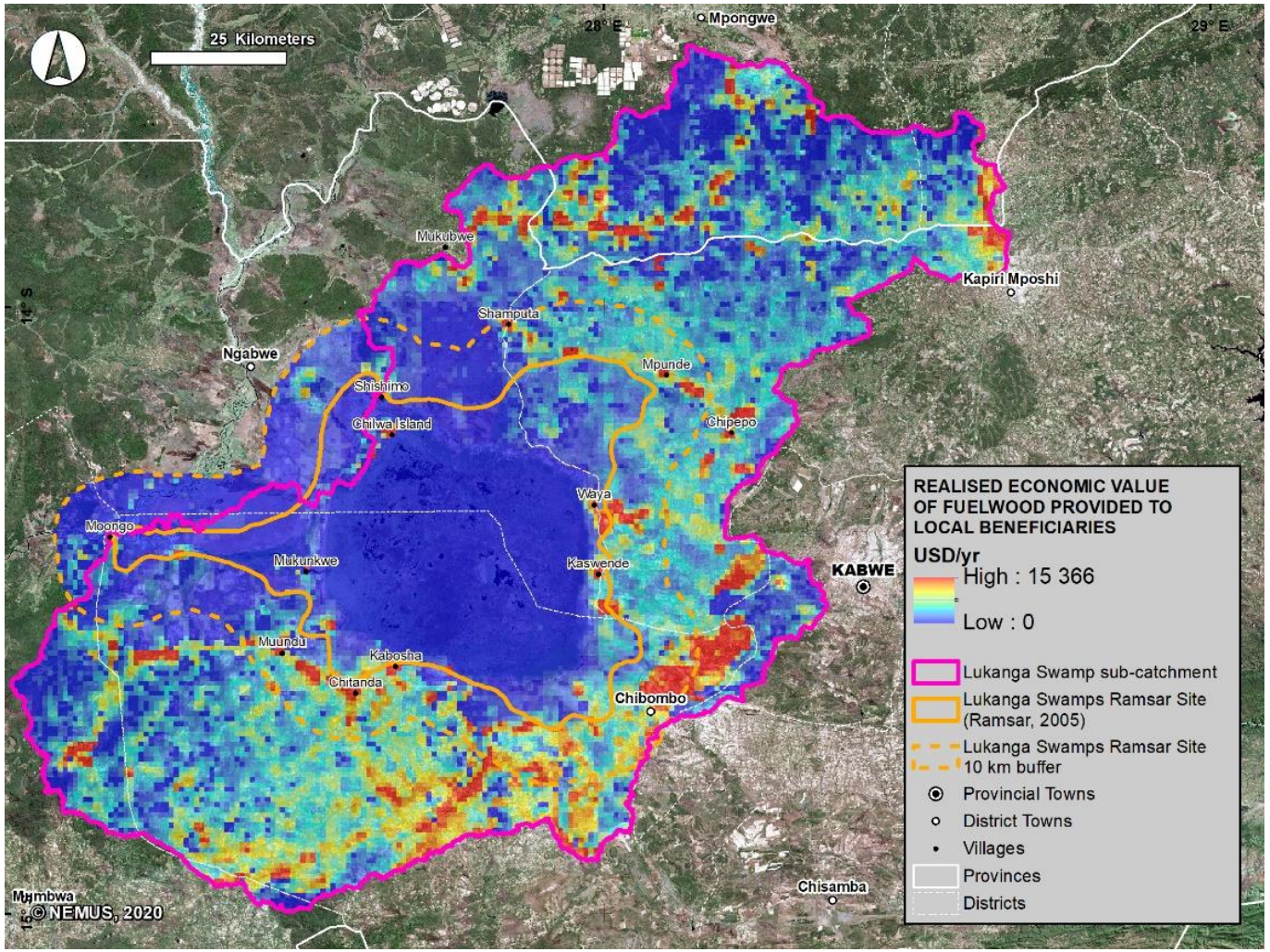


Figure 79 – Economic value of fuelwood in Lukanga Swamp Sub-catchment (baseline scenario, 3% discount rate, USD/ year – 2050)

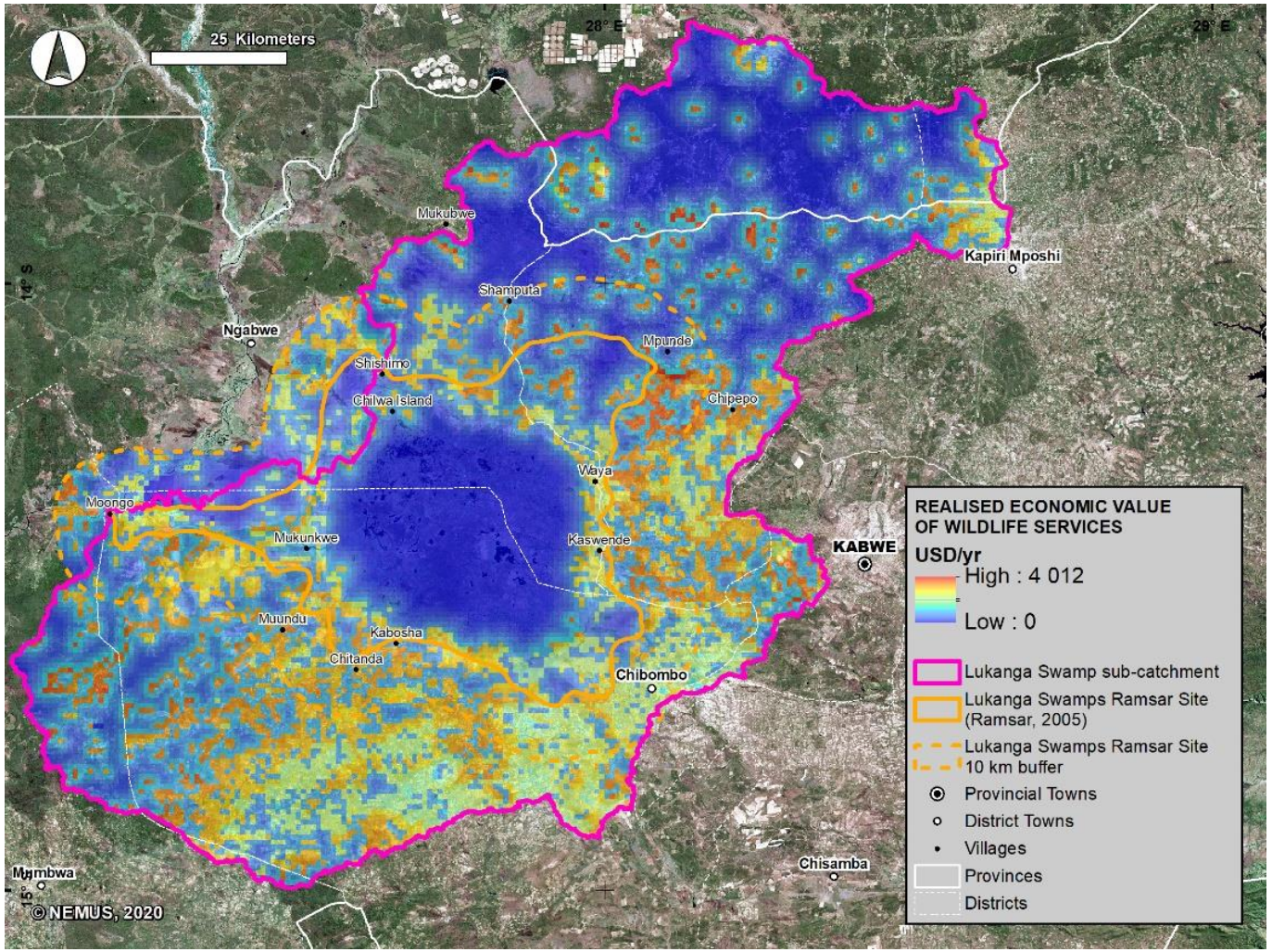


Figure 80 – Economic value of wildlife services in Lukanga Swamp Sub-catchment (baseline scenario, 3% discount rate, USD/ year – 2050)

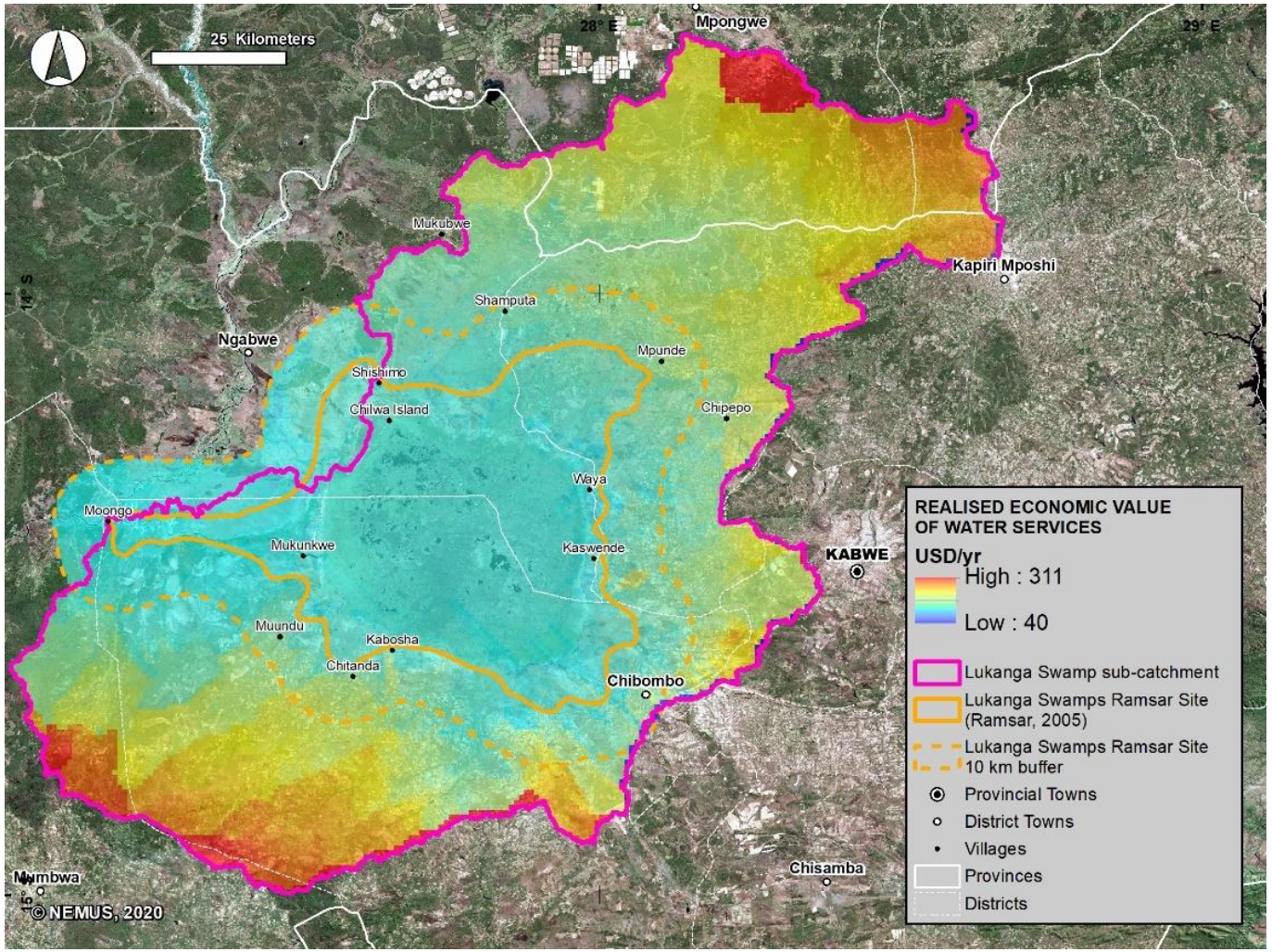


Figure 81 – Economic value of water services in Lukanga Swamp Sub-catchment (baseline scenario, 3% discount rate, USD/ year – 2050)

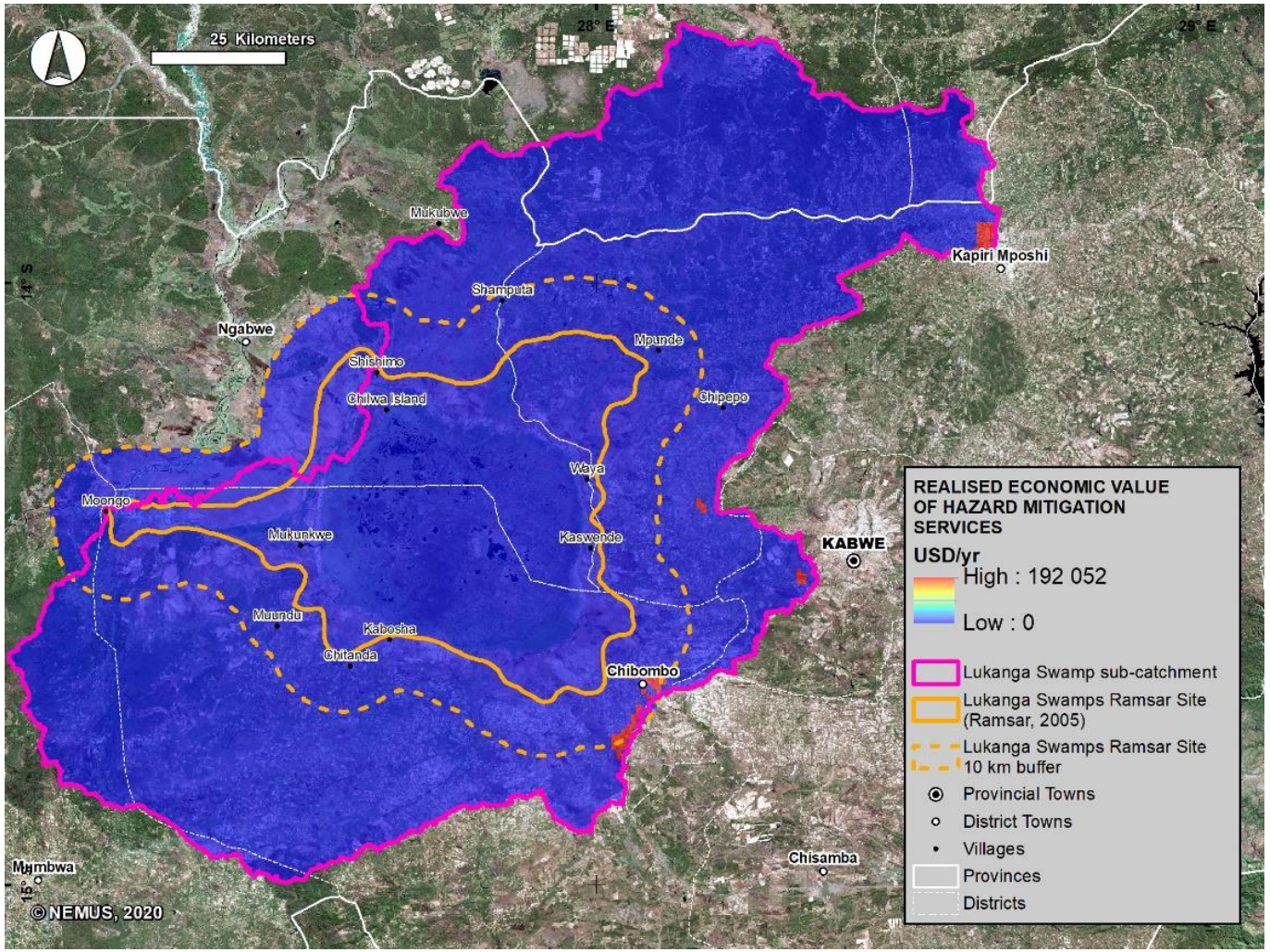
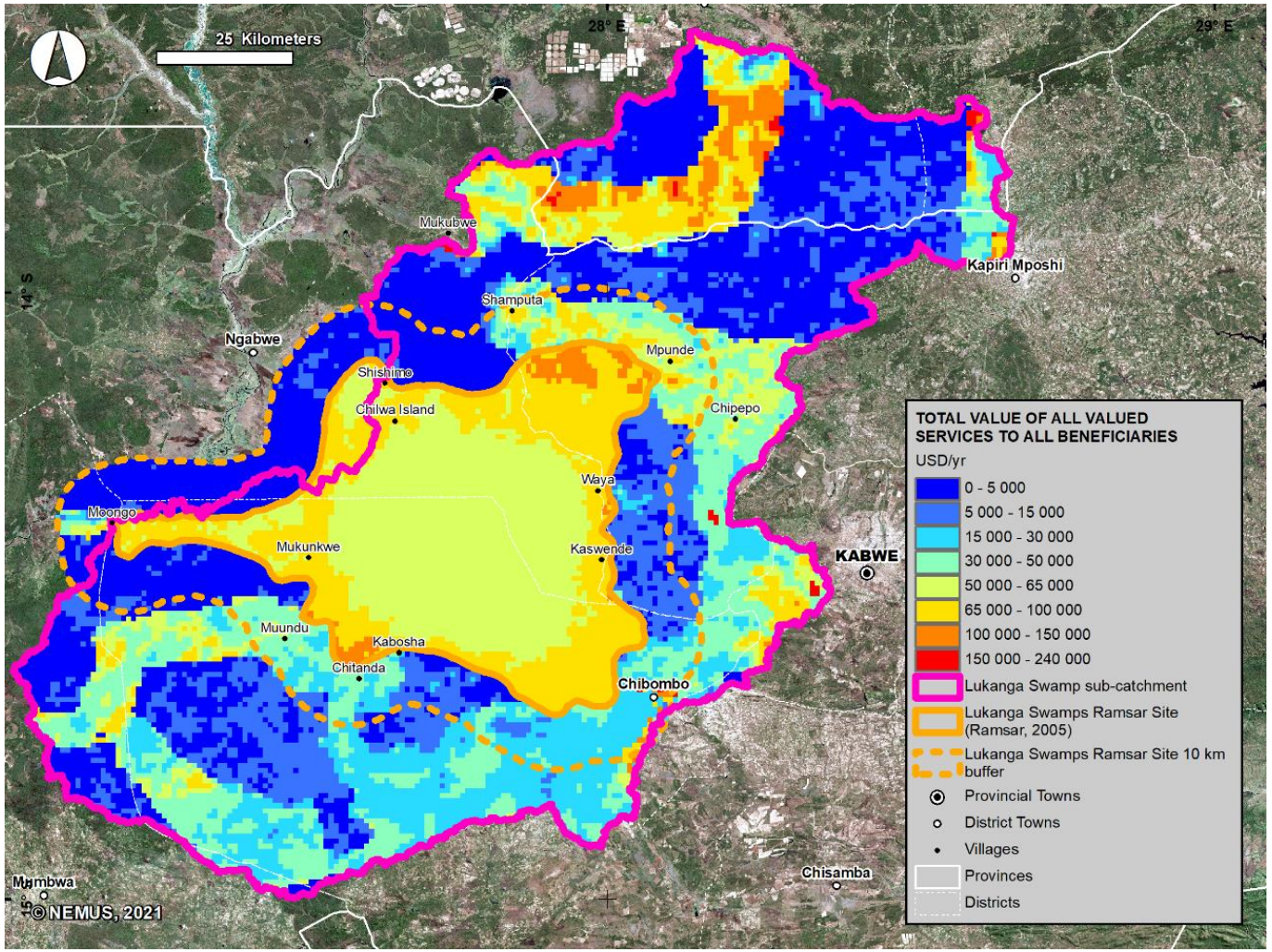


Figure 82 – Economic value of hazard mitigation services in Lukanga Swamp Sub-catchment (baseline scenario, 3% discount rate, USD/ year – 2050)

The total value of ecosystem services per area (not considering agriculture) can be seen in Figure 83. Because timber is considered the most valuable service (in baseline scenario/ 3% discount rate), the areas in which this service is provided are the most valuable areas, according this analysis. However, it is necessary to evaluate other scenarios of evolution in order to be able to have a more comprehensive analysis of the services provided by the Lukanga Swamp Sub-catchment (see next sections).



Note: *the following services are not considered: cultivated plants; animals reared.

Figure 83 – Total ecosystem services value per area* (baseline scenario, 3% discount rate, USD/ year – 2050)

6.2. Scenario with 10% deforestation

The **scenario with 10% deforestation** considers current resource exploitation and land uses, but with a total deforestation rate of 10% until 2050, *i.e.*, around a 0.35% average annual rate of deforestation. Furthermore, this scenario can be considered optimistic as it corresponds to about $^2/_3$ of the expected annual rate of deforestation for the next 30 years. The deforestation is considered equal across the area in this scenario. Specific scenarios for localized deforestation will be created going forward to evaluate the action plan.

Considering the above, the economic valuation of the scenario with 10% deforestation for Lukanga Swamp Sub-catchment's ecosystem services, for the 3% discount rate, is presented in Table 53. Thus, the present economic value of the considered ecosystem services in the Lukanga Swamp Sub-catchment is estimated at around USD 235 million (with a 3% discount rate) for 2050, in a scenario with 10% deforestation. This value decreases to around USD 36 million if a 10% discount rate is applied.

Table 53 – 10% deforestation scenario valuation – 10^3 USD/ year (2050)

Ecosystem service	Discount rate = 3%
Cultivated terrestrial plants grown for nutritional purpose	$10,706
Animals reared for nutritional purposes	$17,438
Non-wood forest products provided to the local beneficiaries	$168
Commercial and domestic timber provided	$50,467
Fuelwood provided to local beneficiaries	$6,490
Inland fisheries catch	$2,882
Water for drinking	$2,164
Hazard mitigation services	$1,938
Wildlife services (pollination, pest control)	$9,123
Decomposition and fixing processes and their effect on soil quality	$4,196
Regulation of the chemical condition of freshwater by living organisms	$127,828
Regulation of the chemical composition of the atmosphere	$18
Characteristics of living systems that enable scientific investigation/ traditional knowledge	$1,115
Total	$234,531

Source: Nemus' calculations based on Mulligan (2018).

In this scenario (10% deforestation), **regulation of the chemical condition of freshwater by living organisms** is considered the most valuable ecosystem service, at around USD 128 million with a 3% discount rate, or USD 18 million with a 10% discount rate (in 2050). The value of timber services shows a significant decrease in the 10% deforestation scenario in comparison with the baseline scenario. The distribution of this service (timber) in the Lukanga Swamp Sub-catchment can be seen in Figure 84, for the current scenario in analysis.

The total value of ecosystem services per area (not considering agriculture) for the 10% deforestation scenario can be seen in Figure 85.

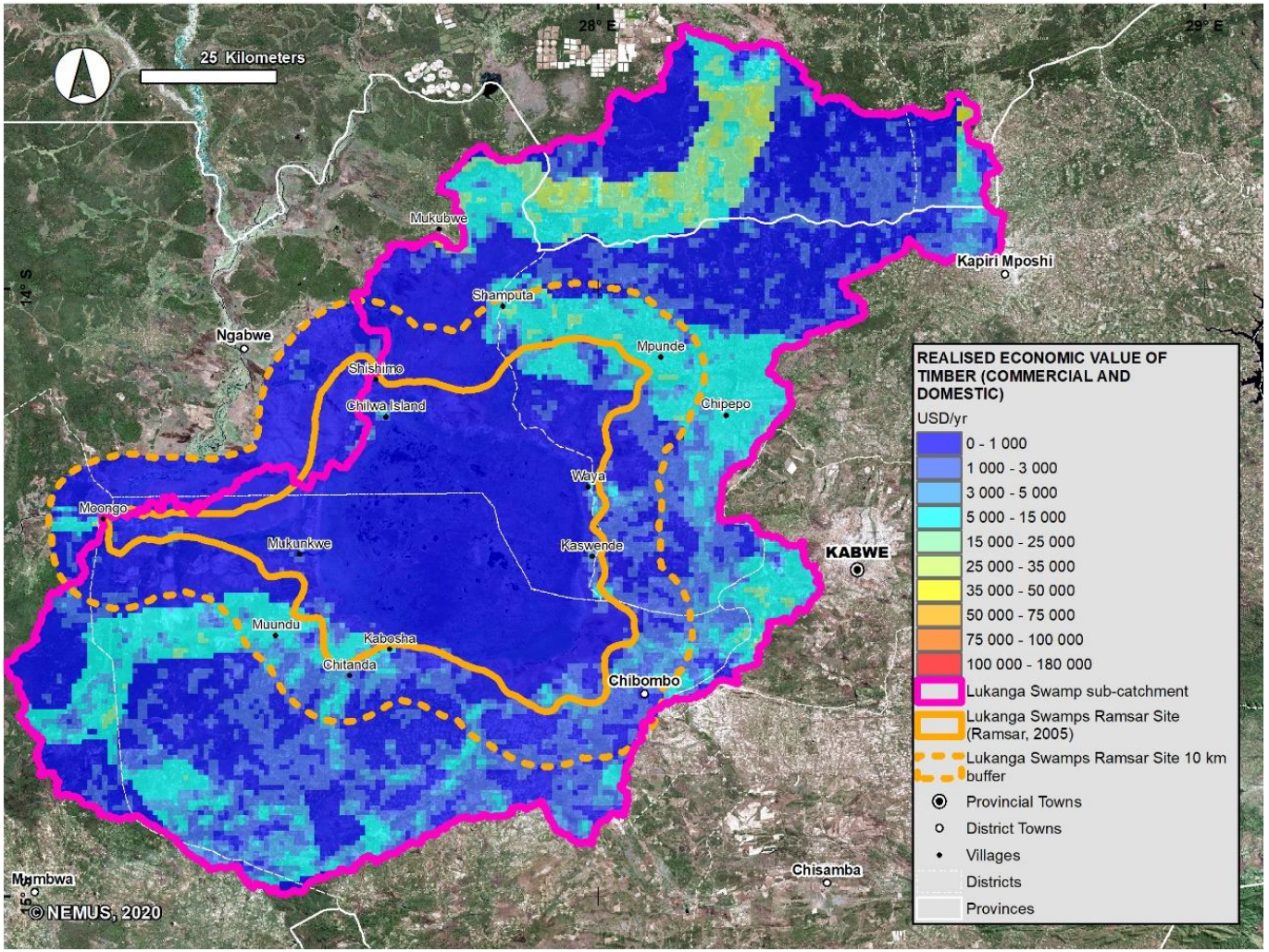
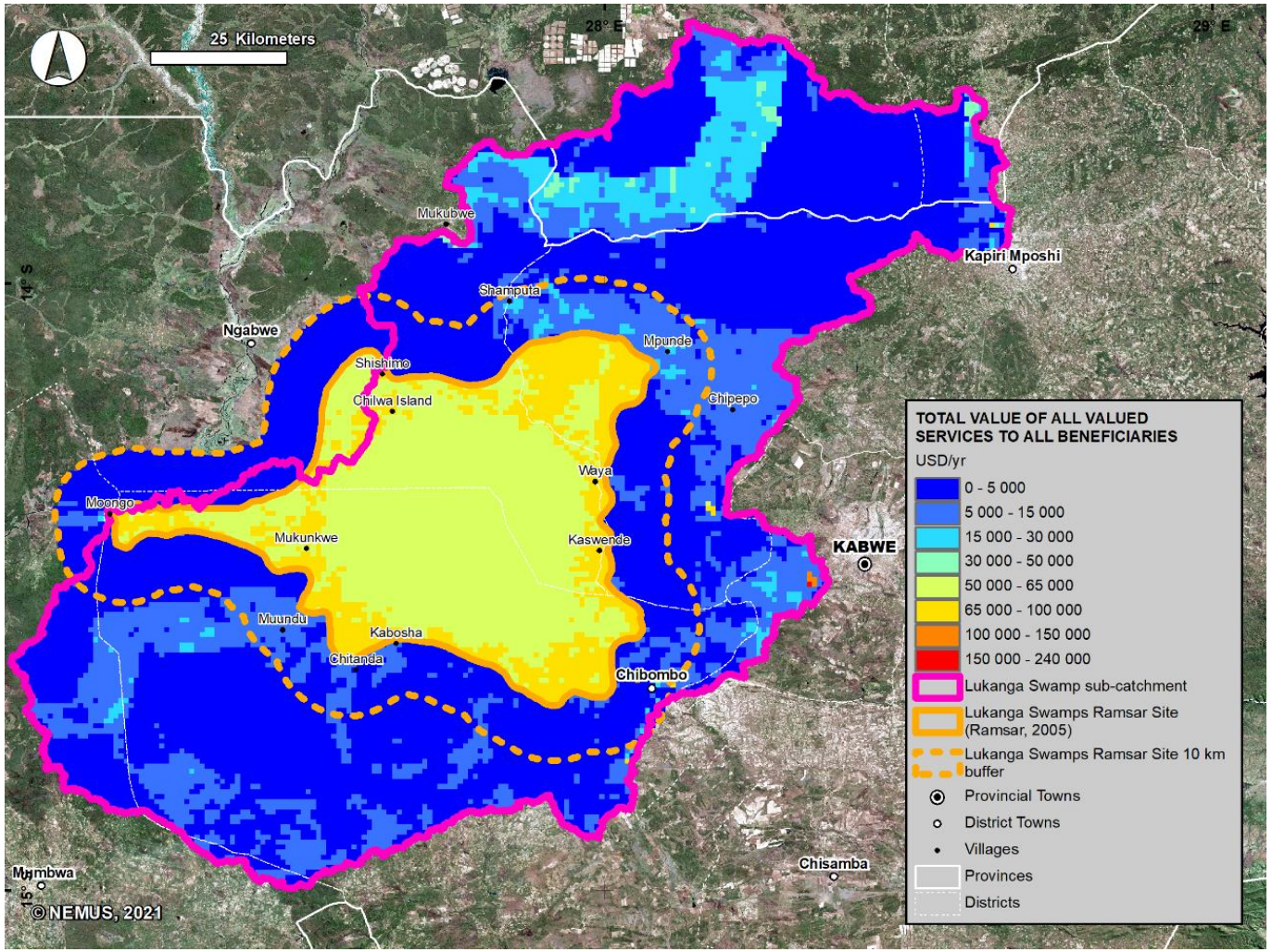


Figure 84 – Economic value of timber in Lukanga Swamp Sub-catchment (10% deforestation scenario, 3% discount rate, USD/ year – 2050)



Note: *the following services are not considered: cultivated plants; animals reared.

Figure 85 – Total ecosystem services value per area* (10% deforestation scenario, 3% discount rate, USD/ year – 2050)

6.3. Scenario with 15% deforestation

The **scenario with 15% deforestation** considers current resource exploitation and land uses, but with a total deforestation rate of 15% until 2050, *i.e.*, around a 0.54% average annual rate of deforestation. Furthermore, this scenario can be considered as the *business as usual scenario* as it corresponds to around the expected annual rate of deforestation for the next 30 years. The deforestation is considered equal across the area in this scenario. As stated before, specific scenarios for localized deforestation will be created going forward to evaluate the action plan.

Considering the above, the economic valuation of the scenario with 15% deforestation for Lukanga Swamp Sub-catchment's ecosystem services, for the 3% discount rate, is presented in Table 54. Thus, the present economic value of the considered ecosystem services in the Lukanga Swamp Sub-catchment is estimated at around USD 217 million (with a 3% discount rate) for 2050, in a scenario with 15% deforestation. This value decreases to around USD 33 million if a 10% discount rate is applied.

Table 54 – 15% deforestation scenario valuation – 10^3 USD/ year (2050)

Ecosystem service	Discount rate = 3%
Cultivated terrestrial plants grown for nutritional purpose	$11,144
Animals reared for nutritional purposes	$18,152
Non-wood forest products provided to the local beneficiaries	$109
Commercial and domestic timber provided	$35,034
Fuelwood provided to local beneficiaries	$4,570
Inland fisheries catch	$2,882
Water for drinking	$2,164
Hazard mitigation services	$1,154
Wildlife services (pollination, pest control)	$9,123
Decomposition and fixing processes and their effect on soil quality	$3,994
Regulation of the chemical condition of freshwater by living organisms	$127,828
Regulation of the chemical composition of the atmosphere	$18
Characteristics of living systems that enable scientific investigation/ traditional knowledge	$1,115
Total	$217,287

Source: Nemus' calculations based on Mulligan (2018).

In this scenario (15% deforestation), **regulation of the chemical condition of freshwater by living organisms** is considered the most valuable ecosystem service, at around USD 128 million with a 3% discount rate, or USD 18 million with a 10% discount rate (in 2050). The value of timber services also shows a significant decrease in the 15% deforestation scenario in comparison with the 10% deforestation scenario (USD -18 million, 3% discount rate). The distribution of this service (timber) in the Lukanga Swamp Sub-catchment can be seen in Figure 86, for the current scenario in analysis.

The total value of ecosystem services per area (not considering agriculture) for the 15% deforestation scenario can be seen in Figure 87.

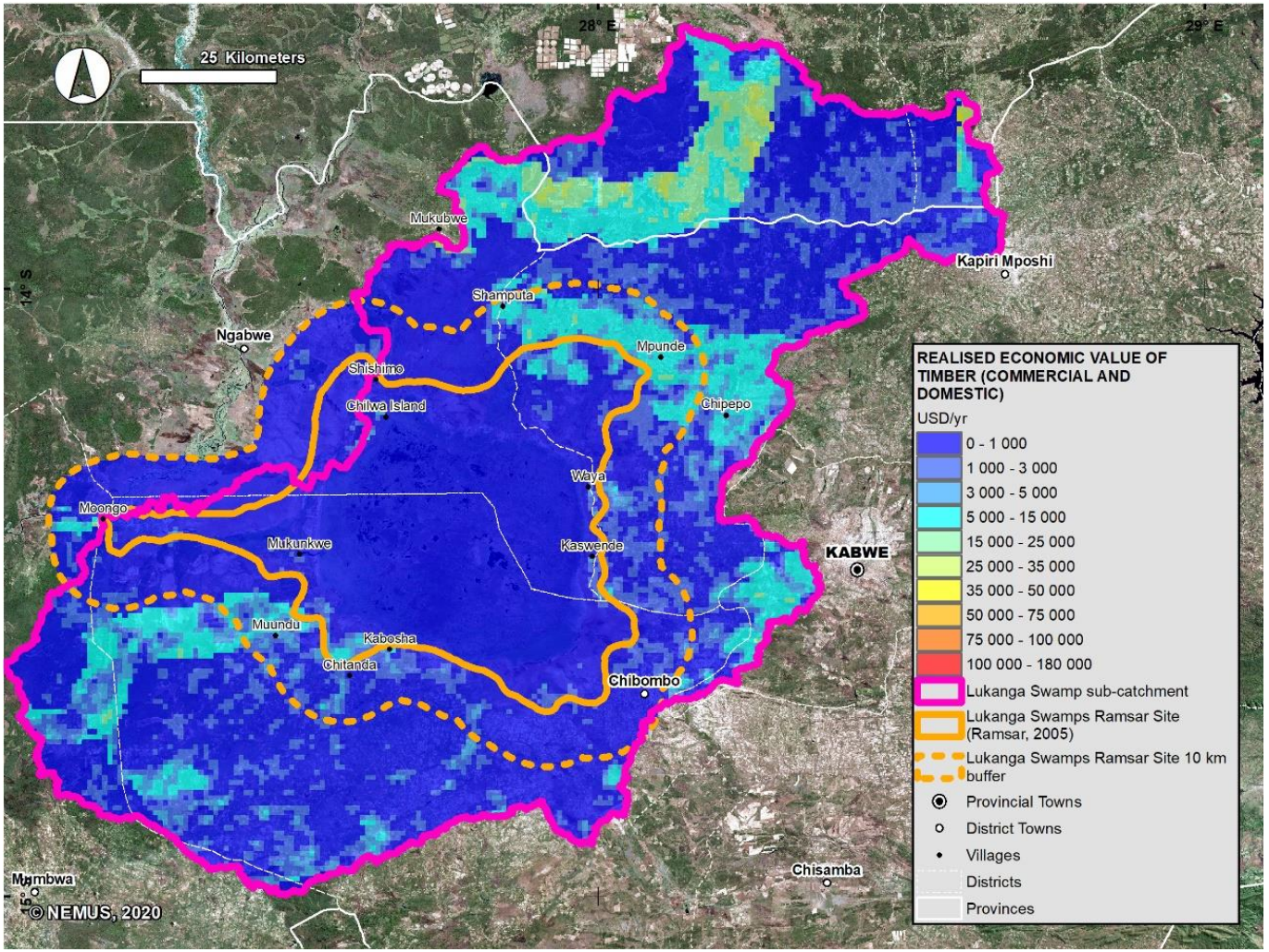
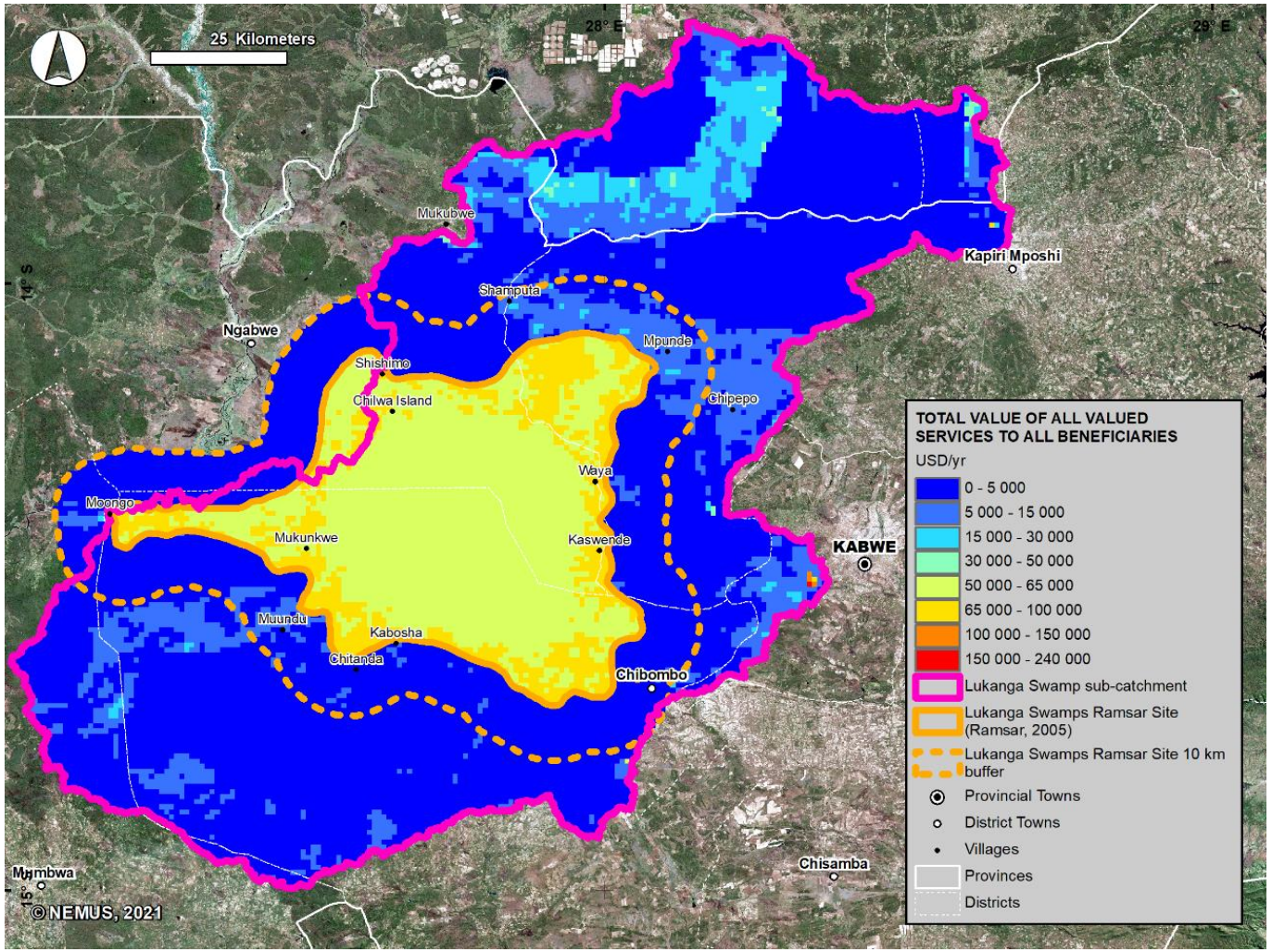


Figure 86 – Economic value of timber in Lukanga Swamp Sub-catchment (15% deforestation scenario, 3% discount rate, USD/ year – 2050)



Note: *the following services are not considered: cultivated plants; animals reared.

Figure 87 – Total ecosystem services value per area* (15% deforestation scenario, 3% discount rate, USD/ year – 2050)

6.4. Scenario with 20% deforestation

The **scenario with 20% deforestation** considers current resource exploitation and land uses, but with a total deforestation rate of 20% until 2050, *i.e.*, around a 0.74% average annual rate of deforestation. Furthermore, this scenario can be considered as pessimistic as it corresponds to significant more than the expected annual rate of deforestation for the next 30 years. The deforestation is considered equal across the area in this scenario. As stated before, specific scenarios for localized deforestation will be created going forward to evaluate the action plan.

Considering the above, the economic valuation of the scenario with 20% deforestation for Lukanga Swamp Sub-catchment's ecosystem services, for the 3% discount rate, is presented in Table 55. Thus, the present economic value of the considered ecosystem services in the Lukanga Swamp Sub-catchment is estimated at around USD 205 million (with a 3% discount rate) for 2050, in a scenario with 20% deforestation. This value decreases to around USD 31 million if a 10% discount rate is applied.

Table 55 – 20% deforestation scenario valuation – 10^3 USD/ year (2050)

Ecosystem service	Discount rate = 3%
Cultivated terrestrial plants grown for nutritional purpose	$11,583
Animals reared for nutritional purposes	$18,866
Non-wood forest products provided to the local beneficiaries	$70
Commercial and domestic timber provided	$23,678
Fuelwood provided to local beneficiaries	$3,122
Inland fisheries catch	$2,882
Water for drinking	$2,164
Hazard mitigation services	$881
Wildlife services (pollination, pest control)	$9,123
Decomposition and fixing processes and their effect on soil quality	$3,792
Regulation of the chemical condition of freshwater by living organisms	$127,828
Regulation of the chemical composition of the atmosphere	$18
Characteristics of living systems that enable scientific investigation/ traditional knowledge	$1,115
Total	$205,122

Source: Nemus' calculations based on Mulligan (2018).

In this scenario (20% deforestation), **regulation of the chemical condition of freshwater by living organisms** is again considered the most valuable ecosystem service. The value of timber services also shows a significant decrease in the 20% deforestation scenario in comparison with the 15% deforestation scenario (USD -11 million, 3% discount rate). The distribution of this service (timber) in the Lukanga Swamp Sub-catchment can be seen in Figure 88, for the current scenario in analysis.

The total value of ecosystem services per area (not considering agriculture) for the 20% deforestation scenario can be seen in Figure 89.

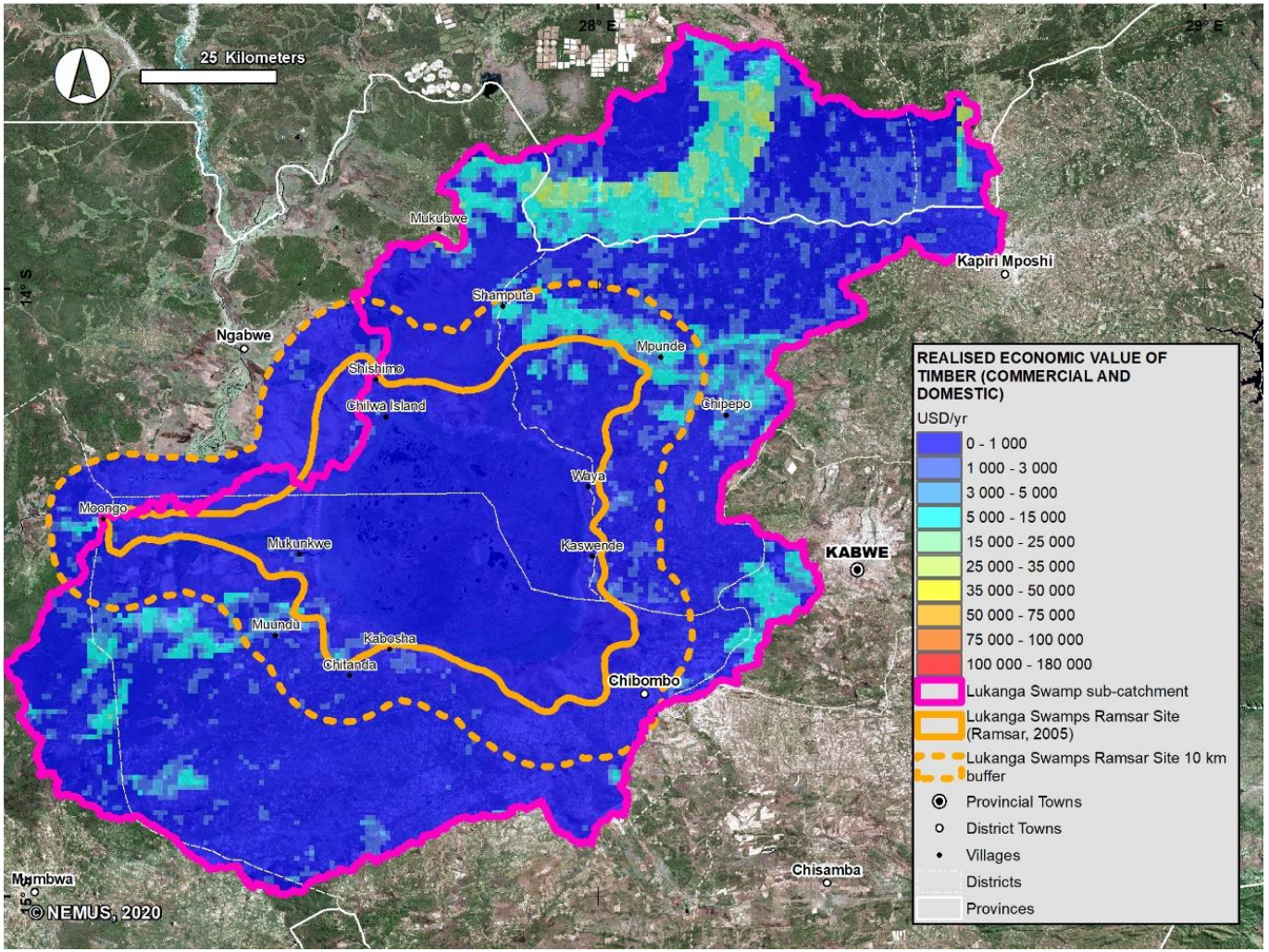
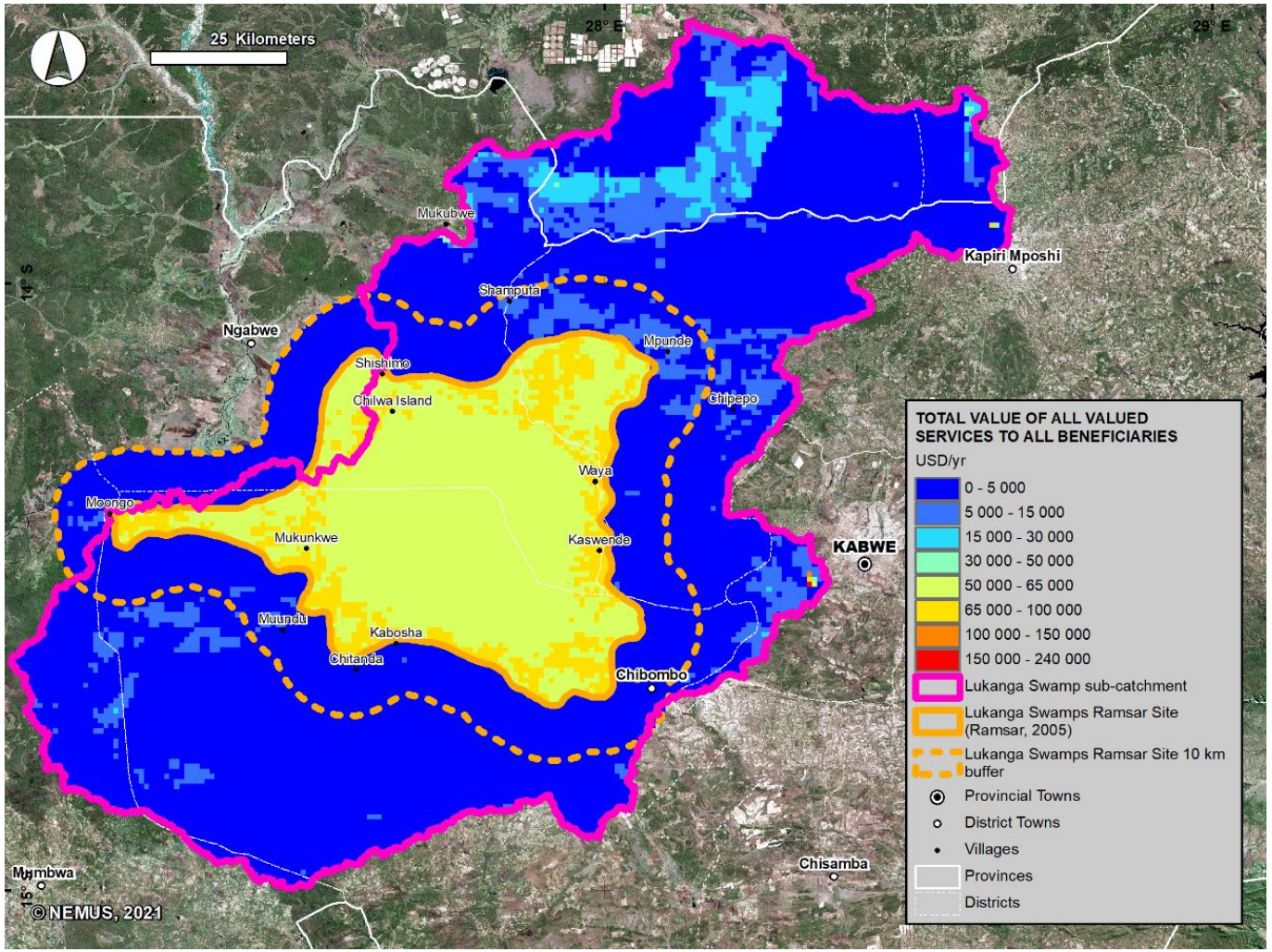


Figure 88 – Economic value of timber in Lukanga Swamp Sub-catchment (20% deforestation scenario, 3% discount rate, USD/ year – 2050)



Note: *the following services are not considered: cultivated plants; animals reared.

Figure 89 – Total ecosystem services value per area* (20% deforestation scenario, 3% discount rate, USD/ year – 2050)

6.5. Scenario with 25% deforestation

The **scenario with 25% deforestation** considers current resource exploitation and land uses, but with a total deforestation rate of 25% until 2050, *i.e.*, around a 0.95% average annual rate of deforestation. Furthermore, this scenario can be considered as the most pessimistic in this analysis as it corresponds to considerably more than the expected annual rate of deforestation for the next 30 years. The deforestation is considered equal across the area in this scenario. As stated before, specific scenarios for localized deforestation will be created going forward to evaluate the action plan.

Considering the above, the economic valuation of the scenario with 25% deforestation for Lukanga Swamp Sub-catchment's ecosystem services, for the 3% discount, is presented in Table 56. Thus, the present economic value of the considered ecosystem services in the Lukanga Swamp Sub-catchment is estimated at around USD 197 million (with a 3% discount rate) for 2050, in a scenario with 25% deforestation. This value decreases to around USD 30 million if a 10% discount rate is applied.

Table 56 – 25% deforestation scenario valuation – 10^3 USD/ year (2050)

Ecosystem service	Discount rate = 3%
Cultivated terrestrial plants grown for nutritional purpose	$12,021
Animals reared for nutritional purposes	$19,581
Non-wood forest products provided to the local beneficiaries	$45
Commercial and domestic timber provided	$15,886
Fuelwood provided to local beneficiaries	$2,136
Inland fisheries catch	$2,882
Water for drinking	$2,164
Hazard mitigation services	$775
Wildlife services (pollination, pest control)	$9,123
Decomposition and fixing processes and their effect on soil quality	$3,591
Regulation of the chemical condition of freshwater by living organisms	$127,828
Regulation of the chemical composition of the atmosphere	$18
Characteristics of living systems that enable scientific investigation/ traditional knowledge	$1,115
Total	$197,165

Source: Nemus' calculations based on Mulligan (2018).

In this scenario (25% deforestation), **regulation of the chemical condition of freshwater by living organisms** is again considered the most valuable ecosystem service. The value of timber services also shows a significant decrease in the 25% deforestation scenario in comparison with the 20% deforestation scenario (USD -8 million, 3% discount rate). The distribution of this service (timber) in the Lukanga Swamp Sub-catchment can be seen in Figure 90, for the current scenario in analysis.

The total value of ecosystem services per area (not considering agriculture and regulation of the chemical condition of freshwater by living organisms) for the 20% deforestation scenario can be seen in Figure 91.

The service providing the greatest economic value (not considering agriculture) per area in the Lukanga Swamp Sub-catchment for the 25% deforestation scenario (3% discount rate) can be seen in Figure 92. As shown, timber is no longer the most valuable ecosystem service across large areas of the Lukanga Swamp Sub-catchment (as was the case in the baseline scenario). In this case, regulation of water and wildlife services are significantly more valuable in Lukanga Swamp Sub-catchment.

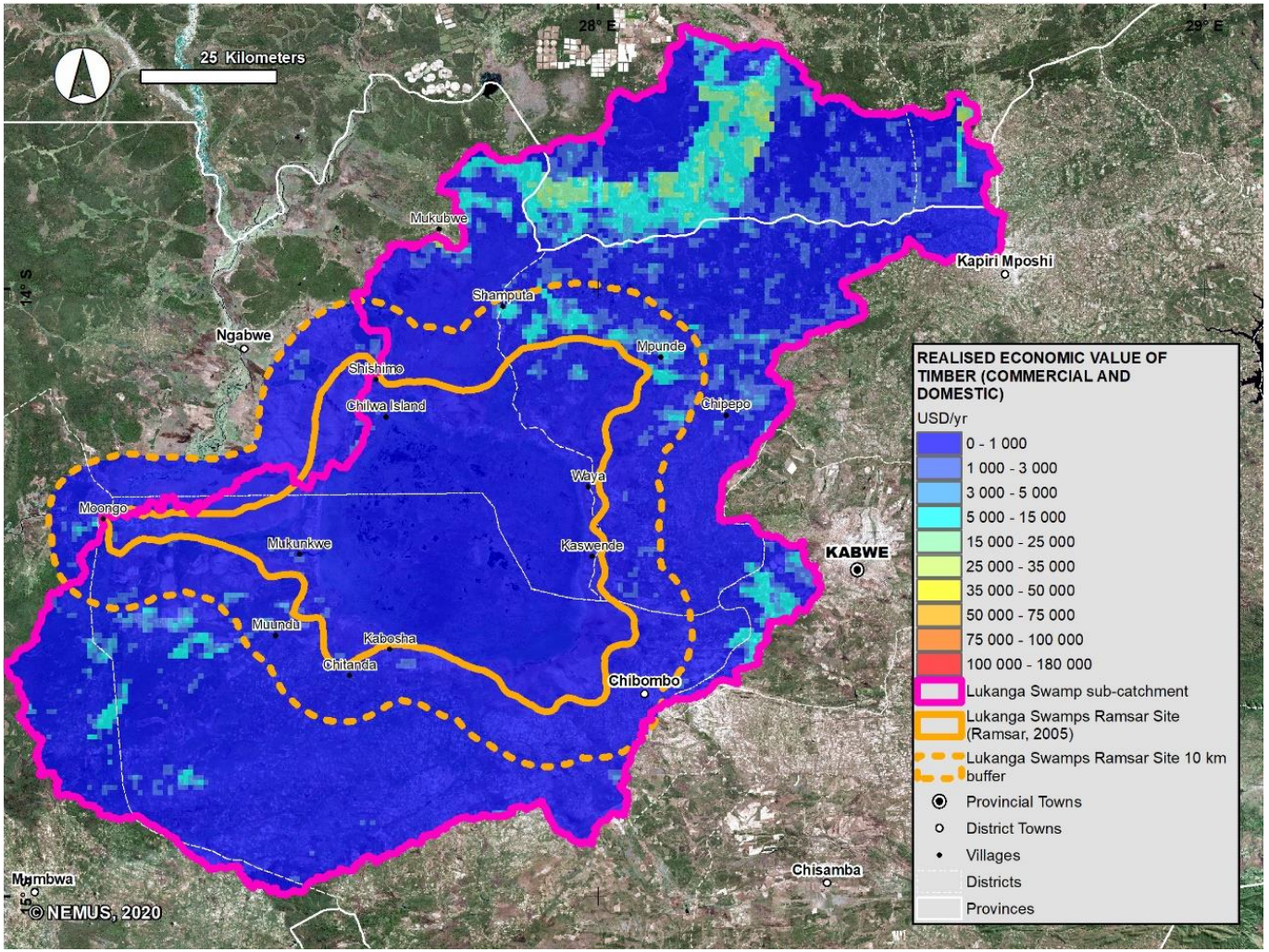
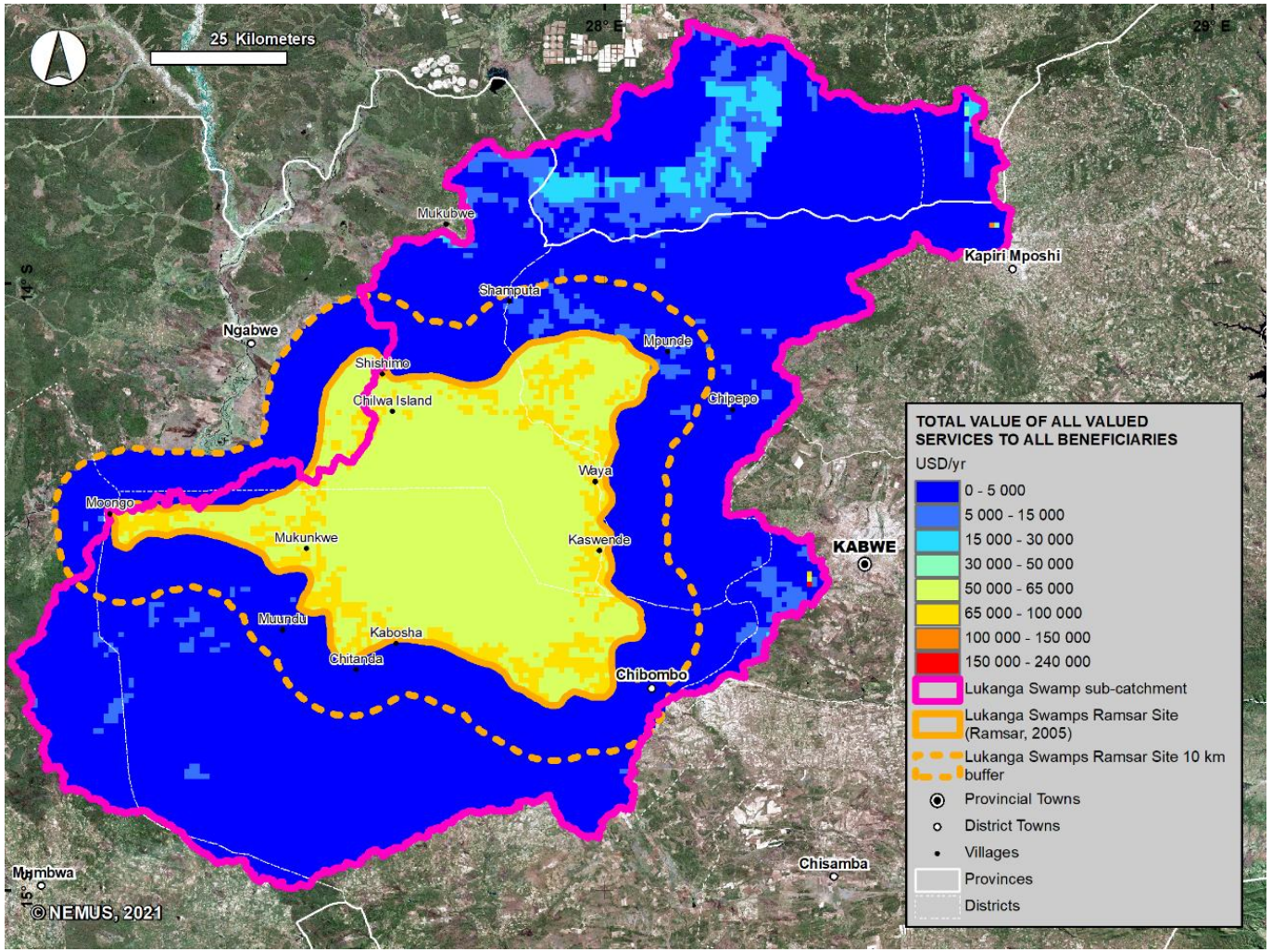
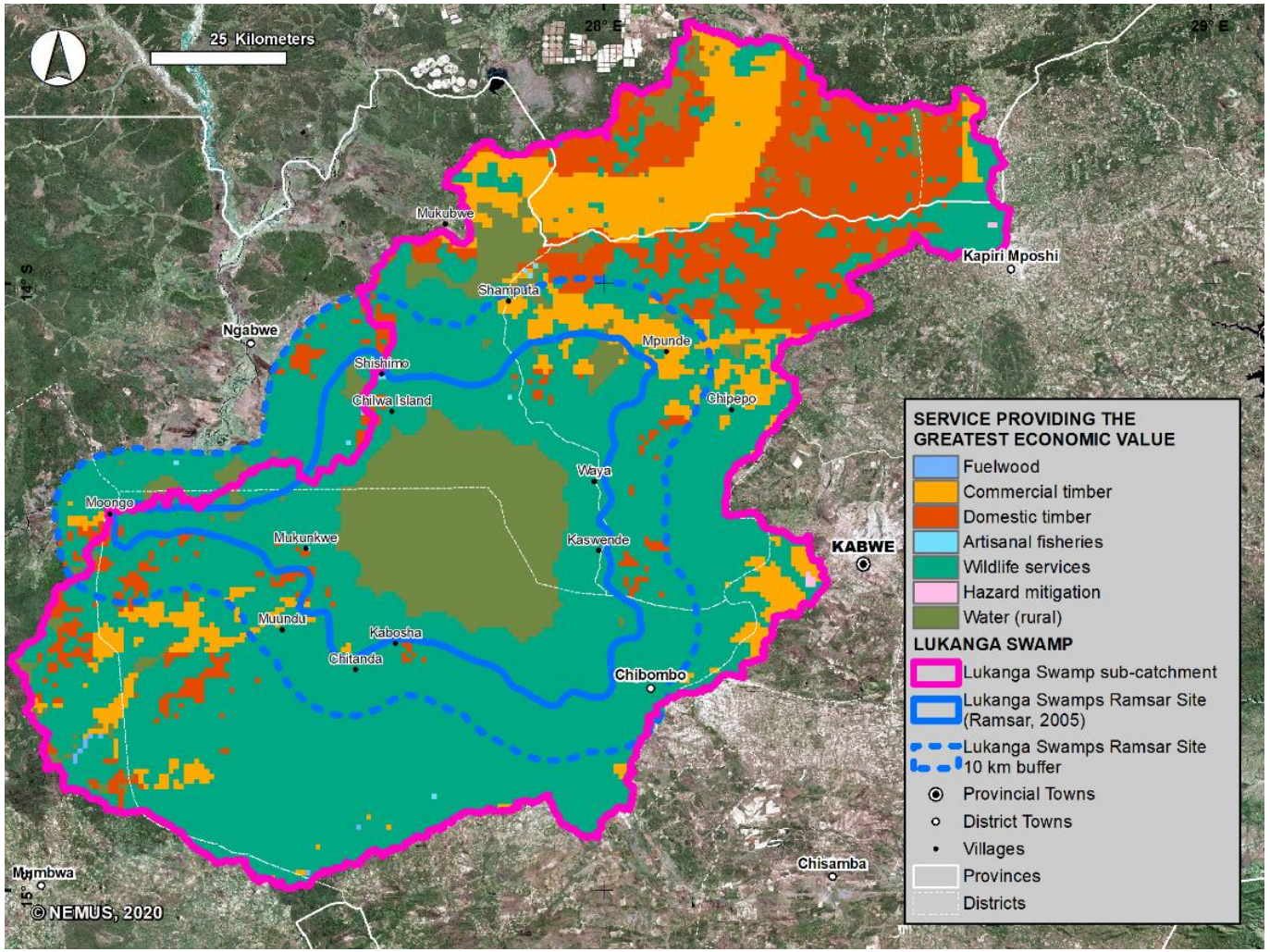


Figure 90 – Economic value of timber in Lukanga Swamp Sub-catchment (25% deforestation scenario, 3% discount rate, USD/ year – 2050)



Note: *the following services are not considered: cultivated plants; animals reared.

Figure 91 – Total ecosystem services value per area* (25% deforestation scenario, 3% discount rate, USD/ year – 2050)



Note: * not considering cultivated plants, animals reared, and regulation of freshwater by living organisms.

Figure 92 – Service providing the greatest economic value* (25% deforestation scenario, 3% discount rate, USD/ year – 2050)

6.6. Conclusion and decision-making framework

As mentioned before, the Co$ting Nature (version 3) multi-service tool/model was selected to support the ECBA and decision-making under the Conservation Plan for Lukanga Swamp and Upper Kafue Basin.

Costing Nature incorporates ecosystem service provision and benefits information into conservation prioritisation and planning; it focuses on water, carbon and tourism related services and on defining the magnitude and geographic pattern of these as potential services and as those realised (used) by local and global beneficiaries (Mulligan, 2018). Besides being a simpler tool for modelling a wider range of ecosystem services (water, carbon, tourism, hazard mitigation, biodiversity), pressures, threats and thus overall conservation priority, when compared to similar models/tools, its selection is justified by the following features:

- it was created as a testbed for the development and implementation of conservation strategies focused on improving ecosystem services;
- it incorporates detailed spatial datasets at 1-square km and 1-hectare resolution for the entire World, spatial models for biophysical and socioeconomic processes along with scenarios for climate and land use;
- it maps 13 ecosystem services and then combines them with different analyses (current pressure, future threats, biodiversity and delphic conservation priority) to produce an assessment of priority areas for conservation;
- it values and examines the impacts – in terms of change in ecosystem services – and implications for beneficiaries (global and local);
- it calculates a baseline for ecosystem service provision and allows a series of interventions or scenarios of change (user priorities for conservation and ecosystem services; different economic valuation matrix per ecosystem service; various land use change scenarios, including different settings for deforestation) to be used to understand their impact on ecosystem service delivery;
- economic valuation may also be carried out, using the economic valuation customisation and completing the economic valuation matrix; this economic valuation component of Co$ting Nature is developed in collaboration with the International Institute for Environment and Development (IIED).

This decision-making framework has the following available policy options to evaluate different scenarios for the ecosystem services provided by the Lukanga Sub-Catchment:

- **A.** Changing user priorities for conservation and ecosystem services;
- **B.** Changing economic valuation matrix or assumptions for each ecosystem service;
- **C.** Land use change scenarios, for example impacts of deforestation on ecosystem services;

The last option (land use change scenarios) was used to evaluate different outcomes for the future of the Lukanga Sub-Catchment. Table 57 presents the valuation for each of the base scenarios considered, namely the baseline, 10% deforestation, 15% deforestation, 20% deforestation, 25% deforestation scenarios. Valuations for two discount rates (3% and 10%) were also calculated.

Table 57 – Total valuation for scenarios considered – 10^3 USD/ year (2050)

Scenario	Discount rate = 3%	Discount rate = 10%
Baseline	$502,535	$49,776
10% deforestation	$234,531	$36,171
15% deforestation	$217,287	$33,098
20% deforestation	$205,122	$31,170
25% deforestation	$197,165	$29,972

Source: Nemus' calculations based on Mulligan (2018).

Differences between scenarios are due, in particular, to the timber ecosystem service: in the baseline scenario, sustainable harvest is considered; and in the various deforestations' scenarios, sustainable harvest is not possible in the deforested areas (% per unit area).

The use of Co$ting Nature tool (version 3) makes it possible to further expand the number and variety of scenarios to be evaluated. So, this approach will be used to evaluate different deforestation settings, potential management actions and the conservation plan's options.

7. Conclusion

Part I of the Draft Conservation Plan for Lukanga Swamp and Upper Kafue Basin was presented in this document, comprising the Conservation planning framework; the baseline; Evaluation; Objectives; an assessment of future scenarios and the decision-making framework.

Conservation planning framework

Planning and legal framework. Main government policies relevant to wetland conservation, as well as wetland management legal framework, were summarized, outlining the enabling Acts and a brief description of each one of them.

Stakeholders mapping and engagement. Key stakeholders and institutions were invited to the consultation workshops. Key information holders were met and key informant interviews and focus group discussions with local communities were conducted. These were carried out in two occasions, with distinct goals: for a general socioeconomic characterization of the communities and to perceive their dependence on (or conflicts / malfunctions regarding) ecosystem services (December 2019); to collect specific data to support the quantification and valuation of the benefits derived from the ecosystems in and around Lukanga Swamp (October 2020).

Vision and approach to the Lukanga Conservation Plan. The Conservation Plan for Lukanga Swamp and Upper Kafue Basin envisions a sustainable, integrated and participated planning of Lukanga Swamp, its catchment and Kafue riber basin upstream that addresses human well-being and balances trade-offs among stakeholders, while sustaining and enhancing the ecosystem services provided by the wetland. The time frames proposed for implementation of the Conservation Plan are as follows: short-term (2021-2025); medium-term (2026-2035); long-term (2036-2050).

Baseline of Lukanga Swamp catchment and Kafue River Basin upstream

Climate. Demonstrated that in Zambia there are two main seasons, the rainy season (November to March) corresponding to summer, and the dry season (April to October/November), corresponding to winter; some authors divide the latter into two different sub seasons, cool dry season (May-August) and hot dry season (September-November); average temperatures in the wet season range from 20-23°C and from 16-19°C in the cool part of the dry season (May to August) and from 23-25°C in the hot part of the dry season (September to October); mean annual precipitation for the catchment varies from approximately 900 mm in the vicinity of the swamp to 1,400 mm in the vicinity of the source of the Lukanga River in the north.

Hydrology. Characterisation and assessment of the upper and mid Kafue, the lower Kafue and the Kafue Flats, besides the Lukanga Swamp and its catchment; it showed that the Lukanga Swamp functions like a sponge, absorbing water that comes in during the wet season (or from the periodically flooding of the Kafue through overflow), releasing it slowly during the dry period and having a very high annual inflow variability; the Lukanga Swamp and its watershed are a very important asset for downstream water users in the Kafue River Basin;

Hydrodynamics (of the Lukanga Swamp and its catchment). Showed that the north of the Lukanga watershed which drains to the centre of the swamp is a major source of water, although additional inputs of water from Kafue River overflows also come from the West and Northwest; a volume of 0.31 million cubic meters (MCM) is subtracted from the swamp storage capacity each year due to sedimentation, but this is negligible compared to the volume of water generally stored in the swamp (4,000 – 7,000 MCM) – even after 100 years with this sedimentation rate, the swamp would lose less than 1% of its capacity.

Geology. Below sediment deposits there is an interpreted fault crossing the Lukanga Swamp, according to the geological setting of Zambia; though these structures have minimal or no interference on the surface hydrology, the diversified lithologies that compose the Upper Kafue River Basin and Lukanga Swamp Catchment are, on the other hand, reflected in the different types of aquifers occurring in the area.

Hydrogeology. Groundwater characterisation at the scale of the Kafue Basin showed that there are extensive aquifers in the Kafue River Basin, particularly in the areas of the Copperbelt and Lusaka, though limited exploitation of these aquifers has taken place; at the scale of the Lukanga Swamp and its catchment, groundwater characterisation showed that groundwater in the Lukanga catchment generally flows towards the Swamp and that the flow between the swamp and the Kafue River seems to be dependent on water levels on each one of these, possibly flowing in both ways.

Environmental quality. Surface and groundwater quality, sediment and leaf sampling and analyses were performed covering Lukanga Swamp and the Kafue basin upstream, including 87 sampling stations distributed along the plan areas to properly characterise the upper and middle Kafue and the connections with Lukanga Swamp and its catchment. Results show that surface water characteristics can greatly vary from the Copperbelt Province to the Lukanga Swamp area; conductivity, COD and BOD show higher values in the Copperbelt Province while nitrates, Cr, Pb and Zn are higher in the Lukanga Swamp. The main problem with groundwater quality around the Lukanga Swamp concerns concentrations of metals, particularly of Cd and Pb. Metal concentrations in the sediments are higher in the Copperbelt area when compared to Lukanga Swamp. Concentrations of metals in the analysed leaves also show a predominance of maximum concentrations in the Copperbelt Province and minimum concentrations in the Lukanga Swamp, though Pb and Zn behave the other way around.

Ecology. Included the characterisation and assessment of the designated areas for the protection of biodiversity, the Upper Kafue basin land cover, the Lukanga sub-catchment land cover and the Lukanga swamp land cover, habitats mosaic, flora and fauna.

Socioeconomics. The socio-economic characterization shows that Lukanga Swamp has a population of about 58,000 people, including many retrenched miners from Kabwe, Tonga people from the southern province and seasonal migration of fishermen; the main economic activities in the communities living in and around Lukanga Swamp are farming, charcoal production, livestock rearing and fishing.

Governance. Policy and institutional frameworks for the conservation of Lukanga Swamp; local communities' characterisation and role in wetland management.

Evaluation

Assessment of wetland values (diagnostic). The (hydrological, biogeochemical and ecological) “values” associated with the wetland were identified and classified according to an ecological value scale. The habitats of highest value were found to be the permanent swamp and the edaphic grassland, particularly towards the west, followed by forested land (where it is less degraded), riparian vegetation and lakes. The current state of natural habitats descreases in quality eastward and southward, which is in accordance with the encroachment by human settlements and associated intensification of human activities in that zone. The threats to the healthy functioning and conservation of these values were also identified.

Ecosystem services assessment. Ecosystem services and goods (ES) provided by the biophysical elements of Lukanga Swamp and its catchment were identified following the Common International Classification of Ecosystem Services (CICES) V5.1, the Millennium Ecosystem Assessment (MA) and The Economics of Ecosystems and Biodiversity (TEEB) frameworks. Examples of relevant ecosystems providing those services were identified. Then, the benefits to be considered in the valuation of ecosystem services were categorized according to their Total Economic Value (TEV) types.

Objectives

Conservation objectives. Targets and indicators for prioritary ecological values (ecological components deemed of “very high” and “high” value), like permanent swamp, grasslands, benthic macroinvertebrates, phytoplankton and zooplankton, fish assemblages, aquatic macrophytes, waterbirds and other avifauna, wild ungulates (very high value), forested land and riparian vegetation (high value), were identified.

Historical trends and drivers of change. Past trends on both the socioeconomic (population growth, growth of agricultural area, growth of inshore fishing and intensification of mining activities) and biophysical environments (changes in the hydrological regime and hydrodynamics of lukanga swamp and its catchment; water and sediment/soil quality degradation; land cover change; biodiversity loss; deterioration of conditions; climate change) were characterized. Drivers of change (population growth, climate change) of ecosystem condition and related impacts (land conversion;

overharvesting/exploitation; introduction of exotic species) were also identified and described.

Indicators and Environmental Cost-Benefit Analysis (ECBA). The methodology for the monetary valuation of wetland values under different scenarios, so they could be adequately factored into decision-making, was described here, including the diverse steps involved in this environmental cost-benefit analysis (ECBA): Problem definition (what are the objectives, what are the alternatives / management solutions and over what time period); Identification of relevant impacts; Physical quantification of relevant impacts; Monetary valuation of relevant impacts; Discounting costs and benefit flows; Sensitivity analysis. Yields of food crops (planted area; harvested area; expected production; prices) and Livestock data (livestock units /area) were some of the indicators used, for the physical quantification of the ecosystem services "Cultivated terrestrial plants grown for nutritional purpose" and "Animals reared for nutritional purposes", respectively. Co$ting Nature (version 3), a tool/model developed by King's College London and AmbioTEK CIC, selected to support the ECBA and decision-making under the Conservation Plan for Lukanga Swamp and Upper Kafue Basin, was also introduced.

Assessment of future scenarios and decision-making framework

Finally, the results of the assessment/valuation for each scenario were presented and discussed, namely the baseline, 10% deforestation, 15% deforestation, 20% deforestation and 25% deforestation scenarios; valuations for two discount rates (3% and 10%) were also calculated and presented. Total valuation for these scenarios is between \$502,535 (10^3 USD) per year, in 2050, in the baseline scenario, and \$197,165 (10^3 USD) in the 25% deforestation scenario, for a 3% discount rate. For a 10% discount rate, the values range from \$49,776 (10^3 USD), in the baseline scenario, and \$29,972 (10^3 USD), in the 25% deforestation scenario).

The use of Co$ting Nature tool makes it possible to further expand the number and variety of scenarios to be evaluated. So, Co$ting Nature was further described, as well the available policy options to evaluate different scenarios: Changing user priorities for conservation and ecosystem services; Changing economic valuation matrix or assumptions for each ecosystem service; Land use change scenarios, for example impacts of deforestation on ecosystem services (the one used to evaluate the above different outcomes for the future of the Lukanga catchment).

Final considerations

The development of the Conservation Plan is on track, according to the updated work schedule approved in October 2020.

Regarding the overall objective of the Conservation Plan for Lukanga Swamp – generate both qualitative and quantitative data and tools required to support the participatory management of the area –, a relevant amount of both qualitative and quantitative data has already been compiled and collected; also, its analysis allowed the selection or development of tools (e.g., Environmental Cost-Benefit Analysis, Co$ting Nature, the Lukanga Conservation Plan website) that will support the participatory management of the area.

The body of information collected and analysed and these tools, whose preliminary results are shown in this report, will allow the assessment of different conservation scenarios and actions to maximize the benefits provided by the swamp and thus improve the quality of life of the populations that depend upon these resources, while protecting existing natural ecosystems. Next steps include:

- Part II of the Draft Conservation Plan, comprising the Action Plan, which will be presented in Progress report No. 5 (D6);
- Draft Conservation Plan for Lukanga Swamp and Upper Kafue Basin, integrating, reviewing and updating Parts I and II according to comments from ZEMA and other relevant stakeholders, as well as stakeholder consultation actions conducted thus far, which will be the object of the Draft Report (D7).

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Appendixes

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Appendix 1 – Stakeholder consultation – Focus group discussions held in Chilwa Island, Chipepo, Mulongoti, Shamputa, Waya, and Mpusu/Chisoka communities, October 2020: questionnaires

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FOCUS GROUPS – QUESTIONNAIRE

I. SESSION IDENTIFICATION	No. of the session	1
Inquirer Name:	Emma Sitambuli	
Province:	Central	
District:	Ngabwe	
Locality:	Chilwa Island	
Community name:	Malipilo (FGDs with men)	
Coordinates GPS (Latitude & Longitude):		
Date & time of beginning (HH/MM):	13th October 2020; 13:00 hrs	



Photo

MODULE A: WOOD FOREST PRODUCTS (wood only)			
Product/ question	**1. Does the community collect and consume / sell wood forest products? What kind (i.e. one name / product per line)?**	**2. Unit of measure (per kind of product)**	**3. Price per unit (ZMW) (per kind of product)**
Fuelwood	Musalindi (mostly used for home use and fish preservation)	Oxcart	K80
	Mufuka (mostly used for home use and fish preservation)	Sold in packs of 2-3 logs	K15
	Mushikwalila (also known as Zayelo) –the best for fish preservation.		
	This community is on the island so there are very few trees and farming is a secondary activity		
Commercial Timber (wood for commercial exchange)	No timber in the locality		
	No timber in the locality		
	No timber in the locality		
	No timber in the locality		
	No timber in the locality		
Domestic Timber (wood for domestic use)	Susunkwale (used to make poles for construction)	Each	K7.00

MODULE B: NON-WOOD FOREST PRODUCTS

Most important (non-wood forest) products collected by the community?

Mention the more important products (non-wood forest products)

	Product (name input)	Unit of measure	Subsistence/ Sell/ Both	Price per unit (ZMW)	Medium productivity per household per year (in the unit of measure)
1	Reeds (mostly harvested by women)	Bundle of 20 reeds	Both	K20 per bundle	400 bundles
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					

MODULE C: FISH PRODUCTS

Most important (fish) products collected by the community?

Mention the more important products (fishes)

	Product (name input)	Unit of measure	Subsistence/ Sell/ Both	Price per unit (ZMW)	Medium productivity per household per year (in the unit of measure)
1	Red breams	Each	Both	K12.50	300
2	Bubble fish	Each	Both	K12.50	400
3	Matuku	Bowl (200 grams)	Both	K12.50	150 bowls
4	Minsenga	Bowl (200 grams)	Both	K12.50	100 bowls
5	Tiger fish	Each	Both	K12.50	300
6					
7					
8					
9					
10					
11					
12					

MODULE D: AGRICULTURAL PRODUCTS

Most important (agriculture) products harvested in the community?

Mention the more important products (at least 8 products) (agricultural products)

	Product (name input)	Unit of measure	Subsistence/ Sell/ Both	Price per unit (ZMW)	Medium productivity per household per year (in the unit of measure)
1	Maize	50 kg	Both	K180	100 x 50Kg
2	Groundnuts	5Kg (shelled)	Both	K100	10 x 5 KGs
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					

MODULE E: LIVESTOCK

Most important (livestock) products harvested in the community?

Mention the more important products (at least 8 products) (animals)

	Product (animal)	Unit of measure (e.g.: animal)	Subsistence/ Sell/ Both	Price per unit (ZMW)	Medium productivity per household per year (in the unit of measure)	Fodder (Without pasture land, how much would animal feed cost per year?)	
						Unit	Cost (ZMW)
1	Cattle	Each	Sell	K5, 000	10	They don't know, they have never bought feed for livestock	
2	Goats	Each	Both	K300	40	They don't know, they have never bought feed for livestock	
3	Pigs	Each	Both	K600	30	Buy Maize Bran	K600
4	Chickens	Each	Both	K70	60	They don't know, they have never bought feed for livestock	
5	Ducks	Each	Both	K80	60	They don't know, they have never bought feed for livestock	
6	Dogs	Each	Sell	K100	10	They don't know, they have never bought feed for livestock	
7							
8							
9							
10							

MODULE F: QUESTIONS		
Questions (Please put only one response per box)	**Response**	
1. If the community did not have water, how much would the community be willing to pay per person / year to gain access? Price (ZMW) per person per year willing to pay to consume water	K20 fixed charge per month/ household	
2. Does the community use pesticides in agriculture? Yes/ No/ Some people only	Some people only	
3. Price of pesticides for agriculture per year/ per area? 1. Area (e.g.: ha); 2. Price of pesticides for that area per year.	1. Area 0.25 Hectares	2. Price (ZMW) K700
4. Has the community experienced material damages from floods, droughts or other type of natural events in recent years? 1. Yes; 2. No.	YES	
5. Specify year and type of natural event.	Description Drought Floods	Year. 2019 2010
6. What were the costs of recovery from this event in the community? Average costs (ZMW) per household.	K5, 000	

CLOSING OF THE SESSION	
Inquirer Signature:	Emma Sitambuli
Language used in the focus group:	Bemba, Nyanja and Lenje

I. SESSION IDENTIFICATION / Women	No. of the session	2
Inquirer Name:	Christopher Sinyinza	
Province:	Central	
District:	Ngabwe	
Locality:	Chilwa Island	
Community name:	Malipilo (FGDs with women only)	
Coordinates GPS (Latitude & Longitude):		
Date & time of beginning (HH/MM):	13th October 2020; 12:15 hrs	



Photo

MODULE A: WOOD FOREST PRODUCTS (wood only)			
Product/ question	**1. Does the community collect and consume / sell wood forest products? What kind (i.e. one name / product per line)?**	**2. Unit of measure (per kind of product)**	**3. Price per unit (ZMW) (per kind of product)**
Fuelwood	Umulanda nkwale (Lenje)	Oxcart load	K80
	Umufuka (mostly used for home use and fish preservation)	Oxcart load	K80
	Mwanchunga (Lenje)	Oxcart load	K80
Commercial Timber (wood for commercial exchange)	No timber in the locality		
Domestic Timber (wood for domestic use)	Mupapa (Lenje) Afzelia quanzensis Welw (Latin)	A log with below 5cm diameter and below 3 meters height	K40.00
	Umufungufungu (Bemba) Kigelia Africana Benth (Latin)	A log with below 5cm diameter and below 3 meters height	K40.00
	Utumbili (Lenje)	A log with below 5cm diameter and below 3 meters height	K40.00

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MODULE B: NON-WOOD FOREST PRODUCTS

Most important (non-wood forest) products collected by the community?

Mention the more important products (non-wood forest products)

	Product (name input)	Unit of measure	Subsistence/ Sell/ Both	Price per unit (ZMW)	Medium productivity per household per year (in the unit of measure)
1	Utusongole (Lenje) Strychnos cocculoides (Latin)	Reed Basket (20kg)	Both	K5	20 baskets x K5 / K100
2	Impundu (bemba) Parinari Curatellifolia Planch (Latin)	Reed Basket (20kg)	Both	K5	200 baskets x K5 / K1000
3	Infilo (Lenje)	Reed Basket (2kg)	Both	K5	30 baskets x K5 / K150
4	Reeds (mostly harvested by women	Bundle of 20 reeds	Both	K20 per bundle	400 bundles x K20 / K8000
5	Ubusala (Lenje)	Bowl (estimate weight 5kg)	Both	K25	50 Bowls x k25 / K1250
6	Insoke (Lenje)	Bowl (estimate weight 5kg)	Both	K20	50 Bowls x k20 / K1000
7	Thatching grass	Bundles of grass	Both	K5 per bundle	100 bundles x 5 /K500
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MODULE C: FISH PRODUCTS

Most important (fish) products collected by the community?

Mention the more important products (fishes)

	Product (name input)	Unit of measure	Subsistence/ Sell/ Both	Price per unit (ZMW)	Medium productivity per household per year (in the unit of measure)
1	Imilonge (Lenje) Bubble fish	Each fish sold by Size and length	Both	Small in size @ K5.00 and largest @ K50	400 fish 200 fish
2	Amatuku (Bemba)	Bowl (200 grams)	Both	K12.50	150 bowls
3	Minsenga (Bemba)	Bowl (200 grams)	Both	K12.50	100 bowls
4	Tiger fish	Each fish sold by Size and length	Both	Small in size @ K5.00 and largest @ K50	200 fish 150 fish
5	Red breams	Small in size @ K5.00 and largest @ K50	Both	Small in size @ K10.00 and largest @ K30	200 fish 150 fish
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MODULE D: AGRICULTURAL PRODUCTS

Most important (agriculture) products harvested in the community?

Mention the more important products (at least 8 products) (agricultural products)

	Product (name input)	Unit of measure	Subsistence/ Sell/ Both	Price per unit (ZMW)	Medium productivity per household per year (in the unit of measure)
1	Maize	50 kg Meda (5kg)	Both	K120 per 50kg bag Meda @ K10	2000kg (50kg) 2000kg (meda)
2	Groundnuts	Meda (5kg)	Both	K120	20 bags x 50kg / 1000 kg
3	Yams	Sold each by size	Both	Small size @K2 Big size @K5	50 small size x K2 / K100 50 big size x K5 / K250
4	Sweet potatoes	Sacks (25Kg)	Both	K40	25bags x K40 / K1000
5	Pumpkin	Sold each by size	Both	Small size @K2 Big size @K5	50 small size x K2 / K100 50 big size x K5 / K250
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MODULE E: LIVESTOCK

Most important (livestock) products harvested in the community?

Mention the more important products (at least 8 products) (animals)

	Product (animal)	Unit of measure (e.g.: animal)	Subsistence/ Sell/ Both	Price per unit (ZMW)	Medium productivity per household per year (in the unit of measure)	Fodder (Without pasture land, how much would animal feed cost per year?)	
						Unit	Cost (ZMW)
1	Pigs	Each	Both	K300	10 pigs x K300 / K3000	Supplement feeding with leftover food mixed with 10 x 50 kg bags of Maize @ K25 Each	K250
2	Ducks	Each	Both	K60	10 ducks x K60 / K6 00	They are kept as free range	
3	Chickens	Sold each by size	Both	Hen @ K40 Cockerel @ K70	10 Hens x K40 /K400 4 Cockerels x K70 /K280	They are kept as free range	
4	Cattle	Sold each by size and age	Both	K4, 000	10 cows x K4000 / K40000	They are kept as free range	
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MODULE F: QUESTIONS		
Questions (Please put only one response per box)	**Response**	
1. If the community did not have water, how much would the community be willing to pay per person / year to gain access? Price (ZMW) per person per year willing to pay to consume water	K50 fixed charge per year / household	
2. Does the community use pesticides in agriculture? Yes/ No/ Some people only	Yes	
3. Price of pesticides for agriculture per year/ per area? 1. Area (e.g.: ha); 2. Price of pesticides for that area per year.	1. Area 0.25 Hectares	2. Price (ZMW) K700
4. Has the community experienced material damages from floods, droughts or other type of natural events in recent years? 1. Yes; 2. No.	Yes	
5. Specify year and type of natural event.	Description Drought Floods	Year. 2019 2010
6. What were the costs of recovery from this event in the community? Average costs (ZMW) per household.	K12 000 per household	

CLOSING OF THE SESSION	
Inquirer Signature:	Christopher Sinyinza
Language used in the focus group:	Bemba, Nyanja and Lenje

I. SESSION IDENTIFICATION	No. of the session	3
Inquirer Name:	Christopher Sinyinza	
Province:	Central	
District:	Kapiri Mposhi	
Locality:	Shamputa	
Community name:	Shamputa (FGDs with men only)	
Coordinates GPS (Latitude & Longitude):		
Date & time of beginning (HH/MM):	14th October 2020; 10:20 hrs	



Photo no. 1



Photo no. 2

MODULE A: WOOD FOREST PRODUCTS (wood only)			
Product/ question	**1. Does the community collect and consume / sell wood forest products? What kind (i.e. one name / product per line)?**	**2. Unit of measure (per kind of product)**	**3. Price per unit (ZMW) (per kind of product)**
Fuelwood	Umusamba (Lenje)	Oxcart load	K70
	Umupundu (bemba) Parinari Curatellifolia Planch (latin)	Oxcart load	K70
	Mutondo (Lenje) Cordyla Africana Lour (latin)	Oxcart load	K70
	Mubanga (bemba) Pericopsis angolensis van meeuwen (Latin)	Oxcart load	K70
Commercial Timber (wood for commercial exchange)	There is no commercial timber selling (though there were unconfirmed reports that there were trucks seen in the location transporting truckloads of timer logs to Kabwe town)		
Domestic Timber (wood for domestic use)	Mupundu (Lenje) for trusses Parinari Curatellifolia Planch (latin)	Each	K2
	Kalunguti (Lenje)	Each	K5
	Musokolobe (Lenje) making doors	Each	K10
	Mubwabwa (Lenje)	Each	K10
	Mubanga (bemba) for making support pillars) Pericopsis angolensis van meeuwen (latin)	Each	K10

MODULE B: NON-WOOD FOREST PRODUCTS

Most important (non-wood forest) products collected by the community?

Mention the more important products (non-wood forest products)

	Product (name input)	Unit of measure	Subsistence/ Sell/ Both	Price per unit (ZMW)	Medium productivity per household per year (in the unit of measure)
1	Grass for thatching houses	Bundle	Both	K5	100 Bundles
2	Fibre	Bundles (5kg)	Both	K5	20 Bundles
3	Chikanda (bemba)	Meda (5ltrs)	Both	K10	20 medas
4	Caterpillars	Meda (5ltr bucket)	Both	K80	12 medas
5	Honey	Cup (250 mls)	Both	K10	100 Cups
6	Amasuku (Wild Fruits]	Basket (10kg)	Both	K50	100 kg
7	Mushrooms	Bowl (estimate weight 5kg)	Both	K5	150 Bowls
8	Busala (lenje) edible roots	Bowl (estimate weight 5kg)	Both	K25	50 Bowls
9	Impundu (wild fruits)	Bowl (estimate weight 5kg)	Both	K20	50 Bowls
10	Infungo (wild fruits)	Bowl (estimate weight 5kg)	Both	K20	50 Bowls
11	Insole (wild fruits)	Bowl (estimate weight 5kg)	Both	K20	50 Bowls
12	Tusongole	Bowl (estimate weight 5kg)	Both	K20	50 Bowls

MODULE C: FISH PRODUCTS

Most important (fish) products collected by the community?

Mention the more important products (fishes)

	Product (name input)	Unit of measure	Subsistence/ Sell/ Both	Price per unit (ZMW)	Medium productivity per household per year (in the unit of measure)
1	Inkomo	Heap of 15 Fishes	Both	K15	40 heaps of fish
2	Mpende (bream fish)	Heap of 4 Fishes	Both	K15	100 heaps of fish
3	Ngola	Heap of 15 Fishes	Both	K15	40 heaps of fish
4	Kasepa (small fishes)	Plastic plate (750mls)	Both	K10	50 plastics plates
5	Imilonge (lenje) Bubble fish)	Heap of 15 Fishes	Both	K15	40 heaps of fish
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MODULE D: AGRICULTURAL PRODUCTS

Most important (agriculture) products harvested in the community?

Mention the more important products (at least 8 products) (agricultural products)

	Product (name input)	Unit of measure	Subsistence/ Sell/ Both	Price per unit (ZMW)	Medium productivity per household per year (in the unit of measure)
1	Maize	50 kg Meda (5kg)	Both	K120 per 50kg bag Meda @ K10	2000kg (50kg) 2000kg (meda)
2	Soya beans	Meda (5ltr container) Per kg	Both	K25 K5	140 meda x k25 meda / 3500 kg 70 bags x50kg / 3500 kg
3	Groundnuts (shelled)	Meda (5kg)	Both	K150	20 bags x 50kg / 1000 kg
4	Cow peas	140 mls plastic plate	Both	K10	1000 plates x K10 / K1000
5	Sweet potatoes	Sacks (25Kg)	Both	K50	40 bags x K50 / K2000
6	Sorghum	Meda (5kg)	Both	K10	10 bags x50kg / 500 kg
7	Sunflower	Per Kg	Both	K2	15bags x 50kg / 750kg
8	Water melon	Sold each by size	Both	Small size @K5 Big size @K15	150 small size x K5 / K750 100 big size x K15 / K1500
9	Pumpkins	Sold each by size	Both	Small size @K5 Big size @K10	50 small size x K5 / K250 50 big size x K15 / K1250
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12					

MODULE E: LIVESTOCK

Most important (livestock) products harvested in the community?

Mention the more important products (at least 8 products) (animals)

	Product (animal)	Unit of measure (e.g.: animal)	Subsistence/ Sell/ Both	Price per unit (ZMW)	Medium productivity per household per year (in the unit of measure)	Fodder (Without pasture land, how much would animal feed cost per year?)	
						Unit	Cost (ZMW)
1	Cattle	Sold each by size and age	Both	K4, 000	10 cows x K4000 / K40000	They are kept as free range	
2	Goats	Sold each by size	Both	K300	20 Goats x K300 / K6000	They are kept as free range	
3	Chickens	Sold each by size	Both	Hen @ K40 Cockerel @ K70	10 Hens x K40 /K400 4 Cockerels x K70 /K280	They are kept as free range	
4	Pigs	Each	Both	K300	10 pigs x K300 / K4000	6 x 50 kg bags of Maize @ K25 Each	K130
5	Pigeons	Each	Both	K20	50 pigeons x K20 / K1000	They are kept as free range	
6	Ducks	Each	Both	K80	50 ducks x K80 / K4000	They are kept as free range	
7	Guinea fowls	Each	Both	K70	50 guinea fowls x K70 / K3500	They are kept as free range	Guinea fowls
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MODULE F: QUESTIONS		
Questions (Please put only one response per box)	**Response**	
1. If the community did not have water, how much would the community be willing to pay per person / year to gain access? Price (ZMW) per person per year willing to pay to consume water	20 ngwee Fixed charge per month per household Per year K2.40	
2. Does the community use pesticides in agriculture? Yes/ No/ Some people only	YES – in the cotton fields	
3. Price of pesticides for agriculture per year/ per area? 1. Area (e.g.: ha); 2. Price of pesticides for that area per year.	1. Area Hectare	2. Price (ZMW) K85
4. Has the community experienced material damages from floods, droughts or other type of natural events in recent years? 1. Yes; 2. No.	Yes	
5. Specify year and type of natural event.	Description Drought experienced Dry swamps and crops withered	Year. 1995/96
6. What were the costs of recovery from this event in the community? Average costs (ZMW) per household.	On average household lost was K10,000 (average was calculated based on loss of garden inputs such as fertilizers, seeds, and the death of livestock)	

CLOSING OF THE SESSION	
Inquirer Signature:	Christopher Sinyinza
Language used in the focus group:	Bemba and Lenje

I. SESSION IDENTIFICATION	No. of the session	4
Inquirer Name:	Emma Sitambuli	
Province:	Central	
District:	Kapiri Mposhi	
Locality:	Shamputa	
Community name:	Shamputa (FGDs with women only)	
Coordinates GPS (Latitude & Longitude):		
Date & time of beginning (HH/MM):	14th October 2020; 10:25 to 12:20 hrs	
		
Photo no. 1	**Photo no. 2**	

MODULE A: WOOD FOREST PRODUCTS (wood only)			
Product/ question	**1. Does the community collect and consume / sell wood forest products? What kind (i.e. one name / product per line)?**	**2. Unit of measure (per kind of product)**	**3. Price per unit (ZMW) (per kind of product)**
Fuelwood	MUTONDO (more expensive because its fire is very hot and most preferred by fishermen)	OXCART	K100
	MUSAMBA	OXCART	K00
	MUBULA	OXCART	K80
	MUKOKA	OXCART	K70
	KALUNGUTI	OXCART	K80
Commercial Timber (wood for commercial exchange)	NOT AVAILABLE IN THE LOCATION		
Domestic Timber (wood for domestic use)	MUBANGA	EACH	K12
	CHIBOBO	EACH	K12

MODULE B: NON-WOOD FOREST PRODUCTS

Most important (non-wood forest) products collected by the community?

Mention the more important products (non-wood forest products)

	Product (name input)	Unit of measure	Subsistence/ Sell/ Both	Price per unit (ZMW)	Medium productivity per household per year (in the unit of measure)
1	THATCHING GRASS	BUNDLE	BOTH	K5	70
2	BUSANGA (REEDS - for making mats and doors) (Labour intensive)	BUNDLE	BOTH	K20	10
3	MATETE (For making baskets)	BUNDLE	SELL	K20	10
4	LWEWO (special grass for making brooms AND THATCHING ROOFS)	BUNDLE	SELL	K15	40
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MODULE C: FISH PRODUCTS

Most important (fish) products collected by the community?

Mention the more important products (fishes)

	Product (name input)	Unit of measure	Subsistence/ Sell/ Both	Price per unit (ZMW)	Medium productivity per household per year (in the unit of measure)
1	BUBBLE FISH	Each when very big (smaller fish size sold as a bundle 4)	BOTH	K15 to K35	K10, 000 (catches are high from Jan to December)
2	KASEPA	BASIN (Looks like kapenta)	BOTH	K60	K1, 000 (catches are high rom March to June)
3	MINTESA	Heap (use a basin)	BOTH	K100	K3, 000 (March)
4	KAMATA (Very tasty hence expensive)	Sold in basin (10 Litre container)	BOTH	K150	5,000 (sold from March to June)
5	MILONGE	Sold in 10 litre container	BOTH	K150	K5, 000 (women transport to Democratic Republic of Congo where there is good market in Congo)
6	BAMPATA (has a lot of sharp bones hence customers do not like them hence price i=is cheap)	Sold in 10 Litre container	BOTH	K20	K1,000 (usually exchanged for maize, it has no market value in town)
7	INKOMO (Poor market)	Sold in 10 litres	BOTH	K20	K1, 000
8	MPENDE (BREAMS) (mostly for home consumption because catches are less)	Sold according to Size, (3-5 fishes)	SELL	K15	K500
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MODULE D: AGRICULTURAL PRODUCTS

Most important (agriculture) products harvested in the community?

Mention the more important products (at least 8 products) (agricultural products)

	Product (name input)	Unit of measure	Subsistence/ Sell/ Both	Price per unit (ZMW)	Medium productivity per household per year (in the unit of measure)
1	Maize	5kg	both	May to September K10 Oct to Dec – K15 Jan- March –K25	30 x 50 KGS
2	Groundnuts	5kg	BOTH	K50	5 X 50KGS
3	Cotton	PER KGS	SELL	K3.20	400 KGS
4	Soya beans	PER KGS	SELL	K4.20	500KGS
5	Sunflower	5KG	BOTH	K25	500 KGS
6	Popcorn	5KG	BOTH	K12	500KGS
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MODULE E: LIVESTOCK

Most important (livestock) products harvested in the community?

Mention the more important products (at least 8 products) (animals)

	Product (animal)	Unit of measure (e.g.: animal)	Subsistence/ Sell/ Both	Price per unit (ZMW)	Medium productivity per household per year (in the unit of measure)	Fodder (Without pasture land, how much would animal feed cost per year?)	
						Unit	Cost (ZMW)
1	CATTLE	ANIMAL	BOTH	K5, 000	10 (majority lost them to cattle diseases)	N/A	
2	GOATS	EACH	BOTH	K350	15	N/A	
3	PIGS	EACH	BOTH	K500	20	N/A	
4	DUCKS	EACH	BOTH	K50	4 (Most of the ducks died with diseases)	N/A	
5	PIGEONS	EACH	BOTH	K10	15	N/A	
6	GUINEA FOWLS	EACH	BOTH	K60	8	N/A	
7	DOGS	EACH	SELL	K50	2	N/A	
8	CATS	EACH	SELL	NOT SOLD (they loan each other)	1	N/A	
9							
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MODULE F: QUESTIONS		
Questions (Please put only one response per box)	**Response**	
1. If the community did not have water, how much would the community be willing to pay per person / year to gain access? Price (ZMW) per person per year willing to pay to consume water	50 NGWEE	
2. Does the community use pesticides in agriculture? Yes/ No/ Some people only	YES – FARMERS THAT GROW COTTON	
3. Price of pesticides for agriculture per year/ per area? 1. Area (e.g.: ha); 2. Price of pesticides for that area per year.	1. Area HECTARE	2. Price (ZMW) K225
4. Has the community experienced material damages from floods, droughts or other type of natural events in recent years? 1. Yes; 2. No.	YES	
5. Specify year and type of natural event.	Description DROUGHT FLOODS (fields and homes – some had to camp in schools)	Year. 2017, 2018, 2019 2000,2001, 2002
6. What were the costs of recovery from this event in the community? Average costs (ZMW) per household.	K10, 000	

CLOSING OF THE SESSION	
Inquirer Signature:	
Language used in the focus group:	

I. SESSION IDENTIFICATION	No. of the session	5
Inquirer Name:	Emma Sitambuli	
Province:	Central	
District:	Kapiri Mposhi	
Locality:	Chipepo	
Community name:	Chipepo (FGDs with women only)	
Coordinates GPS (Latitude & Longitude):		
Date & time of beginning (HH/MM):	14th October 2020; 15:20 hrs	



Photo

MODULE A: WOOD FOREST PRODUCTS (wood only)			
Product/ question	**1. Does the community collect and consume / sell wood forest products? What kind (i.e. one name / product per line)?**	**2. Unit of measure (per kind of product)**	**3. Price per unit (ZMW) (per kind of product)**
Fuelwood	MUTONDO	OXCART	K50
	MUBULA	OXCART	K50
	MUSEKESE	OXCART	K50
	MUBOMBO/MUPANSE	OXCART	K50
	MUSMBA	OXCART	K50
Commercial Timber (wood for commercial exchange)	MULOMBE	20 PLANKS /PER TREE	K50
	MUBANGA	20 PLANKS /PER TREE	K50
Domestic Timber (wood for domestic use)	MUBANGA	EACH POLE	K5
	MUKOSO	EACH POLE	K5

MODULE B: NON-WOOD FOREST PRODUCTS

Most important (non-wood forest) products collected by the community?

Mention the more important products (non-wood forest products)

	Product (name input)	Unit of measure	Subsistence/ Sell/ Both	Price per unit (ZMW)	Medium productivity per household per year (in the unit of measure)
1	THATCHING GRASS	BUNDLE	BOTH	K5	40 BUNDLES
2	MASUKO (FRUITS)	BOWL (1 KG)	BOTH	K5	50KG
3	BOWA (MUSHROOMS)	BOWL (1 KG)	BOTH	K5	20KG
4	FUNGO	BOWL (1KG)	BOTH	K1	20KG
5	TUNGULU (FRUITS)	4 FRUITS	BOTH	K1	100KGS
6	BUSALA (EDIBLE ROOTS)	BOWL	BOTH	K5	50KG
7	WILD VEGETABLES	BOWL	BOTH	K3	50KG
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MODULE C: FISH PRODUCTS

Most important (fish) products collected by the community?

Mention the more important products (fishes)

	Product (name input)	Unit of measure	Subsistence/ Sell/ Both	Price per unit (ZMW)	Medium productivity per household per year (in the unit of measure)
1	KASEPA	BOWL (1 KILOGRAM)	BOTH	K10	250KGS
2	TUBEU	BOWL (1 KILOGRAM)	BOTH	K10	150KGS
3	BAMPATA (very bitter yet very common)	BOWL (1 KILOGRAM)	BOTH	K10	300KGS
4	NCHENGA	15 FISHES	BOTH	K10	150KGS
5	INGOLA	3 FISHES	BOTH	K10	50KGS
6	INKOMO	BOWL (1 KILOGRAM)	BOTH	K10	20KG (CATCHES ARE VERY LOW)
7	MALEMBA	10 FISHES	BOTH	K10	50KGS
8	MATULU	10 FISHES	BOTH	K10	50KGS
9	MPENDE	2 FISHES	BOTH	K50	50KG
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11					
12					

MODULE D: AGRICULTURAL PRODUCTS

Most important (agriculture) products harvested in the community?

Mention the more important products (at least 8 products) (agricultural products)

	Product (name input)	Unit of measure	Subsistence/ Sell/ Both	Price per unit (ZMW)	Medium productivity per household per year (in the unit of measure)
1	MAIZE	5 KILOGRAM	BOTH	MAY TO OCT PRICE IS K5 OCT TO DEC PRICE IS K10	1000 KGS
2	GROUNDNUTS	5 KILOGRAM	BOTH	K80	150KGS
3	SOYABEANS	5 KILOGRAM	BOTH	K3	500KGS
4	POPCORN	5 KILOGRAM	BOTH	K30	500KGS
5	SUNFLOWER	50 KILOGRAM	BOTH	K120	600KGS
6	SWEET POTATOES	25 KILOGRAM	BOTH	K40	750KGS
7	COTTON	KILOGRAM	SELL	K3.50/KG	1000KGS
8	COWPEAS	KILOGRAM	BOTH	K5	250KGS
9	WATER MELONS	EACH	BOTH	K10	1000 MELONS
10	PUMPKINS	EACH	BOTH	K10	500 PUMKINS
11	OKRA	25 KILOGRAM	BOTH	K40	325 KGS

MODULE E: LIVESTOCK

Most important (livestock) products harvested in the community?

Mention the more important products (at least 8 products) (animals)

	Product (animal)	Unit of measure (e.g.: animal)	Subsistence/ Sell/ Both	Price per unit (ZMW)	Medium productivity per household per year (in the unit of measure)	Fodder (Without pasture land, how much would animal feed cost per year?)	
						Unit	Cost (ZMW)
1	CATTLE	EACH	BOTH	K6000	20	NO FEED BOUGHT	
2	GOATS	EACH	BOTH	K200	10	NO FEED BOUGHT	
3	PIGS	EACH	BOTH	K500	20	NO FEED BOUGHT	
4	CHICKENS	EACH	BOTH	K50	20	NO FEED BOUGHT	
5	SHEEPS	EACH	BOTH	K500	20	NO FEED BOUGHT	
6	GUINEA FOWLS	EACH	BOTH	K45	15	NO FEED BOUGHT	
7	PIGEONS	EACH	BOTH	K20	30	NO FEED BOUGHT	
8	DUCKS	EACH	BOTH	K50	10	NO FEED BOUGHT	
9	TURKEY	EACH	BOTH	K150	6	NO FEED BOUGHT	
10	DOGS	EACH	BOTH	K50	20	NO FEED BOUGHT	
11	CATS	EACH	BOTH	NEVER SOLD	5	NO FEED BOUGHT	
12							

MODULE F: QUESTIONS		
Questions (Please put only one response per box)	**Response**	
1. If the community did not have water, how much would the community be willing to pay per person / year to gain access? Price (ZMW) per person per year willing to pay to consume water	HOUSEHOLDS PAY K20 PER FIXED AMOUNT PER MONTH (This is what they are paying now since their borehole stopped working)	
2. Does the community use pesticides in agriculture? Yes/ No/ Some people only	YES – COTTON FARMERS	
3. Price of pesticides for agriculture per year/ per area? 1. Area (e.g.: ha); 2. Price of pesticides for that area per year.	1. Area A HECTARE	2. Price (ZMW) K360
4. Has the community experienced material damages from floods, droughts or other type of natural events in recent years? 1. Yes; 2. No.	YES	
5. Specify year and type of natural event.	Description DROUGHTS FLOODS	Year 2017,2018,2019 2018.
6. What were the costs of recovery from this event in the community? Average costs (ZMW) per household.	K10, 000	

CLOSING OF THE SESSION	
Inquirer Signature:	EMMA SITAMBULI
Language used in the focus group:	TONGA AND LENJE

I. SESSION IDENTIFICATION	No. of the session	6
Inquirer Name:	Emma Sitambuli	
Province:	Central	
District:	Kapiri Mposhi	
Locality:	Mulongoti	
Community name:	Mulongoti (FGDs with women only)	
Coordinates GPS (Latitude & Longitude):		
Date & time of beginning (HH/MM):	15th October 2020; 11:30 hrs	



Photo no. 1



Photo no. 2

MODULE A: WOOD FOREST PRODUCTS (wood only)			
Product/ question	**1. Does the community collect and consume / sell wood forest products? What kind (i.e. one name / product per line)?**	**2. Unit of measure (per kind of product)**	**3. Price per unit (ZMW) (per kind of product)**
Fuelwood	MUTONDO (Have heard that firewood is sold but here no firewood is sold	OXCART	K50
	MUSAMBA	OXCART	K50
	MUBULA	OXCART	K50
	MULAMA	OXCART	K50
	MUSEKESE	OXCART	K50
Commercial Timber (wood for commercial exchange)	MULOMBE	10 PLANKS PER TREE	K100
	MUBUBA	10 PLANKS PER TREE	K100
Domestic Timber (wood for domestic use)	KALONGUTI (USED FOR MAKING POLES FOR CONSTRUCTION)	EACH	K10

MODULE B: NON-WOOD FOREST PRODUCTS

Most important (non-wood forest) products collected by the community?

Mention the more important products (non-wood forest products)

	Product (name input)	Unit of measure	Subsistence/ Sell/ Both	Price per unit (ZMW)	Medium productivity per household per year (in the unit of measure)
1	MUSHROOM	BASKET (20KG)	BOTH	K100	200KGS
2	MASUKU (WILD FRUITS)	BASKET (50KG)	BOTH	K300	100KGS
3	REEDS (WOMEN USE TO MAKE MATS)	BUNDLE (30 REEDS)	BOTH	K50	600 REEDS
4	GRASS	BUNDLE	BOTH	K6	100 BUNDLES
6	MUNKOYO ROOTS (USED TO BREW A LOCAL SWEET DRINK)	50KG VOLUME	BOTH	K90	90 BAGS X 50KGS
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MODULE C: FISH PRODUCTS

Most important (fish) products collected by the community?

Mention the more important products (fishes)

	Product (name input)	Unit of measure	Subsistence/ Sell/ Both	Price per unit (ZMW)	Medium productivity per household per year (in the unit of measure)
1	MULONGE (BUBBLE FISH)	COUNT 15 FISHES PER PACK	BOTH	K10	30 PACKS
2	KASEPA	BOWL (200GRAMS)	BOTH	K10	40 BOWLS
3	MATULU	COUNT 15 FISHES PER PACK	BOTH	K10	20 PACKS
4	MALEMBA	COUNT 15 FISHES PER PACK	BOTH	K10	20 PACKS
5	MINTESA (SMALL FISH)	BOWL (200GRAMS)	BOTH	K10 PER BOWL	50 BOWLS (HAVE GOOD MARKET)
6	NKOMO (NOT LIKED BECAUSE IT DOESN'T LOOK NICE IN THE POT)	BOWL (200GRAMS)	BOTH	K5	40 BOWLS
7	BAMPATA (HAS MANY BONES NOT LIKED BY PEOPLE HENCE IS VERY CHEAP THROUGH CATCHES ARE PLENTY)	COUNT 15 FISHES PER PACK	BOTH	K10	300 PACKS
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MODULE D: AGRICULTURAL PRODUCTS

Most important (agriculture) products harvested in the community?

Mention the more important products (at least 8 products) (agricultural products)

	Product (name input)	Unit of measure	Subsistence/ Sell/ Both	Price per unit (ZMW)	Medium productivity per household per year (in the unit of measure)
1	MAIZE	5KG (GRAIN)	BOTH	FROM MAY – JULY PRICE IS K7/5KG FROM AUG – NOV PRICE IS – K10 FROM JAN – MARCH PRICE IS K20	2,500 KILOGRAMS
2	GROUNDNUTS	5KG (SHELLED)	BOTH	K70	750 KILOGRAMS
3	SWEET POTATOES	50 KILOGRAMS	BOTH	K120	2,000 KILOGRAMS
4	SOYABEANS	KILOGRAM	BOTH	K3.50	1,000 KILOGRAMS
5	SUNFLOWER	50 KILOGRAMS	BOTH	K60	500 KILOGRAMS
6	COTTON	KILOGRAM	SELL	K3	400 KILOGRAMS
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MODULE E: LIVESTOCK

Most important (livestock) products harvested in the community?

Mention the more important products (at least 8 products) (animals)

	Product (animal)	Unit of measure (e.g.: animal)	Subsistence/ Sell/ Both	Price per unit (ZMW)	Medium productivity per household per year (in the unit of measure)	Fodder (Without pasture land, how much would animal feed cost per year?)	
						Unit	Cost (ZMW)
1	CATTTLE	EACH	BOTH	K7, 000	50	THEY DON'T BUY	
2	GOATS	EACH	BOTH	K400	20	THEY DON'T BUY	
3	CHICKENS	EACH	BOTH	K70	50	THEY DON'T BUY	
4	GUINEA FOWLS	EACH	BOTH	K50	11	THEY DON'T BUY	
5	PIGS	EACH	BOTH	K500	12	50KGS	K280 MAIZE BRAN
6	PIGEONS	PAIR	BOTH	K20	100	THEY DON'T BUY	
7	TURKEYS	EACH	BOTH	K150	5	THEY DON'T BUY	
8	DUCKS	EACH	BOTH	K60	20	THEY DON'T BUY	
9	DOGS (GUARD ANIMALS)	EACH	BOTH	K150	7	THEY DON'T BUY	
10	CATS	EACH	BOTH	NEVER SELL BUT JUST GIVE AWAY	3	THEY DON'T BUY	
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MODULE F: QUESTIONS		
Questions (Please put only one response per box)	**Response**	
1. If the community did not have water, how much would the community be willing to pay per person / year to gain access? Price (ZMW) per person per year willing to pay to consume water	K20 FIXED CHARGE PER MONTH /HOUSEHOLD	
2. Does the community use pesticides in agriculture? Yes/ No/ Some people only	YES – COTTON FARMERS MOSTLY	
3. Price of pesticides for agriculture per year/ per area? 1. Area (e.g.: ha); 2. Price of pesticides for that area per year.	1. Area HECTARE	2. Price (ZMW) K140
4. Has the community experienced material damages from floods, droughts or other type of natural events in recent years? 1. Yes; 2. No.	YES	
5. Specify year and type of natural event.	Description DROUGHTS FLOODS	Year. 2018 2000
6. What were the costs of recovery from this event in the community? Average costs (ZMW) per household.	K3, 000	

CLOSING OF THE SESSION	
Inquirer Signature:	EMMA SITAMBULI
Language used in the focus group:	LENJE AND TONGA

I. SESSION IDENTIFICATION	No. of the session	7
Inquirer Name:	Christopher Sinyinza	
Province:	Central	
District:	Kapiri Mposhi	
Locality:	Mulongoti	
Community name:	Mulongoti (FGDs with men only)	
Coordinates GPS (Latitude & Longitude):		
Date & time of beginning (HH/MM):	15th October 2020; 11:30 hrs	



Photo no. 1



Photo no. 2

MODULE A: WOOD FOREST PRODUCTS (wood only)			
Product/ question	**1. Does the community collect and consume / sell wood forest products? What kind (i.e. one name / product per line)?**	**2. Unit of measure (per kind of product)**	**3. Price per unit (ZMW) (per kind of product)**
Fuelwood (1)	Mutondo (Lenje) Cordyla Africana Lour (Latin)	Oxcart load	K80
	Kaputu (Lenje)		
	Musamba (Lenje)		
	Mukoka (Lenje)		
Commercial Timber (2) (wood for commercial exchange)	Mukwa (Bemba) Pterocarpus angolensis (Latin)	A log with below 50cm diameter and below 4 meters height	K600
	Mupapa (Lenje) Afzelia quanzensisi Welw (Latin)		
	Musase (Bemba) Albizia antunesiana Harms (Latin)		
	Mububa (Lenje)		
	Mulombe (Lenje)		
Domestic Timber (3) (wood for domestic use)	Mubanga (Bemba) Pericopsis angolensis van meeuwen (Latin)	A log with below 5cm diameter and below 3meters height	K4
	Mukoso (Lenje)		
	Musase (Lenje) Albizia antunesiana Harms (Latin)		
	Mwenge (Lenje) diplorhynchus Condylocarpon muell (Latin)		

(1) In this community, firewood is collected at household level for domestic use only. The price per unit was an estimate if they were to sell to a neighbour. It is estimated that a pile of firewood would last a minimum of 4 days, usage at the household level.

(2) There are no sawmills for cutting timber. However, the saw millers from town purchase the standing trees, cut them down and load them on trucks to town. The stated unit of measures in diameter and height is applied all tree species

(3) Domestic timber is cut to make structures of a house as trusses, timber to support walls, and making doors. The unit of measure and the unit cost is applied to all tree species.

MODULE B: NON-WOOD FOREST PRODUCTS

Most important (non-wood forest) products collected by the community?

Mention the more important products (non-wood forest products)

	Product (name input)	Unit of measure	Subsistence/ Sell/ Both	Price per unit (ZMW)	Medium productivity per household per year (in the unit of measure)
1	Grass for thatching houses	Bundle	Both	K5	75 bundles of grass
2	Tree fibre for tying the thatching roof grass	Bundles	Both	K2	30 bundles
3	Mushroom	Reed baskets (estimate weight 10kg)	Both	K50	70kg of mushroom
4	Honey	750ml plastic plate of unprocessed honey	Both	K10	20lts
6	Mpundu (Wild fruits)	Basket (20kg)	Both	K5	200 kg
7	Masuku (Wild fruits)	Basket (20kg)	Both	K300	100 kg
8	Busala (Wild fruits)	Basket (50kg)	Both	K200	100 kg
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MODULE C: FISH PRODUCTS

Most important (fish) products collected by the community?

Mention the more important products (fishes)

	Product (name input)	Unit of measure	Subsistence/ Sell/ Both	Price per unit (ZMW)	Medium productivity per household per year (in the unit of measure)
1	Kasepa (Lenje)	Plastic plate (750mls)	Both	K10	50 plastics plates
2	Imilonge (Lenje) cat fish	Heap of 15 Fishes	Both	K10	40 heaps of fish
3	Mintesa	Bowl (200Grams)	Both	K10 per bowl	70 bowls
4	Bangola (Lenje) Bubble fish	Size of fish	Both	K20 – K50	Small sizes K 200 Big sizes K500
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MODULE D: AGRICULTURAL PRODUCTS

Most important (agriculture) products harvested in the community?

Mention the more important products (at least 8 products) (agricultural products)

	Product (name input)	Unit of measure	Subsistence/ Sell/ Both	Price per unit (ZMW)	Medium productivity per household per year (in the unit of measure)
1	Cotton	Per kg	Sell	K3	400 kg
2	GROUNDNUTS	A 5 ltr plastic container called meda	Both	K80	960kg
3	Maize	A 5 ltr plastic container called meda	Both	During harvest time Price per meda is K7 The price revised in the periods August _November @K10 per meda Finally during period of January to March the price of meda is @ K20	7,000 kg 2,450 Kg 3,500kg
4	SOYABEANS	Per kg	Both	K3.50	300 Kg
5	Popcorn	Per 50 kg	Both	K60	250 kg
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MODULE E: LIVESTOCK

Most important (livestock) products harvested in the community?

Mention the more important products (at least 8 products) (animals)

	Product (animal)	Unit of measure (e.g.: animal)	Subsistence/ Sell/ Both	Price per unit (ZMW)	Medium productivity per household per year (in the unit of measure)	Fodder (Without pasture land, how much would animal feed cost per year?)	
						Unit	Cost (ZMW)
1	Chicken	Size and characteristics	Both	K70 hen K80 cockerel	50 12	Kept as free range	
2	Goats	Size and characteristics	Both	K400 female K600 male	20 15	Kept as free range	
3	Cattle	Size and characteristics	Both	K5, 000	50	Kept as free range	
4	PIGS	Size and characteristics	Both	K400	15	60kg	10 medas of maize @K10 accumulative K1000
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MODULE F: QUESTIONS		
Questions (Please put only one response per box)	**Response**	
1. If the community did not have water, how much would the community be willing to pay per person / year to gain access? Price (ZMW) per person per year willing to pay to consume water	K20 Fixed charge per household payment	
2. Does the community use pesticides in agriculture? Yes/ No/ Some people only	Yes – farmers are sullied with cotton seed and fertiliser	
3. Price of pesticides for agriculture per year/ per area? 1. Area (e.g.: ha); 2. Price of pesticides for that area per year.	1. Area Hectare	2. Price (ZMW) K140
4. Has the community experienced material damages from floods, droughts or other type of natural events in recent years? 1. Yes; 2. No.	Yes	
5. Specify year and type of natural event.	Description Droughts Floods	Year. 2018 2000
6. What were the costs of recovery from this event in the community? Average costs (ZMW) per household.	K3,500	

CLOSING OF THE SESSION	
Inquirer Signature:	Christopher Sinyinza
Language used in the focus group:	Bemba

I. SESSION IDENTIFICATION	No. of the session	8
Inquirer Name:	Christopher Sinyinza	
Province:	Central	
District:	Kapiri Mposhi	
Locality:	Chipepo	
Community name:	Chipepo (FGDs with men only)	
Coordinates GPS (Latitude & Longitude):		
Date & time of beginning (HH/MM):	15th October 2020; 15:00 hrs	



Photo

MODULE A: WOOD FOREST PRODUCTS (wood only)			
Product/ question	**1. Does the community collect and consume / sell wood forest products? What kind (i.e. one name / product per line)?**	**2. Unit of measure (per kind of product)**	**3. Price per unit (ZMW) (per kind of product)**
Fuelwood	Mutondo (Lenje) Cordyla Africana Lour (Latin)	Oxcart load	K40
	Kaputu (Bemba)	Oxcart load	K40
	Umukoka (Lenje)	Oxcart load	K40
	Umusamba (Lenje)	Oxcart load	K40
	Umupundu (Bemba) Parinari Curatellifolia Planch (Latin)	Oxcart load	K40
Commercial Timber (wood for commercial exchange)	Mukwa (Bemba) Pterocarpus angolensis (Latin)	Truck load	K800
	Umupapa (Bemba) Afzelia quanzensisi Welw (Latin)	Truck load	K800
	Umusase (Bemba) Albizia antunesiana Harms (Latin)	Truck load	K800
	Mubula (Lenje)	Truck load	K800
	Kayimbi (Bemba)	Truck load	K800
Domestic Timber (wood for domestic use)	Musase (Lenje) Albizia antunesiana Harms (Latin)	Each	K60
	Umukoso (Lenje)	Each	K30
	Mukwa (Bemba) Pterocarpus angolensis (Latin)	Each	K15
	Umubwabwa (Lenje)	Each	K15

MODULE B: NON-WOOD FOREST PRODUCTS

Most important (non-wood forest) products collected by the community?

Mention the more important products (non-wood forest products)

	Product (name input)	Unit of measure	Subsistence/ Sell/ Both	Price per unit (ZMW)	Medium productivity per household per year (in the unit of measure)
1	Grass for thatching houses	Bundle	Both	K7	100 Bundles
2	Fibre	Bundles (5kg)	Both	K10	20 Bundles
3	Rafters for houses	Oxcart	Both	K40	3 Oxcarts
4	Caterpillars	Meda (5ltr bucket)	Both	K150	12 medas
5	Honey	Cup (250 mls)	Both	K10	100 Cups
6	Amasuku (Wild Fruits]	Basket (10kg)	Both	K5	100 kg
7	Mushrooms	Bowl (estimate weight 5kg)	Both	K5	150 Bowls
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MODULE C: FISH PRODUCTS

Most important (fish) products collected by the community?

Mention the more important products (fishes)

	Product (name input)	Unit of measure	Subsistence/ Sell/ Both	Price per unit (ZMW)	Medium productivity per household per year (in the unit of measure)
1	Imilonge (Lenje) Bubble fish)	Heap of 15 Fishes	Both	K15	40 heaps of fish
2	Kasepa (small fishes)	Plastic plate (750mls)	Both	K10	50 plastics plates
3	Imintesa	Heap of 15 Fishes	Both	K15	40 heaps of fish
4	Pampata (small fishes)	Meda (5ltr)	Both	K30	70 medas
5	Mpende (bream fish)	each fish	Both	K40	K4, 000
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MODULE D: AGRICULTURAL PRODUCTS

Most important (agriculture) products harvested in the community?

Mention the more important products (at least 8 products) (agricultural products)

	Product (name input)	Unit of measure	Subsistence/ Sell/ Both	Price per unit (ZMW)	Medium productivity per household per year (in the unit of measure)
1	Maize	50 kg Meda (5kg)	Both	K120 per 50kg bag Meda @ K10	2000kg (50kg) 2000kg (meda)
2	Sorghum	Meda (5kg)	Both	K10	10 bags x50kg / 500 kg
3	Sunflower	Per Kg	Both	K2	15bags x 50kg / 750kg
4	Groundnuts (shelled)	Meda (5kg)	Both	K30	20 bags x50kg / 1000 kg
5	Soya beans	Per kg	Both	K3	70 bags x50kg / 3500 kg
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MODULE E: LIVESTOCK

Most important (livestock) products harvested in the community?

Mention the more important products (at least 8 products) (animals)

	Product (animal)	Unit of measure (e.g.: animal)	Subsistence/ Sell/ Both	Price per unit (ZMW)	Medium productivity per household per year (in the unit of measure)	Fodder (Without pasture land, how much would animal feed cost per year?)	
						Unit	Cost (ZMW)
1	Cattle	Sold each by size and age	Both	K5, 000	10 cows x K5000 / K50000	They are kept as free range	
2	Guinea fowls	Each	Both	K70	50 guinea fowls x K70 / K3500	They are kept as free range	
3	Lamb	Each	BOTH	K1500	12 lamb x K1500 / K18000	They are kept as free range	
4	Pigeons	Each	Both	K20	50 pigeons x K20 / K1000	They are kept as free range	
5	Goats	Sold each by size	Both	K350	20 Goats x K350 / K7000	They are kept as free range	
6	Pigs	Each	Both	K500	10 pigs x K500 / K5000	12 x 50 kg bags of Maize @ K25 Each	K300
7	Chickens	Sold each by size	Both	Hen @ K50 Cockerel @ K80	15 Hens x K50 / K650 6 Cockerels x 80 / K480	They are kept as free range	
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MODULE F: QUESTIONS		
Questions (Please put only one response per box)	**Response**	
1. If the community did not have water, how much would the community be willing to pay per person / year to gain access? Price (ZMW) per person per year willing to pay to consume water	K20 Fixed charge per month per household Per year K240	
2. Does the community use pesticides in agriculture? Yes/ No/ Some people only	YES – in the tomato fields	
3. Price of pesticides for agriculture per year/ per area? 1. Area (e.g.: ha); 2. Price of pesticides for that area per year.	1. Area Hectare	2. Price (ZMW) K40
4. Has the community experienced material damages from floods, droughts or other type of natural events in recent years? 1. Yes; 2. No.	Yes	
5. Specify year and type of natural event.	Description Drought experienced dry wells, less rainfall and river grazing areas dry	Year. 2016
6. What were the costs of recovery from this event in the community? Average costs (ZMW) per household.	On average household lost was K17,000 (average was calculated based on loss of garden inputs such as fertilizers, seeds, and the death of livestock)	

CLOSING OF THE SESSION	
Inquirer Signature:	Christopher Sinyinza
Language used in the focus group:	Bemba and Lenje

I. SESSION IDENTIFICATION	No. of the session	9
Inquirer Name:	Emma Sitambuli	
Province:	Central	
District:	Kapiri Mposhi	
Locality:	Waya	
Community name:	Waya (FGDs with men only)	
Coordinates GPS (Latitude & Longitude):		
Date & time of beginning (HH/MM):	16th October 2020	



Photo no. 1



Photo no. 2

MODULE A: WOOD FOREST PRODUCTS (wood only)			
Product/ question	**1. Does the community collect and consume / sell wood forest products? What kind (i.e. one name / product per line)?**	**2. Unit of measure (per kind of product)**	**3. Price per unit (ZMW) (per kind of product)**
Fuelwood	MUKOKA	OXCART	K50
	MUTONDO – VERY GOOD IN FISH PRESERVATION)	OXCART	K50
	MULAMA	OXCART	K50
	CHIBOBO (FISH PRESERVATION)	OXCART	K50
	MUSOMBO	OXCART	K50
Commercial Timber (wood for commercial exchange)	N/A – THERE IS NO TIMBER IN THE LOCATION		
Domestic Timber (wood for domestic use)	MUTONDO	EACH	K10
	MUSALALYA	EACH	K10
	MUSEKESE	EACH	K10
	MUSOKOLOBE	EACH	K10
	MUBANGA	EACH	K10

MODULE B: NON-WOOD FOREST PRODUCTS

Most important (non-wood forest) products collected by the community?

Mention the more important products (non-wood forest products)

	Product (name input)	Unit of measure	Subsistence/ Sell/ Both	Price per unit (ZMW)	Medium productivity per household per year (in the unit of measure)
1	GRASS	BUNDLE	BOTH	K5	100 BUNDLES
2	FIBRE (LOSHI)	BUNDLES (10KG)	BOTH	K15	5 BUNDLES
3	RUNNERS	OXCART	BOTH	30	7 OXCART
4	SOIL (BRICKS)	EACH	BOTH	K1.50	5,000 BRICKS
5	HONEY	CUP (250 MLS)	SUBSISTENCE	K15	100 CUPS
6	WILD FRUITS	PLATE (200GRAMS)	BOTH	K5	500KGS
7	MUSHROOM - KAUYUMBWE	BOWL	BOTH	K3	150 BASKETS
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MODULE C: FISH PRODUCTS

Most important (fish) products collected by the community?

Mention the more important products (fishes)

	Product (name input)	Unit of measure	Subsistence/ Sell/ Both	Price per unit (ZMW)	Medium productivity per household per year (in the unit of measure)
1	BUBLE FISHE	COUNT 5 (3 INCHES SIZE) OF FISHES	BOTH	K20	K1, 500 (IT WAS EASY TO COME UP WITH HOW MUCH MONEY THEY MAKE PER SEASON INSTEAD OF WEIGHTS OF TOTALS FISH CATCHES)
2	MPENDE (WHITE BREAM	COUNT 3 (3.5 INCHES SIZE) OF FISHES	BOTH	K20	K10, 000
3	AFRICAN PIKE (SHIMWENGE)	COUNT 3 (3 INCHES SIZE)	BOTH	K15	K10, 000
4	MATULU (DRARF BREAM)	COUNT 8 (2 INCHES IN SIZE)	BOTH	K5	K1, 200
5	MISENGA (STRIPPED ROBBER)	COUNT 30 (1 INCHE IN SIZE)	BOTH	K5	K5, 000
6	MALEMBA (RARELY SEEN - BUT IS THE MOST PREFERED BY PEOPLE)	COUNT FIVE (5) FISHES	BOTH	K20	K15, 000
7	MAKOBO (LARGE MOUTH BREAM)	COUNT EIGHT (8) OF FISHES	BOTH	K10	K10, 000
8	IMBILYA (YELLOW BREAM)	COUNT EIGHT (8) OF FISHES	BOTH	K10	K10, 000
9	BAMBATA (USUALLY DONATED FOR FREE – NO VALUE)	BUCKET CALLED MEDA (5KGS)	BOTH	K30	K3, 000
10	INKULAKULA (RED BREAM)	BUCKET CALLED MEDA (5KGS)	BOTH		K10, 000
11	KASEPA (	BUCKET CALLED MEDA (5KGS)	BOTH	K30	K3, 000

MODULE D: AGRICULTURAL PRODUCTS

Most important (agriculture) products harvested in the community?

Mention the more important products (at least 8 products) (agricultural products)

	Product (name input)	Unit of measure	Subsistence/ Sell/ Both	Price per unit (ZMW)	Medium productivity per household per year (in the unit of measure)
1	MAIZE	50 KGS 5KGS (K10)	BOTH	MAY – JULY – 120 AUG –DEC – 15 180 (50KG)	30 X 50KGS
2	COTTON	KILOGRAM	BOTH	K3.50	600KG
3	SOYA BEANS	KILOGRAM	BOTH	K5.50	10 X50KGS
4	GROUNDNUTS	5KGS	BOTH	K30	10 X50KGS
5	SUNFLOWER	50KGS	BOTH	K2	15 X50KGS
6	OKRA	HALF KILOGRAM	BOTH	K5	5OKG
7	MIYUNGU	COUNT SEVEN (7) FRUITS	SUBSISTENCE	K1	20 X 50KGS VOLUME
8	PUNPMKIN	EACH	BOTH	K5	600 PUMPKINS
9	SWEET POTATOES	BUCKET (10KGS	BOTH	K10	K300 PER OXCART (CAN HARVEST UPTO 5 OXCATS)
10	SORGHUM	5KGS	BOTH	K10	500KGS
12					

MODULE E: LIVESTOCK

Most important (livestock) products harvested in the community?

Mention the more important products (at least 8 products) (animals)

	Product (animal)	Unit of measure (e.g.: animal)	Subsistence/ Sell/ Both	Price per unit (ZMW)	Medium productivity per household per year (in the unit of measure)	Fodder (Without pasture land, how much would animal feed cost per year?)	
						Unit	Cost (ZMW)
1	CATTLE	EACH	BOTH	K7, 000	10	THEY DON'T BUY FEED	
2	GOATS	EACH	BOTH	K300	30	THEY DON'T BUY FEED	
3	CHICKENS	EACH	BOTH	K50	20	THEY DON'T BUY FEED	
4	PIGEIONS	EACH	BOTH	K20	50	THEY DON'T BUY FEED	
5	GUINEA FOWLS	EACH	BOTH	K70	50	THEY DON'T BUY FEED	
6	DUCKS	EACH	BOTH	K60	20	THEY DON'T BUY FEED	
7	SHEEP	EACH	BOTH	K1, 000	15	THEY DON'T BUY FEED	
8	PIGS	EACH	BOTH	K600	10 (MOST DIED OF DISEASES)	12 X50KGS MAIZE BRAN COSTING K25 EACH	K300
9	DOGS	EACH	BOTH	K20	8	THEY DON'T BUY FEED	
10	RABBITS CATS (NEVER SOLD)	EACH	BOTH	K30	2	THEY DON'T BUY FEED	
12							

MODULE F: QUESTIONS		
Questions (Please put only one response per box)	**Response**	
1. If the community did not have water, how much would the community be willing to pay per person / year to gain access? Price (ZMW) per person per year willing to pay to consume water	K20 FIXED PRICE PER MONTH AND HOUSEHOLD	
2. Does the community use pesticides in agriculture? Yes/ No/ Some people only	YES – COTTON FARMERS	
3. Price of pesticides for agriculture per year/ per area? 1. Area (e.g.: ha); 2. Price of pesticides for that area per year.	1. Area HECTARE	2. Price (ZMW) K120
4. Has the community experienced material damages from floods, droughts or other type of natural events in recent years? 1. Yes; 2. No.	YES	
5. Specify year and type of natural event.	Description DROUGHT	Year. 2007
6. What were the costs of recovery from this event in the community? Average costs (ZMW) per household.	K25, 000 (AVERAGE OF 8 PEOPLE PER HOUSEHOLD - AMOUNT IS LESS FOR SMALLER HOUSEHOLDS)	

CLOSING OF THE SESSION	
Inquirer Signature:	EMMA SITAMBULI
Language used in the focus group:	LENJE AND TONGA

I. SESSION IDENTIFICATION	No. of the session	10
Inquirer Name:	Emma Sitambuli	
Province:	Central	
District:	Kapiri Mposhi	
Locality:	Waya	
Community name:	Waya (FGDs with women only)	
Coordinates GPS (Latitude & Longitude):		
Date & time of beginning (HH/MM):	16th October 2020	



Photo no. 1



Photo no. 2

MODULE A: WOOD FOREST PRODUCTS (wood only)			
Product/ question	**1. Does the community collect and consume / sell wood forest products? What kind (i.e. one name / product per line)?**	**2. Unit of measure (per kind of product)**	**3. Price per unit (ZMW) (per kind of product)**
Fuelwood	MULAMA	OXCART	K70
	CHIBOBO	OXCART	K70
	MUTONDO	OXCART	K70
	MUKOKA	OXCART	K70
	MUSEKESE	OXCART	K70
Commercial Timber (wood for commercial exchange)	MUBULA	4 PLANKS PER TREE	K100 DOOR DOOR FRAME K50
	MUKOMBOLA	4 PLANKS PER TREE	K100 DOOR
	MUFWA	4 PLANKS PER TREE	DOOR FRAME K50
	MUBUBA	4 PLANKS PER TREE	K100 DOOR
Domestic Timber (wood for domestic use)	MUBANGA	EACH	K5
	MWENGE	EACH	K5
	MUSEKESE	EACH	K5
	CHIMPAPA	EACH	K5
	MUSWAMALOBA	EACH	K5

MODULE B: NON-WOOD FOREST PRODUCTS

Most important (non-wood forest) products collected by the community?

Mention the more important products (non-wood forest products)

	Product (name input)	Unit of measure	Subsistence/ Sell/ Both	Price per unit (ZMW)	Medium productivity per household per year (in the unit of measure)
1	FIREWOOD	10 PIECES OF WOOD	BOTH	K10	K1, 200
2	GRASS	BUNDLE	BOTH	K5	100 BUNDLES
3	WILD FRUITS	BOWL (200GRAMS)	BOTH	K5	K500
4	MUSHROOM	COUNT THREE (3) BIG MUSHROOM	BOTH	K10	K100
5	BUSALA (EDIBLE ROOTS	5KGS	BOTH	K10	K1, 000
6					
7					
8					
9					
10					
11					
12					

MODULE C: FISH PRODUCTS

Most important (fish) products collected by the community?

Mention the more important products (fishes)

	Product (name input)	Unit of measure	Subsistence/ Sell/ Both	Price per unit (ZMW)	Medium productivity per household per year (in the unit of measure)
1	MATULU (DWARF BREAMS)	COUNT TEN (10) FISHES	BOTH	K10	K3, 000
2	BANGOLA (BUBBLE FISH)	COUNT FOUR (4) FISHES	BOTH	K30	K2, 500
3	MPENDE (RED BREASTED BREAMS)	EACH	BOTH	K30	K10, 000
4	IMBILYA (YELLOW BREAMS)	COUNT SIX (6) FISHES	BOTH	K15	K3, 000
5	BASHIMWENGE (AFRICAN PIKE)	COUNT FOUR (4) FISHES	BOTH	K20	K3, 000
6	MISENGA (STRIPPED ROBBER)	COUNT (35) FISHES	BOTH	K10	K5, 000
7	IMILONGE (CATFISH)	BOWL (200 GRAMS)	BOTH	K10	K3, 000
8	MAKOBO (LARGE MOUTH BREAMS)	COUNT EIGHT (8) FISHES	BOTH	K15	K3, 000
9	CHITAKA /KASEPA (MIXTURE OF SMALL FISHES)	5KGS	BOTH	K100	K8, 000
10	MINTESA (*MARCUSAS-MACROLEPEIDOS*)	COUNT EIGHT (8) FISHES	BOTH	K20	K5, 000
12					

MODULE D: AGRICULTURAL PRODUCTS

Most important (agriculture) products harvested in the community?

Mention the more important products (at least 8 products) (agricultural products)

	Product (name input)	Unit of measure	Subsistence/ Sell/ Both	Price per unit (ZMW)	Medium productivity per household per year (in the unit of measure)
1	MAIZE	50KGS	BOTH	K150	400 X50KGS
2	GROUNDNUTS	5KGS	BOTH	K70	3 X 50KGS
3	SUNFLOWER	5KGS	BOTH	K10	40 X50KGS
4	SOYABEANS	50KGS	BOTH	K300	50 X 50KGS
5	COWPEAS	5KGS	BOTH	K50	20 X50KGS
7	OKRA	5KGS	BOTH	K20	2 X50KGS
8	PUMPKINS	EACH	BOTH	K10	600 PUMPKINS
9	SWEET POTATOES	MEASURE IN BUCKETS (10KGS)	BOTH	K10	1000KGS
10					
11					
12					

MODULE E: LIVESTOCK

Most important (livestock) products harvested in the community?

Mention the more important products (at least 8 products) (animals)

	Product (animal)	Unit of measure (e.g.: animal)	Subsistence/ Sell/ Both	Price per unit (ZMW)	Medium productivity per household per year (in the unit of measure)	Fodder (Without pasture land, how much would animal feed cost per year?)	
						Unit	Cost (ZMW)
1	CATTLE	EACH		K6000	10	THEY DON'T BUY FEED	
2	GOATS	EACH		K300	50	THEY DON'T BUY FEED	
3	PIGS	EACH		K600	3	4 X50 BAGS PER MONTH (K25)	K1, 500
4	SHEEP	EACH		K500	10	THEY DON'T BUY FEED	
5	CHICKENS	EACH		K50	50	THEY DON'T BUY FEED	
6	DUCKS	EACH		K70	10	THEY DON'T BUY FEED	
7	PIGEONS	EACH		K20	60	THEY DON'T BUY FEED	
8	GUINEA FOWLS	EACH		K70	10	THEY DON'T BUY FEED	
9	DOGS	EACH		K100	3	THEY DON'T BUY FEED	
10	CATS	EACH		NEVER SOLD		THEY DON'T BUY FEED	
11							
12							

MODULE F: QUESTIONS		
Questions (Please put only one response per box)	**Response**	
1. If the community did not have water, how much would the community be willing to pay per person / year to gain access? Price (ZMW) per person per year willing to pay to consume water	K20 FIXED CHARGE PER MONTH AND HOUSEHOLD.	
2. Does the community use pesticides in agriculture? Yes/ No/ Some people only	SOME PEOPLE ONLY (WEED KILLERS - HERBICIDES)	
3. Price of pesticides for agriculture per year/ per area? 1. Area (e.g.: ha); 2. Price of pesticides for that area per year.	1. Area HECTARES	2. Price (ZMW) K2000
4. Has the community experienced material damages from floods, droughts or other type of natural events in recent years? 1. Yes; 2. No.	YES	
5. Specify year and type of natural event.	Description DROUGHTS FLOODS	Year. 2018 2019
6. What were the costs of recovery from this event in the community? Average costs (ZMW) per household.	K6, 000	

CLOSING OF THE SESSION	
Inquirer Signature:	EMMA SITAMBULI
Language used in the focus group:	BEMBA AND LENJE

I. SESSION IDENTIFICATION	No. of the session	11
Inquirer Name:	Emma Sitambuli	
Province:	Central	
District:	Mumbwa	
Locality:	Kaingu Chiefdom	
Community name:	Mpusu (FGDs with men only)	
Coordinates GPS (Latitude & Longitude):	-14.459579S 27.062837E	
Date & time of beginning (HH/MM):	19th October 2020	



Photo no. 1



Photo no. 2

MODULE A: WOOD FOREST PRODUCTS (wood only)			
Product/ question	**1. Does the community collect and consume / sell wood forest products? What kind (i.e. one name / product per line)?**	**2. Unit of measure (per kind of product)**	**3. Price per unit (ZMW) (per kind of product)**
Fuelwood	MUTONDO (GOOD FOR PRESERVATION – GIVES A BROWN COLOR	OXCART	K40
	MUKOKA	OXCART	K40
	PANSE	OXCART	K40
	MUBANGA	OXCART	K40
	MULAMA	OXCART	K40
Commercial Timber (wood for commercial exchange)	MUKWA (ONE TREE GIVES 15-20 PLANKS)	EACH	K30
	MUPAPA	EACH	K30
	MUNENGENE	EACH	K30
	MULULU	EACH	K30
Domestic Timber (wood for domestic use)	MUKWA	EACH	K15
	MUBANGA	EACH	K15
	MUKOSO	EACH	K15
	MUSASE	EACH	K15
	NDALE	EACH	K15

MODULE B: NON-WOOD FOREST PRODUCTS

Most important (non-wood forest) products collected by the community?

Mention the more important products (non-wood forest products)

	Product (name input)	Unit of measure	Subsistence/ Sell/ Both	Price per unit (ZMW)	Medium productivity per household per year (in the unit of measure)
1	MUNKOYO ROOTS	BUNDLE (50KG BAG VOLUME)	BOTH	K45	20 X 50KG BAGS BY VOLUME
2	FIBRES	BUNDLE	BOTH	K15	10 BUNDLES
3	MUSHROOM	EACH	BOTH	K15	30 MUSHROOMS
4	GRASS	BUNDLE	BOTH	K7	50 BUNDLES
5	FRUITS (MASUKU)	PLATE	BOTH	K5	5 BUCKETS
6	BRICKS (BURNT)	EACH	BOTH	K1	30,000 BRICKS
7					
8					
9					
10					
11					
12					

MODULE C: FISH PRODUCTS

Most important (fish) products collected by the community?

Mention the more important products (fishes)

	Product (name input)	Unit of measure	Subsistence/ Sell/ Both	Price per unit (ZMW)	Medium productivity per household per year (in the unit of measure)
1	IMBILYA (2.5 INCHES)	12 FISHES	BOTH	K12	K, 1000
2	MUTANDANSWI (4 INCHES)	3 FISHES	BOTH	K12	K3, 000
3	INKULALA	3 FISHES	BOTH	K12	K3, 000
4	BOTTLE FISH	3 FISHES	BOTH	K12	K3, 000
5	ILEMBA /MINTESA	12 FISHES	BOTH	K12	K1, 000
6	CHINYIMBA (1 INCH)	PLATE	BOTH	K10	K5, 000 (THERE IS PLENTY
7	WAMUNYIMA	3 FISHES	BOTH	K12	K3, 000
8	TIGER FISH (3 INCHES	3 FISHES	BOTH	K12	K1, 000 (CAUGHT ONLY FOR TWO WEEKS IN NOVEMBER)
9	MPENDE	3 FISHES	BOTH	K12	K500 (LOW CATCHES – IN THE PAST TEHRE WAS PLENTY)
10					
11					

MODULE D: AGRICULTURAL PRODUCTS

Most important (agriculture) products harvested in the community?

Mention the more important products (at least 8 products) (agricultural products)

	Product (name input)	Unit of measure	Subsistence/ Sell/ Both	Price per unit (ZMW)	Medium productivity per household per year (in the unit of measure)
1	MAIZE	50KGS	BOTH	MAY – AUG – K95 SEPT – DEC - K120 JAN –MAR- K240	60 X 50KGS
2	SOYABEANS	50KG	BOTH	K225	20 X 50KGS
3	COTTON	KILOGRAM	BOTH	K3.70	600KGS
4	GROUNDNUTS	5KG	BOTH	K50	5 X 50KGS
5	COWPEAS	50KGS	BOTH	K180	15 X 50KG
6	VEGETABLES	50KG BAG VOLUME	BOTH	K50	4 X50KGS
7	CABAGGES	EACH	BOTH	K4	1000 HEADS
8					
9					
11					
12					

MODULE E: LIVESTOCK

Most important (livestock) products harvested in the community?

Mention the more important products (at least 8 products) (animals)

	Product (animal)	Unit of measure (e.g.: animal)	Subsistence/ Sell/ Both	Price per unit (ZMW)	Medium productivity per household per year (in the unit of measure)	Fodder (Without pasture land, how much would animal feed cost per year?)	
						Unit	Cost (ZMW)
1	CATTLE	EACH	BOTH	K5, 000	12	DON'T BUY	
2	GOATS	EACH	BOTH	K250	15	DON'T BUY	
3	PIGS	EACH	BOTH	K800	10	50KG X K30	K500
4	CHICKENS	EACH	BOTH	K50	20	DON'T BUY	
5	DUCKS	EACH	BOTH	K70	8	DON'T BUY	
6	DOGS	EACH	BOTH	K150	7	DON'T BUY	
7	PIGEONS	EACH	BOTH	K14	50	DON'T BUY	
8	GUINEA FOWLS	EACH	BOTH	K50	20	DON'T BUY	
11							
12							

MODULE F: QUESTIONS		
Questions (Please put only one response per box)	**Response**	
1. If the community did not have water, how much would the community be willing to pay per person / year to gain access? Price (ZMW) per person per year willing to pay to consume water	K2O FIXED CHARGE PER MONTH	
2. Does the community use pesticides in agriculture? Yes/ No/ Some people only	SOME PEOPLE ONLY COTTON FARMERS HERBICIDES	
3. Price of pesticides for agriculture per year/ per area? 1. Area (e.g.: ha); 2. Price of pesticides for that area per year.	1. Area HECTARE Hectare (herbicides	2. Price (ZMW) K190 (Pack of pesticides) K600 (Herbicides)
4. Has the community experienced material damages from floods, droughts or other type of natural events in recent years? 1. Yes; 2. No.	Yes	
5. Specify year and type of natural event.	Description Drought/ dry spell Floods	Year. 2019 2000
6. What were the costs of recovery from this event in the community? Average costs (ZMW) per household.	K15, 000	

CLOSING OF THE SESSION	
Inquirer Signature:	EMMA SITAMBULI
Language used in the focus group:	LAMBA AND NYANJA

I. SESSION IDENTIFICATION	No. of the session	12
Inquirer Name:	Emma Sitambuli	
Province:	Central	
District:	Mumbwa	
Locality:	Kaingu Chiefdom	
Community name:	Mpusu (FGDs with women only)	
Coordinates GPS (Latitude & Longitude):	-14.459579S 27.062837E	
Date & time of beginning (HH/MM):	19th October 2020	
		
Photo no. 1	**Photo no. 2**	

MODULE A: WOOD FOREST PRODUCTS (wood only)			
Product/ question	**1. Does the community collect and consume / sell wood forest products? What kind (i.e. one name / product per line)?**	**2. Unit of measure (per kind of product)**	**3. Price per unit (ZMW) (per kind of product)**
Fuelwood	MUTONDO	OX CART	K50
	MISAMBA	OX CART	K50
	PANSE	OX CART	K50
	MILAMA	OX CART	K50
	MUBANGA	OX CART	K50
Commercial Timber (wood for commercial exchange)	MUPAPA (EACH TREE PRODUCES 15 PLANKS USED IN CONSTRUCTION)	EACH PLANK	K40 PER PLANK
	MILUNGU	EACH PLANK	K40 PER PLANK
	NDOMBE	EACH PLANK	K40 PER PLANK
Domestic Timber (wood for domestic use)	KATENGE	EACH	K5
	NDOMBE	EACH	K5
	MPUNDU	EACH	K5

MODULE B: NON-WOOD FOREST PRODUCTS

Most important (non-wood forest) products collected by the community?

Mention the more important products (non-wood forest products)

	Product (name input)	Unit of measure	Subsistence/ Sell/ Both	Price per unit (ZMW)	Medium productivity per household per year (in the unit of measure)
1	BUSALA	50KGS VOLUME	BOTH	K200	CAN HARVEST 5 X 50KGS BAGS
2	IMPAMA	50KGS	BOTH	K50	50 KGS
3	THATCHING GRASS	BUNDLE	BOTH	K5	60 BUNDLES
4	MUNKOYO	50KGS	BOTH	K30	500KGS
5	CATERPILLARS	5KG	BOTH	K50	100KGS
6					(Population increase has reduced quantities of non-wood forest products)
7					
8					
9					
10					
11					
12					

MODULE C: FISH PRODUCTS

Most important (fish) products collected by the community?

Mention the more important products (fishes)

	Product (name input)	Unit of measure	Subsistence/ Sell/ Both	Price per unit (ZMW)	Medium productivity per household per year (in the unit of measure)
1	MPENDE	EACH	BOTH	K20	K800
2	MUBONDO	EACH	BOTH	K20	K1, 000
3	KASEPA	5KG	BOTH	K50	K300
4	MALEMBA (SMALL FISHES)	COUNT 12 FISHES	BOTH	K20	K1, 000
5	CHINYIMBA	5KG	BOTH	K30	K500
6	(It was much easier for the respondents to determine the incomes rather than quantities harvested per season)				
7					
8					
9					
10					
11					
12					

MODULE D: AGRICULTURAL PRODUCTS

Most important (agriculture) products harvested in the community?

Mention the more important products (at least 8 products) (agricultural products)

	Product (name input)	Unit of measure	Subsistence/ Sell/ Both	Price per unit (ZMW)	Medium productivity per household per year (in the unit of measure)
1	MAIZE	50KGS	BOTH	MAY –JULY K75 AUG – OCT –K110 NOV-DEC- K200 JAN – MAR – K300	30 X50KGS (prices of maize grain varies across the year depending on market forces of supply and demand)
2	SOYABEAN	50KGS	BOTH	K215	50 X 50KGS
3	GROUNDNUTS	5KG	BOTH	K40	2 X 50KGS (SHELLED
4	BEANS	5KGS	BOTH	K80	2 X 50KGS
5	SUNFLOWER	50KGS	BOTH	K80	5 X50KGS
6					
7					
8					
9					
10					
11					

MODULE E: LIVESTOCK

Most important (livestock) products harvested in the community?

Mention the more important products (at least 8 products) (animals)

	Product (animal)	Unit of measure (e.g.: animal)	Subsistence/ Sell/ Both	Price per unit (ZMW)	Medium productivity per household per year (in the unit of measure)	Fodder (Without pasture land, how much would animal feed cost per year?)	
						Unit	Cost (ZMW)
1	CATTLE	EACH	SELL	K3, 000	15	They don't buy	
2	PIGS	EACH	BOTH	K800	15	4 X 50KG @K35 EACH/ MONTH	K1, 680
3	GOATS	EACH	BOTH	K300	10	They don't buy	
4	CHICKENS	EACH	BOTH	K35	20	They don't buy	
5	DUCKS	EACH	BOTH	K50	20	They don't buy	
6	GUINEA FOWLS	EACH	BOTH	K50	10	They don't buy	
7	SHEEP	EACH	BOTH	K1,000	50	They don't buy	
8							
11							
12							

MODULE F: QUESTIONS		
Questions (Please put only one response per box)	**Response**	
1. If the community did not have water, how much would the community be willing to pay per person / year to gain access? Price (ZMW) per person per year willing to pay to consume water	K20 FIXED CHARGE PER HOUSEHOLD PER MONTH	
2. Does the community use pesticides in agriculture? Yes/ No/ Some people only	SOME PEOPLE ONLY	
3. Price of pesticides for agriculture per year/ per area? 1. Area (e.g.: ha); 2. Price of pesticides for that area per year.	1. Area HECTARE	2. Price (ZMW) K175 (PESTICIDES) K600 (HERBICIDES
4. Has the community experienced material damages from floods, droughts or other type of natural events in recent years? 1. Yes; 2. No.	YES	
5. Specify year and type of natural event.	Description DROUGHT	Year 2019.
6. What were the costs of recovery from this event in the community? Average costs (ZMW) per household.	K6, 000	

CLOSING OF THE SESSION	
Inquirer Signature:	EMMA SITAMBULI
Language used in the focus group:	NYANJA AND LAMBA

Appendix 2 – Environmental quality assessment

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CONSERVATION PLAN FOR LUKANGA SWAMP AND UPPER KAFUE BASIN

Environmental quality assessment

TABLE OF CONTENTS

1. Introduction; scope and methodology 1

1.1. Field sampling and sample preparation 2

2. Groundwater (well water) 9

2.1. Description of results 9

2.2. Comparison to guideline values 13

2.3. Assessment of contamination 16

2.3.1. Nitrates 16

2.3.2. Organic contamination 16

2.3.3. Trace metals 17

3. Surface water 19

3.1. Description of results 19

3.2. Water uses and comparison to guideline values 32

3.3. Assessment of contamination 40

3.3.1. Nitrates 40

3.3.2. Organic contamination 40

3.3.3. Trace metals 41

4. Sediment **43**

4.1. Grain-size analysis 43

4.2. Chemical analyses 46

4.3. Comparison with quality guidelines 203

4.4. Assessment of contamination 205

4.4.1. Concentrations of Pb and Zn 205

4.4.2. Enrichment factors 206

5. Leaves **213**

5.1. Comparison with reference values; assessment of contamination 217

6. Discussion **219**

6.1. Upper Kafue River Basin 219

6.2. Lukanga Swamp 220

6.2.1. Main water quality problems of the Lukanga Swamp 220

6.2.2. Hydrodynamics of the Lukanga Swamp inferred from water characteristics 222

6.2.3. Effects of the mining activities from the Copperbelt Province 223

7. Conclusion **225**

8. References **227**

Appendix A – Description of the sampling stations **229**

Appendix B – Parameters analysed and laboratory procedures **237**

Appendix C – Laboratory results **241**

Appendix D – Spatial distribution of the parameters determined in the sampled media **387**

1. Introduction; scope and methodology

That ecosystem services of the Lukanga Swamp have been degraded over the past decades is undisputed (*e.g.,* McCartney *et al*., 2011). However, the factors that have led to this degradation are not always clear. Chemical pollution is highlighted in some documents (*e.g.,* Terms of Reference for conducting this Conservation Plan) as one of these drivers, together with others such as loss of natural habitat, unsustainable resource use, drying of the wetlands, droughts, and overgrowing of weeds.

The main goal of the present assessment is to evaluate the current state of the Lukanga Swamp in what concerns chemical pollution in different media. It includes the Upper Kafue Basin as it is directly linked to the area of interest and may function as a source of chemicals to the swamp.

This assessment will allow understanding if chemical pollution is a driver of ecosystem services' degradation in the Lukanga Swamp, possible sources for those potential chemicals and stablishing measures to minimize the degradation.

The assessment of the contamination existing in the Lukanga Swamp and Kafue basin upstream uses primary data specifically obtained for this purpose, but also data from other previous studies that have been carried out in Zambia, particularly in the Copperbelt area or in the Lukanga Swamp (e.g. Pettersson, 2002; Kříbek *et al*., 2011; Hunink *et al*., 2017).

Physical and chemical data were obtained in surface water, groundwater, stream/swamp sediments and leaves from *Phragmites* spp in two campaigns conducted in September and October 2019.

General procedures used in those campaigns and their results are presented in the sections below.

1.1. Field sampling and sample preparation

The two field campaigns were done between 6 and 14 of September 2019 and between 10 and 23 of October 2019.

During these campaigns the following type and number of samples were collected (Figure 1 and Figure 2):

- Surface water (42 samples);
- Groundwater (14 samples);
- Stream/swamp sediments (21 samples);
- Leaves (*Phragmites* spp.) (10 samples).



Figure 1 – Acquiring *in-situ* surface water parameters (left) and collecting leaves of *Phragmites* spp. in a stream (right)



Figure 2 – Acquiring groundwater samples from well (left) and collecting sediment sample in the Kafue River (right)

The location of sampling points for the different media are depicted in Figure 3, Figure 4, Figure 5 and Figure 6. The station reference may use “Oc” or “S” after the station number as an indication of the month when the sample was collected: October or September 2019, respectively.

Geographical coordinates and a description of the different sampling stations can be found in Note 1 (end of this Appendix).

The parameters analysed and laboratory procedures are presented in Note 2.

Original results from the laboratories are presented in Note 3 and analysed parameters are shown in maps in Note 4.

Surface water was collected in streams from the Upper Kafue River Basin or at the Lukanga Swamp area (including the actual swamp and streams draining into it). In the Upper Kafue River Basin, the sampling focused in the streams affected by mining activities, however the other basins (Lufwanyama, Luswishi and Kafulafuta rivers) were also sampled.

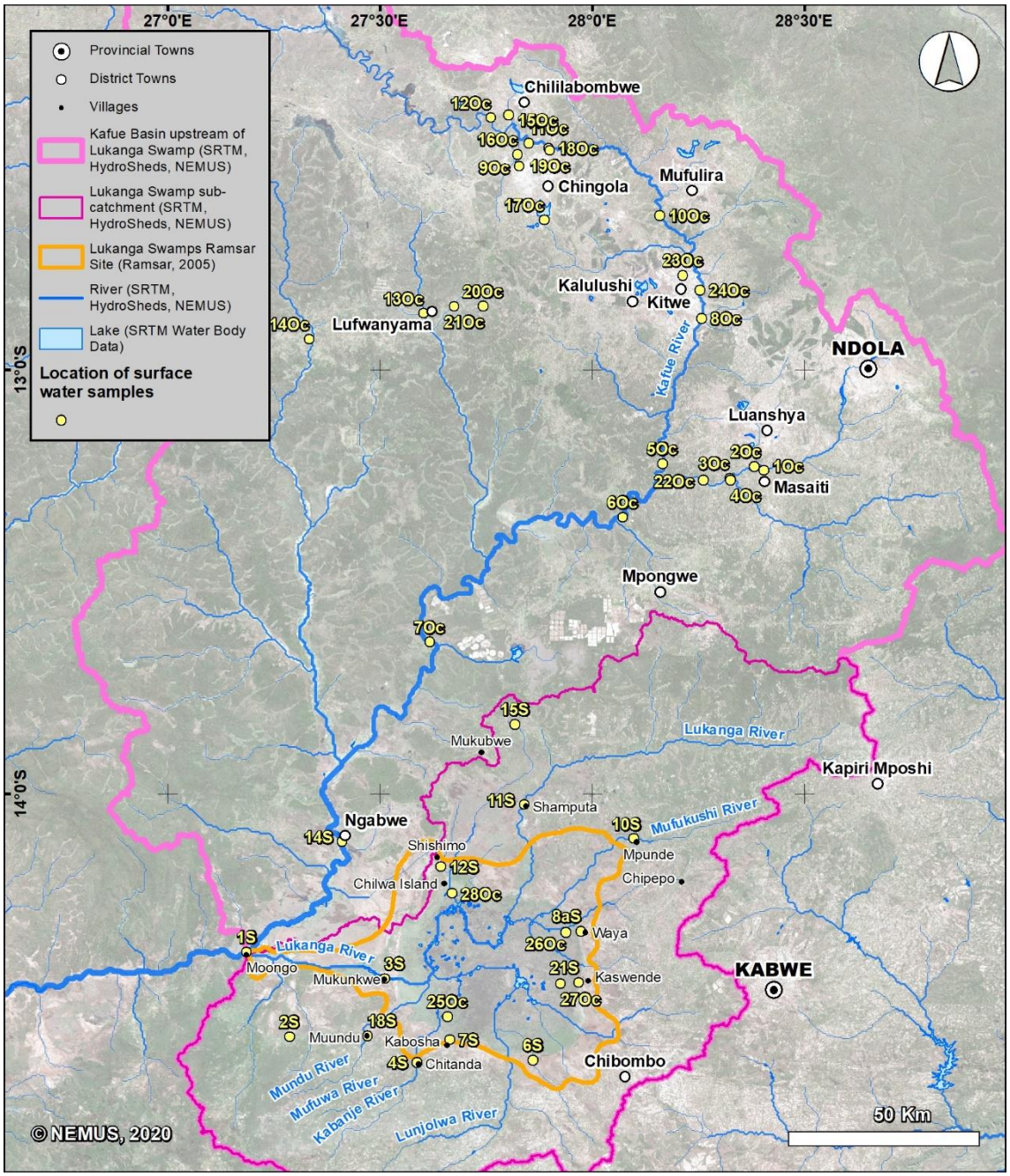


Figure 3 – Location of stations where surface water samples were collected

Groundwater was collected in wells from villages surrounding the Lukanga Swamp since is not reasonable that groundwater from the Upper Kafue River Basin affects the Lukanga Swamp.

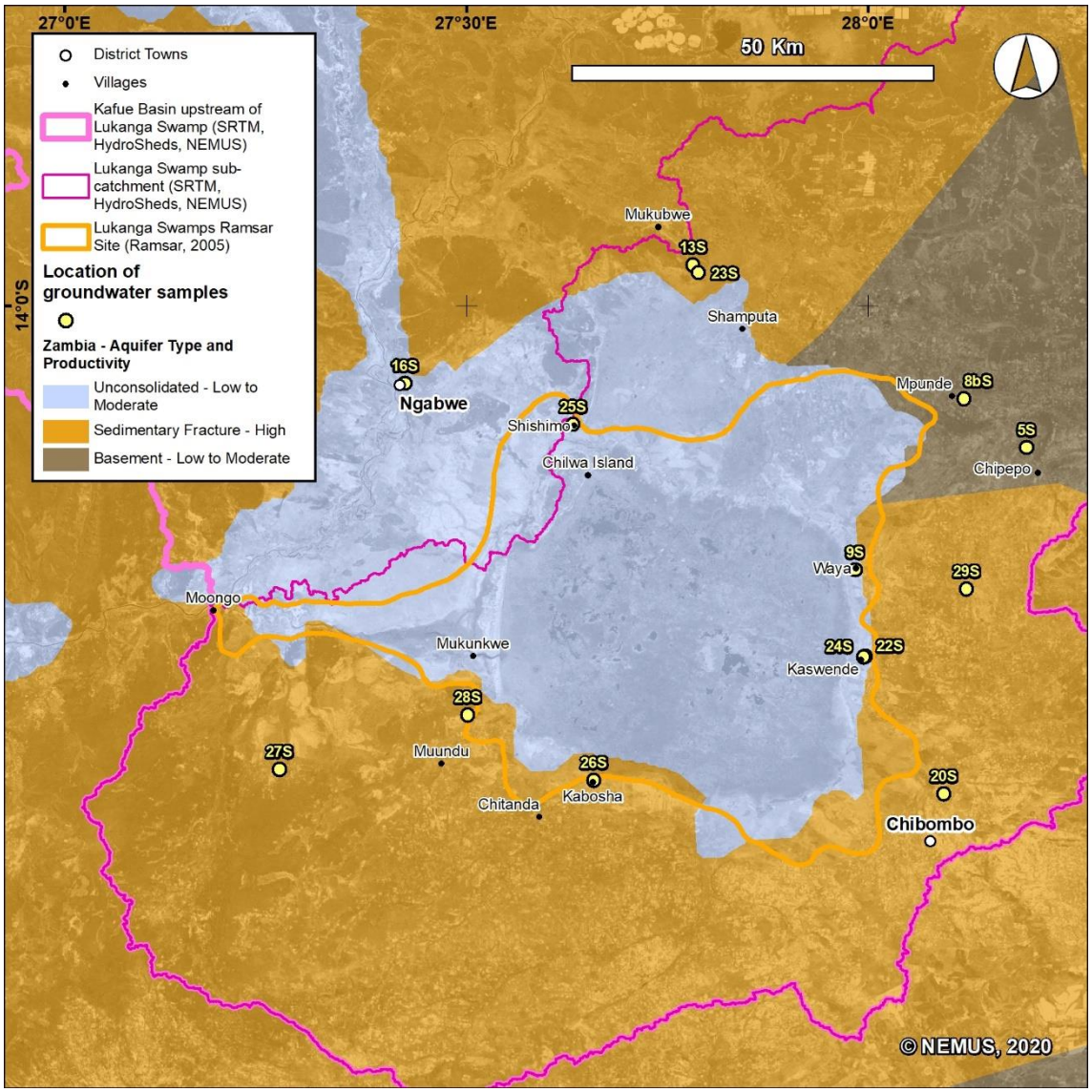


Figure 4 – Location of stations where groundwater samples were collected

Sediment samples were collected in the two main areas: Lukanga Swamp area and areas of the Copperbelt Province more affected by mining activities. It was not possible to collect sediment samples in the inner part of the swamp because its floor is covered by a thick layer of plant material.

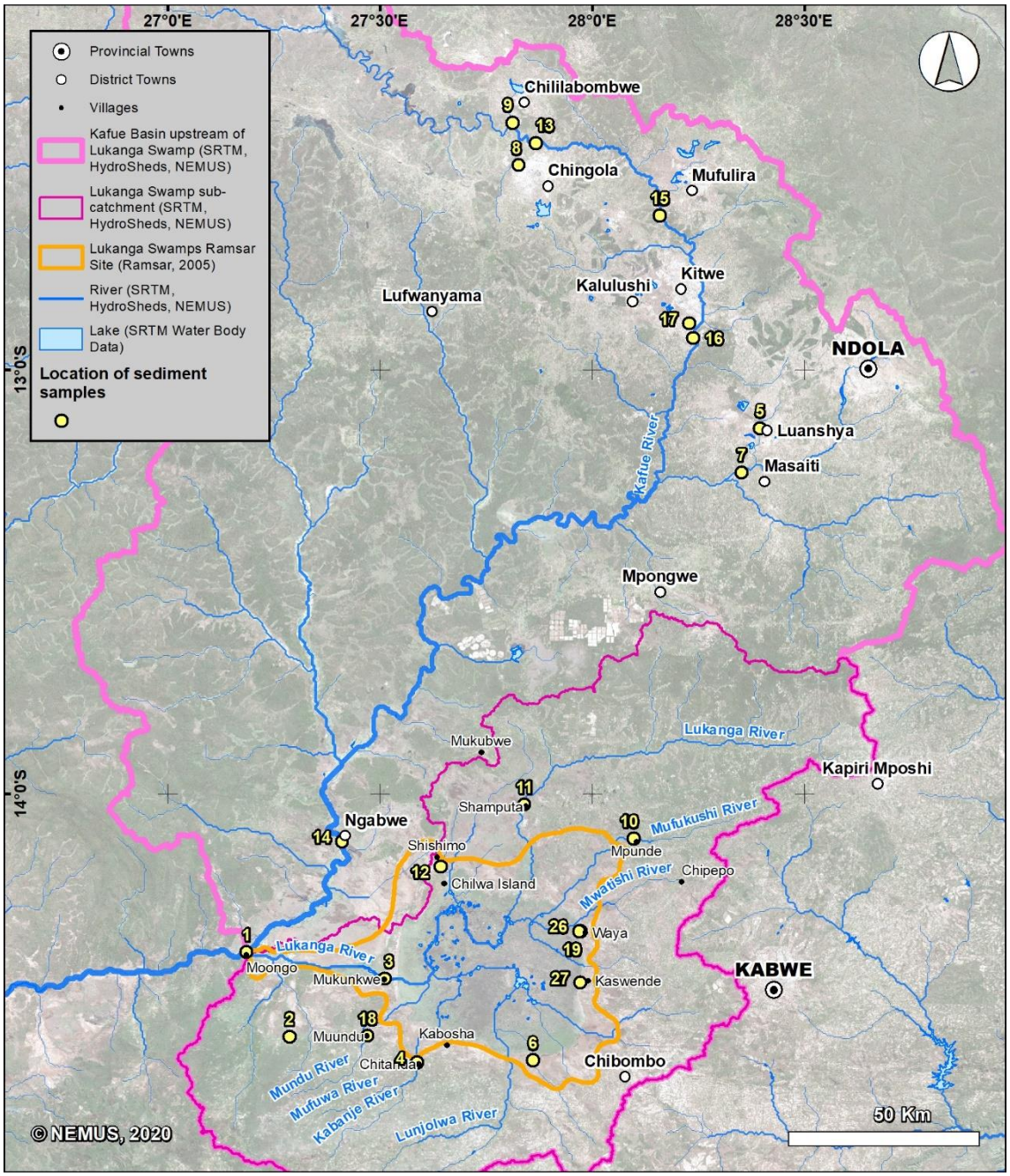


Figure 5 – Location of stations where sediment samples were collected

Leaves of *Phragmites* spp. were collected in the Lukanga Swamp area and at the Copperbelt province. Sampling of leaves in the Copperbelt will allow to understand how this plant behaves in areas where contents of metals are certainly high in the soil. Stations where leaves were collected were also sampled for surface water.

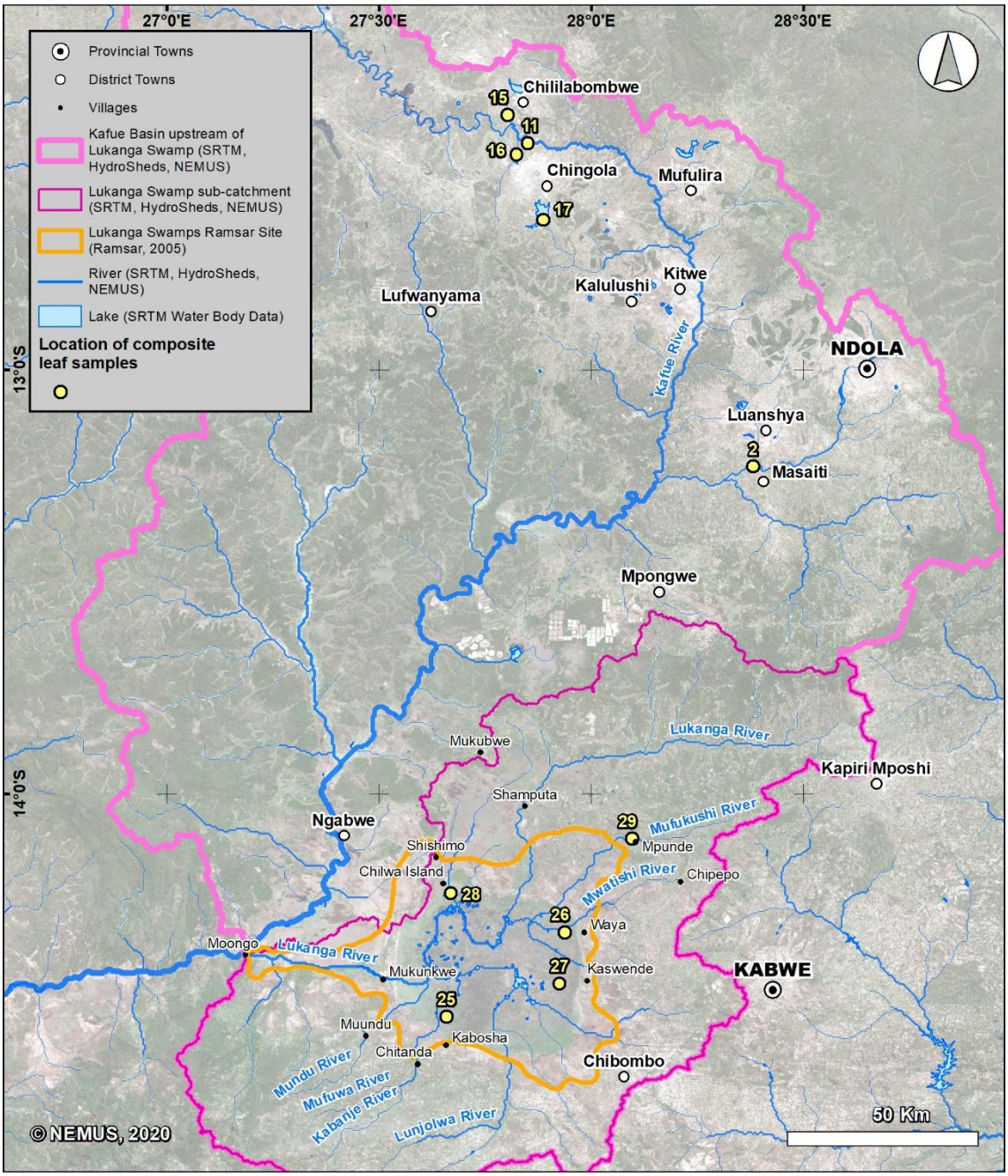


Figure 6 – Location of stations where composite leaf samples were collected

After collection, water and sediment samples were maintained in cooled conditions until analyses were performed. Leaves were cleaned from dust with tap water and dried before analyses were performed.

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2. Groundwater (well water)

2.1. Description of results

Fourteen groundwater samples were collected in wells from villages around the Lukanga Swamp.

According to the hydrogeological map, samples were collected in wells dug in different lithological units: Basement Complex: undifferentiated (1), Katanga Supergroup (8), Quaternary Alluvium (4) and Tertiary: Kalahari Group (1).

Parameters analysed *in situ* were pH, dissolved oxygen, conductivity and temperature:

- pH – 6.6 (5.7 to 7.4);
- Dissolved oxygen – 30% (21% to 40%);
- Conductivity – 326 µS/cm (47 µS/cm to 812 µS/cm);
- Temperature – 25ºC (21 ºC to 28ºC).

While pH and dissolved oxygen show characteristic values for groundwater and span a relatively small range, conductivity span a wide range of values.

It is not certain what causes this differentiation in conductivities because values seem not specifically associated with the dominant lithologies. In fact, two wells located 225 m apart from each other were sampled in Kaswende, supposedly dug in the same lithologies, and both samples show conductivities somewhat different (243 µS/cm and 495 µS/cm). Most likely both wells capture water from different aquifers or different levels within the same aquifer system.

Chemical oxygen demand (COD) is constantly below 4 mg/l (the detection limit), which is an indication of the low amount of oxidizable pollutants in the water.

Biochemical oxygen demand (BOD) is commonly below 1 mg/l. Only samples 5S (north of Chipepo), 23S (between Shamputa and Mukubwe), 25S (Shishimo) show 1 mg/l, 1 mg/l and 2 mg/l, respectively.

As for the nutrients analysed, phosphorus shows concentrations higher than 0,1 mg/l in samples 28S (between Muundu and Mukunkwe), 25S (Shishimo), 26S (Kabosha) and 29S (between Waya and Kabwe). This value is however arbitrary and is used to show the highest four values.

Nitrates vary greatly between 0.04 mg/l and 80.7 mg/l and tend to be higher in wells located outside villages (Figure 7), where small cultivations are near the houses. Figure 8 shows examples of these two situations.

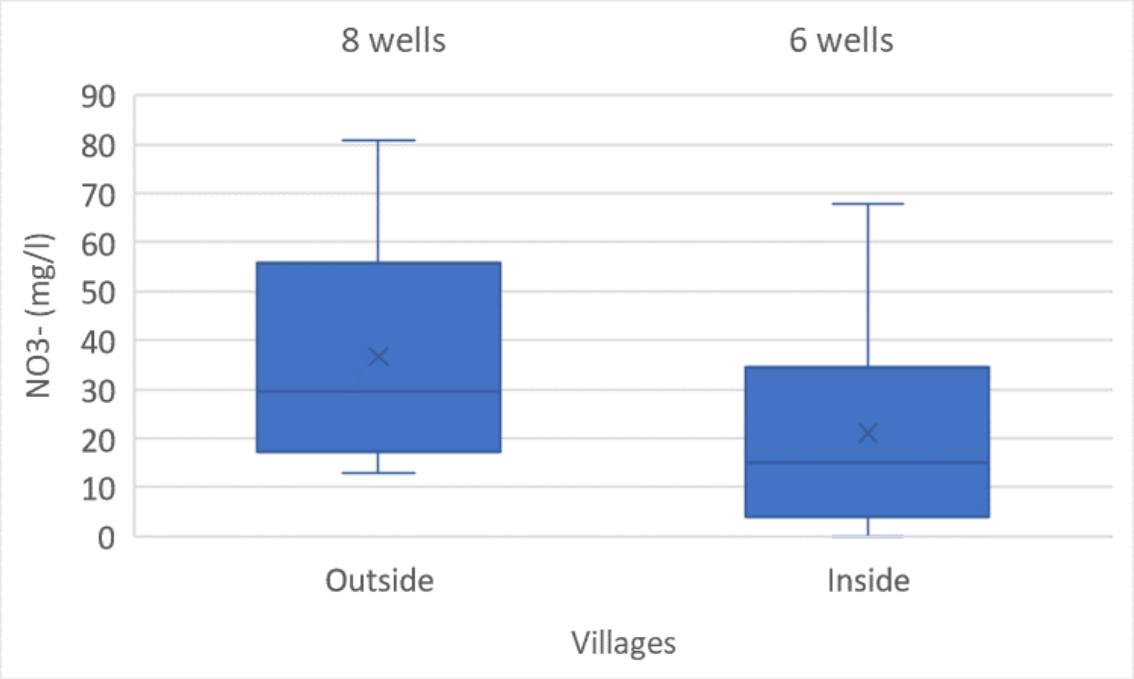


Figure 7 – Concentration of nitrates in wells divided by their location: inside or outside villages

With regard to metals (and metalloids), Hg and As are consistently below detection limits, 0.3 mg/l and 0.2 mg/l, respectively.

Mean concentration of Cd is 0.074 mg/l and concentrations span from 0.009 mg/l to 0.190 mg/l. Concentrations above 0.1 mg/l occur in two wells located between Shamputa and Mukubwe, in the north area of the swamp.

Cobalt concentrations vary between <0.0005 mg/l and 9.4003 mg/l, through at least 5 orders of magnitude. Samples with concentrations above 1 mg/l also show dissolved oxygen below 30%, but not all samples with low DO show concentrations of Co higher than 1 mg/l.

Chromium concentrations vary between 0.0003 mg/l and 0.4810 mg/l. Concentrations above 0.1 mg/l occur in Shishimo, Kaswende and in a well half-way between Kabwe and Waya.



Figure 8 – Sampling of groundwater in two different wells (13S – up and 26S – down): outside and inside village, respectively

Copper concentrations vary between 0.024 mg/l and 0.202 mg/l. The highest concentrations (>0.1 mg/l) are found in Shishimo, north of Chibombo and Kabosha.

Nickel concentrations vary between 0.0011 and 6.7005 mg/l. The maximum value is an outlier as the remaining samples show concentrations below 0.15 mg/l.

Lead concentrations vary between 0.297 mg/l and 1.655 mg/l. Higher concentrations tend to occur in wells to the east of the swamp.

Zinc concentrations vary between 0.006 mg/l and 0.986 mg/l. Higher concentrations tend to occur in wells to the east of the swamp.

No obvious relationship was found between DO and trace metal concentrations.

Organic compounds were analysed only in samples 23S (between Shamputa and Mukubwe), 24S (Kaswende) and 26S (Kabosha). For these three samples values of 16 Polycyclic Aromatic Hydrocarbons (PAH), 5 Hexachlorocyclohexanes (HCH) and Hexachlorobenzene (HCB) were below detection limits, 0.370 µg/L, 0.050 µg/L and 0.005 µg/L, respectively.

2.2. Comparison to guideline values

All but one (24S) sampled wells are used for drinking purposes. All wells are used also for irrigation, and washing of clothes, utensils and tools. In terms of water quality, since the most demanding water use is human consumption, guideline values summarised in Zambian Standard (ZS) 190:2010 and/or in the World Health Organization (WHO) Guidelines for Drinking-water Quality (2011) (Table 2) are used to assess the suitability of this use.

Below the results are summarised according to the guidelines for drinking water:

- According to the ZS, **pH** should be between 6.5 and 8.0. Six wells fail to attend this guideline for having values lower than 6.5 (8bS, 16S, 24S, 25S, 26S, 28S);
- **Conductivity** values never exceed ZS' threshold (1500 µS/cm);
- All values found for **phosphorus** are lower than the threshold value defined for drinking purposes (1 mg/l) by ZABS;
- The threshold values of **nitrates** (NO3-) defined by ZS/WHO (44.3 mg/l and 50 mg/l, respectively) are only exceeded in the following samples: 28S (between Muundu and Mukunkwe), 29S (north of Chibombo) and 20S (between Waya and Kabwe), with 80.7 mg/l, 67.9 mg/l and 61.0 mg/l, respectively.
- **Hg** and **As** are consistently below detection limits, 0.3 mg/l and 0.2 mg/l, respectively. However, the threshold value defined for drinking purposes by ZS/WHO are both lower than these values (0.001 mg/l and 0.01 mg/l, respectively), so it is still unknown if these samples are good for drinking purposes considering these elements.
- As for **Cd** the threshold value defined by ZS/WHO is 0.003 mg/l, so this concentration is exceeded in 10 samples out of 14. The four remaining samples have concentrations below the detection limits (0.005 mg/l).
- As for **Co** the threshold value defined by ZS is 0.5 mg/l, and 6 samples have higher concentrations than this value: 20S (north of Chibombo), 22S (Kaswende), 24S (Kaswende), 25S (Shishimo), 27S (in the road between Muundu and Moongo), 29S (north of Chibombo).
- The threshold value of **Cr** defined by ZS is 0.05 mg/l, and 3 samples have higher concentrations than this value: 24S (Kaswende), 25S (Shishimo), 29S (north of Chibombo).

- All **Cu** concentrations found are below the threshold value defined by ZS/WHO (2 mg/l). Considering the Portuguese guideline for water consumption (0.05 mg/l) all but one sample (5S) surpass this value.
- The threshold value of **Ni** defined by WHO is 0.07 mg/l, and 6 samples have higher concentrations than this value: 13 (between Shamputa and Mukubwe), 20 (north of Chibombo), 23 (between Shamputa and Mukubwe), 25S (Shishimo), 27 (in the road between Muundu and Moongo), 29S (north of Chibombo).
- Twelve samples have concentrations above the threshold value defined for **Pb** by ZS/WHO (0.01 mg/l). The remaining two samples show values below the detection limits (0.02 mg/l).
- All samples show concentrations of **Zn** below the threshold value defined by ZS (3 mg/l).

Since the ZS and WHO Guidelines for Drinking-water Quality do not refer threshold values for COD and BOD, European standards were used just to have an idea on how the results stand for this purpose:

- Chemical oxygen demand (COD) is constantly below 4 mg/l. In European standards it must be below 30 mg/l to be able to be treated for consumption.
- Biochemical oxygen demand (BOD) is commonly below 1 mg/l. Only samples 5S (north of Chipepo), 23S (between Shamputa and Mukubwe), 25S (Shishimo) show 1 mg/l, 1 mg/l and 2 mg/l, respectively. In European standards, it must below 3 mg/l for minimal treatment (physical and disinfection) before consumption.

The following table summarises the parameters that do not respect guideline values for water for drinking purposes (ZS, WHO). As one may see from the table, the main problem of the quality of groundwater is related with concentrations of metals, particularly of Cd and Pb. High concentrations of nitrates and low pH also occur in some groundwater samples. The search for the causes of these high values will be developed afterwards.

Table 1 – List of all 14 groundwater samples and parameters that exceed (or stand below for the case of pH) guideline values for drinking purposes

Samples	Parameters
5S – North of Chipepo	Cd, Pb(?)
8bS – South of Mpunde	Cd, pH, Pb
9S – Waya	Cd(?), Pb
13S – Between Mukubwe and Shamputa	Cd, Pb, Ni
16S – Ngabwe	Cd, pH, Pb
20S – North of Chibombo	Cd, Nitrates, Pb, Co, Ni
22S – Kaswende	Cd(?), Pb, Co
23S – Between Mukubwe and Shamputa	Cd, Pb, Ni
24S – Kaswende	Cd(?), pH, Pb, Co
25S – Shishimo	Cd, pH, Pb, Co, Ni
26S – Kabosha	Cd(?), pH, Pb
27S – Road between Moongo and Muundu	Cd, Pb, Co, Ni
28S – Between Muundu and Mukunkwe	Cd, pH, Nitrates, Pb(?)
29S – Between Waya and Kabwe	Cd, Nitrates, Pb, Co, Ni

Note: (?) - means that detection limit is higher than guideline value

2.3. Assessment of contamination

2.3.1. Nitrates

Natural nitrate levels in groundwater are generally very low (typically less than 10 mg/l NO_3), but nitrate concentrations grow due to human activities, such as agriculture, industry, domestic effluents and emissions from combustion engines.

Except for the well from Ngabwe (0.04 mg/l) and perhaps the one from Kabosha (5.07 mg/l) the others show concentrations of nitrates that certainly reveal influence of human activities. Nitrate levels vary significantly, but levels in well water are often higher than those in surface water and, unless heavily influenced by surface water, are less likely to fluctuate. Concentrations often approach or exceed 50 mg/l where there are significant sources of contamination (WHO, 2017). Considering the land use in the study area, these human activities refer essentially to agriculture and domestic effluents.

Figure 7 suggests that nitrates tend to be higher in wells located outside villages (Figure 8), which implies that agriculture (use of fertilizers) has higher effects on nitrates concentrations than domestic effluents.

2.3.2. Organic contamination

BOD and COD also have low values in all wells, indicating low amount of oxidizable pollutants in the water. Phosphorus shows also relatively low concentrations and higher values (>0.1 mg/l in four samples) are accompanied by high concentrations of nitrates, which indicates that inputs of phosphorus must be coming also from the agriculture activities. However, phosphorus concentrations are not yet considered high.

There is no sign of enrichment of organic compounds such as PAH, HCB or HCH.

2.3.3. Trace metals

Concentrations of certain metals (Ni, Cr, Co) are high in analysed groundwater samples (when compared to average surface water samples).

The exception refers to two analysed wells dug in the Basement Complex (undifferentiated) which show low contents of Cr, Cu and Co, and low conductivity values. While Cr and Co may show higher concentrations in groundwater due to enrichment of these metals in rocks and soils from the Katanga Supergroup, other metals such as Pb, Zn, Ni and Cd may be coming also from fertilizers used.

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3. Surface water

3.1. Description of results

Forty-two surface water samples were collected in water streams throughout the whole upper Kafue river basin and in the Lukanga Swamp.

Parameters analysed *in situ* were pH, dissolved oxygen, conductivity and temperature:

- pH – 7.7 (6.2 to 9.1);
- Dissolved oxygen (DO) – 79% (19% to 192%);
- Conductivity – 674 µS/cm (47 µS/cm to 6039 µS/cm);
- Temperature – 24ºC (16ºC to 29ºC).

Given the wide geographical range of these different samples, it is no surprise the wide range of pH, dissolved oxygen and conductivity values found. Particularly the low values of dissolved oxygen and high values of conductivity are a warning for contamination or specific conditions.

pH values from water samples collected in the Kafue River and those collected in tributaries and closer to the Kafue River are shown in Figure 9.

Generally, pH values are lower in tributaries than in nearby samples collected in the Kafue River.

The exception was a point in the Kafue River immediately downstream Kitwe (near Luangwa, under the bridge of the road that connects Kitwe to Ndola) that shows pH of 6.2, and upstream tributaries (Kitwe and Mindolo streams) have pH above 7.3 and 7.5. Possibly this decrease of pH was due to discharges from one or both other two streams (Uchi and Wusakili streams) that connect with the Kafue River downstream from those streams sampled. The Uchi stream, comes from the Uchi Tailings Dam and the Wusakili stream has a mine in its headwaters.

In the following downstream sample (56 km apart), the river seems to have recovered from low pH values and shows pH of 8.5. This capacity of the Kafue River to recover a neutral pH is referred in Pettersson (2002).

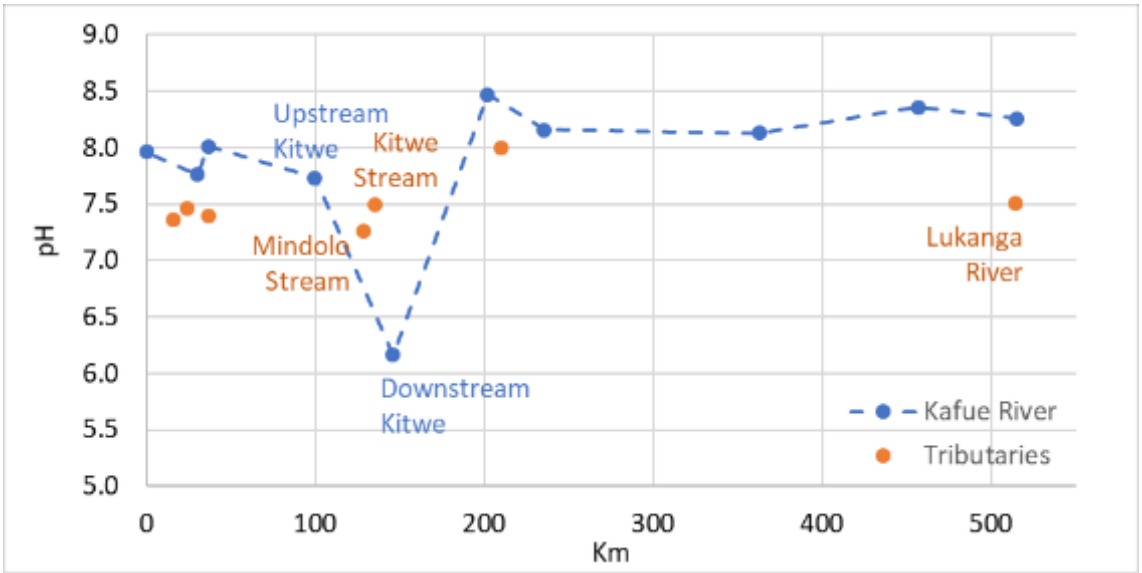


Figure 9 – pH values along the Kafue River and selected tributaries

Inside the Lukanga Swamp, pH tends to be above 7. Close to Chipito a surface water sample in the swamp shows pH of 6.6, but this and other features make one think this water is coming from a nearby spring. Along the Waya and Kaswende transects pH values are constant and similar to each other (around 8 or a little than that). In the other two transects (Kabosha and Chilwa) there is an increase inward.

Conductivity values are generally higher in the Copperbelt Province, probably due to the higher content of metals. The highest value (6039 µS/cm) was found immediately downstream of the Muntimpa dam. In the Copperbelt Province, values above 1000 µS/cm were also found in the Chingola River (1785 µS/cm), in the Muchichima River (1079 µS/cm) and in the Mindolo Stream in Kitwe (1646 µS/cm).

Considering the distribution along the Kafue River, one notice that the lowest values (~200 µS/cm) were found in the most upstream sample, in the nearby Lubengele Stream and in the Lukanga River. Downstream from Lubengele junction with the Kafue River conductivity increases reaching the highest values in the Kitwe area (until upstream of the Kafubu River) with values near 600 µS/cm. This increase occurs due to several tributaries with very high conductivity values (> 1000 µS/cm) as stated above.

Downstream from junction with the Kafubu River, conductivity values decrease consistently, reaching 483 µS/cm near the junction with the Lukanga River.

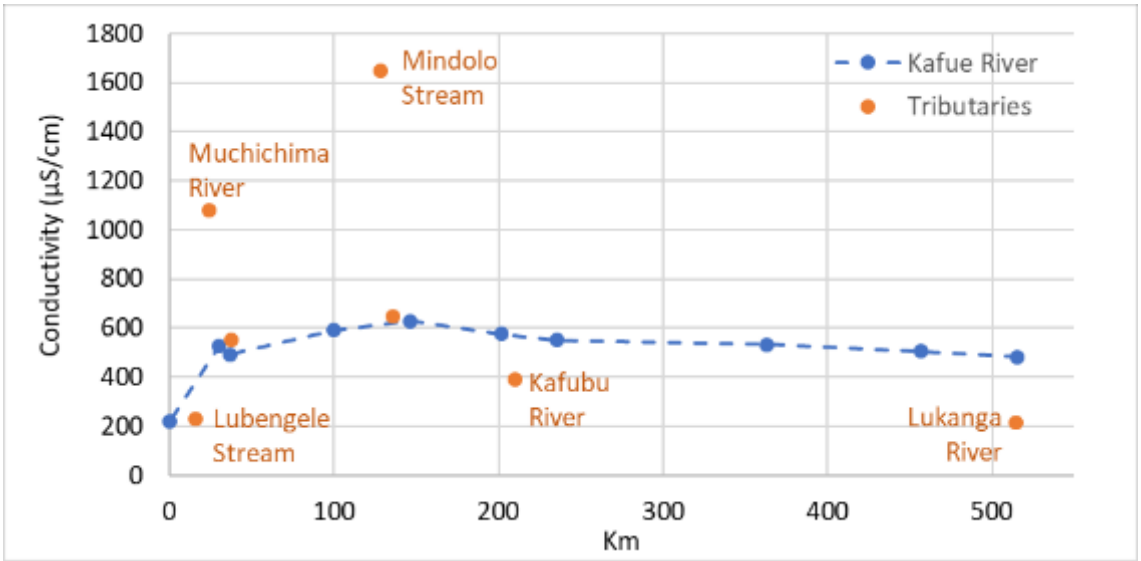


Figure 10 – Conductivity values along the Kafue River and selected tributaries

Inside the Lukanga Swamp higher values than 1000 µS/cm were also found. Figure 16b shows that different areas of the swamp show different signatures of conductivity. Kabosha and Chilwa transects have similar and lower conductivities (300 – 400 µS/cm), Waya transect has intermediate values (700 – 800 µS/cm), and Kaswende has the highest values (1250 – 1350 µS/cm). This differentiation should be related with hydrodynamics of the swamp.

Considering the distribution of dissolved oxygen (DO) along the Kafue River, concentrations are consistently above 69% and vary considerably along the river (Figure 11). In addition, concentrations are lower in tributaries than in nearby samples collected in the Kafue River. The lowest value is found in the Mindolo Stream in Kitwe.

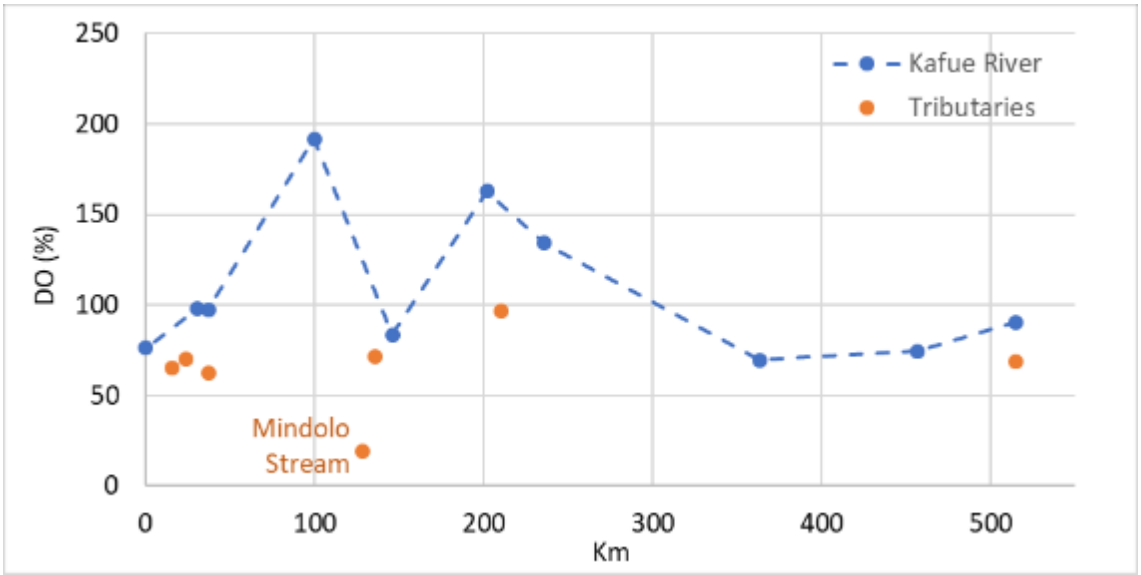


Figure 11 – Dissolved oxygen concentrations along the Kafue River and selected tributaries

Inside the Lukanga Swamp concentrations vary significantly (Figure 16c). In two transects there is an increase while in the other two it decreases, but in a less pronounced manner. The reason for the conspicuous increases in the first transects is because inner samples were collected in open lakes.

Chemical oxygen demand (COD) varies between 3 mg/l and 121 mg/l, but there are 6 surface water samples with COD below 4 mg/l (the detection limit for one the laboratories). In the Lukanga Swamp area values are lower in streams draining into the swamp, and in the Kafue River (< 8 mg/l). Inside the swamp values increase (> 15 mg/l) and reach the highest value of 121 mg/l.

In the Copperbelt Province, COD values are commonly higher than 15 mg/l, probably because of wastewater coming from cities and villages. There was a peak in the amount of oxidizable pollutants (organic contaminants) downstream Chililabombwe that seems to be explained in part by the Muchichima River (Figure 12). In the Kafue River, values decrease below 10 mg/l only near the Lukanga Swamp, and it seems that the swamp may contribute to increase the COD in the Kafue River.

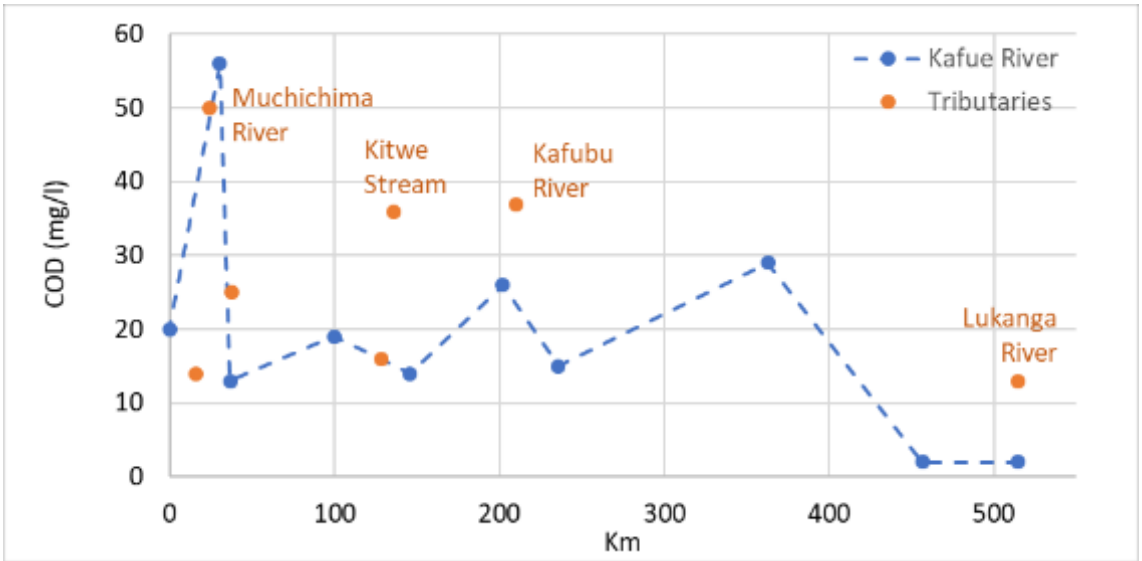


Figure 12 – Chemical oxygen demand along the Kafue River and selected tributaries

Figure 16d shows that different areas of the Lukanga Swamp show different signatures of COD. Chilwa and Kabosha transects have lower conductivities (< 20 mg/l and 20-30 mg/l, respectively), Waya transect has intermediate values (40 – 50 mg/l), and Kaswende has the highest values (80 – 120 mg/l). This differentiation should be related with hydrodynamics of the swamp.

Biochemical oxygen demand (BOD) varies between 1 mg/l and 26 mg/l, but seven surface water samples show BOD values below 1 mg/l, all of them in the Lukanga Swamp Area. In the Lukanga Swamp Area, values follow a similar pattern to COD: lower values in streams draining into the swamp and generally higher values inside the swamp (<1 mg/l – 14.8 mg/l).

In the Copperbelt Province BOD values are commonly higher than 3 mg/l, probably because of wastewater coming from cities and villages.

The amount of dissolved oxygen needed by aerobic biological organisms to break down organic material reach its highest in the Kafue River in a remote area, between the Copperbelt Province and the Lukanga Swamp area, however, near the Junction with the Lukanga River values are the lowest near 1 mg/l.

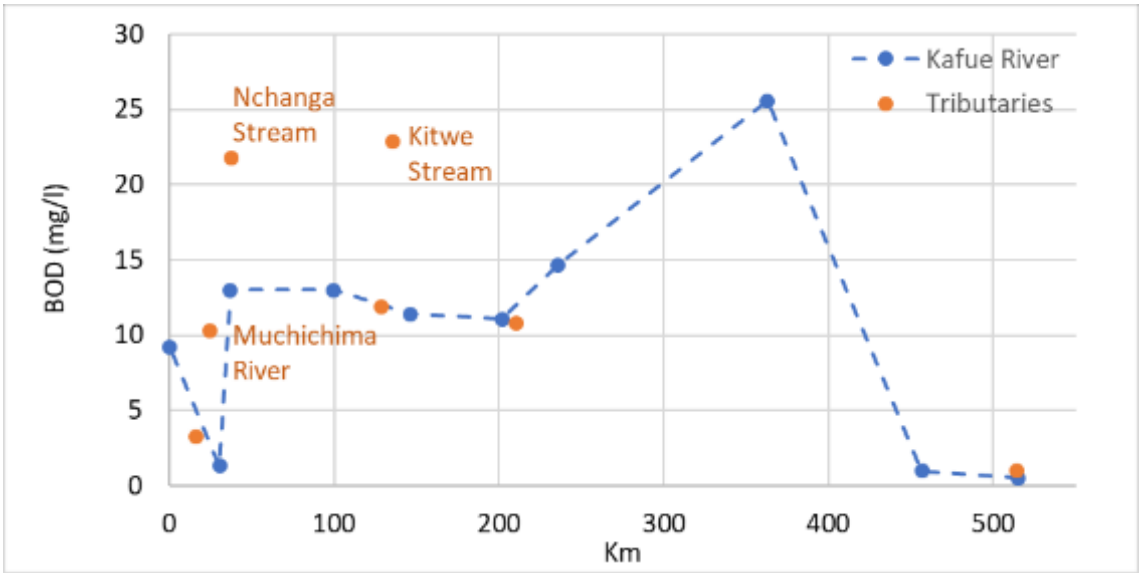


Figure 13 – Biochemical oxygen demand along the Kafue River and selected tributaries

Inside the Lukanga Swamp, transects show increases of BOD inward (Figure 16e). With this parameter is not possible to differentiate areas in the swamp.

As for the nutrients analysed, phosphorus shows a wide range of values from 0.0002 mg/l to 1.5000 mg/l, with mean concentration of 0.3160 mg/l.

In streams draining into the swamp, concentrations tend to be lower than 0.100 mg/l, while in the swamp there is a wide range of concentrations (0.0065 – 1.5000 mg/l).

In the Copperbelt Province concentrations are consistently higher than 0.100 mg/l. There is high oscillation of P concentrations along the Kafue River. The highest increase occurs in Kitwe, and concentrations decrease consistently in the last 250 km until the junction with the Lukanga River.

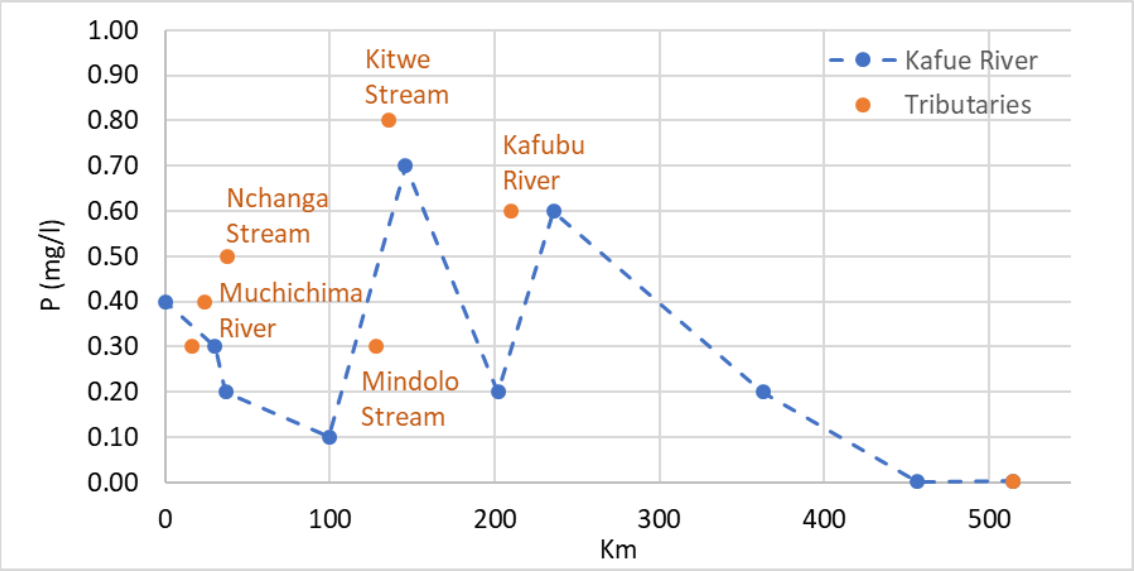


Figure 14 – Phosphorus along the Kafue River and selected tributaries

Inside the Lukanga Swamp, concentrations of P increase inward (Figure 16f). This is in accordance with the inward increase of COD and BOD. It seems there is more organic matter in the water towards the centre of the swamp.

Nitrates range from 0.007 mg/l to 104.08 mg/l with mean concentration of 8.98 mg/l.

Considering the distribution of nitrates along the Kafue River, values increase above 2 mg/l downstream from the junction with the Muchichima River until downstream from Kitwe. Nitrates suffer a significant increase downstream closer to the Lukanga River junction. The Lukanga Swamp which has high concentrations of nitrates contributes to Kafue River, but upstream there are certainly more streams contributing with high concentrations of nitrates.

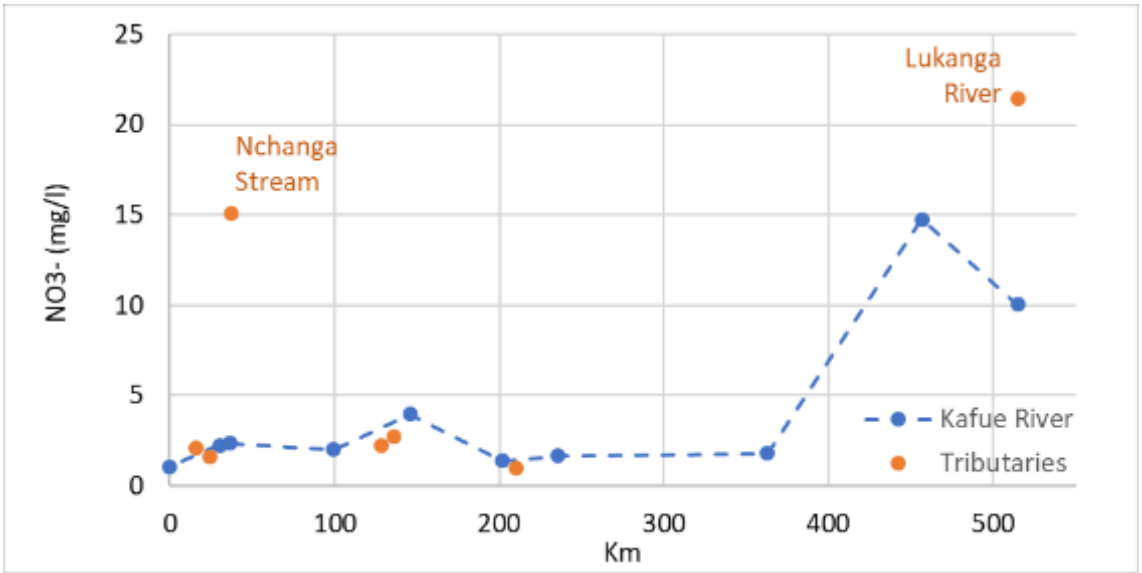


Figure 15 – Nitrates along the Kafue River and selected tributaries

The highest concentrations are found in the Lukanga Swamp Area (> 15 mg/l). These values may occur inside the swamp, but also in water streams draining into the swamp. Inside de swamp concentrations decrease inwards (Figure 16g) which indicates the inland origin of nitrates.

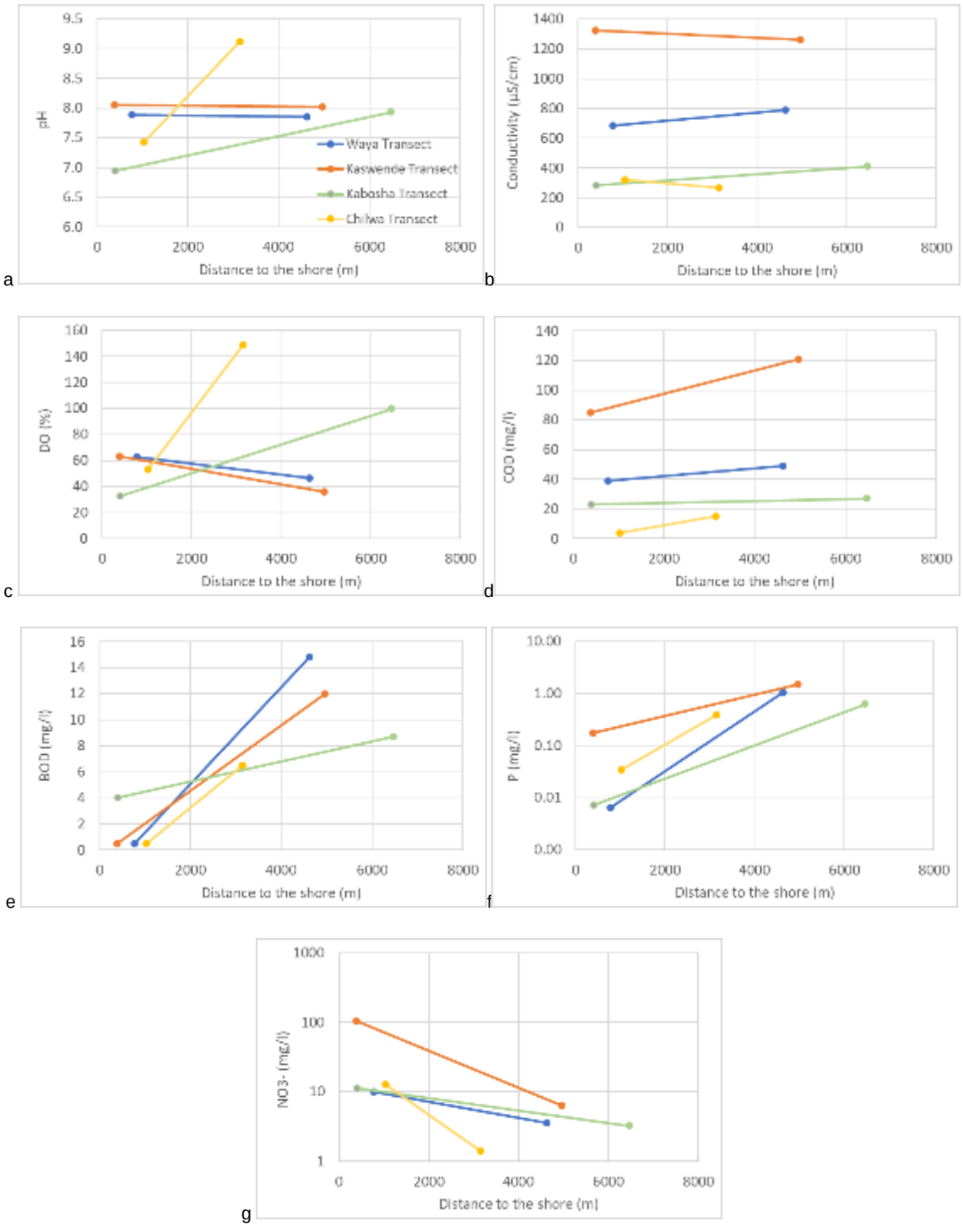


Figure 16 – Different parameters in transects along the Lukanga Swamp

With regard to metals (and metalloids), Hg and As are consistently below detection limits, 0.3 and 0.05 mg/l and 0.2 and 0.01 mg/l, respectively.

Cobalt concentrations vary between 0.0009 mg/l and 4.997 mg/l, with mean value of 0.245 mg/l. These are extremely high concentrations taking into account dissolved concentrations reported in Pettersson (2002) for the dry season: 3.9E-6 mg/l and 2.1E-5 mg/l in Kafironda and Fisher's Farm, up- and downstream Muntimpa stream, respectively. This is because results from this study refer to dissolved + suspended Co.

In the Copperbelt Province concentrations seem very much related to mining areas. The highest concentration of Co is found just downstream from the Muntimpa dam, a stream which then connections to the Kafue River immediately upstream from Kitwe. In the Kafue River the sample collected downstream from Kitwe receives the above inputs but also those from the Mindolo Stream. Upstream in the Kafue River, concentrations of Co slightly increase near Chingola (Figure 17).

In the sub-basin of the Kafubu River, concentrations of Co are below 0.001 mg/l in all 5 surface water samples. The same happens in the samples collected in the Lufwanyama and Luswishi rivers.

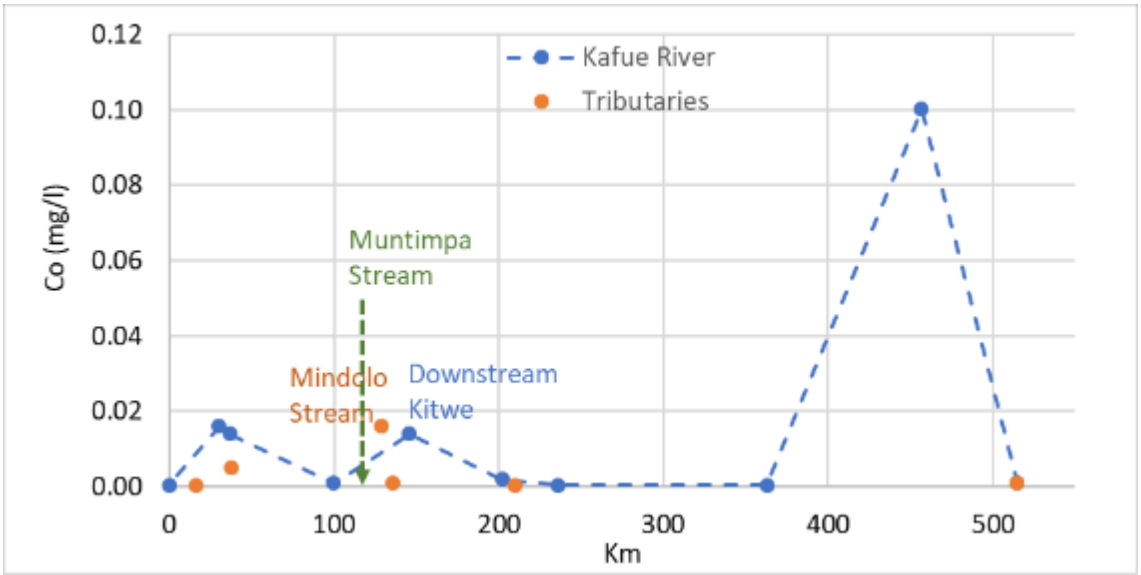


Figure 17 – Cobalt along the Kafue River and selected tributaries

In the Lukanga Swamp Area, concentrations vary from <0.0005 mg/l to >0.1000 mg/l. Inside the swamp concentrations of Co tend to decrease towards the inside of the swamp (Figure 19a). This might be due to higher turbation closer to the shore and dissolved Co release from pore water to surface water.

Chromium concentrations vary from 0.0001 mg/l to 0.0145 mg/l, with mean concentration of 0.005 mg/l. Chromium in the Copperbelt Province is consistently below 0.001 mg/l,

while in the Lukanga Swamp Area concentrations reach 0.0145 mg/l in the Mufukushi River. Too many samples show concentrations below the detection limits, so it is not possible to establish conclusions.

Copper concentrations vary from 0.020 mg/l to 0.957 mg/l, with mean value of 0.198 mg/l. These are extremely high concentrations taking into account dissolved concentrations reported in Pettersson (2002) for the dry season: 4.0E-5 mg/l and 1.8E-5 mg/l in Kafironda and Fisher's Farm, up- and downstream Muntimpa stream, respectively. In the same way as for Co, this is because results from this study refer to dissolved + suspended Cu.

Copper concentrations higher than 0.100 mg/l occur in the Copperbelt area close to Chingola and in southwest part of the Lukanga Swamp area.

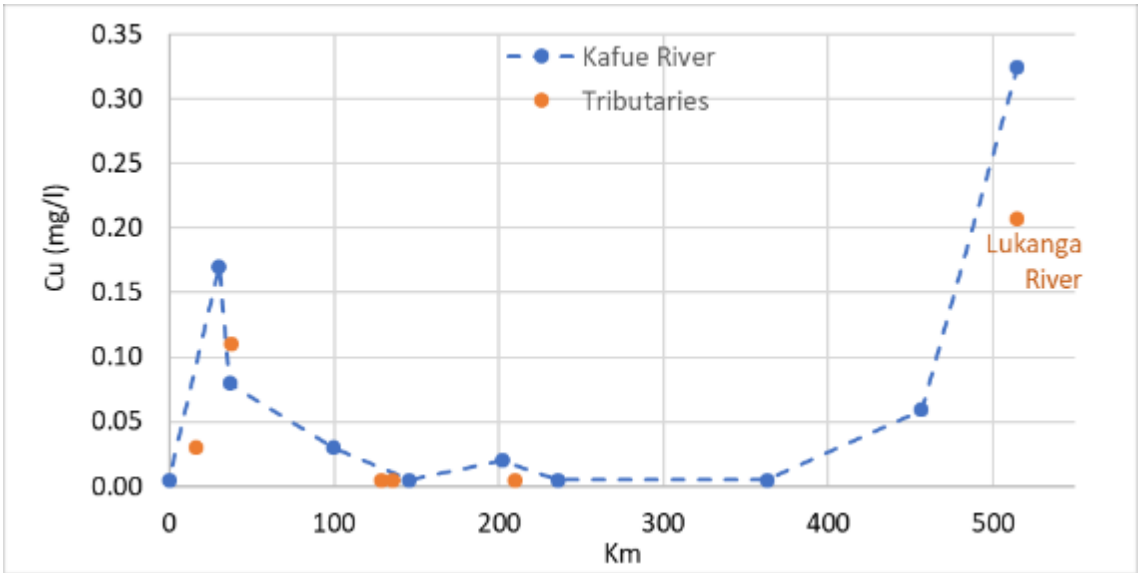


Figure 18 – Copper along the Kafue River and selected tributaries

Inside the Lukanga Swamp, as for Co concentration of Cu decrease inwards (Figure 19b).

Nickel concentrations vary from 0.001 mg/l to 0.162 mg/l, with mean value of 0.043 mg/l. The highest value was found just downstream from the Muntimpa dam, however, the second highest (0.124 mg/l) occurred in the Lukanga Swamp.

Inside the Lukanga Swamp, as for Co concentration of Ni decrease inwards (Figure 18c).

Lead concentrations vary from 0.01 mg/l to 1.86 mg/l, with mean value of 0.80 mg/l. It is worth noting that 26 water surface samples have concentrations below detection limit (0.01 mg/l). Concentrations are consistently higher in the Lukanga Swamp compared to those found in the Copperbelt Province.

Inside the Lukanga Swamp, as for Co concentration of Pb decrease inwards (Figure 18d).

Zinc concentrations vary from 0.01 mg/l to 0.979 mg/l, with mean value of 0.239 mg/l. It is worth noting that 21 water surface samples have concentrations below detection limit (0.006 mg/l). As for Pb, concentrations are consistently higher in the Lukanga Swamp compared to those found in the Copperbelt Province. In this previous area the highest value occurred again just downstream from the Muntimpa dam.

Inside the Lukanga Swamp, as for Co concentration of Zn decrease inwards (Figure 18d). This decrease of all trace metals should be also related to higher turbation closer to the shore.

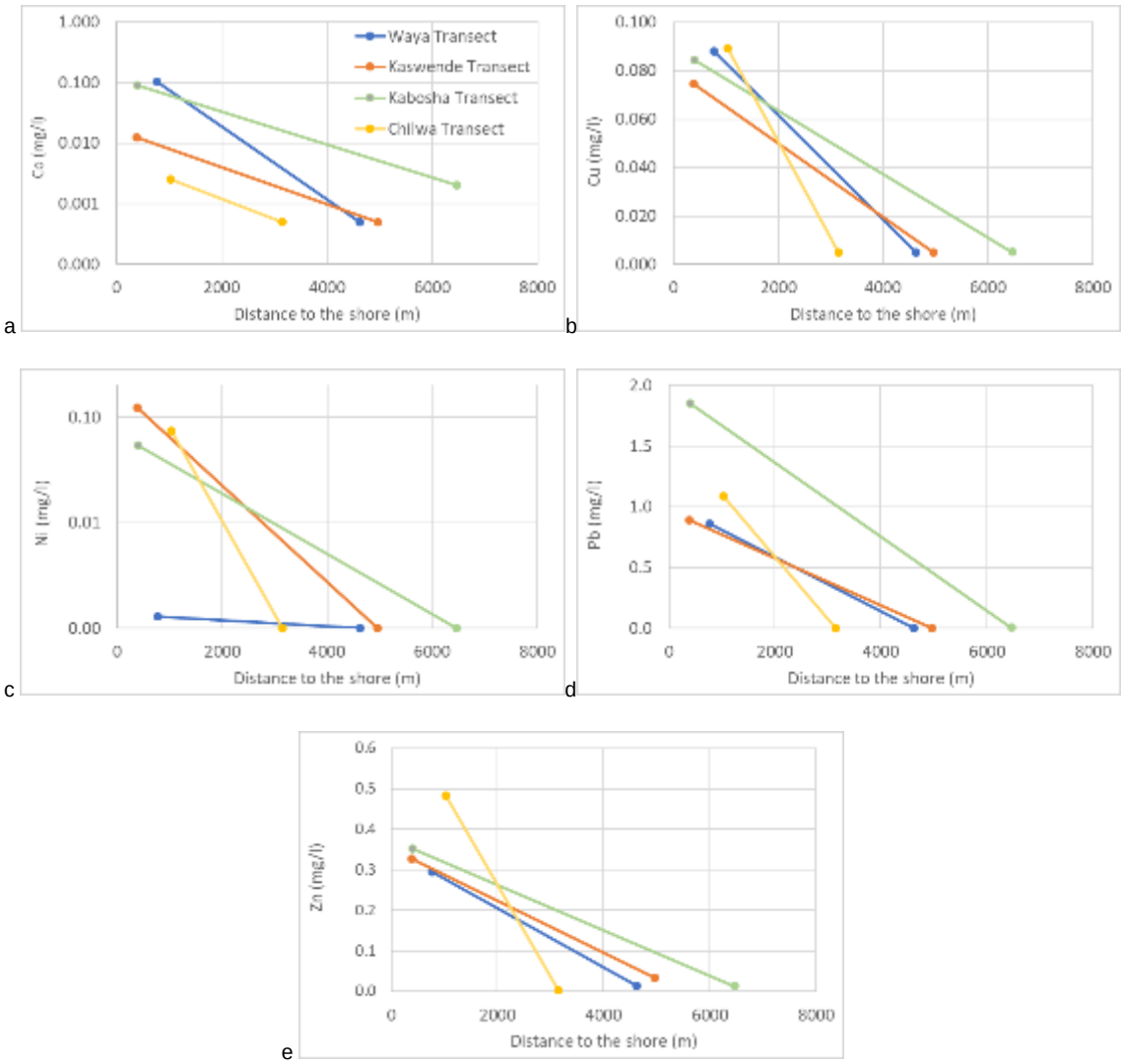


Figure 19 – Concentrations of different trace metals in transects along the Lukanga Swamp

3.2. Water uses and comparison to guideline values

Fishing is obviously the main activity practiced in the swamp, and fishermen use its water for drinking purposes while in the swamp (Figure 20). Surface water of the Lukanga Swamp and streams draining into the swamp are also used for drinking by grazing animals (Figure 20) and bathing/recreational use.



Figure 20 – Fisherman and grazing animals from the Lukanga Swamp

Table 2 shows standard and guideline values for different parameters in water for drinking and irrigation purposes. Guideline values defined for minimum environmental quality defined in European standards were also used to have reference values for COD, BOD and P, and have a less demanding perspective on water quality.

Table 2 – Guideline and standard values for different water uses

Parameter	Drinking water		Irrigation water	Minimum Environmental Quality
	Zambian Standard	WHO Guideline	FAO Guideline	European standards
pH	6.5 – 8.5	6.5 – 8.5	6.5 – 8.4	5.0 – 9.0
Conductivity (µS/cm)	1500	-	700 - 3000**	-
Chemical Oxygen Demand (mg/L)	-	-	-	30.0***
Biochemical Oxygen Demand (mg/L)	-	-	-	5.0
Nitrates (NO3-)	44.3	50	22.15 – 132.9**	-
Phosphorus	-	-	-	1.0
As (mg/l)	0.01	0.01	0.1¥	0.1
Cd (µg/L)	0.003	0.003	0.01¥	0.01
Cr (mg/L)	0.05	0.05	0.1¥	0.05
Co (mg/l)	0.5	-	0.05¥	-
Cu (mg/l)	1.0	2.0	0.2¥	0.1
Hg (mg/l)	0.001	0.006	-	0.001
Pb (mg/L)	0.01	0.01	5¥	0.05
Zn (mg/L)	3.0	-	2.0¥	0.5

Notes: ǂ Maximum values recommended assuming there will be physical treatment and disinfection of the water to be potable;
* Recommended maximum value assuming physical and chemical treatment for tuning and disinfection of the water to be potable
** Interval corresponds to “slight to moderate” degree of restriction class; ¥ Recommended Maximum Concentration; *** According to European standards, it must be below 30 mg/l to be able to be treated for human consumption

Almost all water samples have problems for the different uses analysed. Exceptions are 1Oc (Kafubu River – upstream from Luanshya River), 15Oc (Lubengele Stream), 18Oc

(Kafue River – upstream from Chingola, and immediately upstream from the public water abstraction plant) (Table 3).

Table 3 – Analysis of surface water samples for different water uses considering different guidelines values

Sta./Param.	pH	Cond.	COD	BOD	NO3-	P	As	Cd	Cr	Co	Cu	Hg	Pb	Zn	S/GNC
1S	8.26	483	<4	<1	10.05	0.0031	<0.2	0.23	0.009	0.0009	0.3247	<0.3	0.2664	0.2247	**ZS** (Cd, Pb) **WHO** (Cd, Pb) **FAO** (Cu) **ES** (Cu)
2S	7.62	268	<4	1	0.13	0.0034	<0.2	0.41	0.002	0.0600	0.1034	<0.3	1.346	<0.002	**ZS** (Cd, Pb) **WHO** (Cd, Pb) **FAO** (Cd, Co) **ES** (Cd, Cu, Pb)
3S	7.51	218	13	1	21.45	0.0012	<0.2	0.17	0.003	0.001	0.207	<0.3	0.7376	0.3348	**ZS** (Cd, Pb) **WHO** (Cd, Pb) **FAO** (Cd, Cu) **ES** (Cd, Cu, Pb)
4S	7.51	474	<4	<1	30.54	0.3023	<0.2	0.23	0.001	0.0021	0.0618	<0.3	0.8018	0.1177	**ZS** (Cd, Pb) **WHO** (Cd, Pb) **FAO** (Cd, NO3) **ES** (Cd, Pb)
6S	6.64	347	43	1	4.01	0.043	<0.2	<0.005	0.014	<0.0005	0.0521	<0.3	0.3473	0.2153	**ZS** (Pb) **WHO** (Pb) FAO **ES** (COD, Pb)
7S	6.94	283	23	4	11.23	0.0071	<0.2	0.11	0.0041	0.0891	0.0843	<0.3	1.856	0.3516	**ZS** (Cd, Pb) **WHO** (Cd, Pb) **FAO** (Cd, Co) **ES** (Cd, Pb)
8aS	7.89	684	39	<1	10	0.0065	<0.2	0.24	0.0001	0.102	0.088	<0.3	0.8624	0.295	**ZS** (Cd, Pb) **WHO** (Cd, Pb) **FAO** (Cd, Co) **ES** (Cd, COD. Pb)
10S	7.34	161	8	1	11.9	0.0065	<0.2	0.05	0.0145	0.0369	0.6669	<0.3	0.0467	0.9794	**ZS** (Cd, Pb) **WHO** (Cd, Pb) **FAO** (Cd, Cu) **ES** (Cd, Cu, Zn)
11S	7.18	196	17	1	17.01	0.0002	<0.2	0.22	0.0021	<0.0005	0.0646	<0.3	0.9295	<0.002	**ZS** (Cd, Pb) **WHO** (Cd, Pb) **FAO** (Cd) **ES** (Cd, Pb)
12S	7.43	320	4	<1	12.87	0.034	<0.2	0.03	0.0011	<0.0005	0.0891	<0.3	1.089	0.4835	**ZS** (Cd, Pb) **WHO** (Cd, Pb) **FAO** (Cd) **ES** (Cd, Pb)
14S	8.36	505	<4	1	14.76	0.002	<0.2	0.19	<0.0001	0.1002	0.0591	<0.3	1.203	0.2149	**ZS** (Cd, Pb) **WHO** (Cd, Pb) **FAO** (Cd, Co) **ES** (Cd, Pb)

Sta./Param.	pH	Cond.	COD	BOD	NO3-	P	As	Cd	Cr	Co	Cu	Hg	Pb	Zn	S/GNC
15S	7.21	707	<4	<1	0.0067	0.024	<0.2	<0.005	0.0084	0.0177	0.0773	<0.3	1.244	0.6944	**ZS** (Cd, Pb) **WHO** (Cd, Pb) **FAO** (Cond.) **ES** (Pb, Zn)
18S	7.48	452	<4	<1	53.56	0.0932	<0.2	0.10	<0.0001	0.0129	0.957	<0.3	1.157	0.0933	**ZS** (Cd, Pb, NO3) **WHO** (Cd, Pb, NO3) **FAO** (Cd, Cu, NO3) **ES** (Cd, Cu, Pb)
21S	8.05	1324	85	<1	104.08	0.174	<0.2	0.23	<0.0001	0.0125	0.0746	<0.3	0.8908	0.3269	**ZS** (Cd, NO3, Pb) **WHO** (Cd, NO3, Pb) **FAO** (Cd, Cond, NO3) **ES** (Cd, COD, Pb)
1Oc	6.86	398	2.5	1.4	1.54	0.3	< 0.01	< 0.001	< 0.001	< 0.001	< 0.01	< 0.05	< 0.01	< 0.006	ZS WHO FAO ES
2Oc	6.94	393	19	11.1	1.21	0.2	< 0.01	< 0.001	< 0.001	< 0.001	< 0.01	< 0.05	< 0.01	< 0.006	ZS WHO FAO **ES** (BOD)
3Oc	7.2	391	13	10.8	1.90	0.3	< 0.01	< 0.001	< 0.001	< 0.001	< 0.01	< 0.05	< 0.01	< 0.006	ZS WHO FAO **ES** (BOD)
4Oc	6.95	349	17	8.6	1.64	0.2	< 0.01	< 0.001	< 0.001	< 0.001	< 0.01	< 0.05	< 0.01	< 0.006	ZS WHO FAO **ES** (BOD)
5Oc	8.47	576	26	11.1	1.36	0.2	< 0.01	< 0.001	< 0.001	0.002	0.02	< 0.05	< 0.01	< 0.006	ZS WHO **FAO** (pH) **ES** (BOD)
6Oc	8.16	552	15	14.7	1.66	0.6	< 0.01	< 0.001	< 0.001	< 0.001	< 0.01	< 0.05	< 0.01	< 0.006	ZS WHO FAO **ES** (BOD)
7Oc	8.13	533	29	25.6	1.80	0.2	< 0.01	< 0.001	< 0.001	< 0.001	< 0.01	< 0.05	< 0.01	0.089	ZS WHO FAO **ES** (BOD)
8Oc	6.16	628	14	11.4	3.95	0.7	< 0.01	< 0.001	< 0.001	0.014	< 0.01	< 0.05	< 0.01	< 0.006	**ZS** (pH) **WHO** (pH) **FAO** (pH) **ES** (BOD)

Sta./Param.	pH	Cond.	COD	BOD	NO3-	P	As	Cd	Cr	Co	Cu	Hg	Pb	Zn	S/GNC
9Oc	8.67	1785	22	5.4	7.76	< 0.1	< 0.01	< 0.001	< 0.001	0.098	0.66	< 0.05	< 0.01	< 0.006	**ZS** (Cond, pH) **WHO** (pH) **FAO** (Cond, Co, Cu, pH) **ES** (BOD, Cu)
10Oc	7.73	590	19	13	2.01	0.1	< 0.01	< 0.001	< 0.001	0.001	0.03	< 0.05	< 0.01	< 0.006	ZS WHO FAO **ES** (BOD)
11Oc	7.76	528	56	9.2	2.25	0.3	< 0.01	< 0.001	< 0.001	0.016	0.17	< 0.05	< 0.01	< 0.006	ZS WHO FAO **ES** (COD, Cu, BOD)
12Oc	7.96	221	20	6.6	1.05	0.4	< 0.01	< 0.001	< 0.001	< 0.001	< 0.01	< 0.05	0.01	< 0.006	ZS WHO FAO **ES** (BOD)
13Oc	8.1	423	16	11.9	1.50	0.4	< 0.01	< 0.001	< 0.001	< 0.001	< 0.01	< 0.05	< 0.01	< 0.006	ZS WHO FAO **ES** (BOD)
14Oc	7.87	431	15	11.4	1.31	0.2	< 0.01	< 0.001	< 0.001	< 0.001	< 0.01	< 0.05	< 0.01	0.007	ZS WHO FAO **ES** (BOD)
15Oc	7.46	230	14	3.3	2.08	0.3	< 0.01	< 0.001	< 0.001	< 0.001	0.03	< 0.05	< 0.01	< 0.006	ZS WHO FAO ES
16Oc	7.36	1079	50	10.3	1.57	0.4	< 0.01	< 0.001	< 0.001	0.025	0.13	< 0.05	< 0.01	< 0.006	ZS WHO **FAO** (Cond) **ES** (BOD, COD, Cu)
17Oc	7.49	6039	40	12	1.81	0.5	< 0.01	< 0.001	< 0.001	4.997	0.42	< 0.05	0.02	0.024	**ZS** (Co, Pb, Cond) **WHO** (Pb) **FAO** (Co, Cu, Cond) **ES** (Cu, COD)
18Oc	8.01	493	13	1.3	2.35	0.2	< 0.01	< 0.001	< 0.001	0.014	0.08	< 0.05	< 0.01	< 0.006	ZS WHO FAO ES
19Oc	7.4	552	25	21.8	15.05	0.5	< 0.01	< 0.001	< 0.001	0.005	0.11	< 0.05	< 0.01	< 0.006	ZS WHO FAO **ES** (BOD, Cu)

Sta./Param.	pH	Cond.	COD	BOD	NO3-	P	As	Cd	Cr	Co	Cu	Hg	Pb	Zn	S/GNC
20Oc	7.84	47	19	13.6	0.28	0.5	< 0.01	< 0.001	< 0.001	< 0.001	< 0.01	< 0.05	< 0.01	0.029	ZS WHO FAO **ES** (BOD)
21Oc	7.84	248	21	13.6	0.95	0.5	< 0.01	< 0.001	< 0.001	< 0.001	< 0.01	< 0.05	< 0.01	< 0.006	ZS WHO FAO **ES** (BOD)
22Oc	8	389	37	10.8	0.95	0.6	< 0.01	< 0.001	< 0.001	< 0.001	< 0.01	< 0.05	< 0.01	< 0.006	ZS WHO FAO **ES** (COD, BOD)
23Oc	7.26	1646	16	11.9	2.23	0.3	< 0.01	< 0.001	< 0.001	0.016	< 0.01	< 0.05	< 0.01	< 0.006	**ZS** (Cond) WHO **FAO** (Cond) **ES** (BOD)
24Oc	7.5	646	36	22.9	2.70	0.8	< 0.01	< 0.001	< 0.001	0.001	< 0.01	< 0.05	< 0.01	< 0.006	ZS WHO FAO **ES** (COD, BOD)
25Oc	7.93	410	27	8.7	3.23	0.62	< 0.01	0.001	< 0.001	0.002	< 0.01	< 0.05	< 0.01	0.012	ZS WHO FAO **ES** (BOD)
26Oc	7.85	789	49	14.8	3.54	1.04	< 0.01	< 0.001	< 0.001	< 0.001	< 0.01	< 0.05	< 0.01	0.014	ZS WHO **FAO** (Cond) **ES** (COD, BOD, P)
27Oc	8.02	1263	121	12.0	6.37	1.50	< 0.01	< 0.001	< 0.001	< 0.001	< 0.01	< 0.05	< 0.01	0.034	**ZS** (Cond) WHO **FAO** (Cond) **ES** (COD, BOD, P)
28Oc	9.12	269	15	6.5	1.41	0.39	< 0.01	< 0.001	< 0.001	< 0.001	< 0.01	< 0.05	< 0.01	< 0.006	**ZS** (pH) **WHO** (pH) **FAO** (pH) **ES** (BOD)

Notes: Conductivity is expressed in µS/cm and the other are in mg/l; S/GNC – Standard/Guideline Non-Compliance; dark orange cells: values failing water quality standards used; light orange cells: values below the detection limits.

Upstream from sample 18Oc in the Kafue River, samples 11Oc and 12 Oc do not respect the minimum environmental quality of European standards and this is due to BOD, COD, Cu and BOD, respectively. The same happens to sample 10Oc (BOD), located downstream from sample 18Oc and upstream from Kitwe. However, according to the analysed parameters and to the Zambian Standard and WHO guidelines this water could be used for drinking purposes. Note that microbiological parameters were not analysed. According to FAO guidelines this water could also be used for irrigation.

Downstream from Kitwe, samples 8Oc and 5Oc are in the “slight to moderate” degree of restriction class for irrigation due to pH. The former is also restricted for drinking purposes because of pH. Both samples and samples 6Oc and 7Oc (located in the Kafue River downstream from 5Oc) do not respect the minimum environmental quality of European standards because of BOD.

In the Kafubu River Basin, as referred sample 1Oc respects all guidelines analysed. Downstream from that area all three samples fail to reach the minimum environmental quality of European standards because of BOD (3Oc, 4Oc, 22Oc) and COD (22Oc).

A similar situation occurs in samples collected from the Lufwanyama and Luswishi rivers because of high values of BOD.

Samples collected in the Kafue River close to the Lukanga Swamp fail all the water uses because of concentrations of Cd, Cu and Pb.

Inside the swamp only two inner samples (25Oc and 26Oc) show good results for drinking purposes. Note however that microbiological parameters were not analysed. Sample 25Oc also shows good results for irrigation purposes. None of the samples would pass the minimum environmental quality of European standards and this is because of BOD, COD and P in the inner samples and because of metals in outer samples.

In water streams draining to the swamp, none of the samples show good results for drinking purposes (ZS and WHO) and they do not respect the minimum environmental quality of European standards. Samples from the north part of the swamp fail due to metal concentrations. Samples from the south fail due to metals and nitrates. Two of these samples (15S and 6S) were collected very close to springs and even those show low patterns of water quality.

3.3. Assessment of contamination

In general, quality of surface water is a function of both natural influences and human activities. Without human influences, water quality would be determined by: 1) weathering of bedrock minerals; 2) atmospheric processes; 3) natural leaching of organic matter and nutrients from soil, 4) hydrological factors that lead to runoff; 5) biological processes within the aquatic environment that can alter the physical and chemical composition of water (UNEP, 2006).

However, water quality is also affected by human induced factors like soil erosion from agriculture and mining activities, lack of wastewater treatment facilities, application of pesticides and fertilizers, and so forth.

3.3.1. Nitrates

The Lukanga Swamp Area is enriched in nitrates. Concentrations show the following trend: Streams draining into the swamp (>30 mg/l) > Near shore water (>10 mg/l) > Swamp inner water (>1.5 mg/l). Considering the land use in the study area, this trend also shows agriculture and domestic effluents as the source for nitrates in surface water.

3.3.2. Organic contamination

In the Copperbelt area COD tends to increase in the Kafue River while crossing main cities (Chingola and Kitwe), which implies sources of organic matter from industrial and household sources.

In the Lukanga Swamp area, concentrations show the following trend: Swamp inner water (15 - 121 mg/l) > Near shore water (4 - 85 mg/l) > Streams draining into the swamp (<4 - 17 mg/l). In the swamp area the origin for the organic material is not wastewater but rather natural decomposition of vegetation inside the swamp. Relatively similar results are obtained for BOD which has higher values inside the swamp.

There is no sign of enrichment of organic compounds such as PAH, HCB or HCH.

3.3.3. Trace metals

In the Lukanga, except for Cr and Co, which show relatively low concentrations in surface water, concentrations of dissolved metals (Cu, Zn, Pb, Cd, Ni) vary considerably throughout the whole system.

Sources for these metals in the area go from the use of fertilizers rich in Zn and Cd to dust fallout coming from smelters in Kabwe, particularly enriched in Pb and Zn. Tembo *et al*. (2006) and Kribek *et al*. (2018) conclude that around Kabwe topsoil has been contaminated with metals by dust fallout from smelters operating in the city. Given the prevailing wind direction to the West and Northwest the study area is in fact in the path of this dust.

Rock formations of the area also show local enrichments in metals [e.g. pyrite and pyrrhotite are common accessory minerals in lower Kundelungu marble; aggregates of pyrite occur scattered throughout quartz veins – Vrana (1974)].

In the Copperbelt typical waste rocks and tailings contain pyrite and have high metal concentrations, in particular of Cu and Co. Due to high carbonate content, resulting in a high buffering capacity, sulphide oxidation does not result in a major production of acid drainage (Pettersson, 2002).

During the rainy season, it is likely that washout of secondarily retained weathering products from mining waste is the main source for Cu and other metals in the Kafue River. During the low discharge season, point sources such as the Konkola mine (Muchichima stream) and the Muntimpa dam have a major influence on the water quality of the river. However, data here presented also indicate that the Uchi and Wusakili streams may have been releasing acid water into the Kafue River during the period of the field visits (October 2019).

According to Pettersson (2002), during this season water from the Konkola mine may contribute about 40% of the total discharge of the river. The mine water has high concentration of Ca and S from pyrite oxidation and carbonate buffering and a relatively high Cu concentration, and therefore has a strong influence on the water quality of the river. These observations are also visible from our data in the Kafue River, and in October 2019 the streams coming from the referred dam and mine have the highest conductivity value recorded and the highest concentration of Co, Zn, Cu and Ni, and other parameters.

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4. Sediment

Chemical and physical analyses were performed to the 21 sediment samples collected in the Lukanga Swamp area and the upper Kafue River. Grain-size data and specific weight are shown in Table 4. Concentrations of metals and metalloids are shown in Table 5, concentrations of organic compounds and total organic carbon in Table 8.

4.1. Grain-size analysis

Grain-size analysis shows that “sand” and “loamy sand” dominate sediment analysed. However, sediment samples span from a classification of clay (maximum value of 50% in sample 6) to sand (maximum value of 94% in sample 15).

Table 4 – Specific weight and grain-size classification of sediment samples collected in the Lukanga Swamp Area and Upper Kafue River Basin

Sta./Param.	Specific weight (g/l)	Grain-size (%)				Classification*
		< 2 µm	2 - 63 µm	63 µm - 2 mm	> 2 mm	
1	2179	43	27	26	4	Clay
2	2565	5.8	15.2	76	3	Loamy Sand
3	2190	<1	15	73	11	Loamy Sand
4	2556	<1	3.8	93.2	2	Sand
5	2716	2.8	59.2	25	13	Silt Loam
6	2147	50	15	24	11	Clay
7	2338	29	7	45	19	Sandy Clay Loam
8	2419	8	55	11	26	Silt Loam
9	2570	<1	12	80	7	Sand
10	2141	49	19	21	11	Clay
11	2546	<1	5.5	90.5	3	Sand
12	2071	14	26	16	44	Sandy Loam
13	2487	15	21	64	0	Sandy Loam
14	2514	1.9	3.8	92.3	2	Sand
15	2514	<1	4.2	93.8	1	Sand
16	2256	34	42	14	10	Clay Loam
17	2505	8.5	19.5	67	5	Sandy Loam
18	2432	24	22	46	8	Sandy Clay Loam
19	2300	30	21	38	11	Sandy Clay Loam
26	1821	26	10	17	47	Sandy Clay Loam
27	2114	11	14	39	36	Sandy Loam

*Classification according to Figure 21

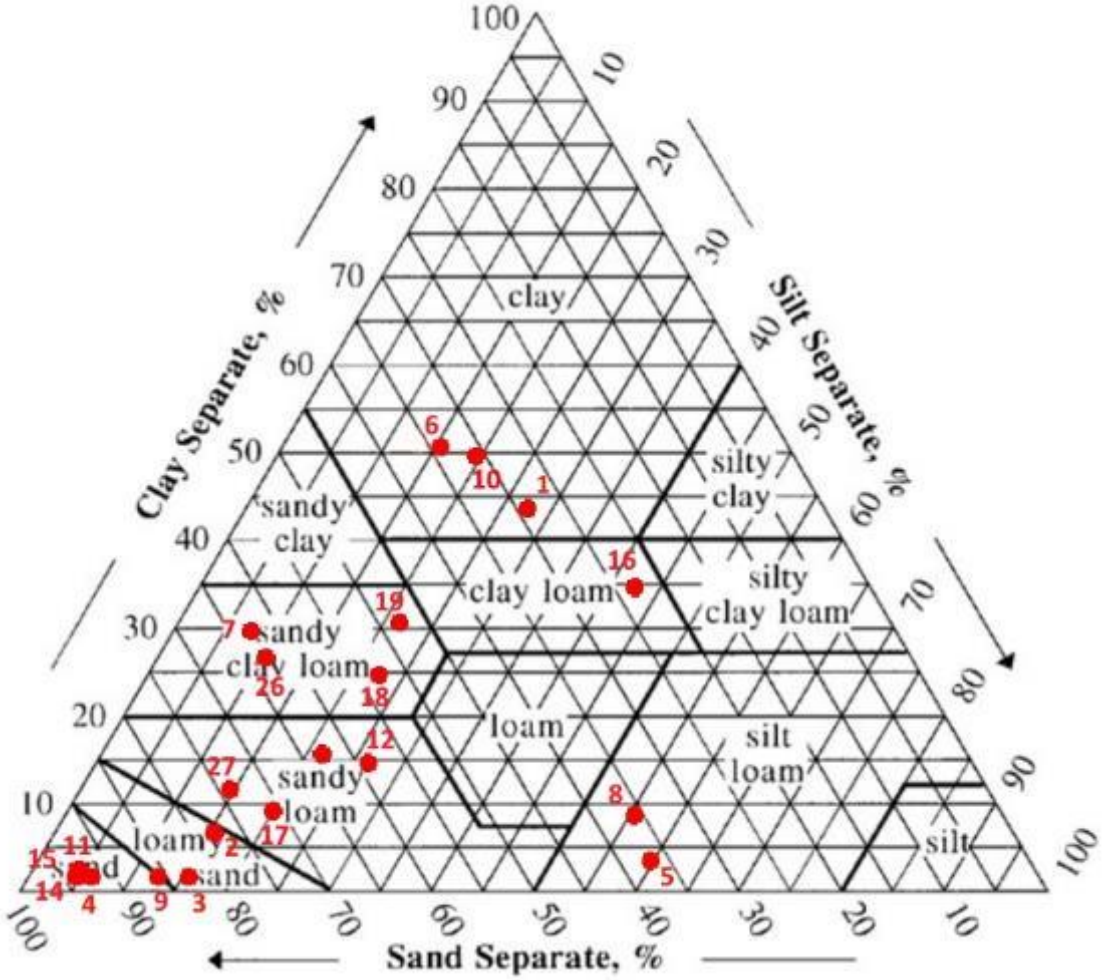


Figure 21 – Sediment texture classification triangle plot for sediment samples collected in the Lukanga Swamp area and Upper Kafue River Basin

4.2. Chemical analyses

Major elements Al and Fe show average low concentrations of 1.8% (range from 0.1% to 4.5%) and 1.9% (0.2% - 8.5%), respectively. In accordance, concentration of clay-sized particles is also relatively low (average = 17%, range = <1% - 50%). In fact, there is a slight correlation (0.79) between clay-sized particles and Al (Table 7).

These sediments have low contents of aluminosilicates and are probably enriched in other types of minerals such as quartz, carbonates or even sulphides. In accordance, Vrana (1974) for the area south of the Lukanga Swamp states that most of the area is covered by eluvial soils of the Plateau type, which are fine- to medium-grained sandy soils, with low content of clay at the surface.

Copper is the trace metal with the highest concentrations (average of 888 mg/kg), followed by Co (average of 91 mg/kg), Cr (average of 34 mg/kg) and Zn (average of 30 mg/kg).

Metal concentrations are in fact higher in the Copperbelt area in comparison to the Lukanga Swamp, respectively (average values):

- Cu – 2247 vs. 44 mg/kg;
- Co – 222 vs. 10 mg/kg;
- Zn – 59 vs. 13 mg/kg*;
- Cr – 47 vs. 34 mg/kg;
- Ni – 19 vs. 14 mg/kg;
- Pb – 14 vs. 7 mg/kg*;
- Fe – 2.5 vs. 1.7 %;
- Al – 2.0 vs. 1.8 %.

* More than half of the samples have concentrations below the detection limits so these average values must be looked at with caution.

Except for sample 16 (Copperbelt), Cd and Hg concentrations are consistently below detection limits.

Through the correlation analysis between metals (Table 6) one may conclude that:

- Fe, Cr, Co and Ni are those with more correlations with other metals;
- Fe in these samples seems to represent better oxides than aluminosilicates;
- As, Co, Cr and Cu are better associated to oxides;
- Ni, but also Cr and Zn seem better associated to aluminosilicates.

Table 7 shows correlations between metals and TOC (concentrations of TOC are found in Table 8, and clay and fine-grained content, and these agree with the above conclusions. It is not possible to evaluate the importance of carbonates or sulphides in relation to these metals. However, one knows these minerals are important given the geological context of the area.

In fact, according to De Putter *et al.* (2011) in the Katanga Copperbelt Cu-bearing minerals/ore typically malachite (copper carbonate hydroxide mineral) and associated mineral species, are highly diversified though generally depleted in most trace metals. This explains Cu weak correlations with most of the other metals (except Co).

In addition, Co-bearing minerals/ores are essentially represented by heterogenite (CoOOH). As most oxyhydroxides, this mineral acts as a chemical “sponge”, trapping many trace metals. This explains Co positive correlations with Fe, Ni, Cu, Cr and Zn.

Table 5 – Elemental concentrations (mg/kg) of sediment samples collected in the Lukanga Swamp area and Upper Kafue River Basin

Sta./Param.	Al	As	Cd	Co	Cu	Cr	Fe	Pb	Hg	Ni	Zn
1	2.70	<4	<0.2	19	190	29	1.4	<10	<0.05	18	<20
2	0.46	<4	<0.2	4.7	6.8	23	1.9	<10	<0.05	4.5	<20
3	0.15	<4	<0.2	<1.5	<5	5	0.17	<10	<0.05	<3	27
4	0.96	57	<0.2	20	49	170	8.5	<10	<0.05	31	26
5	2.90	8.8	<0.2	570	2600	140	6.4	<10	<0.05	24	51
6	2.80	<4	<0.2	6	39	29	0.83	<10	<0.05	19	<20
7	4.30	<4	<0.2	30	180	55	1.4	10	<0.05	32	45
8	1.30	5.5	<0.2	180	3700	19	2.1	10	<0.05	17	40
9	1.20	4.4	<0.2	140	5000	14	1.4	<10	<0.05	13	38
10	4.50	<4	<0.2	10	55	20	0.93	14	<0.05	14	<20
11	0.17	<4	<0.2	4.1	8.7	12	0.65	13	<0.05	<3	<20
12	3.50	<4	<0.2	13	42	30	0.59	<10	<0.05	28	<20
13	1.60	<4	<0.2	86	1300	24	1.60	10	<0.05	15	24
14	0.22	<4	<0.2	7.7	92	<10	0.28	<10	<0.05	<3	<20
15	0.28	<4	<0.2	160	800	18	0.72	<10	<0.05	6	<20
16	3.10	7.6	0.53	450	3300	43	3.20	60	0.24	34	250
17	0.89	6.1	<0.2	160	1100	63	3.20	<10	<0.05	8.8	<20
18	1.30	5.5	<0.2	8.4	13	24	1.40	<10	<0.05	9.9	<20
19	2.40	7.5	<0.2	16	28	50	2.50	<10	<0.05	19	<20
26	2.30	<4	<0.2	11	30	34	1.10	15	<0.05	19	<20
27	1.40	<4	<0.2	4.9	15	15	0.62	<10	<0.05	11	<20

Note: When concentration was below detection limit, calculations were done considering half of the detection limit

Table 6 – Spearman correlations between different metals analysed in sediment samples

Metals	Al	As	Co	Cu	Cr	Fe	Pb	Ni	Zn
Al	1.00								
As	0.25, p 0.54	1.00							
Co	0.32, p 0.15	0.28, p 0.51	1.00						
Cu	0.28, p 0.22	-0.31, p 0.45	0.90, p 0	1.00					
Cr	0.55, p 0.01	0.90, p 0	0.51, p 0.02	0.22, p 0.33	1.00				
Fe	0.22, p 0.35	0.94, p 0	0.66, p 0	0.45, p 0.04	0.72, p 0	1.00			
Pb	0.30, p 0.52	-	-0.04, p 0.94	-0.26, p 0.57	0.19, p 0.69	-0.04, p 0.94	1.00		
Ni	0.80, p 2E-05	0.74, p 0.03	0.51, p 0.02	0.36, p 0.11	0.78, p 3E-05	0.49, p 0.02	0.26, p 0.57	1.00	
Zn	0.67, p 0.07	-	0.69, p 0.06	0.40, p 0.32	0.21, p 0.61	0.19, p 0.65	-	0.59, p 0.12	1.00

Note: Correlation coefficients of As, Zn and Pb were calculated considering only values above detection limits; grey correlations mean that, by normal standards, the association between the two variables would not be considered statistically significant.

Sediments collected in the Lukanga Swamp area are characterised by high contents of organic carbon (organic matter) with average value of 2.9% (<0.1% - 5.7%). On the other hand, sediments collected in the Copperbelt area show low contents of organic matter (average TOC of 0.8%; range between <0.1% and 3.3%). Regarding metals, TOC only correlates significantly with Al (Table 7). This correlation is higher if samples from the Lukanga and Copperbelt areas are analysed separately (not shown).

Table 7 – Spearman correlations between metals and organic carbon and grain-size parameters

Metals	TOC	% clay	% fine-grained fraction
Al	0.56, p 0.03	0.79, p 2E-05	0.78, p 3E-05
As	-	0.01, p 0.98	0.06, p 0.89
Co	-0.35, p 0.21	0.02, p 0.93	0.26, p 0.25
Cu	-0.21, p 0.46	0.02, p 0.94	0.24, p 0.29
Cr	-0.03, p 0.91	0.39, p 0.08	0.36, p 0.11
Fe	-0.44, p 0.10	0.11, p 0.64	0.27, p 0.23
Pb	-	0.48, p 0.27	0.42, p 0.34
Ni	0.48, p 0.07	0.51, p 0.02	0.53, p 0.01
Zn	-	0.51, p 0.19	0.71, p 0.05

Iron concentrations are relatively low in sediments from the Kafue River and associated tributaries (Figure 22). Concentrations are relatively higher downstream Kitwe and in the nearby Mopani stream. Distribution of Al concentrations along the Kafue River is very similar to that of Fe, however concentrations in the tributaries can be behave very differently (Figure 23).

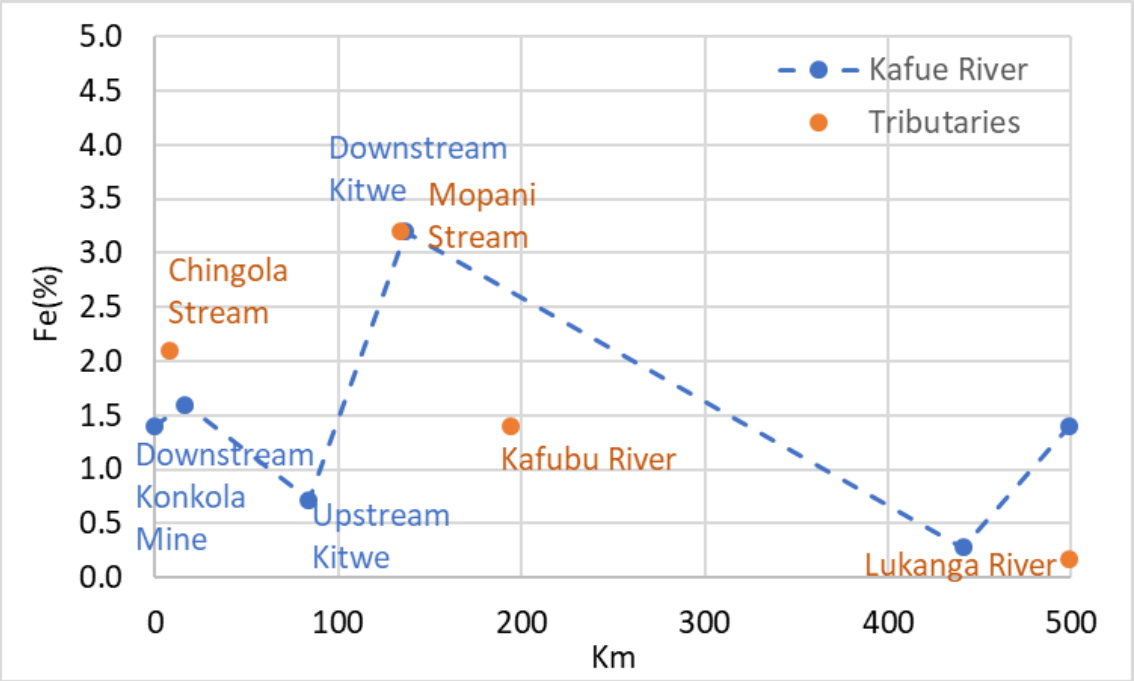


Figure 22 – Iron concentrations in the Kafue River and tributaries

Tributaries associated with mines of Cu and Co (Luanshya, Mopani, Chingola) are enriched in Fe in relation to Al. Along the Kafue River, dilution of metal-bearing minerals with clay minerals and other aluminosilicates (*e.g.* feldspars) redefines the relationship of concentrations of the two metals.

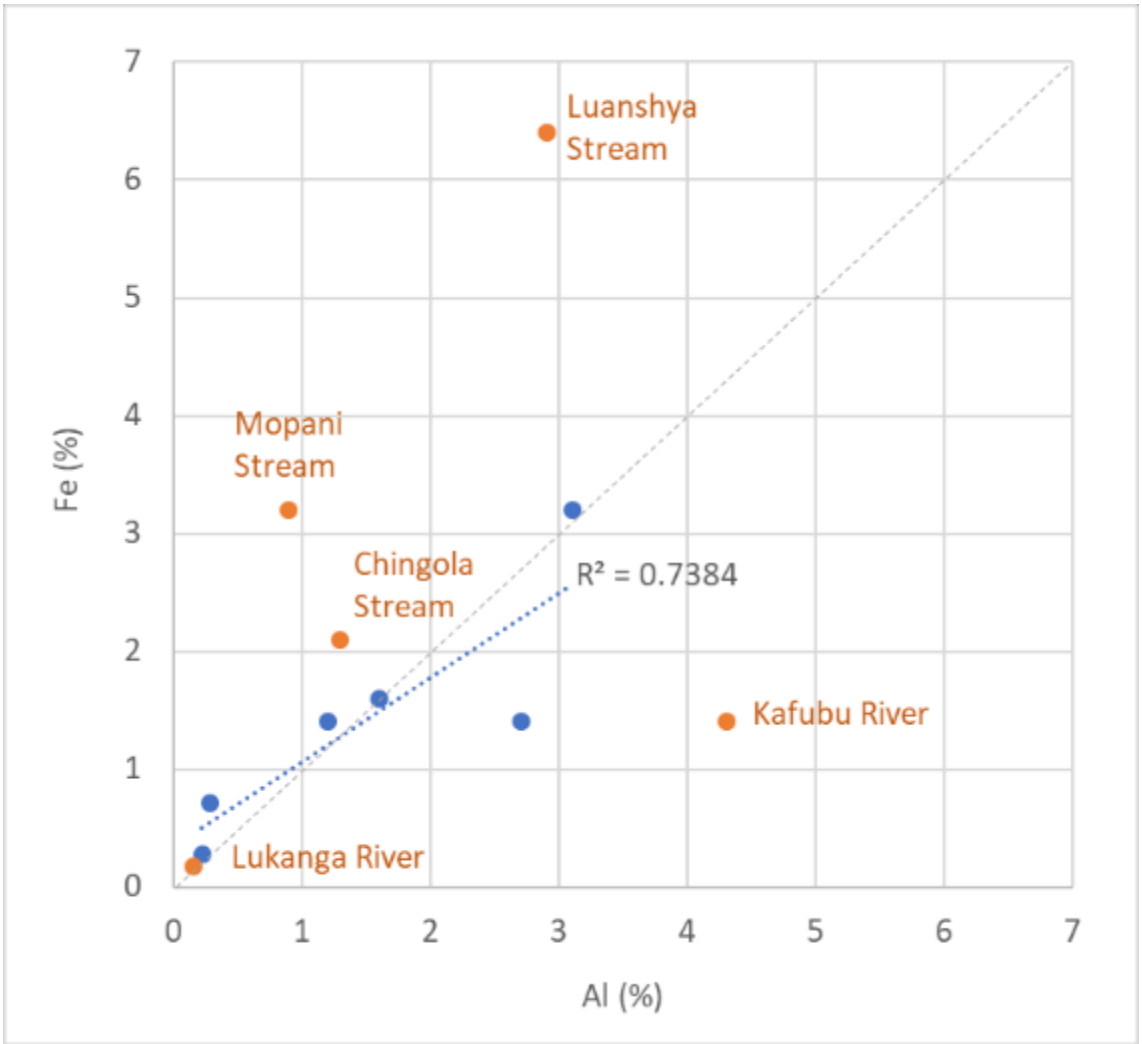


Figure 23 – Concentrations of Fe against Al

Table 8 shows concentrations of TOC and organic compounds determined in sediments (Polycyclic Aromatic Hydrocarbons – PAH, Polychlorinated Biphenyl – PCB and Hexachlorobenzene – HCB). In most sediment samples, concentrations are below the detection limits. For PAH exceptions correspond to samples 5, 13 and 16. These were collected in the Copperbelt area. As for PCB, the exception is sample 16. These samples were collected in the Kafue River (for samples 13 and 16) and Luanshya River (for sample 5), close to urban areas of Chililabombwe, Kitwe and Luanshya, respectively. About Hexachlorobenzene (a toxic fungicide) concentrations were always below detection limits.

Table 8 – Total organic carbon (%) and organic compounds (mg/kg for PAH and µg/kg for PCB and HCB) of sediment samples collected in the Lukanga Swamp area and Upper Kafue River Basin

Sta./Param.	TOC	PAH	PCB	HCB	Sta.	TOC	PAH	PCB	HCB
1	3.3	<0.18	4.9	<0.5	**12**	5.7	<0.45	4.9	<1
2	0.78	<0.18	4.9	<0.5	**13**	1.1	0.42	4.9	<0.5
3	3.0	<0.18	4.9	<0.5	**14**	<0.2	<0.18	4.9	<0.5
4	<0.2	<0.18	4.9	<0.5	**15**	0.31	<0.18	4.9	<0.5
5	<0.2	0.23	4.9	<0.5	**16**	3.3	0.58	9.4	<0.5
6	3.5	<0.18	4.9	<0.5	**17**	0.46	<0.18	4.9	<0.5
7	1.2	<0.18	4.9	<0.5	**18**	1.4	<0.18	4.9	<0.5
8	<0.2	<0.18	4.9	<0.5	**19**	2.1	<0.18	4.9	<0.5
9	<0.2	<0.18	4.9	<0.5	**26**	9.1	<0.36	4.9	<0.74
10	5.0	<0.27	4.9	<0.5	**27**	3.8	<0.27	4.9	<0.51
11	<0.2	<0.18	4.9	<0.5	-	-	-	-	-

Notes: Grey cells represent samples were organic compounds are higher than detection limits; Stations 20 to 25 are not missing; these station numbers were used to maintain the same station number for all media analyses.

4.3. Comparison with quality guidelines

The sediment quality guideline (SQG) of the National Oceanic Atmospheric Administration (NOAA), developed to assess biological effects of metal contamination, classifies different levels of metal concentration as “Effects Range-Low” (ERL) and “Effects Range-Medium” (ERM). These ERL and ERM represent, respectively, the 10th and 50th percentiles of the available dataset for different trace metal components (Long *et al.*, 1995). The ERMs are supposed to represent concentrations above which adverse biological effects are expected to be common (between 17% and 95%, depending on the parameter), whereas ERLs represent concentrations below which effects are expected to be rare. Between these values effects are expected to happen occasionally. Obviously, this classification is rather arbitrary since it is merely based on the statistics of the available data, and chemical concentrations do not directly correspond to sediment toxicity (O’Connor & Paul, 2000).

Table 9 summarises the comparison between concentrations of different parameters and NOAA’s sediment quality guidelines. According to the results there are higher probabilities of having toxicity for all metals in sediments from those places sampled in the Copperbelt Province. Total concentrations of PAH are always below ERL in both areas.

Copper is the element with highest number of samples above ERL, and the only one with concentrations above ERM, which occur in the Copperbelt Province. For this specific element and threshold, adverse biological effects are expected in 83.7% of the cases.

Nickel is the following metal with the highest number of samples above ERL in both areas. Arsenic and Cr are the following ones with samples above ERL in both areas. On the other hand, Pb and Zn only have samples above ERL in the Copperbelt Province (Table 9).

Table 9 – Percentage of sediment samples above the ERL and ERM

Parameters	Lukanga (13 samples)		Copperbelt (8 samples)	
	ERL (%)	EML (%)	ERL (%)	EML (%)
As	7.7	0	12.5	0
Cr	7.7	0	12.5	0
Cu	46.2	0	12.5	87.5
Pb	0	0	12.5	0
Ni	15.4	0	37.5	0

Parameters	Lukanga (13 samples)		Copperbelt (8 samples)	
	ERL (%)	EML (%)	ERL (%)	EML (%)
Zn	0	0	12.5	0
PAH	0	0	0	0

Looking into the Lukanga Swamp Area, sample 4 (located near Chitanda) has higher concentrations than ERL for four elements (As, Cr, Cu and Ni), and sample 12 (near Shishimo) for two elements (Cu and Ni). The other 4 samples have higher concentrations than ERL values only for Cu.

4.4. Assessment of contamination

The assessment of sediment contamination included analysis of metals (Al, As, Cd, Cu, Cr, Co, Fe, Hg, Ni, Pb, Zn).

Results show that Hg and Cd are not contaminants in the sediment analysed as they show concentrations almost consistently below detection limits.

To study the enrichment of trace metals in sediments different approaches will be used according to the metal. For Co, Cu, Cr, As and Ni enrichment factors will be used because these elements show positive correlations with conservative common element (Al and Fe). Given the correlations found between metals (Table 6), Fe was used as normaliser for Co, Cu, Cr, As, and Al for Ni. Enrichment factors will not be calculated for Pb and Zn because they do not show a significant positive correlation with any of the above normalisers.

4.4.1. Concentrations of Pb and Zn

Most of the collected sediment samples show low concentrations of Pb (<10 mg/kg) and Zn (<50 mg/kg). The only exception is a sample collected downstream from Kitwe in the Kafue River which has 60 mg/kg of Pb and 250 mg/kg of Zn.

The relatively low inputs of Pb and Zn in the Kafue River along the industrial Copperbelt area is also shown in Kribek *et al*. (2011). These authors show that Pb concentrations go from 4 -13 mg/kg to 15 - 34 mg/kg and from 45 – 80 mg/kg to 38 – 73 mg/kg for Zn, from upstream to downstream of the industrial Copperbelt area, respectively.

In the Lukanga Swamp, Pb concentrations are consistently lower than 15 mg/kg. These values are in accordance with concentrations found in non-contaminated areas: 4 – 13 mg/kg in sediments from the Kafue River (upstream from industrial Copperbelt area) (Kribek *et al.*, 2011); 9.0 – 9.7 mg/kg in topsoil samples from 20 km to the north and east of Kabwe mine (Tembo *et al*., 2006).

Concentrations of Zn are lower than 27 mg/kg, and as referred above these values are even lower than those found in non-contaminated areas of the Kafue River.

4.4.2. Enrichment factors

In order to calculate enrichment factors (EF), trace metal contents were normalised using a conservative common element.

To calculate EF ideally one should use local background concentrations. However, these are not always available. For this reason, mean concentrations of metals at Chimfunshi published in M'kandawire *et al.* (2017) were used. This is an upstream preindustrial site located in the Kafue River. So, in this report when one says sediment is enriched in a given metal it is in relation to this area.

From the highest number of samples with EF > 1.5 to the lowest results show the following succession: As (75%) > Cu (48%) > Co (38%) ~ Ni (38%) > Cr (5%) (Table 10).

The relatively high number of samples enrichment in arsenic as to what is found at Chimfunshi occurs because most of the samples analysed have concentrations below the detection limit (< 4 mg/kg) and so EF were not calculated in these.

In the Lukanda Swamp and water streams draining into it (excluding the Kafue River samples 1 and 14) Cu, Cr and Co show no signs of enrichment in comparison to Chimfunshi. Regarding Ni, only sample 4 (Chiyuni River, near Chitanda) shows enrichment. For As, enrichment could only be determined in some samples (4, 18, 19), and all of them show enrichment. Besides the Chiyuni River, sample 18 was collected in the Mundu River and 19 in the Waya channel.

Table 10 – Summary of results for the sediment enrichment factors

Element	Lukanga		Copperbelt	
	Number Samples above 1.5	Average EF value	Number Samples above 1.5	Average EF value
As	3 (out of 3)	3.3	3 (out of 5)	1.7
Cr	1 (out of 13)	0.8	0 (out of 8)	0.6
Co	1 (out of 13)	0.7	7 (out of 8)	6.5
Cu	2 (out of 13)	0.9	8 (out of 8)	18.1
Ni	3 (out of 13)	1.5	5 (out of 8)	1.8

It is not surprising that these rivers and channel show some metal enrichments as:

- Some garbage was observed there during the field surveys; and
- There is high sediment turbation. Sediment turbation occurs in these rivers because it is common to see cattle there; for the Waya channel, resuspension occurs due to frequent boat transit propelled by sticks in them. In addition, children were observed bathing in these water streams.



a – Chiyuni River



b – Muundu River

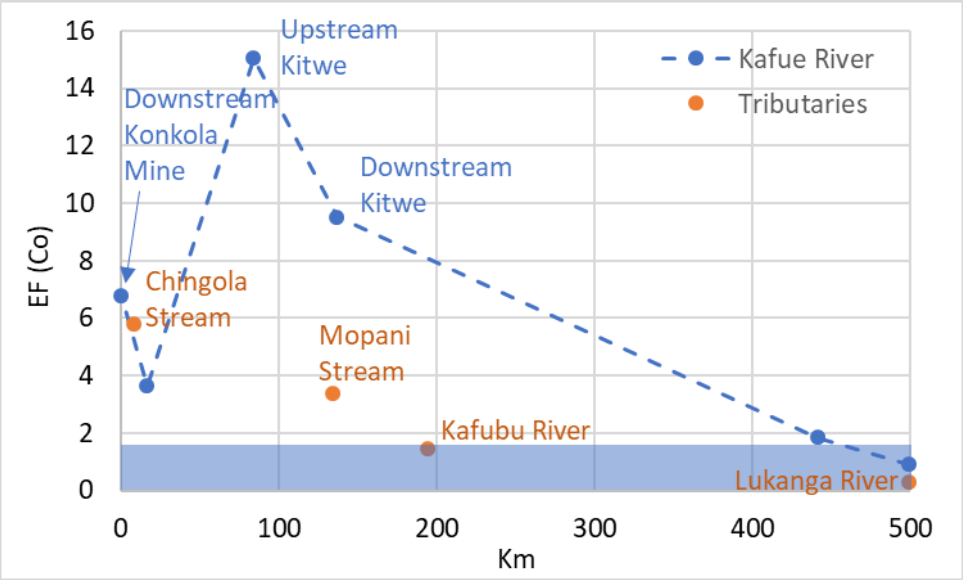


C – Waya Channel

Figure 24 – Sediment sampling stations 4 (a), 18 (b) and 19 (c)

As expected, the highest EF values were found for Cu and Co in the Copperbelt Province. The distribution of EF(Co) along the Upper Kafue River Basin (Figure 25) show that:

- Cobalt is enriched in the Kafue River until around its junction with the Lukanga River;
- Chingola and Mopani streams are also enriched in Co;
- The highest enrichment of Co was found upstream from Kitwe and downstream from the junction of the river with the Chingola stream. The source for this Co is certainly from upstream Kitwe and it may be accumulating in this area for reasons related to hydrodynamics of the river.
- The Kafubu River shows no sign of Co enrichment, however a sediment sample collected in the Luanshya River (upstream tributary of the Kafubu River) shows EF of 6. These results suggest that the amount of unenriched sediment from the Kafubu River is enough to dilute the enriched contributions of the Luanshya River.
- Contributions of Co from the Lukanga Swamp into the Kafue River seem insignificant.

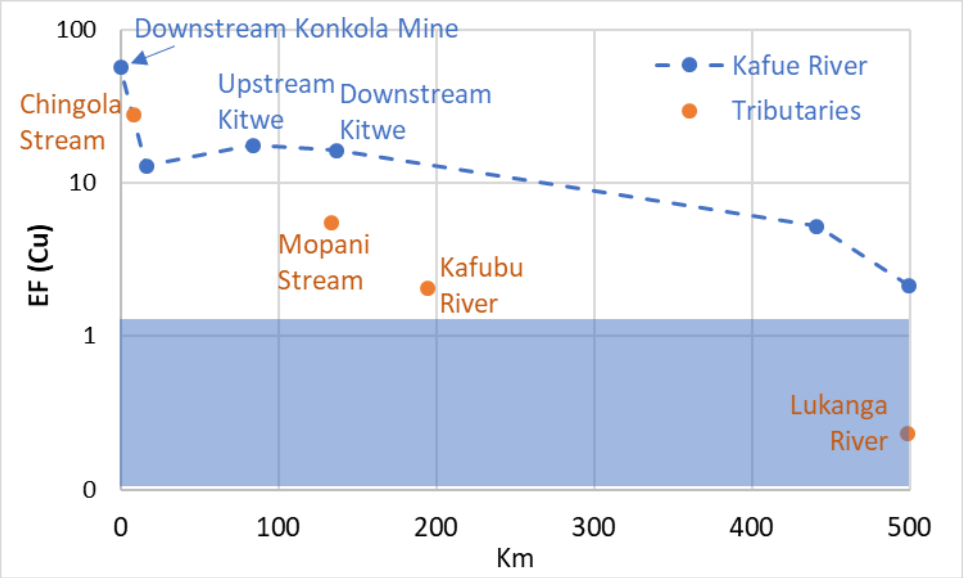


Note: Blue bar highlights values below 1.5

Figure 25 – EF(Co) in sediments collected in the Kafue River and selected tributaries

The distribution of EF(Cu) along the Upper Kafue River Basin (Figure 26) show that:

- Copper is enriched in the Upper Kafue River, including the area of the junction with the Lukanga Swamp;
- Chingola, Mopani and Kafubu streams are also enriched in Cu;
- The highest enrichment of Cu was found downstream Konkola mine, but values continue high in the Kafue river even downstream Kitwe.
- The Kafubu River shows EF(Cu) of 2, and the sediment sample collected in the Luanshya River (upstream tributary of the Kafubu River) shows EF of 6. These results are in accordance with the above idea of dilution along the Kafubu River.
- Contributions of Cu from the Lukanga Swamp into the Kafue River seem insignificant.

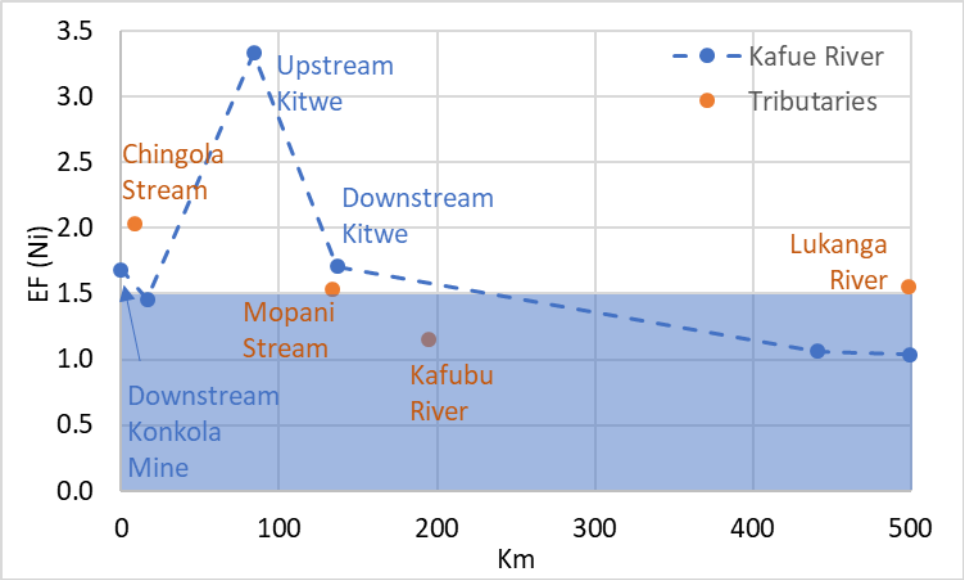


Note: Blue bar highlights values below 1.5

Figure 26 – EF(Cu) in sediments collected in the Kafue River and selected tributaries

The distribution of EF(Ni) along the Upper Kafue River Basin (Figure 27) show that:

- Nickel is enriched in some sediment samples collected in the Copperbelt;
- The highest enrichment of Ni was found upstream from Kitwe and downstream from the junction of the river with the Chingola stream. The source for this Ni is certainly from upstream Kitwe and it may be accumulating in this area for reasons related to hydrodynamics of the river.
- The Lukanga Swamp may be contributing Ni to the Kafue River.



Note: Blue bar highlights values below 1.5

Figure 27 – EF(Ni) in sediments collected in the Kafue River and selected tributaries

The distribution of EF(Cr) along the Upper Kafue River Basin (Figure 28) shows that:

- Chromium is not enriched in the areas studied of the Upper Kafue River;
- The highest values of EF(Cr) were found upstream from Kitwe and downstream from the junction of the river with the Chingola stream;
- The Kafubu River shows EF(Cr) of 1.3, and the sediment sample collected in the Luanshya River (upstream tributary of the Kafubu River) shows EF of 0.7; these results are in accordance with the above idea of dilution along the Kafubu River.
- The Lukanga Swamp may be contributing Cr to the Kafue River.

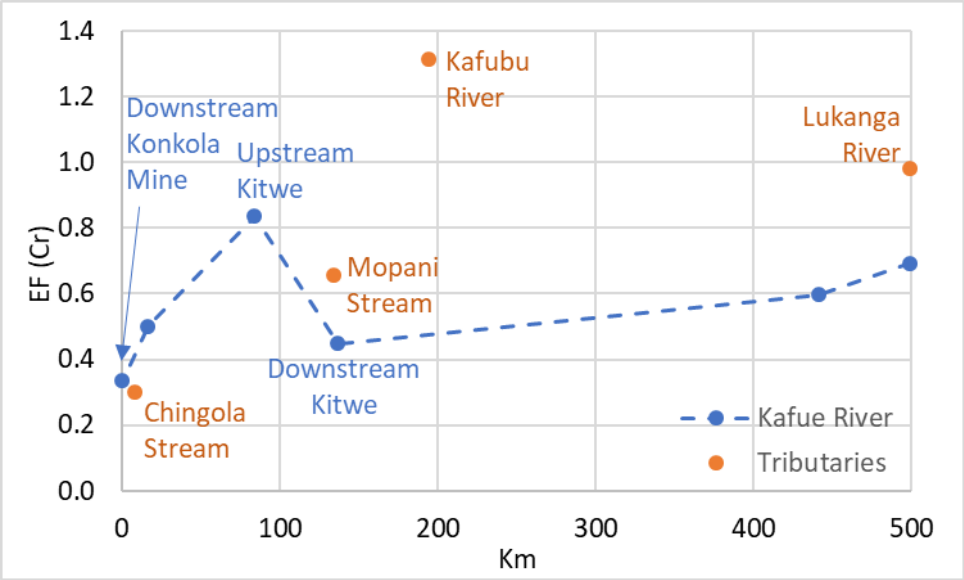


Figure 28 – EF(Cr) in sediments collected in the Kafue River and selected tributaries

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5. Leaves

Bulk concentrations of metals in the analysed leaves follow the pattern: [Zn] > [Cu] > [Cr] ~ [Co] ~ [Ni] > [Pb] ~ [As] > [Hg] ~ [Cd]. Results from analyses performed in leaves are summarised in Table 11.

Table 11 – Elemental concentration in composite leaf samples (in mg/kg)

Sta./Param.	As	Cd	Co	Cu	Cr	Pb	Hg	Ni	Zn
28 – Luk	0.0089	0.0034	0.024	1.5	0.40	0.170	0.0032	0.23	**30**
29 – Luk	0.036	0.0010	0.18	6.6	**1.10**	0.098	0.0045	0.65	26
27 – Luk	0.120	0.0017	0.023	3.9	0.40	0.290	0.0035	0.36	16
25 – Luk	0.110	0.0013	0.013	1.0	0.13	0.049	0.0040	0.10	21
26 – Luk	0.031	0.0020	0.022	3.6	0.24	**0.300**	0.0028	0.18	15
16 – CoBelt	**0.330**	**0.0036**	0.46	12	**1.10**	0.160	0.0036	0.47	7.9
2 – CoBelt	0.011	0.0009	0.049	5.4	**1.10**	0.028	0.0026	**1.00**	11
11 – CoBelt	0.140	0.0022	**1.10**	**19**	**1.10**	0.063	0.0030	0.87	7.5
15 – CoBelt	0.084	0.0030	0.41	12	0.75	0.100	**0.0049**	0.44	11
17 – CoBelt	0.048	0.0021	0.99	11	0.58	0.072	0.0043	0.34	14
AVG – Luk	*0.061*	*0.002*	*0.052*	*3.320*	*0.454*	*0.181*	*0.004*	*0.304*	*21.60*
AVG – CoBelt	*0.123*	*0.002*	*0.602*	*11.880*	*0.926*	*0.085*	*0.004*	*0.624*	*10.28*

Notes: Stat. – Station; Param. – Parameters; Luk – Samples collected in the Lukanga Swamp area; CoBelt – Samples collected in the Copperbelt Province.
Underlined concentrations are minimums and **bold concentrations** are maximums for that specific element.

In the same way as it happens for sediments, there is a predominance of maximum concentrations in the Copperbelt Province and of minimum concentrations in the Lukanga Swamp area (Table 11). In fact, only Pb and Zn behave the other way around.

The comparison between both areas becomes easier when analysing them through box plots for the different elements (Figure 29, Figure 30, Figure 31 and Figure 32). Through these it becomes clear that distributions of Zn, Cu and Co are indeed different in the two areas. Sampled leaves from the Lukanga Swamp area have higher concentrations of Zn, while sampled leaves from the Copperbelt Province have higher concentrations of Cu and Co.

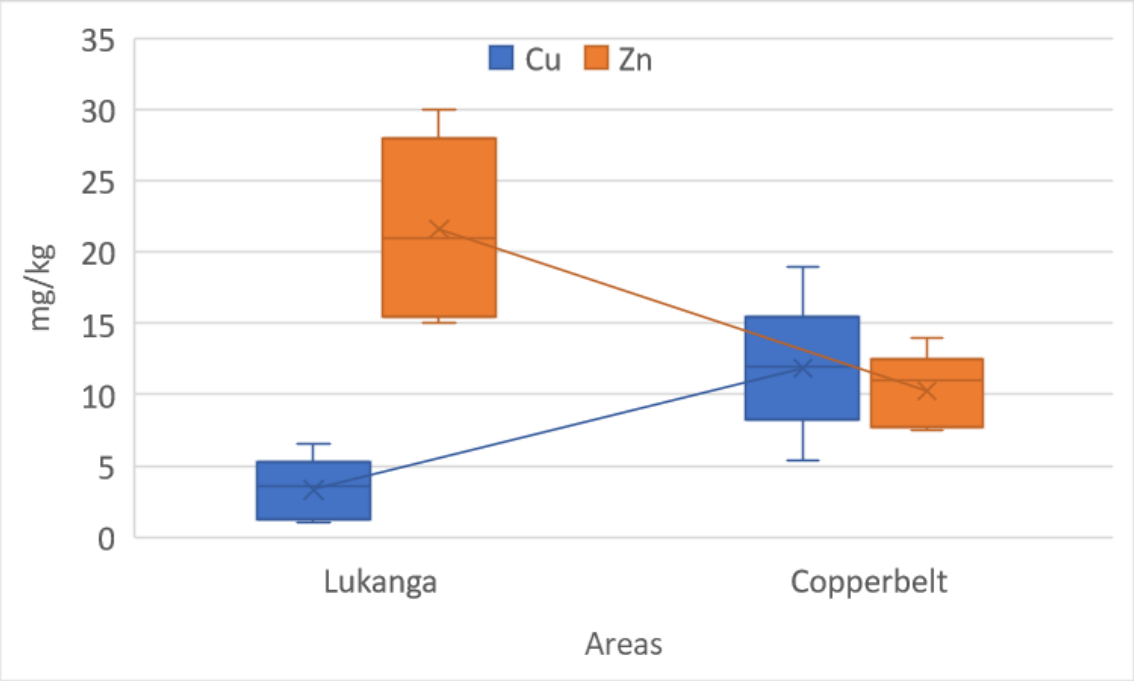


Figure 29 – Concentration distributions of Cu and Zn for the Lukanga and Copperbelt areas

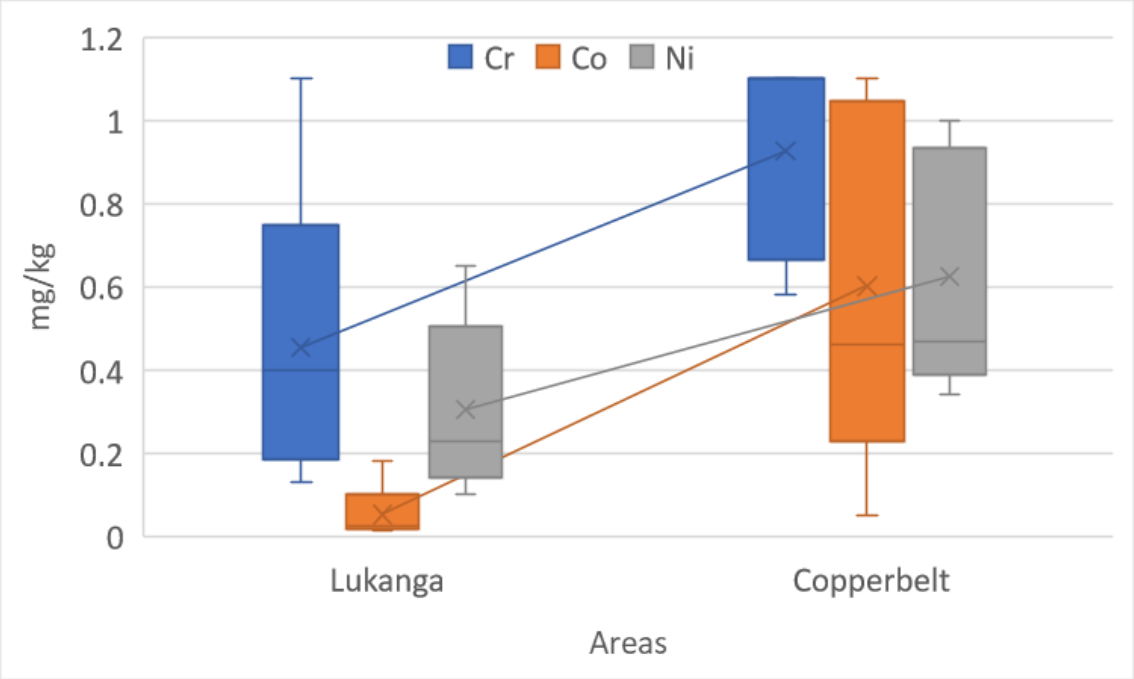


Figure 30 – Concentration distributions of Cr, Co and Ni for the Lukanga and Copperbelt areas

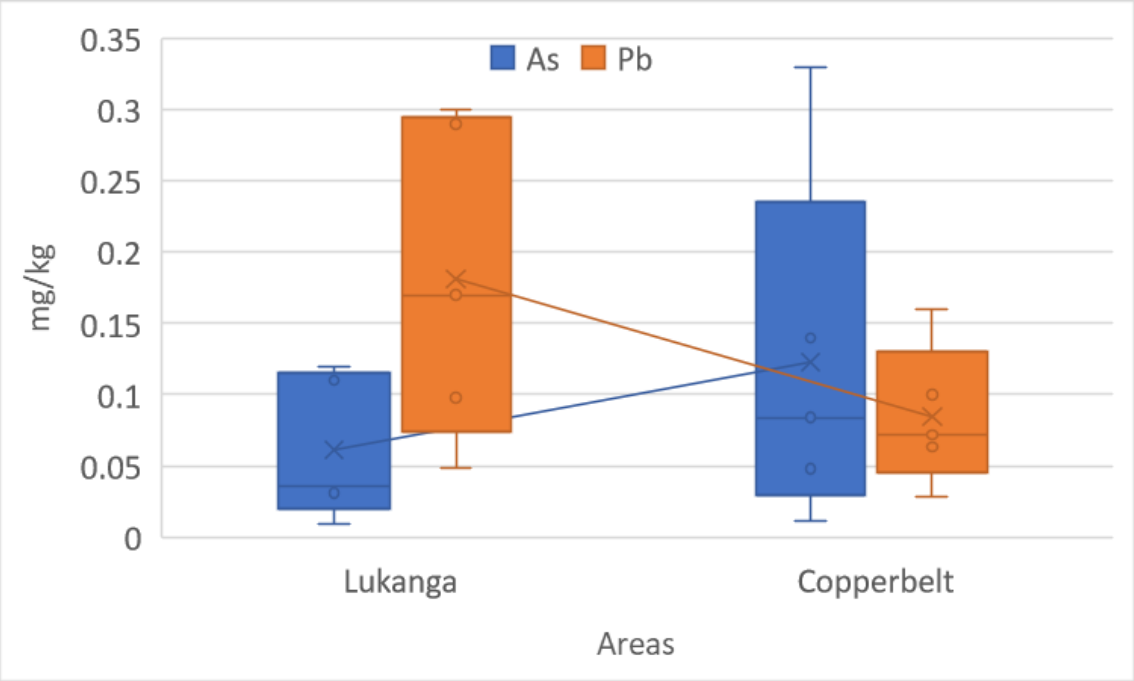


Figure 31 – Concentration distributions of As and Pb for the Lukanga and Copperbelt areas

Mean concentrations of As, Cr, Ni, Cd and Hg are also higher in the Copperbelt Province but both distributions intercept greatly, so the distinction is less clear (Figure 30, Figure 31 and Figure 32). On the other hand, Pb seems also to be higher in the Lukanga Swamp area (Figure 31).

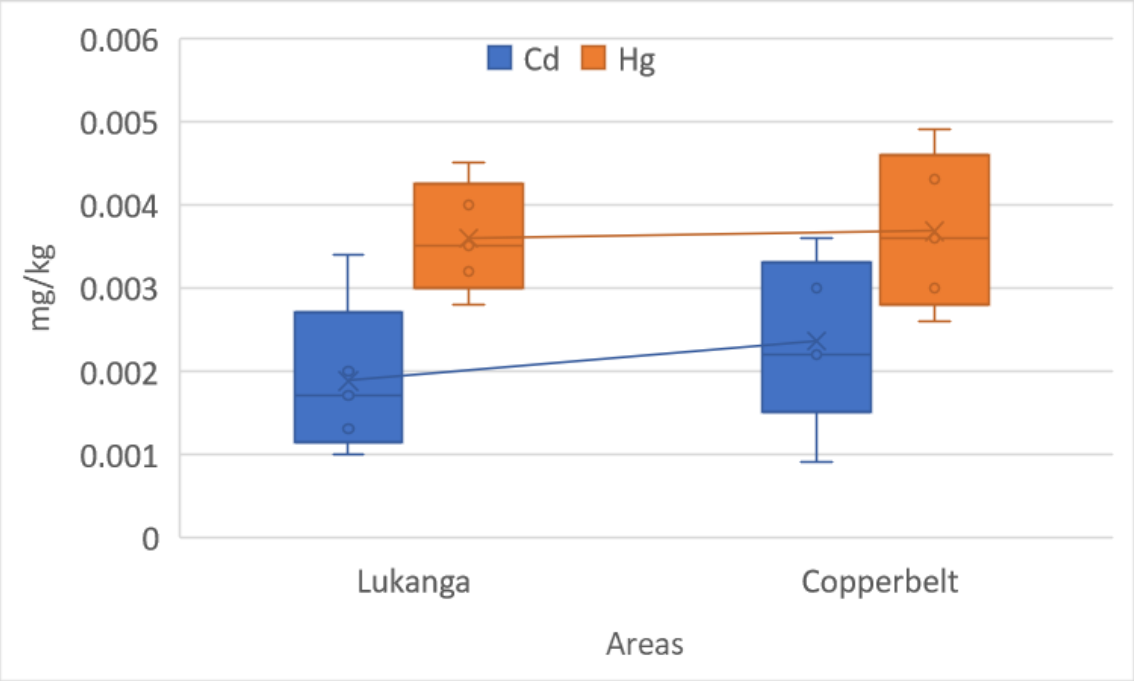


Figure 32 – Concentration distributions of Cd and Hg for the Lukanga and Copperbelt areas

5.1. Comparison with reference values; assessment of contamination

In order to assess the presence of excess or toxic amounts of metals (or metalloids in the case of As) in leaves, the concentrations found are compared to reference values summarised in Kabata-Pendias (2011). These are a range of concentrations of trace elements in mature leaf tissue generalised for various species. Table 12 summarises this classification.

Table 12 – Classification of elemental concentrations (in mg/kg) according to excessive or toxic concentrations indicated in Kabata-Pendias (2011)

Sta./Param.	As	Cd	Co	Cu	Cr	Pb	Hg	Ni	Zn
Excessive or Toxic Concentrations	5-20	5-30	15-50	20-100	5-30	30-300	1-3	10-100	100-400
28 – Luk	0.0089	0.0034	0.024	1.5	0.40	0.170	0.0032	0.23	30
29 – Luk	0.036	0.0010	0.18	6.6	1.10	0.098	0.0045	0.65	26
27 – Luk	0.120	0.0017	0.023	3.9	0.40	0.290	0.0035	0.36	16
25 – Luk	0.110	0.0013	0.013	1.0	0.13	0.049	0.0040	0.10	21
26 – Luk	0.031	0.0020	0.022	3.6	0.24	0.300	0.0028	0.18	15
16 – CoBelt	0.330	0.0036	0.46	12	1.10	0.160	0.0036	0.47	7.9
2 – CoBelt	0.011	0.0009	0.049	5.4	1.10	0.028	0.0026	1.00	11
11 – CoBelt	0.140	0.0022	1.10	19	1.10	0.063	0.0030	0.87	7.5
15 – CoBelt	0.084	0.0030	0.41	12	0.75	0.100	0.0049	0.44	11
17 – CoBelt	0.048	0.0021	0.99	11	0.58	0.072	0.0043	0.34	14

Notes: Reference range of excessive or toxic concentrations according to Kabata-Pendias (2011); Green means concentrations are below excessive or toxic concentrations; Orange means concentrations are very close (< 2 mg/kg) to excessive or toxic concentrations.

In Vymazal *et al.* (2007) metal concentrations from different portions of *Phragmites australis* and *Phalaris arundinacea* are analysed and compared with concentrations found in both natural and constructed wetlands around the world.

Metal concentrations found in leaves here analysed are only comparable to those referred in Vymazal *et al.* (2007) for Cu and Zn. The other metals that are indicated in the referred study (Cd, Cr, Pb, Ni) have concentrations similar to the lowest concentrations found in these studies (Table 13).

Table 13 – Comparison of average concentrations found in leaves with those from leaves of *Phragmites* spp. in natural and constructed wetlands around the world

Stat./Param.	As	Cd	Co	Cu	Cr	Pb	Hg	Ni	Zn
AVG (range) leaves Vymazal *et al.* (2007)	-	2.3 (0.03 – 9.7)	-	7.3 (1.5 – 72)	4.1 (0.39 – 15)	16.9 (0.1 – 264)	-	4.9 (0.64 – 20.7)	22.1 (10 – 277)
AVG – Luk	*0.061*	*0.002*	*0.052*	*3.3*	*0.45*	*0.18*	*0.004*	*0.30*	*21.6*
AVG – CoBelt	*0.123*	*0.002*	*0.602*	*11.9*	*0.93*	*0.09*	*0.004*	*0.62*	*10.3*

Stat. – statistics; Param. – parameters; AVG – average; Luk – Lukanga Swamp Area; CoBelt – Copperbelt Province

According to the above information, elemental concentrations found in leaves from the Lukanga Swamp and the Copperbelt Province are well below the range of excessive or toxic concentrations found in literature. If there is a relative enrichment of metals in the analysed leaves it would be of Cu in the Copperbelt Province and Zn in the Lukanga Swamp.

However, the above information does not confirm that other media (sediment / soil / water) surrounding the plants' environment is not contaminated. First, the mobility and bioavailability of metals in environment is largely controlled by their adsorbent substrates (Wang & Jia, 2009). In addition, according to the experiments done by these same authors, contamination of heavy metals in sediments both as adsorbents and adsorbates were mostly immobilized by *Phragmites australis* in roots with little translocation to aboveground parts due to root bioaccumulation and plaques adsorption.

Concentrations of Pb and Zn are clearly higher in the Lukanga Swamp area compared to those found in the Copperbelt area. It is expected that soil from the Lukanga area is enriched in these two metals because of dust fallout from smelters operating in the past in Kabwe. This was not seen in the sediment samples, but this may be because sediments were collected in aquatic environments and in this context these metals pass to the dissolved phase. In fact, surface water (and even groundwater) shows high contents of these metals and others (Cd and Cu).

6. Discussion

6.1. Upper Kafue River Basin

Mining of Cu and Co has taken place in the Zambian Copperbelt since the early 1920s and during this period the area has developed into a highly urbanised region. For this reason, concentrations of metals can be quite high in water and sediment. Concentrations of metals found in leaves of *Phragmites* sp. are not extraordinarily high, probably because most of the metals are trapped in the roots. However, concentrations of As, Cr, Cu, Co and Ni in leaves collected in the Copperbelt Province are consistently higher than those collected in the Lukanga Swamp.

Sulphide oxidation in mining areas often induces the production of important acid drainage which then causes other kinds of problems on ecosystems downstream. In the Kafue River, this does not happen because of high carbonate content on waste rocks and tailings, and even in the riverbed of the Kafue River.

However, metals do accumulate in the riverbed adsorbed to hydroxides and/or in the dissolved phase in pore water of sediment and are gradually transported downstream in the particulate phase. Several reports (local people during field visits and stakeholders during interviews) indicate that cattle sometimes die after drinking water from the river.

There is also evidence that surface water from streams in the Copperbelt area is contaminated with organic material. For example, COD tends to increase in the Kafue River while crossing main cities (Chingola and Kitwe), which implies sources of organic matter from industrial and household sources.

Agriculture activities do not seem to affect the Kafue River in the Copperbelt area very much. However, this statement is made considering only concentrations of nitrates and results from one campaign during the dry season.

6.2. Lukanga Swamp

6.2.1. Main water quality problems of the Lukanga Swamp

In terms of water quality, Lukanga wetland system seems rather complex because parameters and budgets of water may change drastically.

People living around the Lukanga Swamp use groundwater for their everyday needs, including drinking. All analysed wells fail guideline values (ZS and/or WHO) for this use, and this was because of metal concentrations in all cases[1], because of pH values (6 out of 14) and concentrations of nitrates (3 out of 14). While high concentrations of nitrates are clearly explained by human activities, pH and metal concentrations may or may not be partially explained by them. The fact that most (if not all) of the wells are affected by high concentrations of metals, even in remote areas, indicates that probably there is a natural component to these concentrations. In addition, some metals may be coming from the fertilizers used.

Except for Co and Cr, these relatively high concentrations of metals continue to exist (or they even increase in the case of Cu) in streams and outer parts of the swamp. However, in the inner part of the swamp concentration for all metals decreases drastically.

In fact, surface water in the wetland (swamp and streams) shows significant variations in the parameters analysed. For instance, pH increases gradually and consistently from groundwater (minimum values of 6) to streams (minimum values of 7) and towards inside the swamp (minimum values of 8). The same consistent increase may be observed for conductivity and COD, and DO to a certain extent.

All this information is in accordance with what was observed in other wetlands around the world (e.g. Reid & Mosley, 2015). The density of vegetation in the swamp is quite high and removal of CO_2 during photosynthesis typically causes the pH to increase during the daytime, and CO_2 production from respiration causes the pH to decrease during the night-time. Carbon dioxide is the preferred source of inorganic carbon for plants but under alkaline conditions, free CO_2 becomes limiting for photosynthesis (Reid & Mosley, 2015). If CO_2 is not replaced by diffusion from the surface, then increasing pH should result unless other compensatory reactions occur (e.g. precipitation of Ca and Mg carbonates). However, if divalent metals are limiting, photosynthesis may result in pH

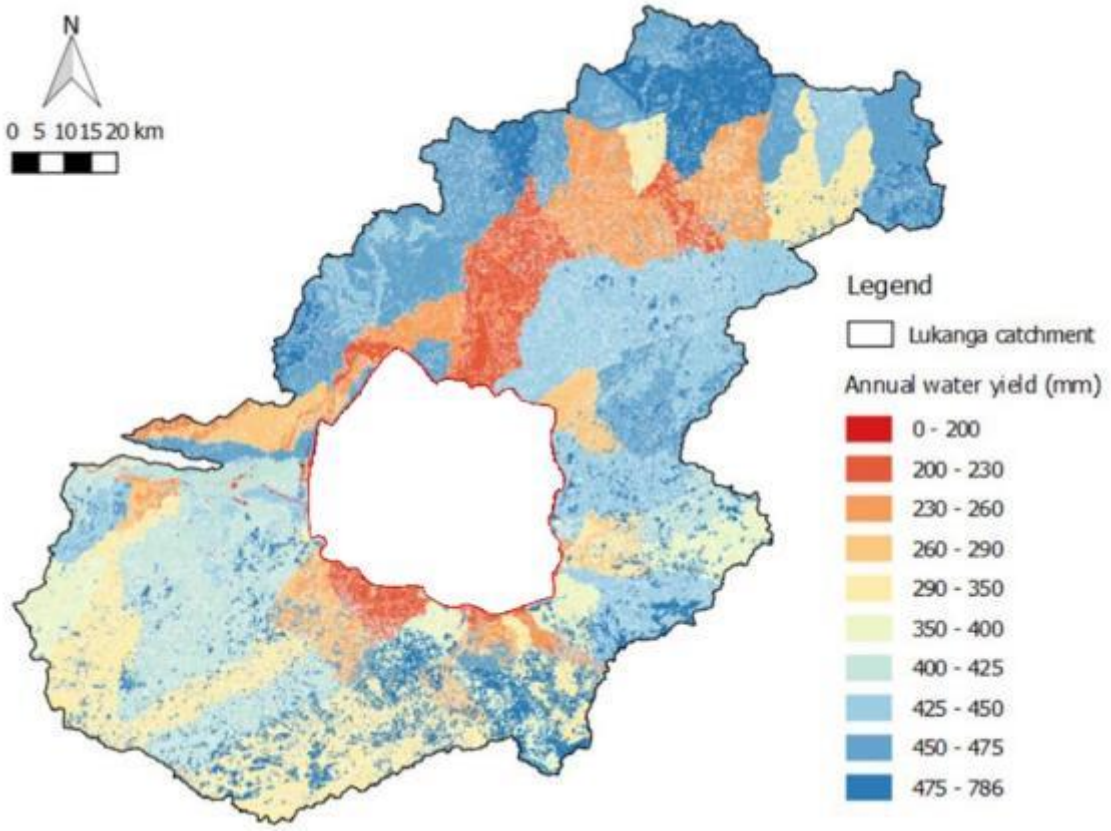
[1] There are two cases where detection limit is higher than guideline value.

increases up to 12.6 (Baas Becking *et al*., 1960). In the Lukanga Swamp divalent metals (e.g. Ca and Mg but also Zn, Cu, Pb, Cd, Ni) are not limiting as seen by the high concentrations of metals in streams and groundwater from the area and because pH was not recorded to be higher than 9. Note that the Lukanga Swamp watershed is partially occupied by carbonate rocks from the Katanga System (e.g. Vrana, 1974).

In accordance, leaves of *Phragmites* sp. collected in the Lukanga Swamp show higher concentrations of Pb and Zn (and similar of Cd and Hg) than those from leaves collected in the Copperbelt Area in areas clearly enriched in metals. As observed in other wetlands, the Lukanga Swamp seems to work as a filter for dissolved metals reaching the swamp. In Hunink *et al*. (2017), the Lukanga Swamp ecosystem service of improving water quality by trapping sediment and absorbing nutrients is highlighted.

6.2.2. Hydrodynamics of the Lukanga Swamp inferred from water characteristics

The parameters analysed also seem to reflect the hydrodynamics of the swamp. The amount of surface water reaching the swamp is clearly higher in the north from the Lukanga and Mufukushi rivers and in the southwest from the Muundu and Mufuwa rivers. To the East and Southwest, the width of the watershed is smaller and consequently there is not major stream. In accordance, field observations between September and October 2019 reveal that there was no stream with surface runoff in this area of the swamp, while the above-mentioned rivers had. The average annual water yield in the Lukanga watershed (Figure 33) determined in Hunink *et al*. (2017) also shows the above.



Source: Hunink *et al.* (2017).

Figure 33 – Average annual water yield in Lukanga watershed (2000 – 2015)

These observations imply that water in the East (Waya) and particularly in the Southeast (Kaswende) parts of the swamp has higher residence time. This would imply higher salinity of water due to evapo-concentration and so water in this area of the swamp tends to have higher conductivities, higher contents of nutrients (phosphorus) and lower oxygen contents.

Apparently, this higher residence time and salinity in the southeast of the swamp is not reflected in different types of habitats present and/or in the degradation state of these. However, fishermen drink water from the swamp while fishing and undoubtedly water in the area of Kaswende and Waya shows lower quality for this purpose.

6.2.3. Effects of the mining activities from the Copperbelt Province

According to Hunink *et al.* (2017), most of the surplus water that the swamp receives during wet years comes from the Lukanga watershed itself, and not overflow from the Kafue River. The overflow was estimated to be maximum 6% of the surface water in the Kafue River. These authors also state that excess loads from upstream in the Kafue River Basin, as well as pollutant loads from the mining industry are likely filtered to some extent in the floodplain of the Kafue River itself. But when the Lukanga Swamp connects with the floodplain it also receives part of the nutrient and pollutant loads. The swamp likely filters these, contributing to cleaner water for downstream users.

Cu and Co are transported downstream, particularly during high water discharge periods, adsorbed by Fe-rich oxyhydroxides (for Cu) and by Mn-rich particles (for Co) (Pettersson, 2002) (*cf.* Table 6). This author continues with saying that impacts from the mining activities can be traced in the Kafue River downstream of the Copperbelt mining area in the dissolved and suspended phase and in the deposited sediment.

Downstream, in less hydrodynamic areas such as the Kafue floodplain and later in the Lukanga Swamp, these particles may rest in the river/swamp bed. However, after deposition, secondary oxyhydroxides dissolve when reaching reducing conditions in the sediment.

In accordance, sediments in streams and near the shore of the Lukanga Swamp show few signs about this transfer of metal pollutants coming from upstream (EF of Cu and Co are higher in the Kafue River compared to near shore sediments of the Lukanga Swamp). Curiously, from near shore sediments of the Lukanga Swamp sample 12 (near Shishimo), located in an area where overflow enters the Lukanga Swamp has the highest concentrations of Cu, Co and Ni.

Besides de above, the main indication that this transport may be happening is the extremely high concentration of dissolved metals near the shore of the swamp. However, these metals also seem to be coming from the swamp's watershed. Moreover, leaves

from the East of the swamp show higher concentrations of Cu and if this metal was mainly coming from the West during overflow, it would have higher concentrations also in the West.

Given the above, it might be said there is transport of particles from the Kafue River to the West and Northwest parts of the swamp, but probably this does not significantly affect other parts of the swamp. Note that according to Hunink *et al*. (2017), most of the surplus water that the swamp receives during wet years comes from the Lukanga watershed itself.

7. Conclusion

Surface and groundwater quality, sediment and leaf sampling and analyses were performed covering Lukanga Swamp and the Kafue basin upstream, including 87 sampling stations distributed along the plan areas to properly characterise the upper and middle Kafue and the connections with Lukanga Swamp and its catchment.

The field sampling results were complemented by a hydrological analysis to understand the hydrodynamics of the Lukanga Swamp and its catchment.

The assessment shows surface water characteristics can greatly vary from the Copperbelt Province to the Lukanga Swamp Area. Conductivity, COD and BOD show higher values in the Copperbelt Province, while nitrates, Cr, Pb and Zn are clearly higher in the Lukanga Swamp Area. Contents of dissolved oxygen lower than 50% occur essentially in some areas of the Lukanga Swamp. Both areas show high concentrations of Cu (>0.1 mg/l) in specific sectors (Chingola and Southwest zone, in the Copperbelt and Lukanga swamp catchment, respectively).

Groundwater samples were only collected in villages around the Lukanga Swamp. The comparison between the concentrations found and guideline concentrations for water for drinking purposes (ZABS, WHO) show that none of the 14 wells studied satisfies the guidelines for this kind of use. The main problem of the quality of groundwater is related with concentrations of metals, particularly of Cd and Pb. High concentrations of nitrates also occur in some groundwater samples.

Grain-size analysis done in sediments shows that “sand” and “loamy sand” are the main type of sediment. Metal concentrations are higher in the Copperbelt Area in comparison to the Lukanga Swamp, respectively (average values): Cu – 2247 vs. 44 mg/kg; Co – 222 vs. 10 mg/kg; Zn – 59 vs. 13 mg/kg, to give some examples.

The correlation analysis between metals showed that Fe in these samples seems to represent better oxides than aluminosilicates; As, Co, Cr and Cu are associated to oxides; Ni, but also Cr and Zn seem associated to aluminosilicates.

Bulk concentrations of metals in the analysed leaves follow the pattern: [Zn] > [Cu] > [Cr] ~ [Co] ~ [Ni] > [Pb] ~ [As] > [Hg] ~ [Cd]. In the same way as it happens for sediments, there is a predominance of maximum concentrations in the Copperbelt Province and of

minimum concentrations in the Lukanga Swamp Area. However, Pb and Zn behave the other way around.

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Appendix A – Description of the sampling stations

Table 14 – Sampling stations of groundwater and surface water

Station No.	X	Y	Description of sampling station
5S	-14.17699600	28.19719000	Well not covered nor sealed near a house. Germs were readily identified in the water. Close to Chipepo.
8bS	-14.11610900	28.11901000	Sealed well in a common area near Mpunde.
9S	-14.32914200	27.98374500	Sealed well in Waya.
13S	-13.94923200	27.78176800	Sealed well in a common area near between Mukubwe e Shamputa.
16S	-14.09690600	27.42346300	Sealed well near Lufubu.
20S	-14.60787600	28.09438600	Sealed well in a common area north of Chibombo.
22S	-14.43639700	27.99655600	Sealed well near Kaswende.
23S	-13.95900400	27.78917200	Sealed well in a common area near between Mukubwe e Shamputa.
24S	-14.43702600	27.99458400	Well not covered nor sealed near Kaswende. Locals say they don't use this water for drinking purposes.
25S	-14.14779700	27.63297300	Sealed well in Shishimo.
26S	-14.59084300	27.65837100	Sealed well in Kabosha with a solar pump. Water was stored in a container.
27S	-14.57748800	27.26712600	Well not covered nor sealed near Mushingashi River.
28S	-14.50943500	27.50210100	Well not covered nor sealed half-way south of Mwanakabwata.
29S	-14.35262200	28.12233100	Sealed well near the road between Waya and Kabwe. There were some houses and stores near the well.
1S	-14.372917	27.18543	Surface water sample collected in the Kafue River. The point is immediately downstream from the junction with the Lukanga River.
2S	-14.572744	27.287036	Surface water sample collected in the Mushingashi River. The stream had few centimetres of water depth and the riverbed is mainly sandy sediment. There was developed vegetation inside the small channel.
3S	-14.436256	27.510353	Surface water sample collected in the Lukanga River, 3.5 km downstream from the swamp outlet.
4S	-14.63323	27.586285	Surface water sample collected in the Mufuwa River, immediately to the west of Chitanda. The stream had few centimetres of water depth.

Station No.	X	Y	Description of sampling station
6S	-14.628043	27.859676	Surface water sample collected in the southeast margin of the Lukanga Swamp; in a channel that is close and hydraulically connected to the swamp; according to the data obtained in situ this channel probably is fed by groundwater (spring).
7S	-14.580316	27.664694	Surface water sample collected in the swamp few hundred meters offshore (near Kabosha). The sampling point was defined when the water appeared clear and transparent.
8aS	-14.323974	27.973234	Surface water sample collected in a human-made channel that connects the swamp to the small port of Waya. At the time of sampling the channel was very shallow (30 – 50 cm water depth).
10S	-14.10578	28.097192	Surface water sample collected in the right margin of the Mufukushi River, close to Mpunde.
11S	-14.025083	27.839621	Surface water sample collected in the right margin of the Lukanga River, near the road between Shamputa and Mukubwe.
12S	-14.171957	27.642776	Surface water sample collected in the channel that separates the Chilwa Island from Shishimo.
14S	-14.112375	27.410839	Surface water sample collected in the left margin of the Kafue River, near Lufubu. Sandy sediments were observed in the sampling point.
15S	-13.836129	27.817638	Surface water sample collected near Chisanga in a spring that drains to the Lukanga River.
18S	-14.570536	27.471297	Surface water sample collected in the Muundu River. The bed of the river is sandy and green algae are visible.
21S	-14.445407	27.968228	Surface water sample collected in the swamp few hundred meters offshore (near Kaswende). The sampling point was defined when the water appeared clear and transparent.
1Oc	-13.237226	28.404075	Surface water sample collected in the Kafubu River upstream from the bridge of the road that connects Masaiti with Luanshya.
2Oc	-13.227906	28.381211	Surface water sample collected in the Kafubu River around 4,5 km downstream from station 1Oc, and immediately downstream from the junction between this river and the Luanshya River.

Station No.	X	Y	Description of sampling station
3Oc	-13.255308	28.323819	Surface water sample collected in the Kafubu River around 8 km downstream from station 2Oc, and immediately upstream from the junction between this river and the Kafulafuta River.
4Oc	-13.259282	28.325365	Surface water sample collected in the Kafulafuta River around 1 km upstream from the junction of this river with the Kafubu River.
5Oc	-13.220429	28.165779	Surface water sample collected in the Kafue River around 8 km upstream from the junction of the Kafubu River with this river. Near this station people were in the river fetching water and swimming.
6Oc	-13.347787	28.072473	Surface water sample collected in the Kafue River around 33 km downstream from station 5Oc. The station is where the road from Nuala encounters the Kafue river. Here people cross the river to the other side in a small boat.
7Oc	-13.64159	27.61706	Surface water sample collected in the Kafue River around 115 km downstream from station 6Oc. The station is where the road from Munkumpu encounters the Kafue river. Here people cross the river to the other side in a small boat or in a barge.
8Oc	-12.878031	28.257556	Surface water sample collected in the Kafue River around 50 km upstream from station 5Oc. The station is near the bridge where the road between Kitwe and Ndola crosses the river.
9Oc	-12.518833	27.82831	Surface water sample collected in the Chingola River immediately upstream from the bridge that crosses the river north of the junction between T3 and T5 roads. Water with a brownish colour. Downstream from the sampling station earthworks could be seen in the riverbank.
10Oc	-12.635245	28.159062	Surface water sample collected in the Kafue River upstream from Kitwe and upstream from a plant of water abstraction in the river.
11Oc	-12.464895	27.851301	Surface water sample collected in the Kafue River, downstream from Chililabombwe and junction with the Michichima River.

Station No.	X	Y	Description of sampling station
12Oc	-12.405138	27.761694	Surface water sample collected in the Kafue River upstream from the junction between this river with the Lubengele River. This is the furthest upstream station where surface water was collected. The riverbed in the station area is sandy with frequent rocky outcrops.
13Oc	-12.866697	27.603139	Surface water sample collected in the Lufwanyama River near the bridge from M18. People were fetching water and water has a milky look even upstream from station.
14Oc	-12.927097	27.333666	Surface water sample collected in the Luswishi River near the bridge from M18. Sandy riverbed with abundant vegetation in the margins. Water looked transparent.
15Oc	-12.398043	27.802978	Surface water sample collected in the Lubengele River 2.3 km upstream from the junction of this river with the Kafue River.
16Oc	-12.49137824	27.82398378	Surface water sample collected in the Muchichima River, 3.8 km upstream from the junction of this river with the Kafue River.
17Oc	-12.645849	27.887393	Surface water sample collected immediately downstream from the Muntimpa Dam. It is a small channelled stream. White precipitates where observed in plants near the water.
18Oc	-12.477025	27.897877	Surface water sample collected in the Kafue River, 6,3 km downstream from station 11Oc. Rocky outcrops are frequent in river. Station is immediately upstream from a plant of water abstraction in the river.
19Oc	-12.481348	27.899956	Surface water sample collected in the Nchanga River, a small river that connects with the Kafue River just 520 m downstream from station 18Oc. Station is 350 m upstream from the junction of this river with the Kafue River.
20Oc	-12.849233	27.742413	Surface water sample collected in the Filando River, a small river that connects with the Katembola River 5.3 km downstream.
21Oc	-12.850402	27.675129	Surface water sample collected in the Katembola River, near M18 road and 730 m downstream from a constructed dam (already visible in satellite images after Jul. 2017 but not in Oct. 2016).

Station No.	X	Y	Description of sampling station
22Oc	-13.25919673	28.26155597	Surface water sample collected in the Kafulafuta River, 15 km upstream from the junction with the Kafue River. It is the furthest downstream station from this river. Frequent rock outcrops in the riverbed.
23Oc	-12.777151	28.213468	Surface water sample collected in the Mindolo River. Station is located in the urban area of Kitwe.
24Oc	-12.811088	28.253964	Surface water sample collected in the Kitwe River. Station is located 620 m upstream from the junction with the Kafue River.
25Oc	-14.52568473	27.65935248	Surface water sample collected in the Lukanga Swamp. Station is in an open water lake inside the swamp area, around 7 km offshore (Kabosha).
26Oc	-14.32614182	27.93779847	Surface water sample collected in the Lukanga Swamp. Station is in an area less dense with vegetation inside the swamp, around 5 km offshore (Waya).
27Oc	-14.44749891	27.92578096	Surface water sample collected in the Lukanga Swamp. Station is in an area less dense with vegetation inside the swamp, around 6 km offshore (Kaswende).
28Oc	-14.23494239	27.66963503	Surface water sample collected in the Lukanga Swamp. Station is in an open water lake inside the swamp area, around 4.5 km offshore (Chilwa Island).

Table 15 – Location and description of the sediment sampling stations

Station No.	X	Y	Description of sampling station
1	27.18543	-14.372917	Inside water near the left margin of the Kafue River. The point is downstream from the junction with the Lukanga River.
2	27.287036	-14.572744	Inside water in the Mushingashi River. The stream had few centimetres of water depth and the riverbed is mainly sandy sediment. There was developed vegetation inside the small channel.
3	27.510353	-14.436256	Inside water in the left margin of the Lukanga River, 3.5 km downstream from the swamp outlet.
4	27.586285	-14.63323	Inside water in the Mufuwa River, immediately to the west of Chitanda. The stream had few centimetres of water depth.
5	28.39472222	-13.13777778	Inside water in the Luanshya River. The sampling point is immediately downstream from the treatment plant of the Baluba mine (close to the Buteko Avenue).
6	27.859676	-14.628043	Inside water in the southeast margin of the Lukanga Swamp; in a channel that is close and hydraulically connected to the swamp; according to the data obtained *in situ* this channel probably is fed by groundwater (spring).
7	28.35230515	-13.24166389	Inside water in the Kafubu River, upstream of its connection with the Kafulafuta River.
8	27.82730972	-12.51699716	Sample collected inside water in the Chingola River, close to the bridge of the T3 highway that crosses that river.
9	27.81222222	-12.41611111	Sample collected inside water in the left margin of the Kafue River in the junction of this river with the smaller Lubengele River.
10	28.097192	-14.10578	Sample collected inside water in the right margin of the Mufukushi River, close to Mpunde.
11	27.839621	-14.025083	Sample collected inside water in the right margin of the Lukanga River near the road between Shamputa and Mukubwe.
12	27.642776	-14.171957	Sample collected inside water in the channel that separates the Chilwa Island from Shishimo. The material collected from the bed of the channel had a high percentage of plant fragments.

Station No.	X	Y	Description of sampling station
13	27.86672231	-12.46415859	Sample collected inside water in the Kafue River, downstream from Chililabombwe and junction with the Michichima River.
14	27.410839	-14.112375	Sample collected inside water in the left margin of the Kafue River, near Lufubu. Sandy sediments were observed in the sampling point.
15	28.15888889	-12.635	Sample collected inside water in the right margin of the Kafue River downstream from Mopani Mine (Mufulira) and upstream from Kitwe.
16	28.23805556	-12.92472222	Sample collected inside water in the right margin of the Kafue River downstream from Luangwa.
17	28.22805556	-12.89	Sample collected inside water in a stream that connects to the Kafue River upstream from the sampling station 16. The station is immediately downstream from another pole of the Mopani mine in Luangwa.
18	27.471297	-14.570536	Sample collected inside water in the Muundu River. The bed of the river is sandy and green algae are visible.
19	27.973234	-14.323974	Sample collected inside water in a human-made channel that connects the swamp to the small port of Waya. At the time of sampling the channel was very shallow (30 – 50 cm water depth). Fishing canoes and “banana boats” were frequently crossing the channel.
26	27.96899606	-14.32329357	Sample collected inside water in the Lukanga Swamp, near Waya. This is a channel from the swamp that develops offshore after the human-made channel referred in the sampling station 19.
27	27.97269244	-14.44498657	Sample collected inside water in the Lukanga Swamp, around few hundred meters from the shore (near Kaswende).

Table 16 – Location and description of stations where composite samples of leaves were collected

Station No.	X	Y	Description of sampling station
2	-13.227906	28.381211	Left margin of the Kafubu River, around 4,5 km downstream from station 1Oc (Table 14), and immediately downstream from the junction between this river and the Luanshya River.
11	-12.464895	27.851301	Right margin of the Kafue River, downstream from Chililabombwe and junction with the Michichima River. Sample was collected in a sandbank immediately after a bridge from the main road T3.
15	-12.398043	27.802978	Inside the bed of the Lubengele River, 2.3 km upstream from the junction of this stream with the Kafue River.
16	-12.49137824	27.82398378	Right margin of the Muchichima River, 3.8 km upstream from the junction of this river with the Kafue River. Plants where leaves where collected are in a sandy substrate.
17	-12.645849	27.887393	Inside the stream immediately downstream from the Muntimpa Dam. It is a small channelled stream. White precipitates where observed in plants near the water.
25	-14.52568473	27.65935248	Station is defined as the path done from the shore until an open water lake inside the Lukanga Swamp, around 7 km offshore (Kabosha).
26	-14.32614182	27.93779847	Station is defined as the path done from the shore until an area with less dense vegetation around 5 km offshore (Waya).
27	-14.44749891	27.92578096	Station is defined as the path done from the shore until an area with less dense vegetation around 6 km offshore (Kaswende).
28	-14.23494239	27.66963503	Station is defined as the path done from the shore until an open water lake inside the swamp area, around 4.5 km offshore (Chilwa Island).
29	-14.105051	28.095597	Surface water sample collected in the Lukanga Swamp. Station is in an open water lake inside the swamp area, around 7 km offshore (Kabosha).

Appendix B – Parameters analysed and laboratory procedures

A) Water samples

All stations sampled for surface water and groundwater were also analysed for temperature, pH, conductivity and dissolved oxygen with a YSI professional plus probe (Table 17).

All water samples were analysed for parameters listed in Table 17, while only selected samples (>1/3) were analysed for parameters in Table 18. The reason for this selection is that parameters from Table 18 are not expected to be contaminants in the plan area.

Parameters from Table 17 were analysed by Food and Drugs Laboratory (FDL - Zambia), Lusaka Water and Sewerage Company (LWSC) and Alfred H Knight Zambia Limited (AHK), while those parameters from Table 18 were analysed by ALS Controlvet – Portugal.

Table 17 and Table 18 also refer the method used to determine a given parameter and its detection limit.

Table 17 – Parameters analysed for all 56 water samples, methods used and detection limits

Parameter	Method	Detection Limit (mg/l)
Arsenic (As)	ICP (both labs)	0.001 (AHK) and 0.2 (FDL)
Cobalt (Co)	ICP (both labs)	0.001 (AHK)
Copper (Cu)	ICP (both labs)	0.01 (AHK)
Chromium (Cr)	ICP (both labs)	0.001 (AHK)
Lead (Pb)	ICP (both labs)	0.01 (AHK)
Mercury (Hg)	Hydride Generation Cold Vapor AAS (by AHK)	0.05 (AHK) and 0.3 (FDL)
Nickel (Ni)	ICP (both labs)	0.002 (AHK)
Zinc (Zn)	ICP (both labs)	0.006 (AHK)
Biochemical Oxygen Demand (BOD5)	Dissolved Oxygen determination done Electrometrically after 5-day incubation test (both labs)	0.1 (AHK) and 1 (LWSC)
Chemical Oxygen Demand (COD)	Refluxing and Spectrophotometric (both labs)	4 (LWSC) and 5 (AHK)

Parameter	Method	Detection Limit (mg/l)
Nitrate	Ultraviolet Spectrophotometry (by AHK)	0.07 (AHK)
Phosphorus	Colorimetry (by AHK)	0.1 (AHK)

Notes: AHK – Alfred H Knight Zambia Limited; LWSC – Lusaka Water and Sewerage Company; FDL - Food and Drugs Laboratory

Table 18 – Parameters analysed for selected water samples (21)

Parameter	Method	LOR[4] (µg/l)
Sum of 16 PAH[1]	W-PAHGMS01[2]	0.370
Hexachlorobenzene (HCB)	W-OCPECD01[3]	0.005
Sum of 5 Hexachlorocyclohexanes (HCH)	W-OCPECD01[3]	0.050

Notes:
[1] Polycyclic Aromatic Hydrocarbons; [2] Determination of semi volatile organic compounds by gas chromatography method with MS or MS/MS detection and calculation of semi volatile organic compounds sums from measured values; [3] Determination of organochlorine pesticides and other halogen compounds by gas chromatography method with ECD detection and calculation of organochlorine pesticides and other halogen compounds sums from measured values. [4] Limit of Reporting.

B) Sediment samples

All 21 sediment samples were analysed for concentrations of metals, organic compounds and total organic carbon. Grain-size analysis was also performed in these samples.

These analyses were carried out in SYNLAB Analytics & Services B.V. (The Netherlands). Table 19 presents the method used to determine a given parameter and its detection limit.

Table 19 – Parameters analysed in sediment samples, methods used and detection limits

Parameter	Method	Detection Limit
Aluminium (Al)	Digestion according to NEN 6961 and measurement according to NEN-EN-ISO 17294-2 (application of ICP-MS)	-
Arsenic (As)	Idem	< 4 mg/kg
Cadmium (Cd)	Idem	< 0.2 mg/kg
Cobalt (Co)	Idem	<1.5 mg/kg
Copper (Cu)	Idem	<5 mg/kg
Chromium (Cr)	Idem	<10 mg/kg
Iron (Fe)	Idem	-
Lead (Pb)	Idem	<10 mg/kg

Parameter	Method	Detection Limit
Mercury (Hg)	Idem	<0.05 mg/kg
Nickel (Ni)	Idem	<3 mg/kg
Zinc (Zn)	Idem	<20 mg/kg
COT	According to NEN-EN 13137	<0.2 mg/kg
Total PCB (7)	Own method, extraction with acetone / hexane and analysis with GC-MS	<7 µg/kg
PAH (9 OSPAR)	Idem	<0.18 mg/kg
Hexachlorobenzene (HCB)	Own method, analysis with GC-MS	<0.5 µg/kg

C) Leaves

Ten composite samples of leaves (*Phragmites* spp.) were collected in two areas: the Lukanga swamp and in streams of the Copperbelt area. Trace elements analysed in leaves are listed in Table 20.

Table 20 – Parameters analysed in leaves, methods used and detection limits

Parameter	Method	Detection Limit (mg/kg)
Arsenic (As)	Sample preparation with HNO3- and pressure digestion; Analysis DIN EN ISO 17294:2017-01	<0.001
Cadmium (Cd)	Idem	<0.0005
Cobalt (Co)	Idem	<0.01
Copper (Cu)	Idem	<0.05
Chromium (Cr)	Idem	<0.05
Lead (Pb)	Idem	<0.05
Mercury (Hg)	Sample preparation with HNO3- and pressure digestion; DIN EN 15763:2010-04	<0.001
Nickel (Ni)	Sample preparation with HNO3- and pressure digestion; Analysis DIN EN ISO 17294:2017-01	<0.05
Zinc (Zn)	Idem	<0.05

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Appendix C – Laboratory results

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Rev No. 03	Copy No. 1
Document No. 1	
Date issued : 18/09/2015	
Effective date : 21/09/2015	

CERTIFICATE OF ANALYSIS

CLIENT

Client name: Nemus (Consultants for ZEMA).
Attention: Pedro Bettencourt

Physical Address: C/o Plot No. 6975, Suez Road
Lusaka

Telephone:

LABORATORY

Certificate No.: *563. (3441-3468) – 09.19*
Date of issue: *October 14, 2019*
Date of sampling: *September 15, 2019*
Date samples received: *September 15, 2019*
Date **analysis commenced:** *September 15, 2019*
Number of pages: 3
Fax:

Notes

'NTU" = Nephelometric Turbidity Units
'-'= Not analysed
'ND' = Not done
'MDL' = Method detection limit
'QC' = Quality Control
'COND' = Conductivity
'BOD' = Biochemical Oxygen Demand
'COD' = Chemical Oxygen Demand
'TDS' = Total Dissolved Solids

Remarks

'S' = Satisfactory according to Public Sewer Discharge Standards
'U' = Unsatisfactory according to Public Sewer Discharge Standards

Method of analysis

pH, Conductivity and TDS: Electrometric
Turbidity: Nephelometric
COD: Refluxing and Spectrophotometric.
BOD: Dissolved Oxygen determination done Electrometrically.

Signature: ……**Designation:** *Senior Chemist*

Date : *October 14, 2019.*

LUKANGA SWAMP - KAFUE RIVER WATER QUALITY – SEPTEMBER 2019

PHYSICAL - CHEMICAL ANALYSIS

		Parameters & Results					
Lab No.	**Sample ID**	pH	COND (µS/cm)	TDS (mg/L)	Turbidity NTU	BOD (mg/L)	COD (mg/L)
3441	1	8.27	555	278	1.30	< 1	< 4
3442	2	8.30	566	283	1.55	1	< 4
3443	3	8.11	261	135	1.46	1	13
3444	4	8.31	553	276	3.12	< 1	< 4
3445	5	7.61	142	71	5.95	1	< 4
3446	6	7.43	404	202	1.68	1	43
3447	7	7.88	348	175	2.07	4	23
3448	8a	8.31	768	382	3.65	< 1	39
3449	8b	7.22	134	67	0.31	< 1	< 4
3450	9	7.87	874	437	26.2	< 1	< 4
3451	10	7.99	202	101	4.31	1	8
3452	11	7.84	243	122	1.88	1	17
3453	12	8.07	382	192	2.84	< 1	4
3454	13	7.83	412	206	9.65	< 1	< 4
3455	14	8.05	586	292	1.85	1	< 4
3456	15	7.91	770	385	0.17	< 1	< 4
3457	16	7.18	89	44	8.51	< 1	< 4
3458	18	8.02	535	265	3.85	< 1	< 4
3459	20	7.69	391	196	6.87	< 1	< 4
3460	21	8.41	1 414	708	0.56	< 1	85

Key

BOD: Biological Oxygen Demand
COD: Chemical Oxygen Demand
COND: Conductivity
TDS: Total Dissolved Solids
NTU: Nephelometric Turbidity Units

		Parameters & Results					
Lab No.	**Sample ID**	pH	COND (µS/cm)	TDS (mg/L)	Turbidity NTU	BOD (mg/L)	COD (mg/L)
3461	22	7.47	550	275	5.37	< 1	< 4
3462	23	8.01	434	216	2.77	1	< 4
3463	24	7.40	288	144	4.29	< 1	< 4
3464	25	6.55	98	49	37.2	2	< 4
3465	26	7.81	522	262	3.54	< 1	< 4
3466	27	7.98	59	29	0.80	< 1	< 4
3467	28	7.08	311	63	24.7	< 1	< 4
3468	29	7.59	625	311	6.74	< 1	< 4

Key

BOD: Biological Oxygen Demand
COD: Chemical Oxygen Demand
COND: Conductivity
TDS: Total Dissolved Solids
NTU: Nephelometric Turbidity Units

Signature: ..... **Designation:** *Senior Chemist*

Date: *October 14, 2019.*

Telephone : 252855/252875
Telefax : 252875

In reply please quote:

No.....

W1906-W1933

REPUBLIC OF ZAMBIA

MINISTRY OF HEALTH

FOOD AND DRUGS CONTROL LABORATORY
P.O. BOX 30138
LUSAKA

11th November, 2019.

WATER CHEMISTRY ANALYSIS REPORT

Customer Details : NEMUS LDA
C/O ZEMA
P.O BOX 35131
LUSAKA

Date of sampling : 16/09/2019

Date of receipt : 16/09/2019

Date of Analysis commenced : 17/09/2019

Date of Analysis completed : 25/09/2019

Analysis Requested for : Routine Analysis

Customers Ref:	Laboratory Ref:	Sample Description
01	W1906	Swamp water
02	W1907	Swamp water
03	W1908	swamp water
04	W1909	Swamp water
05	W1910	SWAMP WATER
06	W1911	SWAMP WATER
07	W1912	SWAMP WATER

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PT0:

08a	W1913	SWAMP WATER
08b	W1914	SWAMP WATER
09	W1915	SWAMP WATER
10	W1916	SWAMP WATER
11	W1917	SWAMP WATER
12	W1918	SWAMP WATER
13	W1919	SWAMP WATER
14	W1920	SWAMP WATER
15	W1921	SWAMP WATER
16	W1922	SWAMP WATER
18	W1923	SWAMP WATER
19	W1924	SWAMP WATER
20	W1925	SWAMP WATER
21	W1926	SWAMP WATER
22	W1927	SWAMP WATER
23	W1928	SWAMP WATER
24	W1929	SWAMP WATER
25	W1930	SWAMP WATER
26	W1931	SWAMP WATER
27	W1932	SWAMP WATER
28	W1933	SWAMP WATER

PHYSICAL AND CHEMICAL EXAMINATIONS DONE

PARAMETER	W1906	W1907	W1908	W1909	W1910	ZABS/WHO
Lead (mg/l)	**0.2664**	**1.346**	**0.7376**	**0.8018**	0.0000	**0.01**
Cadmium(mg/l)	**0.2326**	**0.4114**	**0.1722**	**0.2275**	**0.0426**	**0.003**
Chromium(mg/)	0.0090	0.0020	0.0030	0.0010	0.0110	**0.05**
Copper(mg/l)	0.3247	0.1034	0.2070	0.0618	0.0236	**2**
Phosphorus (mg/l)	0.0031	0.0034	0.0012	0.3023	0.0123	**1.0**
Zinc mg/l	0.2247	0.000	0.3348	0.1177	0.9234	**3**
Cobalt mg/l	0.0009	**0.0600**	0.0010	0.0021	0.0000	**0.05**
Nickel mg/l	0.0778	0.0000	0.0181	0.0101	0.0011	-
Mercury mg/l	0.00	0.00	0.00	0.00	0.00	**0.001**

01/10/19

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Arsenic mg/l	0.00	0.00	0.00	0.00	0.00	**0.01**
Nitrates mg/l	10.0451	0.1294	21.45	30.54	15.04	**45-50**

PARAMETER	**W1911**	**W1912**	**W1913**	**W1914**	**W1915**	**ZABS/WHO**
Lead (mg/l)	**0.3473**	**1.856**	**0.8624**	**1.283**	**1.378**	**0.01**
Cadmium(mg/l)	0.00	**0.1066**	**0.2401**	**0.0285**	0.00	**0.003**
Chromium(mg/)	0.0140	0.0041	0.0001	0.0003	0.00	**0.05**
Copper(mg/l)	0.0521	0.0843	0.0880	0.0715	0.0786	**2**
Phosphorus (mg/l)	0.0430	0.0071	0.0065	0.0024	0.0180	**1**
Zinc mg/l	0.2153	0.3516	0.295	0.0481	0.5980	**3**
Cobalt mg/l	0.00	**0.0891**	0.1020	0.0180	0.0010	**0.05**
Nickel mg/l	6.7005	0.0542	0.0013	0.0588	0.0412	**-**
Mercury mg/l	0.00	0.00	0.00	0.00	0.00	**0.001**
Arsenic mg/l	0.00	0.00	0.00	0.00	0.00	**0.01**
Nitrates mg/l	4.0091	11.23	10.00	24.07	19.04	**45-50**

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PARAMETER	W1916	W1917	W1918	W1919	W1920	ZABS/WHO
Lead (mg/l)	**0.0467**	**0.9295**	**1.089**	**1.203**	**1.203**	**0.01**
Cadmium(mg/l)	0.0469	0.2229	**0.0310**	**0.1898**	**0.1898**	**0.003**
Chromium(mg/)	0.0145	0.0021	0.0011	0.00	0.00	**0.05**
Copper(mg/l)	0.6669	0.0646	0.0891	0.0529	0.0591	2
Phosphorus (mg/l)	0.0065	0.0002	0.0340	0.0054	0.0020	1
Zinc mg/l	0.9794	0.00	0.4835	0.0223	0.2149	3
Cobalt mg/l	0.0369	0.00	0.00	0.0297	0.1002	**0.05**
Nickel mg/l	0.00	0.00	0.074	0.0884	0.0342	-
Mercury mg/l	0.00	0.00	0.00	0.00	0.00	**0.001**
Arsenic mg/l	0.00	0.00	0.00	0.00	0.00	**0.01**
Nitrates mg/l	11.90	17.01	12.87	13.02	14.76	**45-50**

01/11/19

Sign: SF. Kamau

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PARAMETER	W1921	W1922	W1923	W1924	W1925	ZABS/WHO
Lead (mg/l)	**1.244**	**0.7554**	**1.157**	**1.132**	**0.8908**	**0.01**
Cadmium(mg/l)	0.00	0.0378	**0.0957**	**0.0611**	0.2316	**0.003**
Chromium(mg/)	0.0084	0.0061	0.00	0.00	0.00	**0.05**
Copper(mg/l)	0.0773	0.0750	0.957	0.1189	0.0746	**2**
Phosphorus (mg/l)	0.0240	0.0184	0.0932	0.1760	0.1740	**1**
Zinc mg/l	0.6944	0.0056	0.0933	0.3219	0.3269	3
Cobalt mg/l	0.0177	0.1145	0.0129	**9.4003**	0.0125	**0.05**
Nickel mg/l	0.0751	0.0454	0.0406	0.0884	0.1239	
Mercury mg/l	0.00	0.00	0.00	0.00	0.00	**0.001**
Arsenic mg/l	0.00	0.00	0.00	0.00	0.00	**0.01**
Nitrates mg/l	0.0067	0.0416	**53.56**	**61.04**	**104.08**	**45-50**

01/11/19

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PARAMETER	W1926	W1927	W1928	W1929	W1930	ZABS/WHO
Lead (mg/l)	**1.272**	**0.2971**	**1.655**	**0.5326**	**0.9860**	0.01
Cadmium(mg/l)	0.00	**0.1679**	0.00	**0.0397**	0.00	**0.003**
Chromium(mg/)	0.0321	0.0221	0.1101	0.4814	0.00	**0.05**
Copper(mg/l)	0.0955	0.0988	0.0707	0.2021	0.1045	**2**
Phosphorus (mg/l)	0.0890	0.0450	0.0045	0.3780	0.1843	**1**
Zinc mg/l	0.4862	0.4021	0.7891	0.9860	0.00	**3**
Cobalt mg/l	**5.8006**	0.0031	0.00	0.00	0.001	**0.05**
Nickel mg/l	0.0461	0.1053	0.0536	6.7005	0.0632	
Mercury mg/l	0.00	0.00	0.00	0.00	0.00	**0.001**
Arsenic mg/l	0.00	0.00	0.00	0.00	0.00	**0.01**
Nitrates mg/l	11.06	40.03	34.01	23.45	5.067	**45-50**

01/11/19

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PARAMETER	W1931	W1932	W1933	ZABS/WHO
Lead (mg/l)	**0.7216**	0.00	**1.461**	**0.01**
Cadmium(mg/l)	**0.0683**	**0.0912**	**0.0086**	**0.003**
Chromium(mg/)	0.0106	0.00	0.1301	**0.05**
Copper(mg/l)	0.0912	0.0945	0.0855	**2**
Phosphorus (mg/l)	0.0034	0.7340	0.1330	**1**
Zinc mg/l	0.0304	0.0393	0.3218	**3**
Cobalt mg/l	**8.6004**	0.0414	**5.800**	**0.05**
Nickel mg/l	0.1344	0.0327	0.1339	-
Mercury mg/l	0.00	0.00	0.00	**0.001**
Arsenic mg/l	0.00	0.00	0.00	**0.01**
Nitrates mg/l	24.90	**80.74**	**67.91**	**45-50**

01/11/19

Sign: SF. Kaoma

PTO:

REMARKS

The results are as stated.

Note: The standards used are for drinking water

Sumbukeni Kowa (Dr)

Consultant

01/11/19

Sign:

PT0:

ALS Controlvet

Data Emissão: 04-10-2019

N.º de Análise:	QH / 13866 / 19
Data Colheita:	-
Data Receção:	21-09-2019
Data Início Ensaio:	21-09-2019
Data Fim Ensaio:	04-10-2019
Código Cliente:	7401

Exmo(s) Sr(s):
Nemus – Gestão e Req.Ambiental, Lda.
EST. DO PAÇO DO LUMIAR CAMPUS DO LUMIAR ED. D
LISBOA
1649-038 LISBOA

Unidade: Nemus – Gestão e Requalificação Ambiental, Lda.

Identificação da Amostra: **159096 / 19**

Produto: Água Naturais
Referência: Amostra 1
A colheita de amostra não foi efectuada pela Controlvet.

Acondicionamento: frasco
Nº Entrega: 1527/2019

Ensaio	Método	Resultado	Unidade
(a) Parâmetros físico-químicos	Descrição em anexo	Resultado em anexo.	.

Método interno equivalente é aquele que tem a mesma área de aplicação (parâmetros e matrizes) e que cumpre as características de desempenho, obtendo resultados comparáveis ao(s) método(s) normalizado(s) junto indicado(s)

Tondela
Zona Industrial Tondela - ZIM II Lote 2 e 6
3460-070 Tondela
Telef.: 232817817
Fax: 232817819

Eugénia Silva

Técnica Superior de Laboratório
Eugénia Silva

Data Emissão: 04-10-2019

N.º de Análise:	QH / 13866 / 19
Data Colheita:	-
Data Receção:	21-09-2019
Data Início Ensaio:	21-09-2019
Data Fim Ensaio:	04-10-2019
Código Cliente:	7401

Exmo(s) Sr(s):
Nemus – Gestão e Req.Ambiental, Lda.
EST. DO PAÇO DO LUMIAR CAMPUS DO LUMIAR ED. D
LISBOA
1649-038 LISBOA

Unidade: Nemus – Gestão e Requalificação Ambiental, Lda.

Identificação da Amostra: **159096 / 19**

Produto: Água Naturais
Referência: Amostra 1
Acondicionamento: frasco
Nº Entrega: 1527/2019
A colheita de amostra não foi efectuada pela Controlvet.

Notas

Lista de abreviaturas: NE- Número estimado; UFC- Unidades formadoras de colónias; LQ – Limite de quantificação; LD – limite de detecção; V.L. – Valor Limite; V.R. – Valor Recomendado; VP - Valor Paramétrico; C - Conforme; A - Aceitável; NC - Não Conforme; Unid. - Unidade; DO - Densidade óptica.

O ensaio assinalado com (s) foi subcontratado e não é acreditado.
O ensaio assinalado com (a) foi subcontratado e é acreditado.
Nos resultados assinalados com (k) os microrganismos estão presentes, mas inferiores a 3xdiluição (quando aplicável).
Nos resultados assinalados com (y) os microrganismos estão presentes, mas inferiores a 4xdiluição.
Para os ensaios assinalados por tecnicas de cálculo a metodologia seguida pode ser disponibilizada a pedido.

Este Relatório de Ensaio refere-se apenas às amostras analisadas.
Proibida a reprodução parcial deste documento.

Tondela
Zona Industrial Tondela - ZIM II Lote 2 e 6
3460-070 Tondela
Telef.: 232817817
Fax: 232817819

Eugénia Silva

Técnica Superior de Laboratório
Eugénia Silva

CERTIFICATE OF ANALYSIS

Laboratory sample ID	: **PR1999997009**	**Work Order**	: **PR1999997**
		Issue Date	: 03-Oct-2019
Amendment	: **1**		
Customer	: **CONTROLVET - Seguranca Alimentar, S. A.**	Laboratory	: ALS Czech Republic, s.r.o.
Contact	: Subcontratacao Ensaios	Contact	: Client Service
Address	: Zona Industrial de Tondela ZIM II - Lote 6 3460-070 Tondela Portugal	Address	: Na Harfe 336/9 Prague 9 - Vysocany 190 00 Czech Republic
E-mail	: Subcontratacao.Ensaios@alsglobal.com	E-mail	: customer.support@alsglobal.com
Telephone	: ----	Telephone	: +420 226 226 228
Project	: ECF 2019E/155	Page	: 1 of 3
Order number	: ----	Date Samples Received	: 24-Sep-2019
		Quote number	: PR2015CONSE-PT0006 (PT-254-15-0938)
Site	: ----	Date of test	: 24-Sep-2019 - 03-Oct-2019
Sampled by	: client	QC Level	: ALS CR Standard Quality Control Schedule

General Comments

This report shall not be reproduced except in full, without prior written approval from the laboratory.
The laboratory declares that the test results relate only to the listed samples. If the section "Sampled by" of the Certificate of analysis states: "Sampled by Customer" then the results relate to the sample as received.
Amendmend No. 1: Change of COA format as per clients request. This Amendmend No. 1 supersedes test report No. PR1999997 dated 3.10.2019

Signatories

Testing Laboratory No. 1163
Accredited by CAI according to
CSN EN ISO/IEC 17025:2018

Signatories		*Position*
Zdeněk Jirák		Environmental Business Unit Manager

L 1163

Analytical Results

Sub-Matrix: **WATER**			*Laboratory sample ID*	**QH/13866/2019**	
			Client sampling date / time	[23-Sep-2019]	
Parameter	*Method*	*LOR*	*Unit*	**Result**	**MU**
Polycyclic Aromatics Hydrocarbons (PAHs)					
Naphthalene	W-PAHGMS01	0.100	µg/L	<0.100	----
Acenaphthylene	W-PAHGMS01	0.010	µg/L	<0.010	----
Acenaphthene	W-PAHGMS01	0.010	µg/L	<0.010	----
Fluorene	W-PAHGMS01	0.020	µg/L	<0.020	----
Phenanthrene	W-PAHGMS01	0.030	µg/L	<0.030	----
Anthracene	W-PAHGMS01	0.020	µg/L	<0.020	----
Fluoranthene	W-PAHGMS01	0.030	µg/L	<0.030	----
Pyrene	W-PAHGMS01	0.060	µg/L	<0.060	----
Benz(a)anthracene	W-PAHGMS01	0.010	µg/L	<0.010	----
Chrysene	W-PAHGMS01	0.010	µg/L	<0.010	----
Benzo(b)fluoranthene	W-PAHGMS01	0.010	µg/L	<0.010	----
Benzo(k)fluoranthene	W-PAHGMS01	0.010	µg/L	<0.010	----
Benzo(a)pyrene	W-PAHGMS01	0.020	µg/L	<0.020	----
Indeno(1.2.3.cd)pyrene	W-PAHGMS01	0.010	µg/L	<0.010	----
Benzo(g.h.i)perylene	W-PAHGMS01	0.010	µg/L	<0.010	----
Dibenz(a.h)anthracene	W-PAHGMS01	0.010	µg/L	<0.010	----
Sum of 16 PAH	W-PAHGMS01	0.370	µg/L	<0.370	----
Sum of PAH (MoE)	W-PAHGMS01	0.19	µg/L	<0.19	----
Sum of 6 PAH (WHO)	W-PAHGMS01	0.090	µg/L	<0.090	----
Sum of 4 PAH	W-PAHGMS01	0.040	µg/L	<0.040	----
Organochlorine Pesticides					
Hexachloroethane	W-OCPECD01	0.010	µg/L	<0.010	----
Hexachlorobutadiene	W-OCPECD01	0.010	µg/L	<0.010	----
1.2.3.5- & 1.2.4.5-Tetrachlorobenzene	W-OCPECD01	0.020	µg/L	<0.020	----
1.2.3.4-Tetrachlorobenzene	W-OCPECD01	0.010	µg/L	<0.010	----
Pentachlorobenzene	W-OCPECD01	0.010	µg/L	<0.010	----
Trifluralin	W-OCPECD01	0.010	µg/L	<0.010	----
Hexachlorocyclohexane Alpha	W-OCPECD01	0.010	µg/L	<0.010	----
Hexachlorobenzene (HCB)	W-OCPECD01	0.0050	µg/L	<0.0050	----
Hexachlorocyclohexane Beta	W-OCPECD01	0.010	µg/L	<0.010	----
Hexachlorocyclohexane Gamma	W-OCPECD01	0.010	µg/L	<0.010	----
Hexachlorocyclohexane Delta	W-OCPECD01	0.010	µg/L	<0.010	----
Hexachlorocyclohexane Epsilon	W-OCPECD01	0.010	µg/L	<0.010	----
Alachlor	W-OCPECD01	0.010	µg/L	<0.010	----
Heptachlor	W-OCPECD01	0.010	µg/L	<0.010	----
Aldrin	W-OCPECD01	0.0050	µg/L	<0.0050	----
Telodrin	W-OCPECD01	0.010	µg/L	<0.010	----
Isodrin	W-OCPECD01	0.010	µg/L	<0.010	----
Heptachloroepoxide-cis	W-OCPECD01	0.010	µg/L	<0.010	----
Heptachloroepoxide-trans	W-OCPECD01	0.010	µg/L	<0.010	----
2.4-DDE	W-OCPECD01	0.010	µg/L	<0.010	----
alpha-Endosulfan	W-OCPECD01	0.010	µg/L	<0.010	----

4.4`-DDE	W-OCPECD01	0.010	µg/L	<0.010	----
Dieldrin	W-OCPECD01	0.010	µg/L	<0.010	----
2.4-DDD	W-OCPECD01	0.010	µg/L	<0.010	----
Endrin	W-OCPECD01	0.010	µg/L	<0.010	----
beta-Endosulfan	W-OCPECD01	0.010	µg/L	<0.010	----
4.4`-DDD	W-OCPECD01	0.010	µg/L	<0.010	----
2.4-DDT	W-OCPECD01	0.010	µg/L	<0.010	----
4.4`-DDT	W-OCPECD01	0.010	µg/L	<0.010	----
Methoxychlor	W-OCPECD01	0.010	µg/L	<0.010	----
Dichlobenil	W-OCPECD01	0.050	µg/L	<0.050	----
Sum of 3 tetrachlorobenzenes	W-OCPECD01	0.030	µg/L	<0.030	----
Sum of 4 hexachlorcyclohexanes	W-OCPECD01	0.040	µg/L	<0.040	----
Sum of 4 isomers DDT	W-OCPECD01	0.040	µg/L	<0.040	----
Sum of 6 isomers DDT	W-OCPECD01	0.060	µg/L	<0.060	----
Sum of endosulfanes	W-OCPECD01	0.020	µg/L	<0.020	----
Sum of 5 hexachlorocyclohexanes	W-OCPECD01	0.050	µg/L	<0.050	----
Sum of 27 OCPs + 3 CBs	W-OCPECD01	0.290	µg/L	<0.290	----
Sum of 29 OCPs + 3 CBs	W-OCPECD01	0.350	µg/L	<0.350	----

If no sampling time is provided, the sampling time will default 00:00 on the date of sampling. If no sampling date is provided, delivery date in brackets without a time component will be displayed instead. Measurement uncertainty is expressed as expanded measurement uncertainty with coverage factor k = 2, representing 95% confidence level.

Key: LOR = Limit of reporting; MU = Measurement Uncertainty. The MU does not include sampling uncertainty.

The end of result part of the certificate of analysis

Brief Method Summaries

Analytical Methods	*Method Descriptions*
Location of test performance: Na Harfe 336/9 Prague 9 - Vysocany Czech Republic 190 00	
W-OCPECD01	CZ_SOP_D06_03_169 (CSN EN ISO 6468, US EPA 8081, DIN 38407-3, samples prepared as per CZ_SOP_D06_03_P01 chap. 9.1, CZ_SOP_D06_03_P02 chap. 9.1) Determination of organochlorine pesticides and other halogen compounds 12) by gas chromatography method with ECD detection and calculation of organochlorine pesticides and other halogen compounds sums from measured values.
W-PAHGMS01	CZ_SOP_D06_03_161 (US EPA 8270D, US EPA 8082A, CSN EN ISO 6468, US EPA 8000D, samples preparation as per CZ_SOP_D06_03_P01 chap. 9.1). Determination of semi volatile organic compounds by gas chromatography method with MS or MS/MS detection and calculation of semi volatile organic compounds sums from measured values

A `*` symbol preceding any method indicates laboratory or subcontractor non-accredited test. In the case when a procedure belonging to an accredited method was used for non-accredited matrix, would apply that the reported results are non-accredited. Please refer to General Comment section on front page for information. If the report contains subcontracted analysis, those are made in a subcontracted laboratory outside the laboratories ALS Czech Republic, s.r.o.
The calculation methods of summation parameters are available on request in the client service.

ALS Controlvet

Data Emissão: 04-10-2019

N.º de Análise:	QH / 13858 / 19
Data Colheita:	-
Data Receção:	21-09-2019
Data Início Ensaio:	21-09-2019
Data Fim Ensaio:	04-10-2019
Código Cliente:	7401

Exmo(s) Sr(s):
Nemus – Gestão e Req.Ambiental, Lda.
EST. DO PAÇO DO LUMIAR CAMPUS DO LUMIAR ED. D
LISBOA
1649-038 LISBOA

Unidade: Nemus – Gestão e Requalificação Ambiental, Lda.

Identificação da Amostra: **159083 / 19**

Produto: Água Naturais
Referência: Amostra 3
Acondicionamento: frasco
Nº Entrega: 1527/2019
A colheita de amostra não foi efectuada pela Controlvet.

Ensaio	Método	Resultado	Unidade
(a) Parâmetros físico-químicos	Descrição em anexo	Resultado em anexo.	.

Método interno equivalente é aquele que tem a mesma área de aplicação (parâmetros e matrizes) e que cumpre as características de desempenho, obtendo resultados comparáveis ao(s) método(s) normalizado(s) junto indicado(s)

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Data Emissão: 04-10-2019

N.º de Análise:	QH / 13858 / 19
Data Colheita:	-
Data Receção:	21-09-2019
Data Início Ensaio:	21-09-2019
Data Fim Ensaio:	04-10-2019
Código Cliente:	7401

Exmo(s) Sr(s):
Nemus – Gestão e Req.Ambiental, Lda.
EST. DO PAÇO DO LUMIAR CAMPUS DO LUMIAR ED. D
LISBOA
1649-038 LISBOA

Unidade: Nemus – Gestão e Requalificação Ambiental, Lda.

Identificação da Amostra: **159083 / 19**

Produto: Água Naturais
Referência: Amostra 3
Acondicionamento: frasco
Nº Entrega: 1527/2019
A colheita de amostra não foi efectuada pela Controlvet.

Notas

Lista de abreviaturas: NE- Número estimado; UFC- Unidades formadoras de colónias; LQ – Limite de quantificação; LD – limite de detecção; V.L. – Valor Limite; V.R. – Valor Recomendado; VP - Valor Paramétrico; C - Conforme; A - Aceitável; NC - Não Conforme; Unid. - Unidade; DO - Densidade óptica.

O ensaio assinalado com (s) foi subcontratado e não é acreditado.
O ensaio assinalado com (a) foi subcontratado e é acreditado.
Nos resultados assinalados com (k) os microrganismos estão presentes, mas inferiores a 3xdiluição (quando aplicável).
Nos resultados assinalados com (y) os microrganismos estão presentes, mas inferiores a 4xdiluição.
Para os ensaios assinalados por tecnicas de cálculo a metodologia seguida pode ser disponibilizada a pedido.

Este Relatório de Ensaio refere-se apenas às amostras analisadas.
Proibida a reprodução parcial deste documento.

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Eugénia Silva

Técnica Superior de Laboratório
Eugénia Silva

CERTIFICATE OF ANALYSIS

Laboratory sample ID	: **PR1999997001**	**Work Order**	: **PR1999997**
		Issue Date	: 03-Oct-2019
Amendment	: **1**		
Customer	: **CONTROLVET - Seguranca Alimentar, S. A.**	Laboratory	: ALS Czech Republic, s.r.o.
Contact	: Subcontratacao Ensaios	Contact	: Client Service
Address	: Zona Industrial de Tondela ZIM II - Lote 6 3460-070 Tondela Portugal	Address	: Na Harfe 336/9 Prague 9 - Vysocany 190 00 Czech Republic
E-mail	: Subcontratacao.Ensaios@alsglobal.com	E-mail	: customer.support@alsglobal.com
Telephone	: ----	Telephone	: +420 226 226 228
Project	: ECF 2019E/155	Page	: 1 of 3
Order number	: ----	Date Samples Received	: 24-Sep-2019
		Quote number	: PR2015CONSE-PT0006 (PT-254-15-0938)
Site	: ----	Date of test	: 24-Sep-2019 - 03-Oct-2019
Sampled by	: client	QC Level	: ALS CR Standard Quality Control Schedule

General Comments

This report shall not be reproduced except in full, without prior written approval from the laboratory.
The laboratory declares that the test results relate only to the listed samples. If the section "Sampled by" of the Certificate of analysis states: "Sampled by Customer" then the results relate to the sample as received.
Amendmend No. 1: Change of COA format as per clients request. This Amendmend No. 1 supersedes test report No. PR1999997 dated 3.10.2019

Signatories

Testing Laboratory No. 1163
Accredited by CAI according to
CSN EN ISO/IEC 17025:2018

Signatories		*Position*
Zdeněk Jirák		Environmental Business Unit Manager

L 1163

Analytical Results

Sub-Matrix: **WATER**			*Laboratory sample ID*	**QH/13858/2019**	
			Client sampling date / time	[23-Sep-2019]	
Parameter	*Method*	*LOR*	*Unit*	**Result**	**MU**
Polycyclic Aromatics Hydrocarbons (PAHs)					
Naphthalene	W-PAHGMS01	0.100	µg/L	<0.100	----
Acenaphthylene	W-PAHGMS01	0.010	µg/L	<0.010	----
Acenaphthene	W-PAHGMS01	0.010	µg/L	<0.010	----
Fluorene	W-PAHGMS01	0.020	µg/L	<0.020	----
Phenanthrene	W-PAHGMS01	0.030	µg/L	<0.030	----
Anthracene	W-PAHGMS01	0.020	µg/L	<0.020	----
Fluoranthene	W-PAHGMS01	0.030	µg/L	<0.030	----
Pyrene	W-PAHGMS01	0.060	µg/L	<0.060	----
Benz(a)anthracene	W-PAHGMS01	0.010	µg/L	<0.010	----
Chrysene	W-PAHGMS01	0.010	µg/L	<0.010	----
Benzo(b)fluoranthene	W-PAHGMS01	0.010	µg/L	<0.010	----
Benzo(k)fluoranthene	W-PAHGMS01	0.010	µg/L	<0.010	----
Benzo(a)pyrene	W-PAHGMS01	0.020	µg/L	<0.020	----
Indeno(1.2.3.cd)pyrene	W-PAHGMS01	0.010	µg/L	<0.010	----
Benzo(g.h.i)perylene	W-PAHGMS01	0.010	µg/L	<0.010	----
Dibenz(a.h)anthracene	W-PAHGMS01	0.010	µg/L	<0.010	----
Sum of 16 PAH	W-PAHGMS01	0.370	µg/L	<0.370	----
Sum of PAH (MoE)	W-PAHGMS01	0.19	µg/L	<0.19	----
Sum of 6 PAH (WHO)	W-PAHGMS01	0.090	µg/L	<0.090	----
Sum of 4 PAH	W-PAHGMS01	0.040	µg/L	<0.040	----
Organochlorine Pesticides					
Hexachloroethane	W-OCPECD01	0.010	µg/L	<0.010	----
Hexachlorobutadiene	W-OCPECD01	0.010	µg/L	<0.010	----
1.2.3.5- & 1.2.4.5-Tetrachlorobenzene	W-OCPECD01	0.020	µg/L	<0.020	----
1.2.3.4-Tetrachlorobenzene	W-OCPECD01	0.010	µg/L	<0.010	----
Pentachlorobenzene	W-OCPECD01	0.010	µg/L	<0.010	----
Trifluralin	W-OCPECD01	0.010	µg/L	<0.010	----
Hexachlorocyclohexane Alpha	W-OCPECD01	0.010	µg/L	<0.010	----
Hexachlorobenzene (HCB)	W-OCPECD01	0.0050	µg/L	<0.0050	----
Hexachlorocyclohexane Beta	W-OCPECD01	0.010	µg/L	<0.010	----
Hexachlorocyclohexane Gamma	W-OCPECD01	0.010	µg/L	<0.010	----
Hexachlorocyclohexane Delta	W-OCPECD01	0.010	µg/L	<0.010	----
Hexachlorocyclohexane Epsilon	W-OCPECD01	0.010	µg/L	<0.010	----
Alachlor	W-OCPECD01	0.010	µg/L	<0.010	----
Heptachlor	W-OCPECD01	0.010	µg/L	<0.010	----
Aldrin	W-OCPECD01	0.0050	µg/L	<0.0050	----
Telodrin	W-OCPECD01	0.010	µg/L	<0.010	----
Isodrin	W-OCPECD01	0.010	µg/L	<0.010	----
Heptachloroepoxide-cis	W-OCPECD01	0.010	µg/L	<0.010	----
Heptachloroepoxide-trans	W-OCPECD01	0.010	µg/L	<0.010	----
2.4-DDE	W-OCPECD01	0.010	µg/L	<0.010	----
alpha-Endosulfan	W-OCPECD01	0.010	µg/L	<0.010	----

4.4`-DDE	W-OCPECD01	0.010	µg/L	<0.010	----
Dieldrin	W-OCPECD01	0.010	µg/L	<0.010	----
2.4-DDD	W-OCPECD01	0.010	µg/L	<0.010	----
Endrin	W-OCPECD01	0.010	µg/L	<0.010	----
beta-Endosulfan	W-OCPECD01	0.010	µg/L	<0.010	----
4.4`-DDD	W-OCPECD01	0.010	µg/L	<0.010	----
2.4-DDT	W-OCPECD01	0.010	µg/L	<0.010	----
4.4`-DDT	W-OCPECD01	0.010	µg/L	<0.010	----
Methoxychlor	W-OCPECD01	0.010	µg/L	<0.010	----
Dichlobenil	W-OCPECD01	0.050	µg/L	<0.050	----
Sum of 3 tetrachlorobenzenes	W-OCPECD01	0.030	µg/L	<0.030	----
Sum of 4 hexachlorcyclohexanes	W-OCPECD01	0.040	µg/L	<0.040	----
Sum of 4 isomers DDT	W-OCPECD01	0.040	µg/L	<0.040	----
Sum of 6 isomers DDT	W-OCPECD01	0.060	µg/L	<0.060	----
Sum of endosulfanes	W-OCPECD01	0.020	µg/L	<0.020	----
Sum of 5 hexachlorocyclohexanes	W-OCPECD01	0.050	µg/L	<0.050	----
Sum of 27 OCPs + 3 CBs	W-OCPECD01	0.290	µg/L	<0.290	----
Sum of 29 OCPs + 3 CBs	W-OCPECD01	0.350	µg/L	<0.350	----

If no sampling time is provided, the sampling time will default 00:00 on the date of sampling. If no sampling date is provided, delivery date in brackets without a time component will be displayed instead. Measurement uncertainty is expressed as expanded measurement uncertainty with coverage factor k = 2, representing 95% confidence level.

Key: LOR = Limit of reporting; MU = Measurement Uncertainty. The MU does not include sampling uncertainty.

The end of result part of the certificate of analysis

Brief Method Summaries

Analytical Methods	*Method Descriptions*
Location of test performance: Na Harfe 336/9 Prague 9 - Vysocany Czech Republic 190 00	
W-OCPECD01	CZ_SOP_D06_03_169 (CSN EN ISO 6468, US EPA 8081, DIN 38407-3, samples prepared as per CZ_SOP_D06_03_P01 chap. 9.1, CZ_SOP_D06_03_P02 chap. 9.1) Determination of organochlorine pesticides and other halogen compounds 12) by gas chromatography method with ECD detection and calculation of organochlorine pesticides and other halogen compounds sums from measured values.
W-PAHGMS01	CZ_SOP_D06_03_161 (US EPA 8270D, US EPA 8082A, CSN EN ISO 6468, US EPA 8000D, samples preparation as per CZ_SOP_D06_03_P01 chap. 9.1). Determination of semi volatile organic compounds by gas chromatography method with MS or MS/MS detection and calculation of semi volatile organic compounds sums from measured values

A `*` symbol preceding any method indicates laboratory or subcontractor non-accredited test. In the case when a procedure belonging to an accredited method was used for non-accredited matrix, would apply that the reported results are non-accredited. Please refer to General Comment section on front page for information. If the report contains subcontracted analysis, those are made in a subcontracted laboratory outside the laboratories ALS Czech Republic, s.r.o.
The calculation methods of summation parameters are available on request in the client service.

ALS Controlvet

Data Emissão: 04-10-2019

N.º de Análise:	QH / 13864 / 19
Data Colheita:	-
Data Receção:	21-09-2019
Data Início Ensaio:	21-09-2019
Data Fim Ensaio:	04-10-2019
Código Cliente:	7401

Exmo(s) Sr(s):
Nemus – Gestão e Req.Ambiental, Lda.
EST. DO PAÇO DO LUMIAR CAMPUS DO LUMIAR ED. D
LISBOA
1649-038 LISBOA

Unidade: Nemus – Gestão e Requalificação Ambiental, Lda.

Identificação da Amostra: **159094 / 19**

Produto: Água Naturais
Referência: Amostra 7
Acondicionamento: frasco
Nº Entrega: 1527/2019
A colheita de amostra não foi efectuada pela Controlvet.

Ensaio	Método	Resultado	Unidade
(a) Parâmetros físico-químicos	Descrição em anexo	Resultado em anexo.	.

Método interno equivalente é aquele que tem a mesma área de aplicação (parâmetros e matrizes) e que cumpre as características de desempenho, obtendo resultados comparáveis ao(s) método(s) normalizado(s) junto indicado(s)

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Zona Industrial Tondela - ZIM II Lote 2 e 6
3460-070 Tondela
Telef.: 232817817
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Eugénia Silva

Técnica Superior de Laboratório
Eugénia Silva

Data Emissão: 04-10-2019

N.º de Análise:	QH / 13864 / 19
Data Colheita:	-
Data Receção:	21-09-2019
Data Início Ensaio:	21-09-2019
Data Fim Ensaio:	04-10-2019
Código Cliente:	7401

Exmo(s) Sr(s):
Nemus – Gestão e Req.Ambiental, Lda.
EST. DO PAÇO DO LUMIAR CAMPUS DO LUMIAR ED. D
LISBOA
1649-038 LISBOA

Unidade: Nemus – Gestão e Requalificação Ambiental, Lda.

Identificação da Amostra: **159094 / 19**

Produto: Água Naturais
Referência: Amostra 7
Acondicionamento: frasco
Nº Entrega: 1527/2019
A colheita de amostra não foi efectuada pela Controlvet.

Notas

Lista de abreviaturas: NE- Número estimado; UFC- Unidades formadoras de colónias; LQ – Limite de quantificação; LD – limite de detecção; V.L. – Valor Limite; V.R. – Valor Recomendado; VP - Valor Paramétrico; C - Conforme; A - Aceitável; NC - Não Conforme; Unid. - Unidade; DO - Densidade óptica.

O ensaio assinalado com (s) foi subcontratado e não é acreditado.
O ensaio assinalado com (a) foi subcontratado e é acreditado.
Nos resultados assinalados com (k) os microrganismos estão presentes, mas inferiores a 3xdiluição (quando aplicável).
Nos resultados assinalados com (y) os microrganismos estão presentes, mas inferiores a 4xdiluição.
Para os ensaios assinalados por tecnicas de cálculo a metodologia seguida pode ser disponibilizada a pedido.

Este Relatório de Ensaio refere-se apenas às amostras analisadas.
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Eugénia Silva

Técnica Superior de Laboratório
Eugénia Silva

CERTIFICATE OF ANALYSIS

Laboratory sample ID	: **PR1999997007**	**Work Order**	: **PR1999997**
		Issue Date	: 03-Oct-2019
Amendment	: **1**		
Customer	: **CONTROLVET - Seguranca Alimentar, S. A.**	Laboratory	: ALS Czech Republic, s.r.o.
Contact	: Subcontratacao Ensaios	Contact	: Client Service
Address	: Zona Industrial de Tondela ZIM II - Lote 6 3460-070 Tondela Portugal	Address	: Na Harfe 336/9 Prague 9 - Vysocany 190 00 Czech Republic
E-mail	: Subcontratacao.Ensaios@alsglobal.com	E-mail	: customer.support@alsglobal.com
Telephone	: ----	Telephone	: +420 226 226 228
Project	: ECF 2019E/155	Page	: 1 of 3
Order number	: ----	Date Samples Received	: 24-Sep-2019
		Quote number	: PR2015CONSE-PT0006 (PT-254-15-0938)
Site	: ----	Date of test	: 24-Sep-2019 - 03-Oct-2019
Sampled by	: client	QC Level	: ALS CR Standard Quality Control Schedule

General Comments

This report shall not be reproduced except in full, without prior written approval from the laboratory.
The laboratory declares that the test results relate only to the listed samples. If the section "Sampled by" of the Certificate of analysis states: "Sampled by Customer" then the results relate to the sample as received.
Amendmend No. 1: Change of COA format as per clients request. This Amendmend No. 1 supersedes test report No. PR1999997 dated 3.10.2019

Signatories

Testing Laboratory No. 1163
Accredited by CAI according to
CSN EN ISO/IEC 17025:2018

Signatories		*Position*
Zdeněk Jirák		Environmental Business Unit Manager

L 1163

Analytical Results

Sub-Matrix: **WATER**			*Laboratory sample ID*	**QH/13864/2019**	
			Client sampling date / time	[23-Sep-2019]	
Parameter	*Method*	*LOR*	*Unit*	**Result**	**MU**
Polycyclic Aromatics Hydrocarbons (PAHs)					
Naphthalene	W-PAHGMS01	0.100	µg/L	<0.100	----
Acenaphthylene	W-PAHGMS01	0.010	µg/L	<0.010	----
Acenaphthene	W-PAHGMS01	0.010	µg/L	<0.010	----
Fluorene	W-PAHGMS01	0.020	µg/L	<0.020	----
Phenanthrene	W-PAHGMS01	0.030	µg/L	<0.030	----
Anthracene	W-PAHGMS01	0.020	µg/L	<0.020	----
Fluoranthene	W-PAHGMS01	0.030	µg/L	<0.030	----
Pyrene	W-PAHGMS01	0.060	µg/L	<0.060	----
Benz(a)anthracene	W-PAHGMS01	0.010	µg/L	<0.010	----
Chrysene	W-PAHGMS01	0.010	µg/L	<0.010	----
Benzo(b)fluoranthene	W-PAHGMS01	0.010	µg/L	<0.010	----
Benzo(k)fluoranthene	W-PAHGMS01	0.010	µg/L	<0.010	----
Benzo(a)pyrene	W-PAHGMS01	0.020	µg/L	<0.020	----
Indeno(1.2.3.cd)pyrene	W-PAHGMS01	0.010	µg/L	<0.010	----
Benzo(g.h.i)perylene	W-PAHGMS01	0.010	µg/L	<0.010	----
Dibenz(a.h)anthracene	W-PAHGMS01	0.010	µg/L	<0.010	----
Sum of 16 PAH	W-PAHGMS01	0.370	µg/L	<0.370	----
Sum of PAH (MoE)	W-PAHGMS01	0.19	µg/L	<0.19	----
Sum of 6 PAH (WHO)	W-PAHGMS01	0.090	µg/L	<0.090	----
Sum of 4 PAH	W-PAHGMS01	0.040	µg/L	<0.040	----
Organochlorine Pesticides					
Hexachloroethane	W-OCPECD01	0.010	µg/L	<0.010	----
Hexachlorobutadiene	W-OCPECD01	0.010	µg/L	<0.010	----
1.2.3.5- & 1.2.4.5-Tetrachlorobenzene	W-OCPECD01	0.020	µg/L	<0.020	----
1.2.3.4-Tetrachlorobenzene	W-OCPECD01	0.010	µg/L	<0.010	----
Pentachlorobenzene	W-OCPECD01	0.010	µg/L	<0.010	----
Trifluralin	W-OCPECD01	0.010	µg/L	<0.010	----
Hexachlorocyclohexane Alpha	W-OCPECD01	0.010	µg/L	<0.010	----
Hexachlorobenzene (HCB)	W-OCPECD01	0.0050	µg/L	<0.0050	----
Hexachlorocyclohexane Beta	W-OCPECD01	0.010	µg/L	<0.010	----
Hexachlorocyclohexane Gamma	W-OCPECD01	0.010	µg/L	<0.010	----
Hexachlorocyclohexane Delta	W-OCPECD01	0.010	µg/L	<0.010	----
Hexachlorocyclohexane Epsilon	W-OCPECD01	0.010	µg/L	<0.010	----
Alachlor	W-OCPECD01	0.010	µg/L	<0.010	----
Heptachlor	W-OCPECD01	0.010	µg/L	<0.010	----
Aldrin	W-OCPECD01	0.0050	µg/L	<0.0050	----
Telodrin	W-OCPECD01	0.010	µg/L	<0.010	----
Isodrin	W-OCPECD01	0.010	µg/L	<0.010	----
Heptachloroepoxide-cis	W-OCPECD01	0.010	µg/L	<0.010	----
Heptachloroepoxide-trans	W-OCPECD01	0.010	µg/L	<0.010	----
2.4-DDE	W-OCPECD01	0.010	µg/L	<0.010	----
alpha-Endosulfan	W-OCPECD01	0.010	µg/L	<0.010	----

4.4`-DDE	W-OCPECD01	0.010	µg/L	<0.010	----
Dieldrin	W-OCPECD01	0.010	µg/L	<0.010	----
2.4-DDD	W-OCPECD01	0.010	µg/L	<0.010	----
Endrin	W-OCPECD01	0.010	µg/L	<0.010	----
beta-Endosulfan	W-OCPECD01	0.010	µg/L	<0.010	----
4.4`-DDD	W-OCPECD01	0.010	µg/L	<0.010	----
2.4-DDT	W-OCPECD01	0.010	µg/L	<0.010	----
4.4`-DDT	W-OCPECD01	0.010	µg/L	<0.010	----
Methoxychlor	W-OCPECD01	0.010	µg/L	<0.010	----
Dichlobenil	W-OCPECD01	0.050	µg/L	<0.050	----
Sum of 3 tetrachlorobenzenes	W-OCPECD01	0.030	µg/L	<0.030	----
Sum of 4 hexachlorcyclohexanes	W-OCPECD01	0.040	µg/L	<0.040	----
Sum of 4 isomers DDT	W-OCPECD01	0.040	µg/L	<0.040	----
Sum of 6 isomers DDT	W-OCPECD01	0.060	µg/L	<0.060	----
Sum of endosulfanes	W-OCPECD01	0.020	µg/L	<0.020	----
Sum of 5 hexachlorocyclohexanes	W-OCPECD01	0.050	µg/L	<0.050	----
Sum of 27 OCPs + 3 CBs	W-OCPECD01	0.290	µg/L	<0.290	----
Sum of 29 OCPs + 3 CBs	W-OCPECD01	0.350	µg/L	<0.350	----

If no sampling time is provided, the sampling time will default 00:00 on the date of sampling. If no sampling date is provided, delivery date in brackets without a time component will be displayed instead. Measurement uncertainty is expressed as expanded measurement uncertainty with coverage factor k = 2, representing 95% confidence level.

Key: LOR = Limit of reporting; MU = Measurement Uncertainty. The MU does not include sampling uncertainty.

The end of result part of the certificate of analysis

Brief Method Summaries

Analytical Methods	*Method Descriptions*
Location of test performance: Na Harfe 336/9 Prague 9 - Vysocany Czech Republic 190 00	
W-OCPECD01	CZ_SOP_D06_03_169 (CSN EN ISO 6468, US EPA 8081, DIN 38407-3, samples prepared as per CZ_SOP_D06_03_P01 chap. 9.1, CZ_SOP_D06_03_P02 chap. 9.1) Determination of organochlorine pesticides and other halogen compounds 12) by gas chromatography method with ECD detection and calculation of organochlorine pesticides and other halogen compounds sums from measured values.
W-PAHGMS01	CZ_SOP_D06_03_161 (US EPA 8270D, US EPA 8082A, CSN EN ISO 6468, US EPA 8000D, samples preparation as per CZ_SOP_D06_03_P01 chap. 9.1). Determination of semi volatile organic compounds by gas chromatography method with MS or MS/MS detection and calculation of semi volatile organic compounds sums from measured values

A `*` symbol preceding any method indicates laboratory or subcontractor non-accredited test. In the case when a procedure belonging to an accredited method was used for non-accredited matrix, would apply that the reported results are non-accredited. Please refer to General Comment section on front page for information. If the report contains subcontracted analysis, those are made in a subcontracted laboratory outside the laboratories ALS Czech Republic, s.r.o.
The calculation methods of summation parameters are available on request in the client service.

ALS Controlvet

Data Emissão: 04-10-2019

N.º de Análise:	QH / 13865 / 19
Data Colheita:	-
Data Receção:	21-09-2019
Data Início Ensaio:	21-09-2019
Data Fim Ensaio:	04-10-2019
Código Cliente:	7401

Exmo(s) Sr(s):
Nemus – Gestão e Req.Ambiental, Lda.
EST. DO PAÇO DO LUMIAR CAMPUS DO LUMIAR ED. D
LISBOA
1649-038 LISBOA

Unidade: Nemus – Gestão e Requalificação Ambiental, Lda.

Identificação da Amostra: **159095 / 19**

Produto: Água Naturais
Referência: Amostra 10
Acondicionamento: frasco
Nº Entrega: 1527/2019
A colheita de amostra não foi efectuada pela Controlvet.

Ensaio	Método	Resultado	Unidade
(a) Parâmetros físico-químicos	Descrição em anexo	Resultado em anexo.	.

Método interno equivalente é aquele que tem a mesma área de aplicação (parâmetros e matrizes) e que cumpre as características de desempenho, obtendo resultados comparáveis ao(s) método(s) normalizado(s) junto indicado(s)

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Eugénia Silva

Técnica Superior de Laboratório
Eugénia Silva

Data Emissão: 04-10-2019

N.º de Análise:	QH / 13865 / 19
Data Colheita:	-
Data Receção:	21-09-2019
Data Início Ensaio:	21-09-2019
Data Fim Ensaio:	04-10-2019
Código Cliente:	7401

Exmo(s) Sr(s):
Nemus – Gestão e Req.Ambiental, Lda.
EST. DO PAÇO DO LUMIAR CAMPUS DO LUMIAR ED. D
LISBOA
1649-038 LISBOA

Unidade: Nemus – Gestão e Requalificação Ambiental, Lda.

Identificação da Amostra: **159095 / 19**

Produto: Água Naturais
Referência: Amostra 10
Acondicionamento: frasco
Nº Entrega: 1527/2019
A colheita de amostra não foi efectuada pela Controlvet.

Notas

Lista de abreviaturas: NE- Número estimado; UFC- Unidades formadoras de colónias; LQ – Limite de quantificação; LD – limite de detecção; V.L. – Valor Limite; V.R. – Valor Recomendado; VP - Valor Paramétrico; C - Conforme; A - Aceitável; NC - Não Conforme; Unid. - Unidade; DO - Densidade óptica.

O ensaio assinalado com (s) foi subcontratado e não é acreditado.
O ensaio assinalado com (a) foi subcontratado e é acreditado.
Nos resultados assinalados com (k) os microrganismos estão presentes, mas inferiores a 3xdiluição (quando aplicável).
Nos resultados assinalados com (y) os microrganismos estão presentes, mas inferiores a 4xdiluição.
Para os ensaios assinalados por tecnicas de cálculo a metodologia seguida pode ser disponibilizada a pedido.

Este Relatório de Ensaio refere-se apenas às amostras analisadas.
Proibida a reprodução parcial deste documento.

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Eugénia Silva

Técnica Superior de Laboratório
Eugénia Silva

CERTIFICATE OF ANALYSIS

Laboratory sample ID	: **PR1999997008**	**Work Order**	: **PR1999997**
		Issue Date	: 03-Oct-2019
Amendment	: **1**		
Customer	: **CONTROLVET - Seguranca Alimentar, S. A.**	Laboratory	: ALS Czech Republic, s.r.o.
Contact	: Subcontratacao Ensaios	Contact	: Client Service
Address	: Zona Industrial de Tondela ZIM II - Lote 6 3460-070 Tondela Portugal	Address	: Na Harfe 336/9 Prague 9 - Vysocany 190 00 Czech Republic
E-mail	: Subcontratacao.Ensaios@alsglobal.com	E-mail	: customer.support@alsglobal.com
Telephone	: ----	Telephone	: +420 226 226 228
Project	: ECF 2019E/155	Page	: 1 of 3
Order number	: ----	Date Samples Received	: 24-Sep-2019
		Quote number	: PR2015CONSE-PT0006 (PT-254-15-0938)
Site	: ----	Date of test	: 24-Sep-2019 - 03-Oct-2019
Sampled by	: client	QC Level	: ALS CR Standard Quality Control Schedule

General Comments

This report shall not be reproduced except in full, without prior written approval from the laboratory.
The laboratory declares that the test results relate only to the listed samples. If the section "Sampled by" of the Certificate of analysis states: "Sampled by Customer" then the results relate to the sample as received.
Amendmend No. 1: Change of COA format as per clients request. This Amendmend No. 1 supersedes test report No. PR1999997 dated 3.10.2019

Signatories

Testing Laboratory No. 1163
Accredited by CAI according to
CSN EN ISO/IEC 17025:2018

Signatories		*Position*
Zdeněk Jirák		Environmental Business Unit Manager

L 1163

Analytical Results

Sub-Matrix: **WATER**			*Laboratory sample ID*	**QH/13865/2019**	
			Client sampling date / time	[23-Sep-2019]	
Parameter	*Method*	*LOR*	*Unit*	**Result**	**MU**
Polycyclic Aromatics Hydrocarbons (PAHs)					
Naphthalene	W-PAHGMS01	0.100	µg/L	<0.100	----
Acenaphthylene	W-PAHGMS01	0.010	µg/L	<0.010	----
Acenaphthene	W-PAHGMS01	0.010	µg/L	<0.010	----
Fluorene	W-PAHGMS01	0.020	µg/L	<0.020	----
Phenanthrene	W-PAHGMS01	0.030	µg/L	<0.030	----
Anthracene	W-PAHGMS01	0.020	µg/L	<0.020	----
Fluoranthene	W-PAHGMS01	0.030	µg/L	<0.030	----
Pyrene	W-PAHGMS01	0.060	µg/L	<0.060	----
Benz(a)anthracene	W-PAHGMS01	0.010	µg/L	<0.010	----
Chrysene	W-PAHGMS01	0.010	µg/L	<0.010	----
Benzo(b)fluoranthene	W-PAHGMS01	0.010	µg/L	<0.010	----
Benzo(k)fluoranthene	W-PAHGMS01	0.010	µg/L	<0.010	----
Benzo(a)pyrene	W-PAHGMS01	0.020	µg/L	<0.020	----
Indeno(1.2.3.cd)pyrene	W-PAHGMS01	0.010	µg/L	<0.010	----
Benzo(g.h.i)perylene	W-PAHGMS01	0.010	µg/L	<0.010	----
Dibenz(a.h)anthracene	W-PAHGMS01	0.010	µg/L	<0.010	----
Sum of 16 PAH	W-PAHGMS01	0.370	µg/L	<0.370	----
Sum of PAH (MoE)	W-PAHGMS01	0.19	µg/L	<0.19	----
Sum of 6 PAH (WHO)	W-PAHGMS01	0.090	µg/L	<0.090	----
Sum of 4 PAH	W-PAHGMS01	0.040	µg/L	<0.040	----
Organochlorine Pesticides					
Hexachloroethane	W-OCPECD01	0.010	µg/L	<0.010	----
Hexachlorobutadiene	W-OCPECD01	0.010	µg/L	<0.010	----
1.2.3.5- & 1.2.4.5-Tetrachlorobenzene	W-OCPECD01	0.020	µg/L	<0.020	----
1.2.3.4-Tetrachlorobenzene	W-OCPECD01	0.010	µg/L	<0.010	----
Pentachlorobenzene	W-OCPECD01	0.010	µg/L	<0.010	----
Trifluralin	W-OCPECD01	0.010	µg/L	<0.010	----
Hexachlorocyclohexane Alpha	W-OCPECD01	0.010	µg/L	<0.010	----
Hexachlorobenzene (HCB)	W-OCPECD01	0.0050	µg/L	<0.0050	----
Hexachlorocyclohexane Beta	W-OCPECD01	0.010	µg/L	<0.010	----
Hexachlorocyclohexane Gamma	W-OCPECD01	0.010	µg/L	<0.010	----
Hexachlorocyclohexane Delta	W-OCPECD01	0.010	µg/L	<0.010	----
Hexachlorocyclohexane Epsilon	W-OCPECD01	0.010	µg/L	<0.010	----
Alachlor	W-OCPECD01	0.010	µg/L	<0.010	----
Heptachlor	W-OCPECD01	0.010	µg/L	<0.010	----
Aldrin	W-OCPECD01	0.0050	µg/L	<0.0050	----
Telodrin	W-OCPECD01	0.010	µg/L	<0.010	----
Isodrin	W-OCPECD01	0.010	µg/L	<0.010	----
Heptachloroepoxide-cis	W-OCPECD01	0.010	µg/L	<0.010	----
Heptachloroepoxide-trans	W-OCPECD01	0.010	µg/L	<0.010	----
2.4-DDE	W-OCPECD01	0.010	µg/L	<0.010	----
alpha-Endosulfan	W-OCPECD01	0.010	µg/L	<0.010	----

4.4`-DDE	W-OCPECD01	0.010	µg/L	<0.010	----
Dieldrin	W-OCPECD01	0.010	µg/L	<0.010	----
2.4-DDD	W-OCPECD01	0.010	µg/L	<0.010	----
Endrin	W-OCPECD01	0.010	µg/L	<0.010	----
beta-Endosulfan	W-OCPECD01	0.010	µg/L	<0.010	----
4.4`-DDD	W-OCPECD01	0.010	µg/L	<0.010	----
2.4-DDT	W-OCPECD01	0.010	µg/L	<0.010	----
4.4`-DDT	W-OCPECD01	0.010	µg/L	<0.010	----
Methoxychlor	W-OCPECD01	0.010	µg/L	<0.010	----
Dichlobenil	W-OCPECD01	0.050	µg/L	<0.050	----
Sum of 3 tetrachlorobenzenes	W-OCPECD01	0.030	µg/L	<0.030	----
Sum of 4 hexachlorcyclohexanes	W-OCPECD01	0.040	µg/L	<0.040	----
Sum of 4 isomers DDT	W-OCPECD01	0.040	µg/L	<0.040	----
Sum of 6 isomers DDT	W-OCPECD01	0.060	µg/L	<0.060	----
Sum of endosulfanes	W-OCPECD01	0.020	µg/L	<0.020	----
Sum of 5 hexachlorocyclohexanes	W-OCPECD01	0.050	µg/L	<0.050	----
Sum of 27 OCPs + 3 CBs	W-OCPECD01	0.290	µg/L	<0.290	----
Sum of 29 OCPs + 3 CBs	W-OCPECD01	0.350	µg/L	<0.350	----

If no sampling time is provided, the sampling time will default 00:00 on the date of sampling. If no sampling date is provided, delivery date in brackets without a time component will be displayed instead. Measurement uncertainty is expressed as expanded measurement uncertainty with coverage factor k = 2, representing 95% confidence level.

Key: LOR = Limit of reporting; MU = Measurement Uncertainty. The MU does not include sampling uncertainty.

The end of result part of the certificate of analysis

Brief Method Summaries

Analytical Methods	*Method Descriptions*
Location of test performance: Na Harfe 336/9 Prague 9 - Vysocany Czech Republic 190 00	
W-OCPECD01	CZ_SOP_D06_03_169 (CSN EN ISO 6468, US EPA 8081, DIN 38407-3, samples prepared as per CZ_SOP_D06_03_P01 chap. 9.1, CZ_SOP_D06_03_P02 chap. 9.1) Determination of organochlorine pesticides and other halogen compounds 12) by gas chromatography method with ECD detection and calculation of organochlorine pesticides and other halogen compounds sums from measured values.
W-PAHGMS01	CZ_SOP_D06_03_161 (US EPA 8270D, US EPA 8082A, CSN EN ISO 6468, US EPA 8000D, samples preparation as per CZ_SOP_D06_03_P01 chap. 9.1). Determination of semi volatile organic compounds by gas chromatography method with MS or MS/MS detection and calculation of semi volatile organic compounds sums from measured values

A `*` symbol preceding any method indicates laboratory or subcontractor non-accredited test. In the case when a procedure belonging to an accredited method was used for non-accredited matrix, would apply that the reported results are non-accredited. Please refer to General Comment section on front page for information. If the report contains subcontracted analysis, those are made in a subcontracted laboratory outside the laboratories ALS Czech Republic, s.r.o.
The calculation methods of summation parameters are available on request in the client service.

ALS Controlvet

Data Emissão: 04-10-2019

N.º de Análise:	QH / 13863 / 19
Data Colheita:	-
Data Receção:	21-09-2019
Data Início Ensaio:	21-09-2019
Data Fim Ensaio:	04-10-2019
Código Cliente:	7401

Exmo(s) Sr(s):
Nemus – Gestão e Req.Ambiental, Lda.
EST. DO PAÇO DO LUMIAR CAMPUS DO LUMIAR ED. D
LISBOA
1649-038 LISBOA

Unidade: Nemus – Gestão e Requalificação Ambiental, Lda.

Identificação da Amostra: **159093 / 19**

Produto: Água Naturais
Referência: Amostra 12
Acondicionamento: frasco
Nº Entrega: 1527/2019
A colheita de amostra não foi efectuada pela Controlvet.

Ensaio	Método	Resultado	Unidade
(a) Parâmetros físico-químicos	Descrição em anexo	Resultado em anexo.	.

Método interno equivalente é aquele que tem a mesma área de aplicação (parâmetros e matrizes) e que cumpre as características de desempenho, obtendo resultados comparáveis ao(s) método(s) normalizado(s) junto indicado(s)

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Zona Industrial Tondela - ZIM II Lote 2 e 6
3460-070 Tondela
Telef.: 232817817
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Técnica Superior de Laboratório
Eugénia Silva

Data Emissão: 04-10-2019

N.º de Análise:	QH / 13863 / 19
Data Colheita:	-
Data Receção:	21-09-2019
Data Início Ensaio:	21-09-2019
Data Fim Ensaio:	04-10-2019
Código Cliente:	7401

Exmo(s) Sr(s):
Nemus – Gestão e Req.Ambiental, Lda.
EST. DO PAÇO DO LUMIAR CAMPUS DO LUMIAR ED. D
LISBOA
1649-038 LISBOA

Unidade: Nemus – Gestão e Requalificação Ambiental, Lda.

Identificação da Amostra: **159093 / 19**

Produto: Água Naturais
Referência: Amostra 12
Acondicionamento: frasco
Nº Entrega: 1527/2019
A colheita de amostra não foi efectuada pela Controlvet.

Notas

Lista de abreviaturas: NE- Número estimado; UFC- Unidades formadoras de colónias; LQ – Limite de quantificação; LD – limite de detecção; V.L. – Valor Limite; V.R. – Valor Recomendado; VP - Valor Paramétrico; C - Conforme; A - Aceitável; NC - Não Conforme; Unid. - Unidade; DO - Densidade óptica.

O ensaio assinalado com (s) foi subcontratado e não é acreditado.
O ensaio assinalado com (a) foi subcontratado e é acreditado.
Nos resultados assinalados com (k) os microrganismos estão presentes, mas inferiores a 3xdiluição (quando aplicável).
Nos resultados assinalados com (y) os microrganismos estão presentes, mas inferiores a 4xdiluição.
Para os ensaios assinalados por tecnicas de cálculo a metodologia seguida pode ser disponibilizada a pedido.

Este Relatório de Ensaio refere-se apenas às amostras analisadas.
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Eugénia Silva

Técnica Superior de Laboratório
Eugénia Silva

CERTIFICATE OF ANALYSIS

Laboratory sample ID	: **PR1999997006**	**Work Order**	: **PR1999997**
		Issue Date	: 03-Oct-2019
Amendment	: **1**		
Customer	: **CONTROLVET - Seguranca Alimentar, S. A.**	Laboratory	: ALS Czech Republic, s.r.o.
Contact	: Subcontratacao Ensaios	Contact	: Client Service
Address	: Zona Industrial de Tondela ZIM II - Lote 6 3460-070 Tondela Portugal	Address	: Na Harfe 336/9 Prague 9 - Vysocany 190 00 Czech Republic
E-mail	: Subcontratacao.Ensaios@alsglobal.com	E-mail	: customer.support@alsglobal.com
Telephone	: ----	Telephone	: +420 226 226 228
Project	: ECF 2019E/155	Page	: 1 of 3
Order number	: ----	Date Samples Received	: 24-Sep-2019
		Quote number	: PR2015CONSE-PT0006 (PT-254-15-0938)
Site	: ----	Date of test	: 24-Sep-2019 - 03-Oct-2019
Sampled by	: client	QC Level	: ALS CR Standard Quality Control Schedule

General Comments

This report shall not be reproduced except in full, without prior written approval from the laboratory.
The laboratory declares that the test results relate only to the listed samples. If the section "Sampled by" of the Certificate of analysis states: "Sampled by Customer" then the results relate to the sample as received.
Amendmend No. 1: Change of COA format as per clients request. This Amendmend No. 1 supersedes test report No. PR1999997 dated 3.10.2019

Signatories

Testing Laboratory No. 1163
Accredited by CAI according to
CSN EN ISO/IEC 17025:2018

Signatories		*Position*
Zdeněk Jirák		Environmental Business Unit Manager

L 1163

Analytical Results

Sub-Matrix: **WATER**			*Laboratory sample ID*	**QH/13863/2019**	
			Client sampling date / time	[23-Sep-2019]	
Parameter	*Method*	*LOR*	*Unit*	**Result**	**MU**
Polycyclic Aromatics Hydrocarbons (PAHs)					
Naphthalene	W-PAHGMS01	0.100	µg/L	<0.100	----
Acenaphthylene	W-PAHGMS01	0.010	µg/L	<0.010	----
Acenaphthene	W-PAHGMS01	0.010	µg/L	<0.010	----
Fluorene	W-PAHGMS01	0.020	µg/L	<0.020	----
Phenanthrene	W-PAHGMS01	0.030	µg/L	<0.030	----
Anthracene	W-PAHGMS01	0.020	µg/L	<0.020	----
Fluoranthene	W-PAHGMS01	0.030	µg/L	<0.030	----
Pyrene	W-PAHGMS01	0.060	µg/L	<0.060	----
Benz(a)anthracene	W-PAHGMS01	0.010	µg/L	<0.010	----
Chrysene	W-PAHGMS01	0.010	µg/L	<0.010	----
Benzo(b)fluoranthene	W-PAHGMS01	0.010	µg/L	<0.010	----
Benzo(k)fluoranthene	W-PAHGMS01	0.010	µg/L	<0.010	----
Benzo(a)pyrene	W-PAHGMS01	0.020	µg/L	<0.020	----
Indeno(1.2.3.cd)pyrene	W-PAHGMS01	0.010	µg/L	<0.010	----
Benzo(g.h.i)perylene	W-PAHGMS01	0.010	µg/L	<0.010	----
Dibenz(a.h)anthracene	W-PAHGMS01	0.010	µg/L	<0.010	----
Sum of 16 PAH	W-PAHGMS01	0.370	µg/L	<0.370	----
Sum of PAH (MoE)	W-PAHGMS01	0.19	µg/L	<0.19	----
Sum of 6 PAH (WHO)	W-PAHGMS01	0.090	µg/L	<0.090	----
Sum of 4 PAH	W-PAHGMS01	0.040	µg/L	<0.040	----
Organochlorine Pesticides					
Hexachloroethane	W-OCPECD01	0.010	µg/L	<0.010	----
Hexachlorobutadiene	W-OCPECD01	0.010	µg/L	<0.010	----
1.2.3.5- & 1.2.4.5-Tetrachlorobenzene	W-OCPECD01	0.020	µg/L	<0.020	----
1.2.3.4-Tetrachlorobenzene	W-OCPECD01	0.010	µg/L	<0.010	----
Pentachlorobenzene	W-OCPECD01	0.010	µg/L	<0.010	----
Trifluralin	W-OCPECD01	0.010	µg/L	<0.010	----
Hexachlorocyclohexane Alpha	W-OCPECD01	0.010	µg/L	<0.010	----
Hexachlorobenzene (HCB)	W-OCPECD01	0.0050	µg/L	<0.0050	----
Hexachlorocyclohexane Beta	W-OCPECD01	0.010	µg/L	<0.010	----
Hexachlorocyclohexane Gamma	W-OCPECD01	0.010	µg/L	<0.010	----
Hexachlorocyclohexane Delta	W-OCPECD01	0.010	µg/L	<0.010	----
Hexachlorocyclohexane Epsilon	W-OCPECD01	0.010	µg/L	<0.010	----
Alachlor	W-OCPECD01	0.010	µg/L	<0.010	----
Heptachlor	W-OCPECD01	0.010	µg/L	<0.010	----
Aldrin	W-OCPECD01	0.0050	µg/L	<0.0050	----
Telodrin	W-OCPECD01	0.010	µg/L	<0.010	----
Isodrin	W-OCPECD01	0.010	µg/L	<0.010	----
Heptachloroepoxide-cis	W-OCPECD01	0.010	µg/L	<0.010	----
Heptachloroepoxide-trans	W-OCPECD01	0.010	µg/L	<0.010	----
2.4-DDE	W-OCPECD01	0.010	µg/L	<0.010	----
alpha-Endosulfan	W-OCPECD01	0.010	µg/L	<0.010	----

4.4`-DDE	W-OCPECD01	0.010	µg/L	<0.010	----
Dieldrin	W-OCPECD01	0.010	µg/L	<0.010	----
2.4-DDD	W-OCPECD01	0.010	µg/L	<0.010	----
Endrin	W-OCPECD01	0.010	µg/L	<0.010	----
beta-Endosulfan	W-OCPECD01	0.010	µg/L	<0.010	----
4.4`-DDD	W-OCPECD01	0.010	µg/L	<0.010	----
2.4-DDT	W-OCPECD01	0.010	µg/L	<0.010	----
4.4`-DDT	W-OCPECD01	0.010	µg/L	<0.010	----
Methoxychlor	W-OCPECD01	0.010	µg/L	<0.010	----
Dichlobenil	W-OCPECD01	0.050	µg/L	<0.050	----
Sum of 3 tetrachlorobenzenes	W-OCPECD01	0.030	µg/L	<0.030	----
Sum of 4 hexachlorcyclohexanes	W-OCPECD01	0.040	µg/L	<0.040	----
Sum of 4 isomers DDT	W-OCPECD01	0.040	µg/L	<0.040	----
Sum of 6 isomers DDT	W-OCPECD01	0.060	µg/L	<0.060	----
Sum of endosulfanes	W-OCPECD01	0.020	µg/L	<0.020	----
Sum of 5 hexachlorocyclohexanes	W-OCPECD01	0.050	µg/L	<0.050	----
Sum of 27 OCPs + 3 CBs	W-OCPECD01	0.290	µg/L	<0.290	----
Sum of 29 OCPs + 3 CBs	W-OCPECD01	0.350	µg/L	<0.350	----

If no sampling time is provided, the sampling time will default 00:00 on the date of sampling. If no sampling date is provided, delivery date in brackets without a time component will be displayed instead. Measurement uncertainty is expressed as expanded measurement uncertainty with coverage factor k = 2, representing 95% confidence level.

Key: LOR = Limit of reporting; MU = Measurement Uncertainty. The MU does not include sampling uncertainty.

The end of result part of the certificate of analysis

Brief Method Summaries

Analytical Methods	*Method Descriptions*
Location of test performance: Na Harfe 336/9 Prague 9 - Vysocany Czech Republic 190 00	
W-OCPECD01	CZ_SOP_D06_03_169 (CSN EN ISO 6468, US EPA 8081, DIN 38407-3, samples prepared as per CZ_SOP_D06_03_P01 chap. 9.1, CZ_SOP_D06_03_P02 chap. 9.1) Determination of organochlorine pesticides and other halogen compounds 12) by gas chromatography method with ECD detection and calculation of organochlorine pesticides and other halogen compounds sums from measured values.
W-PAHGMS01	CZ_SOP_D06_03_161 (US EPA 8270D, US EPA 8082A, CSN EN ISO 6468, US EPA 8000D, samples preparation as per CZ_SOP_D06_03_P01 chap. 9.1). Determination of semi volatile organic compounds by gas chromatography method with MS or MS/MS detection and calculation of semi volatile organic compounds sums from measured values

A `*` symbol preceding any method indicates laboratory or subcontractor non-accredited test. In the case when a procedure belonging to an accredited method was used for non-accredited matrix, would apply that the reported results are non-accredited. Please refer to General Comment section on front page for information. If the report contains subcontracted analysis, those are made in a subcontracted laboratory outside the laboratories ALS Czech Republic, s.r.o.
The calculation methods of summation parameters are available on request in the client service.

ALS Controlvet

Data Emissão: 04-10-2019

N.º de Análise:	QH / 13860 / 19
Data Colheita:	-
Data Receção:	21-09-2019
Data Início Ensaio:	21-09-2019
Data Fim Ensaio:	04-10-2019
Código Cliente:	7401

Exmo(s) Sr(s):
Nemus – Gestão e Req.Ambiental, Lda.
EST. DO PAÇO DO LUMIAR CAMPUS DO LUMIAR ED. D
LISBOA
1649-038 LISBOA

Unidade: Nemus – Gestão e Requalificação Ambiental, Lda.

Identificação da Amostra: **159089 / 19**

Produto: Água Naturais
Referência: Amostra 14
Acondicionamento: frasco
Nº Entrega: 1527/2019
A colheita de amostra não foi efectuada pela Controlvet.

Ensaio	Método	Resultado	Unidade
(a) Parâmetros físico-químicos	Descrição em anexo	Resultado em anexo.	.

Método interno equivalente é aquele que tem a mesma área de aplicação (parâmetros e matrizes) e que cumpre as características de desempenho, obtendo resultados comparáveis ao(s) método(s) normalizado(s) junto indicado(s)

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Eugénia Silva

Técnica Superior de Laboratório
Eugénia Silva

Data Emissão: 04-10-2019

N.º de Análise:	QH / 13860 / 19
Data Colheita:	-
Data Receção:	21-09-2019
Data Início Ensaio:	21-09-2019
Data Fim Ensaio:	04-10-2019
Código Cliente:	7401

Exmo(s) Sr(s):
Nemus – Gestão e Req.Ambiental, Lda.
EST. DO PAÇO DO LUMIAR CAMPUS DO LUMIAR ED. D
LISBOA
1649-038 LISBOA

Unidade: Nemus – Gestão e Requalificação Ambiental, Lda.

Identificação da Amostra: **159089 / 19**

Produto: Água Naturais
Referência: Amostra 14
Acondicionamento: frasco
Nº Entrega: 1527/2019
A colheita de amostra não foi efectuada pela Controlvet.

Notas

Lista de abreviaturas: NE- Número estimado; UFC- Unidades formadoras de colónias; LQ – Limite de quantificação; LD – limite de detecção; V.L. – Valor Limite; V.R. – Valor Recomendado; VP - Valor Paramétrico; C - Conforme; A - Aceitável; NC - Não Conforme; Unid. - Unidade; DO - Densidade óptica.

O ensaio assinalado com (s) foi subcontratado e não é acreditado.
O ensaio assinalado com (a) foi subcontratado e é acreditado.
Nos resultados assinalados com (k) os microrganismos estão presentes, mas inferiores a 3xdiluição (quando aplicável).
Nos resultados assinalados com (y) os microrganismos estão presentes, mas inferiores a 4xdiluição.
Para os ensaios assinalados por tecnicas de cálculo a metodologia seguida pode ser disponibilizada a pedido.

Este Relatório de Ensaio refere-se apenas às amostras analisadas.
Proibida a reprodução parcial deste documento.

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Eugénia Silva

Técnica Superior de Laboratório
Eugénia Silva

CERTIFICATE OF ANALYSIS

Laboratory sample ID	: **PR1999997003**	**Work Order**	: **PR1999997**
		Issue Date	: 03-Oct-2019
Amendment	: **1**		
Customer	: **CONTROLVET - Seguranca Alimentar, S. A.**	Laboratory	: ALS Czech Republic, s.r.o.
Contact	: Subcontratacao Ensaios	Contact	: Client Service
Address	: Zona Industrial de Tondela ZIM II - Lote 6 3460-070 Tondela Portugal	Address	: Na Harfe 336/9 Prague 9 - Vysocany 190 00 Czech Republic
E-mail	: Subcontratacao.Ensaios@alsglobal.com	E-mail	: customer.support@alsglobal.com
Telephone	: ----	Telephone	: +420 226 226 228
Project	: ECF 2019E/155	Page	: 1 of 3
Order number	: ----	Date Samples Received	: 24-Sep-2019
		Quote number	: PR2015CONSE-PT0006 (PT-254-15-0938)
Site	: ----	Date of test	: 24-Sep-2019 - 03-Oct-2019
Sampled by	: client	QC Level	: ALS CR Standard Quality Control Schedule

General Comments

This report shall not be reproduced except in full, without prior written approval from the laboratory.
The laboratory declares that the test results relate only to the listed samples. If the section "Sampled by" of the Certificate of analysis states: "Sampled by Customer" then the results relate to the sample as received.
Amendmend No. 1: Change of COA format as per clients request. This Amendmend No. 1 supersedes test report No. PR1999997 dated 3.10.2019

Signatories

Testing Laboratory No. 1163
Accredited by CAI according to
CSN EN ISO/IEC 17025:2018

Signatories		*Position*
Zdeněk Jirák		Environmental Business Unit Manager

L 1163

Analytical Results

Sub-Matrix: **WATER**			*Laboratory sample ID*	**QH/13860/2019**	
			Client sampling date / time	[23-Sep-2019]	
Parameter	*Method*	*LOR*	*Unit*	**Result**	**MU**
Polycyclic Aromatics Hydrocarbons (PAHs)					
Naphthalene	W-PAHGMS01	0.100	µg/L	<0.100	----
Acenaphthylene	W-PAHGMS01	0.010	µg/L	<0.010	----
Acenaphthene	W-PAHGMS01	0.010	µg/L	<0.010	----
Fluorene	W-PAHGMS01	0.020	µg/L	<0.020	----
Phenanthrene	W-PAHGMS01	0.030	µg/L	<0.030	----
Anthracene	W-PAHGMS01	0.020	µg/L	<0.020	----
Fluoranthene	W-PAHGMS01	0.030	µg/L	<0.030	----
Pyrene	W-PAHGMS01	0.060	µg/L	<0.060	----
Benz(a)anthracene	W-PAHGMS01	0.010	µg/L	<0.010	----
Chrysene	W-PAHGMS01	0.010	µg/L	<0.010	----
Benzo(b)fluoranthene	W-PAHGMS01	0.010	µg/L	<0.010	----
Benzo(k)fluoranthene	W-PAHGMS01	0.010	µg/L	<0.010	----
Benzo(a)pyrene	W-PAHGMS01	0.020	µg/L	<0.020	----
Indeno(1.2.3.cd)pyrene	W-PAHGMS01	0.010	µg/L	<0.010	----
Benzo(g.h.i)perylene	W-PAHGMS01	0.010	µg/L	<0.010	----
Dibenz(a.h)anthracene	W-PAHGMS01	0.010	µg/L	<0.010	----
Sum of 16 PAH	W-PAHGMS01	0.370	µg/L	<0.370	----
Sum of PAH (MoE)	W-PAHGMS01	0.19	µg/L	<0.19	----
Sum of 6 PAH (WHO)	W-PAHGMS01	0.090	µg/L	<0.090	----
Sum of 4 PAH	W-PAHGMS01	0.040	µg/L	<0.040	----
Organochlorine Pesticides					
Hexachloroethane	W-OCPECD01	0.010	µg/L	<0.010	----
Hexachlorobutadiene	W-OCPECD01	0.010	µg/L	<0.010	----
1.2.3.5- & 1.2.4.5-Tetrachlorobenzene	W-OCPECD01	0.020	µg/L	<0.020	----
1.2.3.4-Tetrachlorobenzene	W-OCPECD01	0.010	µg/L	<0.010	----
Pentachlorobenzene	W-OCPECD01	0.010	µg/L	<0.010	----
Trifluralin	W-OCPECD01	0.010	µg/L	<0.010	----
Hexachlorocyclohexane Alpha	W-OCPECD01	0.010	µg/L	<0.010	----
Hexachlorobenzene (HCB)	W-OCPECD01	0.0050	µg/L	<0.0050	----
Hexachlorocyclohexane Beta	W-OCPECD01	0.010	µg/L	<0.010	----
Hexachlorocyclohexane Gamma	W-OCPECD01	0.010	µg/L	<0.010	----
Hexachlorocyclohexane Delta	W-OCPECD01	0.010	µg/L	<0.010	----
Hexachlorocyclohexane Epsilon	W-OCPECD01	0.010	µg/L	<0.010	----
Alachlor	W-OCPECD01	0.010	µg/L	<0.010	----
Heptachlor	W-OCPECD01	0.010	µg/L	<0.010	----
Aldrin	W-OCPECD01	0.0050	µg/L	<0.0050	----
Telodrin	W-OCPECD01	0.010	µg/L	<0.010	----
Isodrin	W-OCPECD01	0.010	µg/L	<0.010	----
Heptachloroepoxide-cis	W-OCPECD01	0.010	µg/L	<0.010	----
Heptachloroepoxide-trans	W-OCPECD01	0.010	µg/L	<0.010	----
2.4-DDE	W-OCPECD01	0.010	µg/L	<0.010	----
alpha-Endosulfan	W-OCPECD01	0.010	µg/L	<0.010	----

4.4`-DDE	W-OCPECD01	0.010	µg/L	<0.010	----
Dieldrin	W-OCPECD01	0.010	µg/L	<0.010	----
2.4-DDD	W-OCPECD01	0.010	µg/L	<0.010	----
Endrin	W-OCPECD01	0.010	µg/L	<0.010	----
beta-Endosulfan	W-OCPECD01	0.010	µg/L	<0.010	----
4.4`-DDD	W-OCPECD01	0.010	µg/L	<0.010	----
2.4-DDT	W-OCPECD01	0.010	µg/L	<0.010	----
4.4`-DDT	W-OCPECD01	0.010	µg/L	<0.010	----
Methoxychlor	W-OCPECD01	0.010	µg/L	<0.010	----
Dichlobenil	W-OCPECD01	0.050	µg/L	<0.050	----
Sum of 3 tetrachlorobenzenes	W-OCPECD01	0.030	µg/L	<0.030	----
Sum of 4 hexachlorcyclohexanes	W-OCPECD01	0.040	µg/L	<0.040	----
Sum of 4 isomers DDT	W-OCPECD01	0.040	µg/L	<0.040	----
Sum of 6 isomers DDT	W-OCPECD01	0.060	µg/L	<0.060	----
Sum of endosulfanes	W-OCPECD01	0.020	µg/L	<0.020	----
Sum of 5 hexachlorocyclohexanes	W-OCPECD01	0.050	µg/L	<0.050	----
Sum of 27 OCPs + 3 CBs	W-OCPECD01	0.290	µg/L	<0.290	----
Sum of 29 OCPs + 3 CBs	W-OCPECD01	0.350	µg/L	<0.350	----

If no sampling time is provided, the sampling time will default 00:00 on the date of sampling. If no sampling date is provided, delivery date in brackets without a time component will be displayed instead. Measurement uncertainty is expressed as expanded measurement uncertainty with coverage factor k = 2, representing 95% confidence level.

Key: LOR = Limit of reporting; MU = Measurement Uncertainty. The MU does not include sampling uncertainty.

The end of result part of the certificate of analysis

Brief Method Summaries

Analytical Methods	*Method Descriptions*
Location of test performance: Na Harfe 336/9 Prague 9 - Vysocany Czech Republic 190 00	
W-OCPECD01	CZ_SOP_D06_03_169 (CSN EN ISO 6468, US EPA 8081, DIN 38407-3, samples prepared as per CZ_SOP_D06_03_P01 chap. 9.1, CZ_SOP_D06_03_P02 chap. 9.1) Determination of organochlorine pesticides and other halogen compounds 12) by gas chromatography method with ECD detection and calculation of organochlorine pesticides and other halogen compounds sums from measured values.
W-PAHGMS01	CZ_SOP_D06_03_161 (US EPA 8270D, US EPA 8082A, CSN EN ISO 6468, US EPA 8000D, samples preparation as per CZ_SOP_D06_03_P01 chap. 9.1). Determination of semi volatile organic compounds by gas chromatography method with MS or MS/MS detection and calculation of semi volatile organic compounds sums from measured values

A `*` symbol preceding any method indicates laboratory or subcontractor non-accredited test. In the case when a procedure belonging to an accredited method was used for non-accredited matrix, would apply that the reported results are non-accredited. Please refer to General Comment section on front page for information. If the report contains subcontracted analysis, those are made in a subcontracted laboratory outside the laboratories ALS Czech Republic, s.r.o.
The calculation methods of summation parameters are available on request in the client service.

ALS Controlvet

Data Emissão: 04-10-2019

N.º de Análise:	QH / 13859 / 19
Data Colheita:	-
Data Receção:	21-09-2019
Data Início Ensaio:	21-09-2019
Data Fim Ensaio:	04-10-2019
Código Cliente:	7401

Exmo(s) Sr(s):
Nemus – Gestão e Req.Ambiental, Lda.
EST. DO PAÇO DO LUMIAR CAMPUS DO LUMIAR ED. D
LISBOA
1649-038 LISBOA

Unidade: Nemus – Gestão e Requalificação Ambiental, Lda.

Identificação da Amostra: **159086 / 19**

Produto: Água Naturais
Referência: Amostra 18
Acondicionamento: frasco
Nº Entrega: 1527/2019
A colheita de amostra não foi efectuada pela Controlvet.

Ensaio	Método	Resultado	Unidade
(a) Parâmetros físico-químicos	Descrição em anexo	Resultado em anexo.	.

Método interno equivalente é aquele que tem a mesma área de aplicação (parâmetros e matrizes) e que cumpre as características de desempenho, obtendo resultados comparáveis ao(s) método(s) normalizado(s) junto indicado(s)

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3460-070 Tondela
Telef.: 232817817
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Técnica Superior de Laboratório
Eugénia Silva

Data Emissão: 04-10-2019

N.º de Análise:	QH / 13859 / 19
Data Colheita:	-
Data Receção:	21-09-2019
Data Início Ensaio:	21-09-2019
Data Fim Ensaio:	04-10-2019
Código Cliente:	7401

Exmo(s) Sr(s):
Nemus – Gestão e Req.Ambiental, Lda.
EST. DO PAÇO DO LUMIAR CAMPUS DO LUMIAR ED. D
LISBOA
1649-038 LISBOA

Unidade: Nemus – Gestão e Requalificação Ambiental, Lda.

Identificação da Amostra: **159086 / 19**

Produto: Água Naturais
Referência: Amostra 18
Acondicionamento: frasco
Nº Entrega: 1527/2019
A colheita de amostra não foi efectuada pela Controlvet.

Notas

Lista de abreviaturas: NE- Número estimado; UFC- Unidades formadoras de colónias; LQ – Limite de quantificação; LD – limite de detecção; V.L. – Valor Limite; V.R. – Valor Recomendado; VP - Valor Paramétrico; C - Conforme; A - Aceitável; NC - Não Conforme; Unid. - Unidade; DO - Densidade óptica.

O ensaio assinalado com (s) foi subcontratado e não é acreditado.
O ensaio assinalado com (a) foi subcontratado e é acreditado.
Nos resultados assinalados com (k) os microrganismos estão presentes, mas inferiores a 3xdiluição (quando aplicável).
Nos resultados assinalados com (y) os microrganismos estão presentes, mas inferiores a 4xdiluição.
Para os ensaios assinalados por tecnicas de cálculo a metodologia seguida pode ser disponibilizada a pedido.

Este Relatório de Ensaio refere-se apenas às amostras analisadas.
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Eugénia Silva

Técnica Superior de Laboratório
Eugénia Silva

CERTIFICATE OF ANALYSIS

Laboratory sample ID	: **PR1999997002**	**Work Order**	: **PR1999997**
		Issue Date	: 03-Oct-2019
Amendment	: **1**		
Customer	: **CONTROLVET - Seguranca Alimentar, S. A.**	Laboratory	: ALS Czech Republic, s.r.o.
Contact	: Subcontratacao Ensaios	Contact	: Client Service
Address	: Zona Industrial de Tondela ZIM II - Lote 6 3460-070 Tondela Portugal	Address	: Na Harfe 336/9 Prague 9 - Vysocany 190 00 Czech Republic
E-mail	: Subcontratacao.Ensaios@alsglobal.com	E-mail	: customer.support@alsglobal.com
Telephone	: ----	Telephone	: +420 226 226 228
Project	: ECF 2019E/155	Page	: 1 of 3
Order number	: ----	Date Samples Received	: 24-Sep-2019
		Quote number	: PR2015CONSE-PT0006 (PT-254-15-0938)
Site	: ----	Date of test	: 24-Sep-2019 - 03-Oct-2019
Sampled by	: client	QC Level	: ALS CR Standard Quality Control Schedule

General Comments

This report shall not be reproduced except in full, without prior written approval from the laboratory.
The laboratory declares that the test results relate only to the listed samples. If the section "Sampled by" of the Certificate of analysis states: "Sampled by Customer" then the results relate to the sample as received.
Amendmend No. 1: Change of COA format as per clients request. This Amendmend No. 1 supersedes test report No. PR1999997 dated 3.10.2019

Signatories

Testing Laboratory No. 1163
Accredited by CAI according to
CSN EN ISO/IEC 17025:2018

Signatories		*Position*
Zdeněk Jirák		Environmental Business Unit Manager

L 1163

Analytical Results

Sub-Matrix: **WATER**			*Laboratory sample ID*	**QH/13859/2019**	
			Client sampling date / time	[23-Sep-2019]	
Parameter	*Method*	*LOR*	*Unit*	**Result**	**MU**
Polycyclic Aromatics Hydrocarbons (PAHs)					
Naphthalene	W-PAHGMS01	0.100	µg/L	<0.100	----
Acenaphthylene	W-PAHGMS01	0.010	µg/L	<0.010	----
Acenaphthene	W-PAHGMS01	0.010	µg/L	<0.010	----
Fluorene	W-PAHGMS01	0.020	µg/L	<0.020	----
Phenanthrene	W-PAHGMS01	0.030	µg/L	<0.030	----
Anthracene	W-PAHGMS01	0.020	µg/L	<0.020	----
Fluoranthene	W-PAHGMS01	0.030	µg/L	<0.030	----
Pyrene	W-PAHGMS01	0.060	µg/L	<0.060	----
Benz(a)anthracene	W-PAHGMS01	0.010	µg/L	<0.010	----
Chrysene	W-PAHGMS01	0.010	µg/L	<0.010	----
Benzo(b)fluoranthene	W-PAHGMS01	0.010	µg/L	<0.010	----
Benzo(k)fluoranthene	W-PAHGMS01	0.010	µg/L	<0.010	----
Benzo(a)pyrene	W-PAHGMS01	0.020	µg/L	<0.020	----
Indeno(1.2.3.cd)pyrene	W-PAHGMS01	0.010	µg/L	<0.010	----
Benzo(g.h.i)perylene	W-PAHGMS01	0.010	µg/L	<0.010	----
Dibenz(a.h)anthracene	W-PAHGMS01	0.010	µg/L	<0.010	----
Sum of 16 PAH	W-PAHGMS01	0.370	µg/L	<0.370	----
Sum of PAH (MoE)	W-PAHGMS01	0.19	µg/L	<0.19	----
Sum of 6 PAH (WHO)	W-PAHGMS01	0.090	µg/L	<0.090	----
Sum of 4 PAH	W-PAHGMS01	0.040	µg/L	<0.040	----
Organochlorine Pesticides					
Hexachloroethane	W-OCPECD01	0.010	µg/L	<0.010	----
Hexachlorobutadiene	W-OCPECD01	0.010	µg/L	<0.010	----
1.2.3.5- & 1.2.4.5-Tetrachlorobenzene	W-OCPECD01	0.020	µg/L	<0.020	----
1.2.3.4-Tetrachlorobenzene	W-OCPECD01	0.010	µg/L	<0.010	----
Pentachlorobenzene	W-OCPECD01	0.010	µg/L	<0.010	----
Trifluralin	W-OCPECD01	0.010	µg/L	<0.010	----
Hexachlorocyclohexane Alpha	W-OCPECD01	0.010	µg/L	<0.010	----
Hexachlorobenzene (HCB)	W-OCPECD01	0.0050	µg/L	<0.0050	----
Hexachlorocyclohexane Beta	W-OCPECD01	0.010	µg/L	<0.010	----
Hexachlorocyclohexane Gamma	W-OCPECD01	0.010	µg/L	<0.010	----
Hexachlorocyclohexane Delta	W-OCPECD01	0.010	µg/L	<0.010	----
Hexachlorocyclohexane Epsilon	W-OCPECD01	0.010	µg/L	<0.010	----
Alachlor	W-OCPECD01	0.010	µg/L	<0.010	----
Heptachlor	W-OCPECD01	0.010	µg/L	<0.010	----
Aldrin	W-OCPECD01	0.0050	µg/L	<0.0050	----
Telodrin	W-OCPECD01	0.010	µg/L	<0.010	----
Isodrin	W-OCPECD01	0.010	µg/L	<0.010	----
Heptachloroepoxide-cis	W-OCPECD01	0.010	µg/L	<0.010	----
Heptachloroepoxide-trans	W-OCPECD01	0.010	µg/L	<0.010	----
2.4-DDE	W-OCPECD01	0.010	µg/L	<0.010	----
alpha-Endosulfan	W-OCPECD01	0.010	µg/L	<0.010	----

4.4`-DDE	W-OCPECD01	0.010	µg/L	<0.010	----
Dieldrin	W-OCPECD01	0.010	µg/L	<0.010	----
2.4-DDD	W-OCPECD01	0.010	µg/L	<0.010	----
Endrin	W-OCPECD01	0.010	µg/L	<0.010	----
beta-Endosulfan	W-OCPECD01	0.010	µg/L	<0.010	----
4.4`-DDD	W-OCPECD01	0.010	µg/L	<0.010	----
2.4-DDT	W-OCPECD01	0.010	µg/L	<0.010	----
4.4`-DDT	W-OCPECD01	0.010	µg/L	<0.010	----
Methoxychlor	W-OCPECD01	0.010	µg/L	<0.010	----
Dichlobenil	W-OCPECD01	0.050	µg/L	<0.050	----
Sum of 3 tetrachlorobenzenes	W-OCPECD01	0.030	µg/L	<0.030	----
Sum of 4 hexachlorcyclohexanes	W-OCPECD01	0.040	µg/L	<0.040	----
Sum of 4 isomers DDT	W-OCPECD01	0.040	µg/L	<0.040	----
Sum of 6 isomers DDT	W-OCPECD01	0.060	µg/L	<0.060	----
Sum of endosulfanes	W-OCPECD01	0.020	µg/L	<0.020	----
Sum of 5 hexachlorocyclohexanes	W-OCPECD01	0.050	µg/L	<0.050	----
Sum of 27 OCPs + 3 CBs	W-OCPECD01	0.290	µg/L	<0.290	----
Sum of 29 OCPs + 3 CBs	W-OCPECD01	0.350	µg/L	<0.350	----

If no sampling time is provided, the sampling time will default 00:00 on the date of sampling. If no sampling date is provided, delivery date in brackets without a time component will be displayed instead. Measurement uncertainty is expressed as expanded measurement uncertainty with coverage factor k = 2, representing 95% confidence level.

Key: LOR = Limit of reporting; MU = Measurement Uncertainty. The MU does not include sampling uncertainty.

The end of result part of the certificate of analysis

Brief Method Summaries

Analytical Methods	*Method Descriptions*
Location of test performance: Na Harfe 336/9 Prague 9 - Vysocany Czech Republic 190 00	
W-OCPECD01	CZ_SOP_D06_03_169 (CSN EN ISO 6468, US EPA 8081, DIN 38407-3, samples prepared as per CZ_SOP_D06_03_P01 chap. 9.1, CZ_SOP_D06_03_P02 chap. 9.1) Determination of organochlorine pesticides and other halogen compounds 12) by gas chromatography method with ECD detection and calculation of organochlorine pesticides and other halogen compounds sums from measured values.
W-PAHGMS01	CZ_SOP_D06_03_161 (US EPA 8270D, US EPA 8082A, CSN EN ISO 6468, US EPA 8000D, samples preparation as per CZ_SOP_D06_03_P01 chap. 9.1). Determination of semi volatile organic compounds by gas chromatography method with MS or MS/MS detection and calculation of semi volatile organic compounds sums from measured values

A `*` symbol preceding any method indicates laboratory or subcontractor non-accredited test. In the case when a procedure belonging to an accredited method was used for non-accredited matrix, would apply that the reported results are non-accredited. Please refer to General Comment section on front page for information. If the report contains subcontracted analysis, those are made in a subcontracted laboratory outside the laboratories ALS Czech Republic, s.r.o.
The calculation methods of summation parameters are available on request in the client service.

ALS Controlvet

Data Emissão: 04-10-2019

N.º de Análise:	QH / 13868 / 19
Data Colheita:	-
Data Receção:	21-09-2019
Data Início Ensaio:	21-09-2019
Data Fim Ensaio:	04-10-2019
Código Cliente:	7401

Exmo(s) Sr(s):
Nemus – Gestão e Req.Ambiental, Lda.
EST. DO PAÇO DO LUMIAR CAMPUS DO LUMIAR ED. D
LISBOA
1649-038 LISBOA

Unidade: Nemus – Gestão e Requalificação Ambiental, Lda.

Identificação da Amostra: **159098 / 19**

Produto: Água Naturais
Referência: Amostra 21
Acondicionamento: frasco
Nº Entrega: 1527/2019
A colheita de amostra não foi efectuada pela Controlvet.

Ensaio	Método	Resultado	Unidade
(a) Parâmetros físico-químicos	Descrição em anexo	Resultado em anexo.	.

Método interno equivalente é aquele que tem a mesma área de aplicação (parâmetros e matrizes) e que cumpre as características de desempenho, obtendo resultados comparáveis ao(s) método(s) normalizado(s) junto indicado(s)

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Data Emissão: 04-10-2019

N.º de Análise:	QH / 13868 / 19
Data Colheita:	-
Data Receção:	21-09-2019
Data Início Ensaio:	21-09-2019
Data Fim Ensaio:	04-10-2019
Código Cliente:	7401

Exmo(s) Sr(s):
Nemus – Gestão e Req.Ambiental, Lda.
EST. DO PAÇO DO LUMIAR CAMPUS DO LUMIAR ED. D
LISBOA
1649-038 LISBOA

Unidade: Nemus – Gestão e Requalificação Ambiental, Lda.

Identificação da Amostra: **159098 / 19**

Produto: Água Naturais
Referência: Amostra 21
Acondicionamento: frasco
Nº Entrega: 1527/2019
A colheita de amostra não foi efectuada pela Controlvet.

Notas

Lista de abreviaturas: NE- Número estimado; UFC- Unidades formadoras de colónias; LQ – Limite de quantificação; LD – limite de detecção; V.L. – Valor Limite; V.R. – Valor Recomendado; VP - Valor Paramétrico; C - Conforme; A - Aceitável; NC - Não Conforme; Unid. - Unidade; DO - Densidade óptica.

O ensaio assinalado com (s) foi subcontratado e não é acreditado.
O ensaio assinalado com (a) foi subcontratado e é acreditado.
Nos resultados assinalados com (k) os microrganismos estão presentes, mas inferiores a 3xdiluição (quando aplicável).
Nos resultados assinalados com (y) os microrganismos estão presentes, mas inferiores a 4xdiluição.
Para os ensaios assinalados por tecnicas de cálculo a metodologia seguida pode ser disponibilizada a pedido.

Este Relatório de Ensaio refere-se apenas às amostras analisadas.
Proibida a reprodução parcial deste documento.

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Eugénia Silva

Técnica Superior de Laboratório
Eugénia Silva

CERTIFICATE OF ANALYSIS

Laboratory sample ID	: **PR1999997011**	**Work Order**	: **PR1999997**
		Issue Date	: 03-Oct-2019
Amendment	: **1**		
Customer	: **CONTROLVET - Seguranca Alimentar, S. A.**	Laboratory	: ALS Czech Republic, s.r.o.
Contact	: Subcontratacao Ensaios	Contact	: Client Service
Address	: Zona Industrial de Tondela ZIM II - Lote 6 3460-070 Tondela Portugal	Address	: Na Harfe 336/9 Prague 9 - Vysocany 190 00 Czech Republic
E-mail	: Subcontratacao.Ensaios@alsglobal.com	E-mail	: customer.support@alsglobal.com
Telephone	: ----	Telephone	: +420 226 226 228
Project	: ECF 2019E/155	Page	: 1 of 3
Order number	: ----	Date Samples Received	: 24-Sep-2019
		Quote number	: PR2015CONSE-PT0006 (PT-254-15-0938)
Site	: ----	Date of test	: 24-Sep-2019 - 03-Oct-2019
Sampled by	: client	QC Level	: ALS CR Standard Quality Control Schedule

General Comments

This report shall not be reproduced except in full, without prior written approval from the laboratory.
The laboratory declares that the test results relate only to the listed samples. If the section "Sampled by" of the Certificate of analysis states: "Sampled by Customer" then the results relate to the sample as received.
Amendmend No. 1: Change of COA format as per clients request. This Amendmend No. 1 supersedes test report No. PR1999997 dated 3.10.2019

Signatories

Testing Laboratory No. 1163
Accredited by CAI according to
CSN EN ISO/IEC 17025:2018

Signatories		*Position*
Zdeněk Jirák		Environmental Business Unit Manager

L 1163

Analytical Results

Sub-Matrix: **WATER**			*Laboratory sample ID*	**QH/13868/2019**	
			Client sampling date / time	[23-Sep-2019]	
Parameter	*Method*	*LOR*	*Unit*	**Result**	**MU**
Polycyclic Aromatics Hydrocarbons (PAHs)					
Naphthalene	W-PAHGMS01	0.100	µg/L	<0.100	----
Acenaphthylene	W-PAHGMS01	0.010	µg/L	<0.010	----
Acenaphthene	W-PAHGMS01	0.010	µg/L	<0.010	----
Fluorene	W-PAHGMS01	0.020	µg/L	<0.020	----
Phenanthrene	W-PAHGMS01	0.030	µg/L	<0.030	----
Anthracene	W-PAHGMS01	0.020	µg/L	<0.020	----
Fluoranthene	W-PAHGMS01	0.030	µg/L	<0.030	----
Pyrene	W-PAHGMS01	0.060	µg/L	<0.060	----
Benz(a)anthracene	W-PAHGMS01	0.010	µg/L	<0.010	----
Chrysene	W-PAHGMS01	0.010	µg/L	<0.010	----
Benzo(b)fluoranthene	W-PAHGMS01	0.010	µg/L	<0.010	----
Benzo(k)fluoranthene	W-PAHGMS01	0.010	µg/L	<0.010	----
Benzo(a)pyrene	W-PAHGMS01	0.020	µg/L	<0.020	----
Indeno(1.2.3.cd)pyrene	W-PAHGMS01	0.010	µg/L	<0.010	----
Benzo(g.h.i)perylene	W-PAHGMS01	0.010	µg/L	<0.010	----
Dibenz(a.h)anthracene	W-PAHGMS01	0.010	µg/L	<0.010	----
Sum of 16 PAH	W-PAHGMS01	0.370	µg/L	<0.370	----
Sum of PAH (MoE)	W-PAHGMS01	0.19	µg/L	<0.19	----
Sum of 6 PAH (WHO)	W-PAHGMS01	0.090	µg/L	<0.090	----
Sum of 4 PAH	W-PAHGMS01	0.040	µg/L	<0.040	----
Organochlorine Pesticides					
Hexachloroethane	W-OCPECD01	0.010	µg/L	<0.010	----
Hexachlorobutadiene	W-OCPECD01	0.010	µg/L	<0.010	----
1.2.3.5- & 1.2.4.5-Tetrachlorobenzene	W-OCPECD01	0.020	µg/L	<0.020	----
1.2.3.4-Tetrachlorobenzene	W-OCPECD01	0.010	µg/L	<0.010	----
Pentachlorobenzene	W-OCPECD01	0.010	µg/L	<0.010	----
Trifluralin	W-OCPECD01	0.010	µg/L	<0.010	----
Hexachlorocyclohexane Alpha	W-OCPECD01	0.010	µg/L	<0.010	----
Hexachlorobenzene (HCB)	W-OCPECD01	0.0050	µg/L	<0.0050	----
Hexachlorocyclohexane Beta	W-OCPECD01	0.010	µg/L	<0.010	----
Hexachlorocyclohexane Gamma	W-OCPECD01	0.010	µg/L	<0.010	----
Hexachlorocyclohexane Delta	W-OCPECD01	0.010	µg/L	<0.010	----
Hexachlorocyclohexane Epsilon	W-OCPECD01	0.010	µg/L	<0.010	----
Alachlor	W-OCPECD01	0.010	µg/L	<0.010	----
Heptachlor	W-OCPECD01	0.010	µg/L	<0.010	----
Aldrin	W-OCPECD01	0.0050	µg/L	<0.0050	----
Telodrin	W-OCPECD01	0.010	µg/L	<0.010	----
Isodrin	W-OCPECD01	0.010	µg/L	<0.010	----
Heptachloroepoxide-cis	W-OCPECD01	0.010	µg/L	<0.010	----
Heptachloroepoxide-trans	W-OCPECD01	0.010	µg/L	<0.010	----
2.4-DDE	W-OCPECD01	0.010	µg/L	<0.010	----
alpha-Endosulfan	W-OCPECD01	0.010	µg/L	<0.010	----

4.4`-DDE	W-OCPECD01	0.010	µg/L	<0.010	----
Dieldrin	W-OCPECD01	0.010	µg/L	<0.010	----
2.4-DDD	W-OCPECD01	0.010	µg/L	<0.010	----
Endrin	W-OCPECD01	0.010	µg/L	<0.010	----
beta-Endosulfan	W-OCPECD01	0.010	µg/L	<0.010	----
4.4`-DDD	W-OCPECD01	0.010	µg/L	<0.010	----
2.4-DDT	W-OCPECD01	0.010	µg/L	<0.010	----
4.4`-DDT	W-OCPECD01	0.010	µg/L	<0.010	----
Methoxychlor	W-OCPECD01	0.010	µg/L	<0.010	----
Dichlobenil	W-OCPECD01	0.050	µg/L	<0.050	----
Sum of 3 tetrachlorobenzenes	W-OCPECD01	0.030	µg/L	<0.030	----
Sum of 4 hexachlorcyclohexanes	W-OCPECD01	0.040	µg/L	<0.040	----
Sum of 4 isomers DDT	W-OCPECD01	0.040	µg/L	<0.040	----
Sum of 6 isomers DDT	W-OCPECD01	0.060	µg/L	<0.060	----
Sum of endosulfanes	W-OCPECD01	0.020	µg/L	<0.020	----
Sum of 5 hexachlorocyclohexanes	W-OCPECD01	0.050	µg/L	<0.050	----
Sum of 27 OCPs + 3 CBs	W-OCPECD01	0.290	µg/L	<0.290	----
Sum of 29 OCPs + 3 CBs	W-OCPECD01	0.350	µg/L	<0.350	----

If no sampling time is provided, the sampling time will default 00:00 on the date of sampling. If no sampling date is provided, delivery date in brackets without a time component will be displayed instead. Measurement uncertainty is expressed as expanded measurement uncertainty with coverage factor k = 2, representing 95% confidence level.

Key: LOR = Limit of reporting; MU = Measurement Uncertainty. The MU does not include sampling uncertainty.

The end of result part of the certificate of analysis

Brief Method Summaries

Analytical Methods	*Method Descriptions*
Location of test performance: Na Harfe 336/9 Prague 9 - Vysocany Czech Republic 190 00	
W-OCPECD01	CZ_SOP_D06_03_169 (CSN EN ISO 6468, US EPA 8081, DIN 38407-3, samples prepared as per CZ_SOP_D06_03_P01 chap. 9.1, CZ_SOP_D06_03_P02 chap. 9.1) Determination of organochlorine pesticides and other halogen compounds 12) by gas chromatography method with ECD detection and calculation of organochlorine pesticides and other halogen compounds sums from measured values.
W-PAHGMS01	CZ_SOP_D06_03_161 (US EPA 8270D, US EPA 8082A, CSN EN ISO 6468, US EPA 8000D, samples preparation as per CZ_SOP_D06_03_P01 chap. 9.1). Determination of semi volatile organic compounds by gas chromatography method with MS or MS/MS detection and calculation of semi volatile organic compounds sums from measured values

A `*` symbol preceding any method indicates laboratory or subcontractor non-accredited test. In the case when a procedure belonging to an accredited method was used for non-accredited matrix, would apply that the reported results are non-accredited. Please refer to General Comment section on front page for information. If the report contains subcontracted analysis, those are made in a subcontracted laboratory outside the laboratories ALS Czech Republic, s.r.o.
The calculation methods of summation parameters are available on request in the client service.

ALS Controlvet

Data Emissão: 04-10-2019

N.º de Análise:	QH / 13867 / 19
Data Colheita:	-
Data Receção:	21-09-2019
Data Início Ensaio:	21-09-2019
Data Fim Ensaio:	04-10-2019
Código Cliente:	7401

Exmo(s) Sr(s):
Nemus – Gestão e Req.Ambiental, Lda.
EST. DO PAÇO DO LUMIAR CAMPUS DO LUMIAR ED. D
LISBOA
1649-038 LISBOA

Unidade: Nemus – Gestão e Requalificação Ambiental, Lda.

Identificação da Amostra: **159097 / 19**

Produto: Água Naturais
Referência: Amostra 23
Acondicionamento: frasco
Nº Entrega: 1527/2019
A colheita de amostra não foi efectuada pela Controlvet.

Ensaio	Método	Resultado	Unidade
(a) Parâmetros físico-químicos	Descrição em anexo	Resultado em anexo.	.

Método interno equivalente é aquele que tem a mesma área de aplicação (parâmetros e matrizes) e que cumpre as características de desempenho, obtendo resultados comparáveis ao(s) método(s) normalizado(s) junto indicado(s)

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Técnica Superior de Laboratório
Eugénia Silva

Data Emissão: 04-10-2019

N.º de Análise:	QH / 13867 / 19
Data Colheita:	-
Data Receção:	21-09-2019
Data Início Ensaio:	21-09-2019
Data Fim Ensaio:	04-10-2019
Código Cliente:	7401

Exmo(s) Sr(s):
Nemus – Gestão e Req.Ambiental, Lda.
EST. DO PAÇO DO LUMIAR CAMPUS DO LUMIAR ED. D
LISBOA
1649-038 LISBOA

Unidade: Nemus – Gestão e Requalificação Ambiental, Lda.

Identificação da Amostra: **159097 / 19**

Produto: Água Naturais
Referência: Amostra 23
Acondicionamento: frasco
Nº Entrega: 1527/2019
A colheita de amostra não foi efectuada pela Controlvet.

Notas

Lista de abreviaturas: NE- Número estimado; UFC- Unidades formadoras de colónias; LQ – Limite de quantificação; LD – limite de detecção; V.L. – Valor Limite; V.R. – Valor Recomendado; VP - Valor Paramétrico; C - Conforme; A - Aceitável; NC - Não Conforme; Unid. - Unidade; DO - Densidade óptica.

O ensaio assinalado com (s) foi subcontratado e não é acreditado.
O ensaio assinalado com (a) foi subcontratado e é acreditado.
Nos resultados assinalados com (k) os microrganismos estão presentes, mas inferiores a 3xdiluição (quando aplicável).
Nos resultados assinalados com (y) os microrganismos estão presentes, mas inferiores a 4xdiluição.
Para os ensaios assinalados por tecnicas de cálculo a metodologia seguida pode ser disponibilizada a pedido.

Este Relatório de Ensaio refere-se apenas às amostras analisadas.
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Eugénia Silva

Técnica Superior de Laboratório
Eugénia Silva

CERTIFICATE OF ANALYSIS

Laboratory sample ID	: **PR1999997010**	**Work Order**	: **PR1999997**
		Issue Date	: 03-Oct-2019
Amendment	: **1**		
Customer	: **CONTROLVET - Seguranca Alimentar, S. A.**	Laboratory	: ALS Czech Republic, s.r.o.
Contact	: Subcontratacao Ensaios	Contact	: Client Service
Address	: Zona Industrial de Tondela ZIM II - Lote 6 3460-070 Tondela Portugal	Address	: Na Harfe 336/9 Prague 9 - Vysocany 190 00 Czech Republic
E-mail	: Subcontratacao.Ensaios@alsglobal.com	E-mail	: customer.support@alsglobal.com
Telephone	: ----	Telephone	: +420 226 226 228
Project	: ECF 2019E/155	Page	: 1 of 3
Order number	: ----	Date Samples Received	: 24-Sep-2019
		Quote number	: PR2015CONSE-PT0006 (PT-254-15-0938)
Site	: ----	Date of test	: 24-Sep-2019 - 03-Oct-2019
Sampled by	: client	QC Level	: ALS CR Standard Quality Control Schedule

General Comments

This report shall not be reproduced except in full, without prior written approval from the laboratory.
The laboratory declares that the test results relate only to the listed samples. If the section "Sampled by" of the Certificate of analysis states: "Sampled by Customer" then the results relate to the sample as received.
Amendmend No. 1: Change of COA format as per clients request. This Amendmend No. 1 supersedes test report No. PR1999997 dated 3.10.2019

Signatories

Testing Laboratory No. 1163
Accredited by CAI according to
CSN EN ISO/IEC 17025:2018

Signatories		*Position*
Zdeněk Jirák		Environmental Business Unit Manager

L 1163

Analytical Results

Sub-Matrix: **WATER**

Parameter	Method	LOR	Unit	Laboratory sample ID: QH/13867/2019 Client sampling date / time: [23-Sep-2019] Result	MU
Polycyclic Aromatics Hydrocarbons (PAHs)					
Naphthalene	W-PAHGMS01	0.100	µg/L	<0.100	----
Acenaphthylene	W-PAHGMS01	0.010	µg/L	<0.010	----
Acenaphthene	W-PAHGMS01	0.010	µg/L	<0.010	----
Fluorene	W-PAHGMS01	0.020	µg/L	<0.020	----
Phenanthrene	W-PAHGMS01	0.030	µg/L	<0.030	----
Anthracene	W-PAHGMS01	0.020	µg/L	<0.020	----
Fluoranthene	W-PAHGMS01	0.030	µg/L	<0.030	----
Pyrene	W-PAHGMS01	0.060	µg/L	<0.060	----
Benz(a)anthracene	W-PAHGMS01	0.010	µg/L	<0.010	----
Chrysene	W-PAHGMS01	0.010	µg/L	<0.010	----
Benzo(b)fluoranthene	W-PAHGMS01	0.010	µg/L	<0.010	----
Benzo(k)fluoranthene	W-PAHGMS01	0.010	µg/L	<0.010	----
Benzo(a)pyrene	W-PAHGMS01	0.020	µg/L	<0.020	----
Indeno(1.2.3.cd)pyrene	W-PAHGMS01	0.010	µg/L	<0.010	----
Benzo(g.h.i)perylene	W-PAHGMS01	0.010	µg/L	<0.010	----
Dibenz(a.h)anthracene	W-PAHGMS01	0.010	µg/L	<0.010	----
Sum of 16 PAH	W-PAHGMS01	0.370	µg/L	<0.370	----
Sum of PAH (MoE)	W-PAHGMS01	0.19	µg/L	<0.19	----
Sum of 6 PAH (WHO)	W-PAHGMS01	0.090	µg/L	<0.090	----
Sum of 4 PAH	W-PAHGMS01	0.040	µg/L	<0.040	----
Organochlorine Pesticides					
Hexachloroethane	W-OCPECD01	0.010	µg/L	<0.010	----
Hexachlorobutadiene	W-OCPECD01	0.010	µg/L	<0.010	----
1.2.3.5- & 1.2.4.5-Tetrachlorobenzene	W-OCPECD01	0.020	µg/L	<0.020	----
1.2.3.4-Tetrachlorobenzene	W-OCPECD01	0.010	µg/L	<0.010	----
Pentachlorobenzene	W-OCPECD01	0.010	µg/L	<0.010	----
Trifluralin	W-OCPECD01	0.010	µg/L	<0.010	----
Hexachlorocyclohexane Alpha	W-OCPECD01	0.010	µg/L	<0.010	----
Hexachlorobenzene (HCB)	W-OCPECD01	0.0050	µg/L	<0.0050	----
Hexachlorocyclohexane Beta	W-OCPECD01	0.010	µg/L	<0.010	----
Hexachlorocyclohexane Gamma	W-OCPECD01	0.010	µg/L	<0.010	----
Hexachlorocyclohexane Delta	W-OCPECD01	0.010	µg/L	<0.010	----
Hexachlorocyclohexane Epsilon	W-OCPECD01	0.010	µg/L	<0.010	----
Alachlor	W-OCPECD01	0.010	µg/L	<0.010	----
Heptachlor	W-OCPECD01	0.010	µg/L	<0.010	----
Aldrin	W-OCPECD01	0.0050	µg/L	<0.0050	----
Telodrin	W-OCPECD01	0.010	µg/L	<0.010	----
Isodrin	W-OCPECD01	0.010	µg/L	<0.010	----
Heptachloroepoxide-cis	W-OCPECD01	0.010	µg/L	<0.010	----
Heptachloroepoxide-trans	W-OCPECD01	0.010	µg/L	<0.010	----
2.4-DDE	W-OCPECD01	0.010	µg/L	<0.010	----
alpha-Endosulfan	W-OCPECD01	0.010	µg/L	<0.010	----

4.4`-DDE	W-OCPECD01	0.010	µg/L	<0.010	----
Dieldrin	W-OCPECD01	0.010	µg/L	<0.010	----
2.4-DDD	W-OCPECD01	0.010	µg/L	<0.010	----
Endrin	W-OCPECD01	0.010	µg/L	<0.010	----
beta-Endosulfan	W-OCPECD01	0.010	µg/L	<0.010	----
4.4`-DDD	W-OCPECD01	0.010	µg/L	<0.010	----
2.4-DDT	W-OCPECD01	0.010	µg/L	<0.010	----
4.4`-DDT	W-OCPECD01	0.010	µg/L	<0.010	----
Methoxychlor	W-OCPECD01	0.010	µg/L	<0.010	----
Dichlobenil	W-OCPECD01	0.050	µg/L	<0.050	----
Sum of 3 tetrachlorobenzenes	W-OCPECD01	0.030	µg/L	<0.030	----
Sum of 4 hexachlorcyclohexanes	W-OCPECD01	0.040	µg/L	<0.040	----
Sum of 4 isomers DDT	W-OCPECD01	0.040	µg/L	<0.040	----
Sum of 6 isomers DDT	W-OCPECD01	0.060	µg/L	<0.060	----
Sum of endosulfanes	W-OCPECD01	0.020	µg/L	<0.020	----
Sum of 5 hexachlorocyclohexanes	W-OCPECD01	0.050	µg/L	<0.050	----
Sum of 27 OCPs + 3 CBs	W-OCPECD01	0.290	µg/L	<0.290	----
Sum of 29 OCPs + 3 CBs	W-OCPECD01	0.350	µg/L	<0.350	----

If no sampling time is provided, the sampling time will default 00:00 on the date of sampling. If no sampling date is provided, delivery date in brackets without a time component will be displayed instead. Measurement uncertainty is expressed as expanded measurement uncertainty with coverage factor k = 2, representing 95% confidence level.

Key: LOR = Limit of reporting; MU = Measurement Uncertainty. The MU does not include sampling uncertainty.

The end of result part of the certificate of analysis

Brief Method Summaries

Analytical Methods	*Method Descriptions*
Location of test performance: Na Harfe 336/9 Prague 9 - Vysocany Czech Republic 190 00	
W-OCPECD01	CZ_SOP_D06_03_169 (CSN EN ISO 6468, US EPA 8081, DIN 38407-3, samples prepared as per CZ_SOP_D06_03_P01 chap. 9.1, CZ_SOP_D06_03_P02 chap. 9.1) Determination of organochlorine pesticides and other halogen compounds 12) by gas chromatography method with ECD detection and calculation of organochlorine pesticides and other halogen compounds sums from measured values.
W-PAHGMS01	CZ_SOP_D06_03_161 (US EPA 8270D, US EPA 8082A, CSN EN ISO 6468, US EPA 8000D, samples preparation as per CZ_SOP_D06_03_P01 chap. 9.1). Determination of semi volatile organic compounds by gas chromatography method with MS or MS/MS detection and calculation of semi volatile organic compounds sums from measured values

A `*` symbol preceding any method indicates laboratory or subcontractor non-accredited test. In the case when a procedure belonging to an accredited method was used for non-accredited matrix, would apply that the reported results are non-accredited. Please refer to General Comment section on front page for information. If the report contains subcontracted analysis, those are made in a subcontracted laboratory outside the laboratories ALS Czech Republic, s.r.o.
The calculation methods of summation parameters are available on request in the client service.

ALS Controlvet

Data Emissão: 04-10-2019

N.º de Análise:	QH / 13861 / 19
Data Colheita:	-
Data Receção:	21-09-2019
Data Início Ensaio:	21-09-2019
Data Fim Ensaio:	04-10-2019
Código Cliente:	7401

Exmo(s) Sr(s):
Nemus – Gestão e Req.Ambiental, Lda.
EST. DO PAÇO DO LUMIAR CAMPUS DO LUMIAR ED. D
LISBOA
1649-038 LISBOA

Unidade: Nemus – Gestão e Requalificação Ambiental, Lda.

Identificação da Amostra: **159091 / 19**

Produto: Água Naturais
Referência: Amostra 24
Acondicionamento: frasco
Nº Entrega: 1527/2019
A colheita de amostra não foi efectuada pela Controlvet.

Ensaio	Método	Resultado	Unidade
(a) Parâmetros físico-químicos	Descrição em anexo	Resultado em anexo.	.

Método interno equivalente é aquele que tem a mesma área de aplicação (parâmetros e matrizes) e que cumpre as características de desempenho, obtendo resultados comparáveis ao(s) método(s) normalizado(s) junto indicado(s)

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Eugénia Silva

Técnica Superior de Laboratório
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Data Emissão: 04-10-2019

N.º de Análise:	QH / 13861 / 19
Data Colheita:	-
Data Receção:	21-09-2019
Data Início Ensaio:	21-09-2019
Data Fim Ensaio:	04-10-2019
Código Cliente:	7401

Exmo(s) Sr(s):
Nemus – Gestão e Req.Ambiental, Lda.
EST. DO PAÇO DO LUMIAR CAMPUS DO LUMIAR ED. D
LISBOA
1649-038 LISBOA

Unidade: Nemus – Gestão e Requalificação Ambiental, Lda.

Identificação da Amostra: **159091 / 19**

Produto: Água Naturais
Referência: Amostra 24
Acondicionamento: frasco
Nº Entrega: 1527/2019
A colheita de amostra não foi efectuada pela Controlvet.

Notas

Lista de abreviaturas: NE- Número estimado; UFC- Unidades formadoras de colónias; LQ – Limite de quantificação; LD – limite de detecção; V.L. – Valor Limite; V.R. – Valor Recomendado; VP - Valor Paramétrico; C - Conforme; A - Aceitável; NC - Não Conforme; Unid. - Unidade; DO - Densidade óptica.

O ensaio assinalado com (s) foi subcontratado e não é acreditado.
O ensaio assinalado com (a) foi subcontratado e é acreditado.
Nos resultados assinalados com (k) os microrganismos estão presentes, mas inferiores a 3xdiluição (quando aplicável).
Nos resultados assinalados com (y) os microrganismos estão presentes, mas inferiores a 4xdiluição.
Para os ensaios assinalados por tecnicas de cálculo a metodologia seguida pode ser disponibilizada a pedido.

Este Relatório de Ensaio refere-se apenas às amostras analisadas.
Proibida a reprodução parcial deste documento.

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Eugénia Silva

Técnica Superior de Laboratório
Eugénia Silva

CERTIFICATE OF ANALYSIS

Laboratory sample ID	: **PR1999997004**	**Work Order**	: **PR1999997**
		Issue Date	: 03-Oct-2019
Amendment	: **1**		
Customer	: **CONTROLVET - Seguranca Alimentar, S. A.**	Laboratory	: ALS Czech Republic, s.r.o.
Contact	: Subcontratacao Ensaios	Contact	: Client Service
Address	: Zona Industrial de Tondela ZIM II - Lote 6 3460-070 Tondela Portugal	Address	: Na Harfe 336/9 Prague 9 - Vysocany 190 00 Czech Republic
E-mail	: Subcontratacao.Ensaios@alsglobal.com	E-mail	: customer.support@alsglobal.com
Telephone	: ----	Telephone	: +420 226 226 228
Project	: ECF 2019E/155	Page	: 1 of 3
Order number	: ----	Date Samples Received	: 24-Sep-2019
		Quote number	: PR2015CONSE-PT0006 (PT-254-15-0938)
Site	: ----	Date of test	: 24-Sep-2019 - 03-Oct-2019
Sampled by	: client	QC Level	: ALS CR Standard Quality Control Schedule

General Comments

This report shall not be reproduced except in full, without prior written approval from the laboratory.
The laboratory declares that the test results relate only to the listed samples. If the section "Sampled by" of the Certificate of analysis states: "Sampled by Customer" then the results relate to the sample as received.
Amendmend No. 1: Change of COA format as per clients request. This Amendmend No. 1 supersedes test report No. PR1999997 dated 3.10.2019

Signatories

Testing Laboratory No. 1163
Accredited by CAI according to
CSN EN ISO/IEC 17025:2018

Signatories		*Position*
Zdeněk Jirák		Environmental Business Unit Manager

L 1163

Analytical Results

Sub-Matrix: **WATER**			*Laboratory sample ID*	**QH/13861/2019**	
			Client sampling date / time	[23-Sep-2019]	
Parameter	*Method*	*LOR*	*Unit*	**Result**	**MU**
Polycyclic Aromatics Hydrocarbons (PAHs)					
Naphthalene	W-PAHGMS01	0.100	µg/L	<0.100	----
Acenaphthylene	W-PAHGMS01	0.010	µg/L	<0.010	----
Acenaphthene	W-PAHGMS01	0.010	µg/L	<0.010	----
Fluorene	W-PAHGMS01	0.020	µg/L	<0.020	----
Phenanthrene	W-PAHGMS01	0.030	µg/L	<0.030	----
Anthracene	W-PAHGMS01	0.020	µg/L	<0.020	----
Fluoranthene	W-PAHGMS01	0.030	µg/L	<0.030	----
Pyrene	W-PAHGMS01	0.060	µg/L	<0.060	----
Benz(a)anthracene	W-PAHGMS01	0.010	µg/L	<0.010	----
Chrysene	W-PAHGMS01	0.010	µg/L	<0.010	----
Benzo(b)fluoranthene	W-PAHGMS01	0.010	µg/L	<0.010	----
Benzo(k)fluoranthene	W-PAHGMS01	0.010	µg/L	<0.010	----
Benzo(a)pyrene	W-PAHGMS01	0.020	µg/L	<0.020	----
Indeno(1.2.3.cd)pyrene	W-PAHGMS01	0.010	µg/L	<0.010	----
Benzo(g.h.i)perylene	W-PAHGMS01	0.010	µg/L	<0.010	----
Dibenz(a.h)anthracene	W-PAHGMS01	0.010	µg/L	<0.010	----
Sum of 16 PAH	W-PAHGMS01	0.370	µg/L	<0.370	----
Sum of PAH (MoE)	W-PAHGMS01	0.19	µg/L	<0.19	----
Sum of 6 PAH (WHO)	W-PAHGMS01	0.090	µg/L	<0.090	----
Sum of 4 PAH	W-PAHGMS01	0.040	µg/L	<0.040	----
Organochlorine Pesticides					
Hexachloroethane	W-OCPECD01	0.010	µg/L	<0.010	----
Hexachlorobutadiene	W-OCPECD01	0.010	µg/L	<0.010	----
1.2.3.5- & 1.2.4.5-Tetrachlorobenzene	W-OCPECD01	0.020	µg/L	<0.020	----
1.2.3.4-Tetrachlorobenzene	W-OCPECD01	0.010	µg/L	<0.010	----
Pentachlorobenzene	W-OCPECD01	0.010	µg/L	<0.010	----
Trifluralin	W-OCPECD01	0.010	µg/L	<0.010	----
Hexachlorocyclohexane Alpha	W-OCPECD01	0.010	µg/L	<0.010	----
Hexachlorobenzene (HCB)	W-OCPECD01	0.0050	µg/L	<0.0050	----
Hexachlorocyclohexane Beta	W-OCPECD01	0.010	µg/L	<0.010	----
Hexachlorocyclohexane Gamma	W-OCPECD01	0.010	µg/L	<0.010	----
Hexachlorocyclohexane Delta	W-OCPECD01	0.010	µg/L	<0.010	----
Hexachlorocyclohexane Epsilon	W-OCPECD01	0.010	µg/L	<0.010	----
Alachlor	W-OCPECD01	0.010	µg/L	<0.010	----
Heptachlor	W-OCPECD01	0.010	µg/L	<0.010	----
Aldrin	W-OCPECD01	0.0050	µg/L	<0.0050	----
Telodrin	W-OCPECD01	0.010	µg/L	<0.010	----
Isodrin	W-OCPECD01	0.010	µg/L	<0.010	----
Heptachloroepoxide-cis	W-OCPECD01	0.010	µg/L	<0.010	----
Heptachloroepoxide-trans	W-OCPECD01	0.010	µg/L	<0.010	----
2.4-DDE	W-OCPECD01	0.010	µg/L	<0.010	----
alpha-Endosulfan	W-OCPECD01	0.010	µg/L	<0.010	----

4.4`-DDE	W-OCPECD01	0.010	µg/L	<0.010	----
Dieldrin	W-OCPECD01	0.010	µg/L	<0.010	----
2.4-DDD	W-OCPECD01	0.010	µg/L	<0.010	----
Endrin	W-OCPECD01	0.010	µg/L	<0.010	----
beta-Endosulfan	W-OCPECD01	0.010	µg/L	<0.010	----
4.4`-DDD	W-OCPECD01	0.010	µg/L	<0.010	----
2.4-DDT	W-OCPECD01	0.010	µg/L	<0.010	----
4.4`-DDT	W-OCPECD01	0.010	µg/L	<0.010	----
Methoxychlor	W-OCPECD01	0.010	µg/L	<0.010	----
Dichlobenil	W-OCPECD01	0.050	µg/L	<0.050	----
Sum of 3 tetrachlorobenzenes	W-OCPECD01	0.030	µg/L	<0.030	----
Sum of 4 hexachlorcyclohexanes	W-OCPECD01	0.040	µg/L	<0.040	----
Sum of 4 isomers DDT	W-OCPECD01	0.040	µg/L	<0.040	----
Sum of 6 isomers DDT	W-OCPECD01	0.060	µg/L	<0.060	----
Sum of endosulfanes	W-OCPECD01	0.020	µg/L	<0.020	----
Sum of 5 hexachlorocyclohexanes	W-OCPECD01	0.050	µg/L	<0.050	----
Sum of 27 OCPs + 3 CBs	W-OCPECD01	0.290	µg/L	<0.290	----
Sum of 29 OCPs + 3 CBs	W-OCPECD01	0.350	µg/L	<0.350	----

If no sampling time is provided, the sampling time will default 00:00 on the date of sampling. If no sampling date is provided, delivery date in brackets without a time component will be displayed instead. Measurement uncertainty is expressed as expanded measurement uncertainty with coverage factor k = 2, representing 95% confidence level.

Key: LOR = Limit of reporting; MU = Measurement Uncertainty. The MU does not include sampling uncertainty.

The end of result part of the certificate of analysis

Brief Method Summaries

Analytical Methods	*Method Descriptions*
Location of test performance: Na Harfe 336/9 Prague 9 - Vysocany Czech Republic 190 00	
W-OCPECD01	CZ_SOP_D06_03_169 (CSN EN ISO 6468, US EPA 8081, DIN 38407-3, samples prepared as per CZ_SOP_D06_03_P01 chap. 9.1, CZ_SOP_D06_03_P02 chap. 9.1) Determination of organochlorine pesticides and other halogen compounds 12) by gas chromatography method with ECD detection and calculation of organochlorine pesticides and other halogen compounds sums from measured values.
W-PAHGMS01	CZ_SOP_D06_03_161 (US EPA 8270D, US EPA 8082A, CSN EN ISO 6468, US EPA 8000D, samples preparation as per CZ_SOP_D06_03_P01 chap. 9.1). Determination of semi volatile organic compounds by gas chromatography method with MS or MS/MS detection and calculation of semi volatile organic compounds sums from measured values

A `*` symbol preceding any method indicates laboratory or subcontractor non-accredited test. In the case when a procedure belonging to an accredited method was used for non-accredited matrix, would apply that the reported results are non-accredited. Please refer to General Comment section on front page for information. If the report contains subcontracted analysis, those are made in a subcontracted laboratory outside the laboratories ALS Czech Republic, s.r.o.
The calculation methods of summation parameters are available on request in the client service.

ALS Controlvet

Data Emissão: 04-10-2019

N.º de Análise:	QH / 13862 / 19
Data Colheita:	-
Data Receção:	21-09-2019
Data Início Ensaio:	21-09-2019
Data Fim Ensaio:	04-10-2019
Código Cliente:	7401

Exmo(s) Sr(s):
Nemus – Gestão e Req.Ambiental, Lda.
EST. DO PAÇO DO LUMIAR CAMPUS DO LUMIAR ED. D
LISBOA
1649-038 LISBOA

Unidade: Nemus – Gestão e Requalificação Ambiental, Lda.

Identificação da Amostra: **159092 / 19**

Produto: Água Naturais
Referência: Amostra 26
Acondicionamento: frasco
Nº Entrega: 1527/2019
A colheita de amostra não foi efectuada pela Controlvet.

Ensaio	Método	Resultado	Unidade
(a) Parâmetros físico-químicos	Descrição em anexo	Resultado em anexo.	.

Método interno equivalente é aquele que tem a mesma área de aplicação (parâmetros e matrizes) e que cumpre as características de desempenho, obtendo resultados comparáveis ao(s) método(s) normalizado(s) junto indicado(s)

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Técnica Superior de Laboratório
Eugénia Silva

Data Emissão: 04-10-2019

N.º de Análise:	QH / 13862 / 19
Data Colheita:	-
Data Receção:	21-09-2019
Data Início Ensaio:	21-09-2019
Data Fim Ensaio:	04-10-2019
Código Cliente:	7401

Exmo(s) Sr(s):
Nemus – Gestão e Req.Ambiental, Lda.
EST. DO PAÇO DO LUMIAR CAMPUS DO LUMIAR ED. D
LISBOA
1649-038 LISBOA

Unidade: Nemus – Gestão e Requalificação Ambiental, Lda.

Identificação da Amostra: **159092 / 19**

Produto: Água Naturais
Referência: Amostra 26
Acondicionamento: frasco
Nº Entrega: 1527/2019
A colheita de amostra não foi efectuada pela Controlvet.

Notas

Lista de abreviaturas: NE- Número estimado; UFC- Unidades formadoras de colónias; LQ – Limite de quantificação; LD – limite de detecção; V.L. – Valor Limite; V.R. – Valor Recomendado; VP - Valor Paramétrico; C - Conforme; A - Aceitável; NC - Não Conforme; Unid. - Unidade; DO - Densidade óptica.

O ensaio assinalado com (s) foi subcontratado e não é acreditado.
O ensaio assinalado com (a) foi subcontratado e é acreditado.
Nos resultados assinalados com (k) os microrganismos estão presentes, mas inferiores a 3xdiluição (quando aplicável).
Nos resultados assinalados com (y) os microrganismos estão presentes, mas inferiores a 4xdiluição.
Para os ensaios assinalados por tecnicas de cálculo a metodologia seguida pode ser disponibilizada a pedido.

Este Relatório de Ensaio refere-se apenas às amostras analisadas.
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Eugénia Silva

Técnica Superior de Laboratório
Eugénia Silva

CERTIFICATE OF ANALYSIS

Laboratory sample ID	: **PR1999997005**	**Work Order**	: **PR1999997**
		Issue Date	: 03-Oct-2019
Amendment	: **1**		
Customer	: **CONTROLVET - Seguranca Alimentar, S. A.**	Laboratory	: ALS Czech Republic, s.r.o.
Contact	: Subcontratacao Ensaios	Contact	: Client Service
Address	: Zona Industrial de Tondela ZIM II - Lote 6 3460-070 Tondela Portugal	Address	: Na Harfe 336/9 Prague 9 - Vysocany 190 00 Czech Republic
E-mail	: Subcontratacao.Ensaios@alsglobal.com	E-mail	: customer.support@alsglobal.com
Telephone	: ----	Telephone	: +420 226 226 228
Project	: ECF 2019E/155	Page	: 1 of 3
Order number	: ----	Date Samples Received	: 24-Sep-2019
		Quote number	: PR2015CONSE-PT0006 (PT-254-15-0938)
Site	: ----	Date of test	: 24-Sep-2019 - 03-Oct-2019
Sampled by	: client	QC Level	: ALS CR Standard Quality Control Schedule

General Comments

This report shall not be reproduced except in full, without prior written approval from the laboratory.
The laboratory declares that the test results relate only to the listed samples. If the section "Sampled by" of the Certificate of analysis states: "Sampled by Customer" then the results relate to the sample as received.
Amendmend No. 1: Change of COA format as per clients request. This Amendmend No. 1 supersedes test report No. PR1999997 dated 3.10.2019

Signatories

Testing Laboratory No. 1163
Accredited by CAI according to
CSN EN ISO/IEC 17025:2018

Signatories		*Position*
Zdeněk Jirák		Environmental Business Unit Manager

L 1163

Analytical Results

Sub-Matrix: **WATER**			*Laboratory sample ID*	**QH/13862/2019**	
			Client sampling date / time	[23-Sep-2019]	
Parameter	*Method*	*LOR*	*Unit*	**Result**	**MU**
Polycyclic Aromatics Hydrocarbons (PAHs)					
Naphthalene	W-PAHGMS01	0.100	µg/L	<0.100	----
Acenaphthylene	W-PAHGMS01	0.010	µg/L	<0.010	----
Acenaphthene	W-PAHGMS01	0.010	µg/L	<0.010	----
Fluorene	W-PAHGMS01	0.020	µg/L	<0.020	----
Phenanthrene	W-PAHGMS01	0.030	µg/L	<0.030	----
Anthracene	W-PAHGMS01	0.020	µg/L	<0.020	----
Fluoranthene	W-PAHGMS01	0.030	µg/L	<0.030	----
Pyrene	W-PAHGMS01	0.060	µg/L	<0.060	----
Benz(a)anthracene	W-PAHGMS01	0.010	µg/L	<0.010	----
Chrysene	W-PAHGMS01	0.010	µg/L	<0.010	----
Benzo(b)fluoranthene	W-PAHGMS01	0.010	µg/L	<0.010	----
Benzo(k)fluoranthene	W-PAHGMS01	0.010	µg/L	<0.010	----
Benzo(a)pyrene	W-PAHGMS01	0.020	µg/L	<0.020	----
Indeno(1.2.3.cd)pyrene	W-PAHGMS01	0.010	µg/L	<0.010	----
Benzo(g.h.i)perylene	W-PAHGMS01	0.010	µg/L	<0.010	----
Dibenz(a.h)anthracene	W-PAHGMS01	0.010	µg/L	<0.010	----
Sum of 16 PAH	W-PAHGMS01	0.370	µg/L	<0.370	----
Sum of PAH (MoE)	W-PAHGMS01	0.19	µg/L	<0.19	----
Sum of 6 PAH (WHO)	W-PAHGMS01	0.090	µg/L	<0.090	----
Sum of 4 PAH	W-PAHGMS01	0.040	µg/L	<0.040	----
Organochlorine Pesticides					
Hexachloroethane	W-OCPECD01	0.010	µg/L	<0.010	----
Hexachlorobutadiene	W-OCPECD01	0.010	µg/L	<0.010	----
1.2.3.5- & 1.2.4.5-Tetrachlorobenzene	W-OCPECD01	0.020	µg/L	<0.020	----
1.2.3.4-Tetrachlorobenzene	W-OCPECD01	0.010	µg/L	<0.010	----
Pentachlorobenzene	W-OCPECD01	0.010	µg/L	<0.010	----
Trifluralin	W-OCPECD01	0.010	µg/L	<0.010	----
Hexachlorocyclohexane Alpha	W-OCPECD01	0.010	µg/L	<0.010	----
Hexachlorobenzene (HCB)	W-OCPECD01	0.0050	µg/L	<0.0050	----
Hexachlorocyclohexane Beta	W-OCPECD01	0.010	µg/L	<0.010	----
Hexachlorocyclohexane Gamma	W-OCPECD01	0.010	µg/L	<0.010	----
Hexachlorocyclohexane Delta	W-OCPECD01	0.010	µg/L	<0.010	----
Hexachlorocyclohexane Epsilon	W-OCPECD01	0.010	µg/L	<0.010	----
Alachlor	W-OCPECD01	0.010	µg/L	<0.010	----
Heptachlor	W-OCPECD01	0.010	µg/L	<0.010	----
Aldrin	W-OCPECD01	0.0050	µg/L	<0.0050	----
Telodrin	W-OCPECD01	0.010	µg/L	<0.010	----
Isodrin	W-OCPECD01	0.010	µg/L	<0.010	----
Heptachloroepoxide-cis	W-OCPECD01	0.010	µg/L	<0.010	----
Heptachloroepoxide-trans	W-OCPECD01	0.010	µg/L	<0.010	----
2.4-DDE	W-OCPECD01	0.010	µg/L	<0.010	----
alpha-Endosulfan	W-OCPECD01	0.010	µg/L	<0.010	----

4.4`-DDE	W-OCPECD01	0.010	µg/L	<0.010	----
Dieldrin	W-OCPECD01	0.010	µg/L	<0.010	----
2.4-DDD	W-OCPECD01	0.010	µg/L	<0.010	----
Endrin	W-OCPECD01	0.010	µg/L	<0.010	----
beta-Endosulfan	W-OCPECD01	0.010	µg/L	<0.010	----
4.4`-DDD	W-OCPECD01	0.010	µg/L	<0.010	----
2.4-DDT	W-OCPECD01	0.010	µg/L	<0.010	----
4.4`-DDT	W-OCPECD01	0.010	µg/L	<0.010	----
Methoxychlor	W-OCPECD01	0.010	µg/L	<0.010	----
Dichlobenil	W-OCPECD01	0.050	µg/L	<0.050	----
Sum of 3 tetrachlorobenzenes	W-OCPECD01	0.030	µg/L	<0.030	----
Sum of 4 hexachlorcyclohexanes	W-OCPECD01	0.040	µg/L	<0.040	----
Sum of 4 isomers DDT	W-OCPECD01	0.040	µg/L	<0.040	----
Sum of 6 isomers DDT	W-OCPECD01	0.060	µg/L	<0.060	----
Sum of endosulfanes	W-OCPECD01	0.020	µg/L	<0.020	----
Sum of 5 hexachlorocyclohexanes	W-OCPECD01	0.050	µg/L	<0.050	----
Sum of 27 OCPs + 3 CBs	W-OCPECD01	0.290	µg/L	<0.290	----
Sum of 29 OCPs + 3 CBs	W-OCPECD01	0.350	µg/L	<0.350	----

If no sampling time is provided, the sampling time will default 00:00 on the date of sampling. If no sampling date is provided, delivery date in brackets without a time component will be displayed instead. Measurement uncertainty is expressed as expanded measurement uncertainty with coverage factor k = 2, representing 95% confidence level.

Key: LOR = Limit of reporting; MU = Measurement Uncertainty. The MU does not include sampling uncertainty.

The end of result part of the certificate of analysis

Brief Method Summaries

Analytical Methods	*Method Descriptions*
Location of test performance: Na Harfe 336/9 Prague 9 - Vysocany Czech Republic 190 00	
W-OCPECD01	CZ_SOP_D06_03_169 (CSN EN ISO 6468, US EPA 8081, DIN 38407-3, samples prepared as per CZ_SOP_D06_03_P01 chap. 9.1, CZ_SOP_D06_03_P02 chap. 9.1) Determination of organochlorine pesticides and other halogen compounds 12) by gas chromatography method with ECD detection and calculation of organochlorine pesticides and other halogen compounds sums from measured values.
W-PAHGMS01	CZ_SOP_D06_03_161 (US EPA 8270D, US EPA 8082A, CSN EN ISO 6468, US EPA 8000D, samples preparation as per CZ_SOP_D06_03_P01 chap. 9.1). Determination of semi volatile organic compounds by gas chromatography method with MS or MS/MS detection and calculation of semi volatile organic compounds sums from measured values

A `*` symbol preceding any method indicates laboratory or subcontractor non-accredited test. In the case when a procedure belonging to an accredited method was used for non-accredited matrix, would apply that the reported results are non-accredited. Please refer to General Comment section on front page for information. If the report contains subcontracted analysis, those are made in a subcontracted laboratory outside the laboratories ALS Czech Republic, s.r.o.
The calculation methods of summation parameters are available on request in the client service.

CERTIFICATE OF ASSAY

T0141

ALFRED H KNIGHT

REFERENCE	DATE	PAGE
ASD_Trace/77876	29-Oct-2019	1 of 9

CLIENT
MARIA GRADE- NEMUS-GESTÃO
CASH SALE

MARKS

PACKING

SEALS

CLIENT REFERENCE
WATER SAMPLES

MATERIAL DESCRIBED AS
WATER

ASSAY STATE
AS RECEIVED

SAMPLING DATE	ASSAY TYPE	VESSEL
	PARTY	

SAMPLE ID			1	2	3
DATE RECEIVED			23-OCT-2019	23-OCT-2019	23-OCT-2019
DATE TESTED			29-OCT-2019	29-OCT-2019	29-OCT-2019
Nitrate by AW39	(NO3-)	mg/L	1.54	1.21	1.90
Zinc by AW12	(Zn)	mg/L	< 0.006	< 0.006	< 0.006
Lead by AW12	(Pb)	mg/L	< 0.01	< 0.01	< 0.01
Nickel by AW12	(Ni)	mg/L	< 0.002	< 0.002	< 0.002
Copper by AW12	(Cu)	mg/L	< 0.01	< 0.01	< 0.01
Chromium by AW12	(Cr)	mg/L	< 0.001	< 0.001	< 0.001
Cobalt by AW12	(Co)	mg/L	< 0.001	< 0.001	< 0.001
Cadmium by AW12	(Cd)	mg/L	< 0.001	< 0.001	< 0.001
Arsenic by AW12	(As)	mg/L	< 0.01	< 0.01	< 0.01
Mercury by AG24	(Hg)	mg/L	< 0.05	< 0.05	< 0.05
Phosphorous	(P)	mg/L	0.3	0.2	0.3
Chem O2 Demand by AW33	(COD)	mg/L	< 5	19	13
Biochemical oxygen dema~	(BOD)	mg/L	1.4	7.5	10.8

K. Kalumba
Technical Signatory - Head Of Department-ASD
For and on behalf of Alfred H. Knight (Zambia) Ltd

Alfred H. Knight (Zambia) Ltd
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CERTIFICATE OF ASSAY

T0141

ALFRED H KNIGHT

REFERENCE	DATE	PAGE
ASD_Trace/77876	29-Oct-2019	2 of 9

CLIENT
MARIA GRADE- NEMUS-GESTÃO
CASH SALE

MARKS

PACKING

SEALS

CLIENT REFERENCE
WATER SAMPLES

MATERIAL DESCRIBED AS
WATER

ASSAY STATE
AS RECEIVED

SAMPLING DATE

ASSAY TYPE
PARTY

VESSEL

SAMPLE ID			4	5	6
DATE RECEIVED			23-OCT-2019	23-OCT-2019	23-OCT-2019
DATE TESTED			29-OCT-2019	29-OCT-2019	29-OCT-2019
Nitrate by AW39	(NO3-)	mg/L	1.64	1.36	1.66
Zinc by AW12	(Zn)	mg/L	< 0.006	< 0.006	< 0.006
Lead by AW12	(Pb)	mg/L	< 0.01	< 0.01	< 0.01
Nickel by AW12	(Ni)	mg/L	< 0.002	< 0.002	0.002
Copper by AW12	(Cu)	mg/L	< 0.01	0.02	< 0.01
Chromium by AW12	(Cr)	mg/L	< 0.001	< 0.001	< 0.001
Cobalt by AW12	(Co)	mg/L	< 0.001	0.002	< 0.001
Cadmium by AW12	(Cd)	mg/L	< 0.001	< 0.001	< 0.001
Arsenic by AW12	(As)	mg/L	< 0.01	< 0.01	< 0.01
Mercury by AG24	(Hg)	mg/L	< 0.05	< 0.05	< 0.05
Phosphorous	(P)	mg/L	0.2	0.2	0.6
Chem O2 Demand by AW33	(COD)	mg/L	17	26	15
Biochemical oxygen dema~	(BOD)	mg/L	8.6	11.1	14.7

K. Kalumba
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CERTIFICATE OF ASSAY

T0141

ALFRED H KNIGHT

REFERENCE	DATE	PAGE
ASD_Trace/77876	29-Oct-2019	3 of 9

CLIENT
MARIA GRADE- NEMUS-GESTÃO
CASH SALE

MARKS

PACKING

SEALS

CLIENT REFERENCE
WATER SAMPLES

MATERIAL DESCRIBED AS
WATER

ASSAY STATE
AS RECEIVED

SAMPLING DATE

ASSAY TYPE
PARTY

VESSEL

SAMPLE ID			7	8	9
DATE RECEIVED			23-OCT-2019	23-OCT-2019	23-OCT-2019
DATE TESTED			29-OCT-2019	29-OCT-2019	29-OCT-2019
Nitrate by AW39	(NO3-)	mg/L	1.80	3.95	7.76
Zinc by AW12	(Zn)	mg/L	0.089	< 0.006	< 0.006
Lead by AW12	(Pb)	mg/L	< 0.01	< 0.01	< 0.01
Nickel by AW12	(Ni)	mg/L	< 0.002	0.005	0.002
Copper by AW12	(Cu)	mg/L	< 0.01	< 0.01	0.66
Chromium by AW12	(Cr)	mg/L	< 0.001	< 0.001	< 0.001
Cobalt by AW12	(Co)	mg/L	< 0.001	0.014	0.098
Cadmium by AW12	(Cd)	mg/L	< 0.001	< 0.001	< 0.001
Arsenic by AW12	(As)	mg/L	< 0.01	< 0.01	< 0.01
Mercury by AG24	(Hg)	mg/L	< 0.05	< 0.05	< 0.05
Phosphorous	(P)	mg/L	0.2	0.7	< 0.1
Chem O2 Demand by AW33	(COD)	mg/L	29	14	22
Biochemical oxygen dema~	(BOD)	mg/L	25.6	11.4	5.4

K. Kalumba
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For and on behalf of Alfred H. Knight (Zambia) Ltd

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CERTIFICATE OF ASSAY

T0141

ALFRED H KNIGHT

REFERENCE: ASD_Trace/77876	DATE: 29-Oct-2019	PAGE: 4 of 9
CLIENT: MARIA GRADE- NEMUS-GESTÃO CASH SALE	MARKS:	
	PACKING:	
	SEALS:	
CLIENT REFERENCE: WATER SAMPLES	MATERIAL DESCRIBED AS: WATER	
ASSAY STATE: AS RECEIVED		
SAMPLING DATE:	ASSAY TYPE: PARTY	VESSEL:

SAMPLE ID			10	11	12
DATE RECEIVED			23-OCT-2019	23-OCT-2019	23-OCT-2019
DATE TESTED			29-OCT-2019	29-OCT-2019	29-OCT-2019
Nitrate by AW39	(NO3-)	mg/L	2.01	2.25	1.05
Zinc by AW12	(Zn)	mg/L	< 0.006	< 0.006	< 0.006
Lead by AW12	(Pb)	mg/L	< 0.01	< 0.01	0.01
Nickel by AW12	(Ni)	mg/L	< 0.002	0.006	< 0.002
Copper by AW12	(Cu)	mg/L	0.03	0.17	< 0.01
Chromium by AW12	(Cr)	mg/L	< 0.001	< 0.001	< 0.001
Cobalt by AW12	(Co)	mg/L	0.001	0.016	< 0.001
Cadmium by AW12	(Cd)	mg/L	< 0.001	< 0.001	< 0.001
Arsenic by AW12	(As)	mg/L	< 0.01	< 0.01	< 0.01
Mercury by AG24	(Hg)	mg/L	< 0.05	< 0.05	< 0.05
Phosphorous	(P)	mg/L	0.1	0.3	0.4
Chem O2 Demand by AW33	(COD)	mg/L	19	56	20
Biochemical oxygen dema~	(BOD)	mg/L	13.0	9.2	6.6

K. Kalumba
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For and on behalf of Alfred H. Knight (Zambia) Ltd

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CERTIFICATE OF ASSAY

sanas Testing Laboratory

T0141

ALFRED H KNIGHT

REFERENCE: ASD_Trace/77876	DATE: 29-Oct-2019	PAGE: 5 of 9
CLIENT: MARIA GRADE- NEMUS-GESTÃO CASH SALE	MARKS:	
	PACKING:	
	SEALS:	
CLIENT REFERENCE: WATER SAMPLES	MATERIAL DESCRIBED AS: WATER	
ASSAY STATE: AS RECEIVED		
SAMPLING DATE:	ASSAY TYPE: PARTY	VESSEL:

SAMPLE ID			13	14	15
DATE RECEIVED			23-OCT-2019	23-OCT-2019	23-OCT-2019
DATE TESTED			29-OCT-2019	29-OCT-2019	29-OCT-2019
Nitrate by AW39	(NO3-)	mg/L	1.50	1.31	2.08
Zinc by AW12	(Zn)	mg/L	< 0.006	0.007	< 0.006
Lead by AW12	(Pb)	mg/L	< 0.01	< 0.01	< 0.01
Nickel by AW12	(Ni)	mg/L	0.003	< 0.002	< 0.002
Copper by AW12	(Cu)	mg/L	< 0.01	< 0.01	0.03
Chromium by AW12	(Cr)	mg/L	< 0.001	< 0.001	< 0.001
Cobalt by AW12	(Co)	mg/L	< 0.001	< 0.001	< 0.001
Cadmium by AW12	(Cd)	mg/L	< 0.001	< 0.001	< 0.001
Arsenic by AW12	(As)	mg/L	< 0.01	< 0.01	< 0.01
Mercury by AG24	(Hg)	mg/L	< 0.05	< 0.05	< 0.05
Phosphorous	(P)	mg/L	0.4	0.2	0.3
Chem O2 Demand by AW33	(COD)	mg/L	16	15	14
Biochemical oxygen dema~	(BOD)	mg/L	11.9	11.4	3.3

K. Kalumba
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CERTIFICATE OF ASSAY

T0141

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REFERENCE	DATE	PAGE
ASD_Trace/77876	29-Oct-2019	6 of 9

CLIENT
MARIA GRADE- NEMUS-GESTÃO
CASH SALE

MARKS

PACKING

SEALS

CLIENT REFERENCE
WATER SAMPLES

MATERIAL DESCRIBED AS
WATER

ASSAY STATE
AS RECEIVED

SAMPLING DATE

ASSAY TYPE
PARTY

VESSEL

SAMPLE ID			16	17	18
DATE RECEIVED			23-OCT-2019	23-OCT-2019	23-OCT-2019
DATE TESTED			29-OCT-2019	29-OCT-2019	29-OCT-2019
Nitrate by AW39	(NO3-)	mg/L	1.57	1.81	2.35
Zinc by AW12	(Zn)	mg/L	< 0.006	0.024	< 0.006
Lead by AW12	(Pb)	mg/L	< 0.01	0.02	< 0.01
Nickel by AW12	(Ni)	mg/L	< 0.002	0.162	< 0.002
Copper by AW12	(Cu)	mg/L	0.13	0.42	0.08
Chromium by AW12	(Cr)	mg/L	< 0.001	< 0.001	< 0.001
Cobalt by AW12	(Co)	mg/L	0.025	4.997	0.014
Cadmium by AW12	(Cd)	mg/L	< 0.001	< 0.001	< 0.001
Arsenic by AW12	(As)	mg/L	< 0.01	< 0.01	< 0.01
Mercury by AG24	(Hg)	mg/L	< 0.05	< 0.05	< 0.05
Phosphorous	(P)	mg/L	0.4	0.5	0.2
Chem O2 Demand by AW33	(COD)	mg/L	50	40	13
Biochemical oxygen dema~	(BOD)	mg/L	10.3	12.0	1.3

K. Kalumba
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CERTIFICATE OF ASSAY

T0141

ALFRED H KNIGHT

REFERENCE	DATE	PAGE
ASD_Trace/77876	29-Oct-2019	7 of 9

CLIENT
MARIA GRADE- NEMUS-GESTÃO
CASH SALE

MARKS

PACKING

SEALS

CLIENT REFERENCE
WATER SAMPLES

MATERIAL DESCRIBED AS
WATER

ASSAY STATE
AS RECEIVED

SAMPLING DATE

ASSAY TYPE
PARTY

VESSEL

SAMPLE ID			19	20	21
DATE RECEIVED			23-OCT-2019	23-OCT-2019	23-OCT-2019
DATE TESTED			29-OCT-2019	29-OCT-2019	29-OCT-2019
Nitrate by AW39	(NO3-)	mg/L	15.05	0.28	0.95
Zinc by AW12	(Zn)	mg/L	< 0.006	0.029	< 0.006
Lead by AW12	(Pb)	mg/L	< 0.01	< 0.01	< 0.01
Nickel by AW12	(Ni)	mg/L	< 0.002	< 0.002	< 0.002
Copper by AW12	(Cu)	mg/L	0.11	< 0.01	< 0.01
Chromium by AW12	(Cr)	mg/L	< 0.001	< 0.001	< 0.001
Cobalt by AW12	(Co)	mg/L	0.005	< 0.001	< 0.001
Cadmium by AW12	(Cd)	mg/L	< 0.001	< 0.001	< 0.001
Arsenic by AW12	(As)	mg/L	< 0.01	< 0.01	< 0.01
Mercury by AG24	(Hg)	mg/L	< 0.05	< 0.05	< 0.05
Phosphorous	(P)	mg/L	0.5	0.5	0.5
Chem O2 Demand by AW33	(COD)	mg/L	25	19	21
Biochemical oxygen dema~	(BOD)	mg/L	21.8	13.6	13.6

K. Kalumba
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CERTIFICATE OF ASSAY

T0141

ALFRED H KNIGHT

REFERENCE: ASD_Trace/77876	DATE: 29-Oct-2019	PAGE: 8 of 9
CLIENT: MARIA GRADE- NEMUS-GESTÃO CASH SALE	MARKS:	
	PACKING:	
	SEALS:	
CLIENT REFERENCE: WATER SAMPLES	MATERIAL DESCRIBED AS: WATER	
ASSAY STATE: AS RECEIVED		
SAMPLING DATE:	ASSAY TYPE: PARTY	VESSEL:

SAMPLE ID			22	23	24
DATE RECEIVED			23-OCT-2019	23-OCT-2019	23-OCT-2019
DATE TESTED			29-OCT-2019	29-OCT-2019	29-OCT-2019
Nitrate by AW39	(NO3-)	mg/L	0.95	2.23	2.70
Zinc by AW12	(Zn)	mg/L	< 0.006	< 0.006	< 0.006
Lead by AW12	(Pb)	mg/L	< 0.01	< 0.01	< 0.01
Nickel by AW12	(Ni)	mg/L	< 0.002	< 0.002	< 0.002
Copper by AW12	(Cu)	mg/L	< 0.01	< 0.01	< 0.01
Chromium by AW12	(Cr)	mg/L	< 0.001	< 0.001	< 0.001
Cobalt by AW12	(Co)	mg/L	< 0.001	0.016	0.001
Cadmium by AW12	(Cd)	mg/L	< 0.001	< 0.001	< 0.001
Arsenic by AW12	(As)	mg/L	< 0.01	< 0.01	< 0.01
Mercury by AG24	(Hg)	mg/L	< 0.05	< 0.05	< 0.05
Phosphorous	(P)	mg/L	0.6	0.3	0.8
Chem O2 Demand by AW33	(COD)	mg/L	37	16	36
Biochemical oxygen dema~	(BOD)	mg/L	10.8	11.9	22.9

AHK(Z) Analytical Methods

AG24 - Hydride Generation Cold Vapor AAS (Not SANAS Accredited)
AW12 - Total or Dissolved Elements by ICP
AW33 - Chemical Oxygen Demand (Not SANAS Accredited)
AW39 - Nitrate by ultraviolet spectrophotometry (Not SANAS Accredited).

K. Kalumba
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CERTIFICATE OF ASSAY

T0141

ALFRED H KNIGHT

REFERENCE	DATE	PAGE
ASD_Trace/77876	29-Oct-2019	9 of 9

CLIENT
MARIA GRADE- NEMUS-GESTÃO
CASH SALE

MARKS

PACKING

SEALS

CLIENT REFERENCE
WATER SAMPLES

MATERIAL DESCRIBED AS
WATER

ASSAY STATE
AS RECEIVED

SAMPLING DATE	ASSAY TYPE	VESSEL
	PARTY	

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These test results are from samples of unknown provenance to Alfred H. Knight Zambia, and which were presented to Alfred H. Knight Zambia for chemical analysis. This certificate relates only to the test sample [s] presented to Alfred H. Knight Zambia for chemical

Sample Disposal: As per our Quality System requirements, samples will be kept in storage for six (6) months after which they will be disposed of. Please advise if you have alternative disposal instructions.

K. Kalumba
Technical Signatory - Head Of Department-ASD
For and on behalf of Alfred H. Knight (Zambia) Ltd

Alfred H. Knight (Zambia) Ltd
Corner Mindola/Golf Club Roads, Nkana West, Kitwe, Copperbelt, PO Box 20303, Zambia
Tel: +260 212 226 433/434/306/428 Fax: +260 212 226 306/424 Email: AHK.Zambia@ahkgroup.com

CERTIFICATE OF ASSAY

T0141

ALFRED H KNIGHT

REFERENCE	DATE	PAGE
ASD_Trace/77954	06-Nov-2019	1 of 3

CLIENT
MARIA GRADE- NEMUS
CASH SALE

MARKS

PACKING

SEALS

CLIENT REFERENCE
WATER SAMPLES

MATERIAL DESCRIBED AS
WATER

ASSAY STATE
AS RECEIVED

SAMPLING DATE

ASSAY TYPE
PARTY

VESSEL

SAMPLE ID			25	26	27
DATE RECEIVED			23-OCT-2019	23-OCT-2019	23-OCT-2019
DATE TESTED			01-NOV-2019	01-NOV-2019	01-NOV-2019
Nitrate by AW39	(NO3-)	mg/L	3.23	3.54	6.37
Zinc by AW12	(Zn)	mg/L	0.012	0.014	0.034
Lead by AW12	(Pb)	mg/L	< 0.01	< 0.01	< 0.01
Nickel by AW12	(Ni)	mg/L	< 0.002	< 0.002	< 0.002
Copper by AW12	(Cu)	mg/L	< 0.01	< 0.01	< 0.01
Chromium by AW12	(Cr)	mg/L	< 0.001	< 0.001	< 0.001
Cobalt by AW12	(Co)	mg/L	0.002	< 0.001	< 0.001
Cadmium by AW12	(Cd)	mg/L	0.001	< 0.001	< 0.001
Arsenic by AW12	(As)	mg/L	< 0.01	< 0.01	< 0.01
Mercury by AW26	(Hg)	mg/L	< 0.05	< 0.05	< 0.05
Phosphorous	(P)	mg/L	0.62	1.04	1.50
Chem O2 Demand by AW33	(COD)	mg/L	27	49	121
Biochemical oxygen dema~	(BOD)	mg/L	8.7	14.8	12.0

K. Kalumba
Technical Signatory - Head Of Department-ASD
For and on behalf of Alfred H. Knight (Zambia) Ltd

Alfred H. Knight (Zambia) Ltd
Corner Mindola/Golf Club Roads, Nkana West, Kitwe, Copperbelt, PO Box 20303, Zambia
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CERTIFICATE OF ASSAY

T0141

ALFRED H KNIGHT

REFERENCE	DATE	PAGE
ASD_Trace/77954	06-Nov-2019	2 of 3

CLIENT	MARKS
MARIA GRADE- NEMUS CASH SALE	
	PACKING
	SEALS
CLIENT REFERENCE WATER SAMPLES	MATERIAL DESCRIBED AS WATER
ASSAY STATE AS RECEIVED	
SAMPLING DATE / ASSAY TYPE PARTY	VESSEL

SAMPLE ID			28
DATE RECEIVED			23-OCT-2019
DATE TESTED			01-NOV-2019
Nitrate by AW39	(NO3-)	mg/L	1.41
Zinc by AW12	(Zn)	mg/L	< 0.006
Lead by AW12	(Pb)	mg/L	< 0.01
Nickel by AW12	(Ni)	mg/L	< 0.002
Copper by AW12	(Cu)	mg/L	< 0.01
Chromium by AW12	(Cr)	mg/L	< 0.001
Cobalt by AW12	(Co)	mg/L	< 0.001
Cadmium by AW12	(Cd)	mg/L	< 0.001
Arsenic by AW12	(As)	mg/L	< 0.01
Mercury by AW26	(Hg)	mg/L	< 0.05
Phosphorous	(P)	mg/L	0.39
Chem O2 Demand by AW33	(COD)	mg/L	15
Biochemical oxygen dema~	(BOD)	mg/L	6.5

AHK(Z) Analytical Methods

AW12 - Total or Dissolved Elements by ICP
AW26 - Dissolved As, Bi, Se, Sb, Sn & Hg (Not SANAS Accredited)
AW33 - Chemical Oxygen Demand (Not SANAS Accredited)
AW39 - Nitrate by ultraviolet spectrophotometry (Not SANAS Accredited).

K. Kalumba
Technical Signatory - Head Of Department-ASD
For and on behalf of Alfred H. Knight (Zambia) Ltd

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Corner Mindola/Golf Club Roads, Nkana West, Kitwe, Copperbelt, PO Box 20303, Zambia
Tel: +260 212 226 433/434/306/428 Fax: +260 212 226 306/424 Email: AHK.Zambia@ahkgroup.com

CERTIFICATE OF ASSAY

sanas Testing Laboratory

T0141

ALFRED H KNIGHT

REFERENCE	DATE	PAGE
ASD_Trace/77954	06-Nov-2019	3 of 3

CLIENT MARIA GRADE- NEMUS CASH SALE	MARKS
	PACKING
	SEALS
CLIENT REFERENCE WATER SAMPLES	MATERIAL DESCRIBED AS WATER
ASSAY STATE AS RECEIVED	
SAMPLING DATE / ASSAY TYPE PARTY	VESSEL

This test report shall not be reproduced, except in full, without written approval from Alfred H. Knight (Z) Ltd and if transmitted by fax or e-mail will only be valid when supported by the original document.

These test results are from samples of unknown provenance to Alfred H. Knight Zambia, and which were presented to Alfred H. Knight Zambia for chemical analysis. This certificate relates only to the test sample [s] presented to Alfred H. Knight Zambia for chemical

Sample Disposal: As per our Quality System requirements, samples will be kept in storage for six (6) months after which they will be disposed of. Please advise if you have alternative disposal instructions.

K. Kalumba
Technical Signatory - Head Of Department-ASD
For and on behalf of Alfred H. Knight (Zambia) Ltd

Alfred H. Knight (Zambia) Ltd
Corner Mindola/Golf Club Roads, Nkana West, Kitwe, Copperbelt, PO Box 20303, Zambia
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ALS Controlvet

Correction of Previous Reports
Issue Date 29-11-2019

Analysis n.º:	QH / 15724 / 19
Collection Date:	-
Reception Date:	23-10-2019
Start Date:	24-10-2019
End Date:	29-11-2019
Client nº:	7401

Dear Sir
Nemus – Gestão e Req.Ambiental, Lda.
EST. DO PAÇO DO LUMIAR CAMPUS DO LUMIAR ED. D
LISBOA
1649-038 LISBOA

Unit: Nemus – Gestão e Requalificação Ambiental, Lda.

Sample Identification **178534 / 19**

Product: Natural Water
Reference: Sample 6
Packaging: bottle
Work Order: 1806/2019
The sample collection was not performed by Controlvet.
The results of this test report apply to the sample as received.

Test	Method	Result	Unit
(a) Organochlorine Pesticides (OCP) for GC-ECD	CZ_SOP_D06_03_169 (CSN EN ISO 6468, US EPA 8081, DIN 38407-3, samples prepared as per CZ_SOP_D06_03_P01 chap. 9.1, CZ_SOP_D06_03_P02 chap. 9.1)		
Hexachlorobenzene		<0.0050	µg/L
2,4'-DDT		<0.010	µg/L
4,4'-DDT		<0.010	µg/L
Hexachloroethane		<0.010	µg/L
Hexachlorobutadiene		<0.010	µg/L
1.2.3.5- & 1.2.4.5-Tetrachlorobenzene		<0.020	µg/L
1.2.3.4-Tetrachlorobenzene		<0.010	µg/L
Pentachlorobenzene		<0.010	µg/L
Trifluralin		<0.010	µg/L
Hexachlorocyclohexane Alpha		<0.010	µg/L
Hexachlorocyclohexane Beta		<0.010	µg/L
Hexachlorocyclohexane Gamma		<0.010	µg/L
Hexachlorocyclohexane Delta		<0.010	µg/L
Hexachlorocyclohexane Epsilon		<0.010	µg/L
Alachlor		<0.010	µg/L
Heptachlor		<0.010	µg/L
Aldrin		<0.0050	µg/L
Telodrin		<0.010	µg/L
Isodrin		<0.010	µg/L
Heptachloroepoxide-cis		<0.010	µg/L
Heptachloroepoxide-trans		<0.010	µg/L
2.4-DDE		<0.010	µg/L
alpha-Endosulfan		<0.010	µg/L
4.4`- DDE		<0.010	µg/L
Dieldrin		<0.010	µg/L
2.4-DDD		<0.010	µg/L
Endrin		<0.010	µg/L
beta-Endosulfan		<0.010	µg/L

Tondela
Zona Industrial Tondela - ZIM II Lote 2 e 6
3460-070 Tondela
Telef.: 232817617
Fax: 232817819

Eugénia Silva

Técnica Superior de Laboratório
Eugénia Silva

Analysis n.º:	QH / 15724 / 19
Collection Date:	-
Reception Date:	23-10-2019
Start Date:	24-10-2019
End Date:	29-11-2019
Client nº:	7401

Dear Sir
Nemus – Gestão e Req.Ambiental, Lda.
EST. DO PAÇO DO LUMIAR CAMPUS DO LUMIAR ED. D
LISBOA
1649-038 LISBOA

Unit: Nemus – Gestão e Requalificação Ambiental, Lda.

Sample Identification **178534 / 19**

Product: Natural Water
Reference: Sample 6
The sample collection was not performed by Controlvet.
The results of this test report apply to the sample as received.

Packaging: bottle
Work Order: 1806/2019

Test	Method	Result	Unit
4.4`-DDD		<0.010	µg/L
Methoxychlor		<0.010	µg/L
Dichlobenil		<0.050	µg/L
Sum of 3 tetrachlorobenzenes		<0.030	µg/L
Sum of 4 hexachlorcyclohexanes		<0.040	µg/L
Sum of 4 isomers DDT		<0.040	µg/L
Sum of 6 isomers DDT		<0.060	µg/L
Sum of endosulfanes		<0.020	µg/L
Sum of 5 hexachlorocyclohexanes		<0.050	µg/L
Sum of 27 OCPs + 3 CBs		<0.290	µg/L
Sum of 29 OCPs + 3 CBs		<0.350	µg/L
(a) PAH for GCMS	CZ_SOP_D06_03_161 (US EPA 8270, CSN EN ISO 6468, US EPA 8000D, samples preparation according to CZ_SOP_D06_03_P01 chap. 9.1, 9.4.1)		
Acenaphthene		<0.010 (LQ)	µg/L
Acenaphthylene		<0.010 (LQ)	µg/L
Anthracene		<0.020 (LQ)	µg/L
Benz(a)anthracene		<0.010 (LQ)	µg/L
Benzo(a)pyrene		<0.020 (LQ)	µg/L
Benzo(b)fluoranthene		<0.010 (LQ)	µg/L
Benzo(g.h.i)perylene		<0.010 (LQ)	µg/L
Benzo(k)fluoranthene		<0.010 (LQ)	µg/L
Chrysene		<0.010 (LQ)	µg/L
Dibenz(a.h)anthracene		<0.010 (LQ)	µg/L
Fluoranthene		<0.030 (LQ)	µg/L
Fluorene		<0.020 (LQ)	µg/L
Indeno(1.2.3.cd)pyrene		<0.010 (LQ)	µg/L
Naphthalene		<0.100 (LQ)	µg/L
Phenanthrene		<0.030 (LQ)	µg/L
Pyrene		<0.060 (LQ)	µg/L
Sum of 16 PAH		<0.370 (LQ)	µg/L
Sum of 4 PAH		<0.040 (LQ)	µg/L

Tondela
Zona Industrial Tondela - ZIM II Lote 2 e 6
3460-070 Tondela
Telef.: 232817817
Fax: 232817819

Eugénia Silva

Técnica Superior de Laboratório
Eugénia Silva

Analysis n.º:	QH / 15724 / 19
Collection Date:	-
Reception Date:	23-10-2019
Start Date:	24-10-2019
End Date:	29-11-2019
Client nº:	7401

Dear Sir
Nemus – Gestão e Req.Ambiental, Lda.
EST. DO PAÇO DO LUMIAR CAMPUS DO LUMIAR ED. D
LISBOA
1649-038 LISBOA

Unit: Nemus – Gestão e Requalificação Ambiental, Lda.

Sample Identification **178534 / 19**

Product: Natural Water
Reference: Sample 6
Packaging: bottle
Work Order: 1806/2019
The sample collection was not performed by Controlvet.
The results of this test report apply to the sample as received.

In this report change the report of Organochlorine Pesticides. Motive: laboratory change.

Equivalent internal method is one that has the same area of application (parameters and matrices) and that meets the performance characteristics, obtaining results comparable to the standard method (s)

Eugénia Silva

Técnica Superior de Laboratório
Eugénia Silva

Analysis n.º:	QH / 15724 / 19
Collection Date:	-
Reception Date:	23-10-2019
Start Date:	24-10-2019
End Date:	29-11-2019
Client nº:	7401

Dear Sir
Nemus – Gestão e Req.Ambiental, Lda.
EST. DO PAÇO DO LUMIAR CAMPUS DO LUMIAR ED. D
LISBOA
1649-038 LISBOA

Unit: Nemus – Gestão e Requalificação Ambiental, Lda.

Sample Identification **178534 / 19**

Product: Natural Water
Reference: Sample 6
Packaging: bottle
Work Order: 1806/2019
The sample collection was not performed by Controlvet.
The results of this test report apply to the sample as received.

Notes

List of Abbreviations: EN-Estimated number; CFU-colony forming units; LQ - Limit of quantification; LD - limit of detection; LV - Limit Value; RV - Recommended Value, Pv - Parametric Value; C - According, A - Acceptable, NC - Nonconforming; Unit. - Unit, OD - Optical Density
The test marked with (s) was subcontracted and not accredited.
The test marked with (a) was subcontracted and is accredited.
In the results marked with (k) the microorganisms are present, but less than 3x dilution(if applicable).
In the results marked with (y) the microorganisms are present, but less than 4x dilution.
For the tests indicated by calculation techniques, the methodology followed can be made available on request.

This Test Report refers only to samples analyzed.
Prohibited the partial reproduction of this

Eugénia Silva

Técnica Superior de Laboratório
Eugénia Silva

ALS Controlvet

Correction of Previous Reports
Issue Date 29-11-2019

Analysis n.º:	QH / 15725 / 19
Collection Date:	-
Reception Date:	23-10-2019
Start Date:	24-10-2019
End Date:	29-11-2019
Client nº:	7401

Dear Sir
Nemus – Gestão e Req.Ambiental, Lda.
EST. DO PAÇO DO LUMIAR CAMPUS DO LUMIAR ED. D
LISBOA
1649-038 LISBOA

Unit: Nemus – Gestão e Requalificação Ambiental, Lda.

Sample Identification **178535 / 19**

Product: Natural Water
Reference: Sample 7
Packaging: bottle
Work Order: 1806/2019
The sample collection was not performed by Controlvet.
The results of this test report apply to the sample as received.

Test	Method	Result	Unit
(a) Organochlorine Pesticides (OCP) for GC-ECD	CZ_SOP_D06_03_169 (CSN EN ISO 6468, US EPA 8081, DIN 38407-3, samples prepared as per CZ_SOP_D06_03_P01 chap. 9.1, CZ_SOP_D06_03_P02 chap. 9.1)		
Hexachlorobenzene		<0.0050	µg/L
2,4'-DDT		<0.010	µg/L
4,4'-DDT		<0.010	µg/L
Hexachloroethane		<0.010	µg/L
Hexachlorobutadiene		<0.010	µg/L
1.2.3.5- & 1.2.4.5-Tetrachlorobenzene		<0.020	µg/L
1.2.3.4-Tetrachlorobenzene		<0.010	µg/L
Pentachlorobenzene		<0.010	µg/L
Trifluralin		<0.010	µg/L
Hexachlorocyclohexane Alpha		<0.010	µg/L
Hexachlorocyclohexane Beta		<0.010	µg/L
Hexachlorocyclohexane Gamma		<0.010	µg/L
Hexachlorocyclohexane Delta		<0.010	µg/L
Hexachlorocyclohexane Epsilon		<0.010	µg/L
Alachlor		<0.010	µg/L
Heptachlor		<0.010	µg/L
Aldrin		<0.0050	µg/L
Telodrin		<0.010	µg/L
Isodrin		<0.010	µg/L
Heptachloroepoxide-cis		<0.010	µg/L
Heptachloroepoxide-trans		<0.010	µg/L
2.4-DDE		<0.010	µg/L
alpha-Endosulfan		<0.010	µg/L
4.4`- DDE		<0.010	µg/L
Dieldrin		<0.010	µg/L
2.4-DDD		<0.010	µg/L
Endrin		<0.010	µg/L
beta-Endosulfan		<0.010	µg/L

Tondela
Zona Industrial Tondela - ZIM II Lote 2 e 6
3460-070 Tondela
Telef.: 232817617
Fax: 232817819

Eugénia Silva

Técnica Superior de Laboratório
Eugénia Silva

Analysis n.º:	QH / 15725 / 19
Collection Date:	-
Reception Date:	23-10-2019
Start Date:	24-10-2019
End Date:	29-11-2019
Client nº:	7401

Dear Sir
Nemus – Gestão e Req.Ambiental, Lda.
EST. DO PAÇO DO LUMIAR CAMPUS DO LUMIAR ED. D
LISBOA
1649-038 LISBOA

Unit: Nemus – Gestão e Requalificação Ambiental, Lda.

Sample Identification **178535 / 19**

Product: Natural Water
Reference: Sample 7
Packaging: bottle
Work Order: 1806/2019
The sample collection was not performed by Controlvet.
The results of this test report apply to the sample as received.

Test	Method	Result	Unit
4.4`-DDD		<0.010	µg/L
Methoxychlor		<0.010	µg/L
Dichlobenil		<0.050	µg/L
Sum of 3 tetrachlorobenzenes		<0.030	µg/L
Sum of 4 hexachlorcyclohexanes		<0.040	µg/L
Sum of 4 isomers DDT		<0.040	µg/L
Sum of 6 isomers DDT		<0.060	µg/L
Sum of endosulfanes		<0.020	µg/L
Sum of 5 hexachlorocyclohexanes		<0.050	µg/L
Sum of 27 OCPs + 3 CBs		<0.290	µg/L
Sum of 29 OCPs + 3 CBs		<0.350	µg/L
(a) PAH for GCMS	CZ_SOP_D06_03_161 (US EPA 8270, CSN EN ISO 6468, US EPA 8000D, samples preparation according to CZ_SOP_D06_03_P01 chap. 9.1, 9.4.1)		
Acenaphthene		<0.010 (LQ)	µg/L
Acenaphthylene		<0.010 (LQ)	µg/L
Anthracene		<0.020 (LQ)	µg/L
Benz(a)anthracene		<0.010 (LQ)	µg/L
Benzo(a)pyrene		<0.020 (LQ)	µg/L
Benzo(b)fluoranthene		<0.010 (LQ)	µg/L
Benzo(g.h.i)perylene		<0.010 (LQ)	µg/L
Benzo(k)fluoranthene		<0.010 (LQ)	µg/L
Chrysene		<0.010 (LQ)	µg/L
Dibenz(a.h)anthracene		<0.010 (LQ)	µg/L
Fluoranthene		<0.030 (LQ)	µg/L
Fluorene		<0.020 (LQ)	µg/L
Indeno(1.2.3.cd)pyrene		<0.010 (LQ)	µg/L
Naphthalene		<0.100 (LQ)	µg/L
Phenanthrene		<0.030 (LQ)	µg/L
Pyrene		<0.060 (LQ)	µg/L
Sum of 16 PAH		<0.370 (LQ)	µg/L
Sum of 4 PAH		<0.040 (LQ)	µg/L

Eugénia Silva

Técnica Superior de Laboratório
Eugénia Silva

Analysis n.º:	QH / 15725 / 19
Collection Date:	-
Reception Date:	23-10-2019
Start Date:	24-10-2019
End Date:	29-11-2019
Client nº:	7401

Dear Sir
Nemus – Gestão e Req.Ambiental, Lda.
EST. DO PAÇO DO LUMIAR CAMPUS DO LUMIAR ED. D
LISBOA
1649-038 LISBOA

Unit: Nemus – Gestão e Requalificação Ambiental, Lda.

Sample Identification **178535 / 19**

Product: Natural Water
Reference: Sample 7
Packaging: bottle
Work Order: 1806/2019
The sample collection was not performed by Controlvet.
The results of this test report apply to the sample as received.

In this report change the report of Organochlorine Pesticides. Motive: laboratory change.

Equivalent internal method is one that has the same area of application (parameters and matrices) and that meets the performance characteristics, obtaining results comparable to the standard method (s)

Eugénia Silva

Técnica Superior de Laboratório
Eugénia Silva

Analysis n.º:	QH / 15725 / 19
Collection Date:	-
Reception Date:	23-10-2019
Start Date:	24-10-2019
End Date:	29-11-2019
Client nº:	7401

Dear Sir
Nemus – Gestão e Req.Ambiental, Lda.
EST. DO PAÇO DO LUMIAR CAMPUS DO LUMIAR ED. D
LISBOA
1649-038 LISBOA

Unit: Nemus – Gestão e Requalificação Ambiental, Lda.

Sample Identification **178535 / 19**

Product: Natural Water
Reference: Sample 7
Packaging: bottle
Work Order: 1806/2019
The sample collection was not performed by Controlvet.
The results of this test report apply to the sample as received.

Notes

List of Abbreviations: EN-Estimated number; CFU-colony forming units; LQ - Limit of quantification; LD - limit of detection; LV - Limit Value; RV - Recommended Value, Pv - Parametric Value; C - According, A - Acceptable, NC - Nonconforming; Unit. - Unit, OD - Optical Density
The test marked with (s) was subcontracted and not accredited.
The test marked with (a) was subcontracted and is accredited.
In the results marked with (k) the microorganisms are present, but less than 3x dilution(if applicable).
In the results marked with (y) the microorganisms are present, but less than 4x dilution.
For the tests indicated by calculation techniques, the methodology followed can be made available on request.

This Test Report refers only to samples analyzed.
Prohibited the partial reproduction of this

Tondela
Zona Industrial Tondela - ZIM II Lote 2 e 6
3460-070 Tondela
Telef.: 232817817
Fax: 232817819

Eugénia Silva

Técnica Superior de Laboratório
Eugénia Silva

ALS Controlvet

Correction of Previous Reports
Issue Date 29-11-2019

Analysis n.º:	QH / 15726 / 19
Collection Date:	-
Reception Date:	23-10-2019
Start Date:	24-10-2019
End Date:	29-11-2019
Client nº:	7401

Dear Sir
Nemus – Gestão e Req.Ambiental, Lda.
EST. DO PAÇO DO LUMIAR CAMPUS DO LUMIAR ED. D
LISBOA
1649-038 LISBOA

Unit: Nemus – Gestão e Requalificação Ambiental, Lda.

Sample Identification **178536 / 19**

Product: Natural Water
Reference: Sample 8
Packaging: bottle
Work Order: 1806/2019
The sample collection was not performed by Controlvet.
The results of this test report apply to the sample as received.

Test	Method	Result	Unit
(a) Organochlorine Pesticides (OCP) for GC-ECD	CZ_SOP_D06_03_169 (CSN EN ISO 6468, US EPA 8081, DIN 38407-3, samples prepared as per CZ_SOP_D06_03_P01 chap. 9.1, CZ_SOP_D06_03_P02 chap. 9.1)		
Hexachlorobenzene		<0.0050	µg/L
2,4'-DDT		<0.010	µg/L
4,4'-DDT		<0.010	µg/L
Hexachloroethane		<0.010	µg/L
Hexachlorobutadiene		<0.010	µg/L
1.2.3.5- & 1.2.4.5-Tetrachlorobenzene		<0.020	µg/L
1.2.3.4-Tetrachlorobenzene		<0.010	µg/L
Pentachlorobenzene		<0.010	µg/L
Trifluralin		<0.010	µg/L
Hexachlorocyclohexane Alpha		<0.010	µg/L
Hexachlorocyclohexane Beta		<0.010	µg/L
Hexachlorocyclohexane Gamma		<0.010	µg/L
Hexachlorocyclohexane Delta		<0.010	µg/L
Hexachlorocyclohexane Epsilon		<0.010	µg/L
Alachlor		<0.010	µg/L
Heptachlor		<0.010	µg/L
Aldrin		<0.0050	µg/L
Telodrin		<0.010	µg/L
Isodrin		<0.010	µg/L
Heptachloroepoxide-cis		<0.010	µg/L
Heptachloroepoxide-trans		<0.010	µg/L
2.4-DDE		<0.010	µg/L
alpha-Endosulfan		<0.010	µg/L
4.4`- DDE		<0.010	µg/L
Dieldrin		<0.010	µg/L
2.4-DDD		<0.010	µg/L
Endrin		<0.010	µg/L
beta-Endosulfan		<0.010	µg/L

Tondela
Zona Industrial Tondela - ZIM II Lote 2 e 6
3460-070 Tondela
Telef.: 232817817
Fax: 232817819

Eugénia Silva

Técnica Superior de Laboratório
Eugénia Silva

Analysis n.º:	QH / 15726 / 19
Collection Date:	-
Reception Date:	23-10-2019
Start Date:	24-10-2019
End Date:	29-11-2019
Client nº:	7401

Dear Sir
Nemus – Gestão e Req.Ambiental, Lda.
EST. DO PAÇO DO LUMIAR CAMPUS DO LUMIAR ED. D
LISBOA
1649-038 LISBOA

Unit: Nemus – Gestão e Requalificação Ambiental, Lda.

Sample Identification **178536 / 19**

Product: Natural Water
Reference: Sample 8
Packaging: bottle
Work Order: 1806/2019
The sample collection was not performed by Controlvet.
The results of this test report apply to the sample as received.

Test	Method	Result	Unit
4.4`-DDD		<0.010	µg/L
Methoxychlor		<0.010	µg/L
Dichlobenil		<0.050	µg/L
Sum of 3 tetrachlorobenzenes		<0.030	µg/L
Sum of 4 hexachlorcyclohexanes		<0.040	µg/L
Sum of 4 isomers DDT		<0.040	µg/L
Sum of 6 isomers DDT		<0.060	µg/L
Sum of endosulfanes		<0.020	µg/L
Sum of 5 hexachlorocyclohexanes		<0.050	µg/L
Sum of 27 OCPs + 3 CBs		<0.290	µg/L
Sum of 29 OCPs + 3 CBs		<0.350	µg/L
(a) PAH for GCMS	CZ_SOP_D06_03_161 (US EPA 8270, CSN EN ISO 6468, US EPA 8000D, samples preparation according to CZ_SOP_D06_03_P01 chap. 9.1, 9.4.1)		
Acenaphthene		<0.010 (LQ)	µg/L
Acenaphthylene		<0.010 (LQ)	µg/L
Anthracene		<0.020 (LQ)	µg/L
Benz(a)anthracene		<0.010 (LQ)	µg/L
Benzo(a)pyrene		<0.020 (LQ)	µg/L
Benzo(b)fluoranthene		<0.010 (LQ)	µg/L
Benzo(g.h.i)perylene		<0.010 (LQ)	µg/L
Benzo(k)fluoranthene		<0.010 (LQ)	µg/L
Chrysene		<0.010 (LQ)	µg/L
Dibenz(a.h)anthracene		<0.010 (LQ)	µg/L
Fluoranthene		<0.030 (LQ)	µg/L
Fluorene		<0.020 (LQ)	µg/L
Indeno(1.2.3.cd)pyrene		<0.010 (LQ)	µg/L
Naphthalene		<0.100 (LQ)	µg/L
Phenanthrene		<0.030 (LQ)	µg/L
Pyrene		<0.060 (LQ)	µg/L
Sum of 16 PAH		<0.370 (LQ)	µg/L
Sum of 4 PAH		<0.040 (LQ)	µg/L

Tondela
Zona Industrial Tondela - ZIM II Lote 2 e 6
3460-070 Tondela
Telef.: 232817817
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Eugénia Silva

Técnica Superior de Laboratório
Eugénia Silva

Analysis n.º:	QH / 15726 / 19
Collection Date:	-
Reception Date:	23-10-2019
Start Date:	24-10-2019
End Date:	29-11-2019
Client nº:	7401

Dear Sir
Nemus – Gestão e Req.Ambiental, Lda.
EST. DO PAÇO DO LUMIAR CAMPUS DO LUMIAR ED. D
LISBOA
1649-038 LISBOA

Unit: Nemus – Gestão e Requalificação Ambiental, Lda.

Sample Identification **178536 / 19**

Product: Natural Water
Reference: Sample 8
Packaging: bottle
Work Order: 1806/2019
The sample collection was not performed by Controlvet.
The results of this test report apply to the sample as received.

In this report change the report of organochlorine pesticides. Motive: laboratory source.

Equivalent internal method is one that has the same area of application (parameters and matrices) and that meets the performance characteristics, obtaining results comparable to the standard method (s)

Técnica Superior de Laboratório
Eugénia Silva

Analysis n.º:	QH / 15726 / 19
Collection Date:	-
Reception Date:	23-10-2019
Start Date:	24-10-2019
End Date:	29-11-2019
Client nº:	7401

Dear Sir
Nemus – Gestão e Req.Ambiental, Lda.
EST. DO PAÇO DO LUMIAR CAMPUS DO LUMIAR ED. D
LISBOA
1649-038 LISBOA

Unit: Nemus – Gestão e Requalificação Ambiental, Lda.

Sample Identification **178536 / 19**

Product: Natural Water
Reference: Sample 8
Packaging: bottle
Work Order: 1806/2019
The sample collection was not performed by Controlvet.
The results of this test report apply to the sample as received.

Notes

List of Abbreviations: EN-Estimated number; CFU-colony forming units; LQ - Limit of quantification; LD - limit of detection; LV - Limit Value; RV - Recommended Value, Pv - Parametric Value; C - According, A - Acceptable, NC - Nonconforming; Unit. - Unit, OD - Optical Density
The test marked with (s) was subcontracted and not accredited.
The test marked with (a) was subcontracted and is accredited.
In the results marked with (k) the microorganisms are present, but less than 3x dilution(if applicable).
In the results marked with (y) the microorganisms are present, but less than 4x dilution.
For the tests indicated by calculation techniques, the methodology followed can be made available on request.

This Test Report refers only to samples analyzed.
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Técnica Superior de Laboratório
Eugénia Silva

ALS Controlvet

Correction of Previous Reports
Issue Date 29-11-2019

Analysis n.º:	QH / 15727 / 19
Collection Date:	-
Reception Date:	23-10-2019
Start Date:	24-10-2019
End Date:	29-11-2019
Client nº:	7401

Dear Sir
Nemus – Gestão e Req.Ambiental, Lda.
EST. DO PAÇO DO LUMIAR CAMPUS DO LUMIAR ED. D
LISBOA
1649-038 LISBOA

Unit: Nemus – Gestão e Requalificação Ambiental, Lda.

Sample Identification **178537 / 19**

Product: Natural Water
Reference: Sample 10
Packaging: bottle
Work Order: 1806/2019
The sample collection was not performed by Controlvet.
The results of this test report apply to the sample as received.

Test	Method	Result	Unit
(a) Organochlorine Pesticides (OCP) for GC-ECD	CZ_SOP_D06_03_169 (CSN EN ISO 6468, US EPA 8081, DIN 38407-3, samples prepared as per CZ_SOP_D06_03_P01 chap. 9.1, CZ_SOP_D06_03_P02 chap. 9.1)		
Hexachlorobenzene		<0.0050	µg/L
2,4'-DDT		<0.010	µg/L
4,4'-DDT		<0.010	µg/L
Hexachloroethane		<0.010	µg/L
Hexachlorobutadiene		<0.010	µg/L
1.2.3.5- & 1.2.4.5-Tetrachlorobenzene		<0.020	µg/L
1.2.3.4-Tetrachlorobenzene		<0.010	µg/L
Pentachlorobenzene		<0.010	µg/L
Trifluralin		<0.010	µg/L
Hexachlorocyclohexane Alpha		<0.010	µg/L
Hexachlorocyclohexane Beta		<0.010	µg/L
Hexachlorocyclohexane Gamma		<0.010	µg/L
Hexachlorocyclohexane Delta		<0.010	µg/L
Hexachlorocyclohexane Epsilon		<0.010	µg/L
Alachlor		<0.010	µg/L
Heptachlor		<0.010	µg/L
Aldrin		<0.0050	µg/L
Telodrin		<0.010	µg/L
Isodrin		<0.010	µg/L
Heptachloroepoxide-cis		<0.010	µg/L
Heptachloroepoxide-trans		<0.010	µg/L
2.4-DDE		<0.010	µg/L
alpha-Endosulfan		<0.010	µg/L
4.4`- DDE		<0.010	µg/L
Dieldrin		<0.010	µg/L
2.4-DDD		<0.010	µg/L
Endrin		<0.010	µg/L
beta-Endosulfan		<0.010	µg/L

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Fax: 232817819

Eugénia Silva

Técnica Superior de Laboratório
Eugénia Silva

Analysis n.º:	QH / 15727 / 19
Collection Date:	-
Reception Date:	23-10-2019
Start Date:	24-10-2019
End Date:	29-11-2019
Client nº:	7401

Dear Sir
Nemus – Gestão e Req.Ambiental, Lda.
EST. DO PAÇO DO LUMIAR CAMPUS DO LUMIAR ED. D
LISBOA
1649-038 LISBOA

Unit: Nemus – Gestão e Requalificação Ambiental, Lda.

Sample Identification **178537 / 19**

Product: Natural Water
Reference: Sample 10
The sample collection was not performed by Controlvet.
The results of this test report apply to the sample as received.

Packaging: bottle
Work Order: 1806/2019

Test	Method	Result	Unit
4.4`-DDD		<0.010	µg/L
Methoxychlor		<0.010	µg/L
Dichlobenil		<0.050	µg/L
Sum of 3 tetrachlorobenzenes		<0.030	µg/L
Sum of 4 hexachlorcyclohexanes		<0.040	µg/L
Sum of 4 isomers DDT		<0.040	µg/L
Sum of 6 isomers DDT		<0.060	µg/L
Sum of endosulfanes		<0.020	µg/L
Sum of 5 hexachlorocyclohexanes		<0.050	µg/L
Sum of 27 OCPs + 3 CBs		<0.290	µg/L
Sum of 29 OCPs + 3 CBs		<0.350	µg/L
(a) PAH for GCMS	CZ_SOP_D06_03_161 (US EPA 8270, CSN EN ISO 6468, US EPA 8000D, samples preparation according to CZ_SOP_D06_03_P01 chap. 9.1, 9.4.1)		
Acenaphthene		<0.010 (LQ)	µg/L
Acenaphthylene		<0.010 (LQ)	µg/L
Anthracene		<0.020 (LQ)	µg/L
Benz(a)anthracene		<0.010 (LQ)	µg/L
Benzo(a)pyrene		<0.020 (LQ)	µg/L
Benzo(b)fluoranthene		<0.010 (LQ)	µg/L
Benzo(g.h.i)perylene		<0.010 (LQ)	µg/L
Benzo(k)fluoranthene		<0.010 (LQ)	µg/L
Chrysene		<0.010 (LQ)	µg/L
Dibenz(a.h)anthracene		<0.010 (LQ)	µg/L
Fluoranthene		<0.030 (LQ)	µg/L
Fluorene		<0.020 (LQ)	µg/L
Indeno(1.2.3.cd)pyrene		<0.010 (LQ)	µg/L
Naphthalene		<0.100 (LQ)	µg/L
Phenanthrene		<0.030 (LQ)	µg/L
Pyrene		<0.060 (LQ)	µg/L
Sum of 16 PAH		<0.370 (LQ)	µg/L
Sum of 4 PAH		<0.040 (LQ)	µg/L

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Eugénia Silva

Técnica Superior de Laboratório
Eugénia Silva

Analysis n.º:	QH / 15727 / 19
Collection Date:	-
Reception Date:	23-10-2019
Start Date:	24-10-2019
End Date:	29-11-2019
Client nº:	7401

Dear Sir
Nemus – Gestão e Req.Ambiental, Lda.
EST. DO PAÇO DO LUMIAR CAMPUS DO LUMIAR ED. D
LISBOA
1649-038 LISBOA

Unit: Nemus – Gestão e Requalificação Ambiental, Lda.

Sample Identification **178537 / 19**

Product: Natural Water
Reference: Sample 10
Packaging: bottle
Work Order: 1806/2019
The sample collection was not performed by Controlvet.
The results of this test report apply to the sample as received.

In this report change the report of organochlorine pesticides. Motive: laboratory source.

Equivalent internal method is one that has the same area of application (parameters and matrices) and that meets the performance characteristics, obtaining results comparable to the standard method (s)

Técnica Superior de Laboratório
Eugénia Silva

Analysis n.º:	QH / 15727 / 19
Collection Date:	-
Reception Date:	23-10-2019
Start Date:	24-10-2019
End Date:	29-11-2019
Client nº:	7401

Dear Sir
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EST. DO PAÇO DO LUMIAR CAMPUS DO LUMIAR ED. D
LISBOA
1649-038 LISBOA

Unit: Nemus – Gestão e Requalificação Ambiental, Lda.

Sample Identification **178537 / 19**

Product: Natural Water
Reference: Sample 10
Packaging: bottle
Work Order: 1806/2019
The sample collection was not performed by Controlvet.
The results of this test report apply to the sample as received.

Notes

List of Abbreviations: EN-Estimated number; CFU-colony forming units; LQ - Limit of quantification; LD - limit of detection; LV - Limit Value; RV - Recommended Value, Pv - Parametric Value; C - According, A - Acceptable, NC - Nonconforming; Unit. - Unit, OD - Optical Density
The test marked with (s) was subcontracted and not accredited.
The test marked with (a) was subcontracted and is accredited.
In the results marked with (k) the microorganisms are present, but less than 3x dilution(if applicable).
In the results marked with (y) the microorganisms are present, but less than 4x dilution.
For the tests indicated by calculation techniques, the methodology followed can be made available on request.

This Test Report refers only to samples analyzed.
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Eugénia Silva

ALS Controlvet

Correction of Previous Reports
Issue Date 29-11-2019

Analysis n.º:	QH / 15728 / 19
Collection Date:	-
Reception Date:	23-10-2019
Start Date:	24-10-2019
End Date:	29-11-2019
Client nº:	7401

Dear Sir
Nemus – Gestão e Req.Ambiental, Lda.
EST. DO PAÇO DO LUMIAR CAMPUS DO LUMIAR ED. D
LISBOA
1649-038 LISBOA

Unit: Nemus – Gestão e Requalificação Ambiental, Lda.

Sample Identification **178538 / 19**

Product: Natural Water
Reference: Sample 11
Packaging: bottle
Work Order: 1806/2019
The sample collection was not performed by Controlvet.
The results of this test report apply to the sample as received.

Test	Method	Result	Unit
(a) Organochlorine Pesticides (OCP) for GC-ECD	CZ_SOP_D06_03_169 (CSN EN ISO 6468, US EPA 8081, DIN 38407-3, samples prepared as per CZ_SOP_D06_03_P01 chap. 9.1, CZ_SOP_D06_03_P02 chap. 9.1)		
Hexachlorobenzene		<0.0050	µg/L
2,4'-DDT		<0.010	µg/L
4,4'-DDT		<0.010	µg/L
Hexachloroethane		<0.010	µg/L
Hexachlorobutadiene		<0.010	µg/L
1.2.3.5- & 1.2.4.5-Tetrachlorobenzene		<0.020	µg/L
1.2.3.4-Tetrachlorobenzene		<0.010	µg/L
Pentachlorobenzene		<0.010	µg/L
Trifluralin		<0.010	µg/L
Hexachlorocyclohexane Alpha		<0.010	µg/L
Hexachlorocyclohexane Beta		<0.010	µg/L
Hexachlorocyclohexane Gamma		<0.010	µg/L
Hexachlorocyclohexane Delta		<0.010	µg/L
Hexachlorocyclohexane Epsilon		<0.010	µg/L
Alachlor		<0.010	µg/L
Heptachlor		<0.010	µg/L
Aldrin		<0.0050	µg/L
Telodrin		<0.010	µg/L
Isodrin		<0.010	µg/L
Heptachloroepoxide-cis		<0.010	µg/L
Heptachloroepoxide-trans		<0.010	µg/L
2.4-DDE		<0.010	µg/L
alpha-Endosulfan		<0.010	µg/L
4.4`- DDE		<0.010	µg/L
Dieldrin		<0.010	µg/L
2.4-DDD		<0.010	µg/L
Endrin		<0.010	µg/L
beta-Endosulfan		<0.010	µg/L

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Eugénia Silva

Técnica Superior de Laboratório
Eugénia Silva

Analysis n.º:	QH / 15728 / 19
Collection Date:	-
Reception Date:	23-10-2019
Start Date:	24-10-2019
End Date:	29-11-2019
Client nº:	7401

Dear Sir
Nemus – Gestão e Req.Ambiental, Lda.
EST. DO PAÇO DO LUMIAR CAMPUS DO LUMIAR ED. D
LISBOA
1649-038 LISBOA

Unit: Nemus – Gestão e Requalificação Ambiental, Lda.

Sample Identification **178538 / 19**

Product: Natural Water
Reference: Sample 11
Packaging: bottle
Work Order: 1806/2019
The sample collection was not performed by Controlvet.
The results of this test report apply to the sample as received.

Test	Method	Result	Unit
4.4`-DDD		<0.010	µg/L
Methoxychlor		<0.010	µg/L
Dichlobenil		<0.050	µg/L
Sum of 3 tetrachlorobenzenes		<0.030	µg/L
Sum of 4 hexachlorcyclohexanes		<0.040	µg/L
Sum of 4 isomers DDT		<0.040	µg/L
Sum of 6 isomers DDT		<0.060	µg/L
Sum of endosulfanes		<0.020	µg/L
Sum of 5 hexachlorocyclohexanes		<0.050	µg/L
Sum of 27 OCPs + 3 CBs		<0.290	µg/L
Sum of 29 OCPs + 3 CBs		<0.350	µg/L
(a) PAH for GCMS	CZ_SOP_D06_03_161 (US EPA 8270, CSN EN ISO 6468, US EPA 8000D, samples preparation according to CZ_SOP_D06_03_P01 chap. 9.1, 9.4.1)		
Acenaphthene		<0.010 (LQ)	µg/L
Acenaphthylene		<0.010 (LQ)	µg/L
Anthracene		<0.020 (LQ)	µg/L
Benz(a)anthracene		<0.010 (LQ)	µg/L
Benzo(a)pyrene		<0.020 (LQ)	µg/L
Benzo(b)fluoranthene		<0.010 (LQ)	µg/L
Benzo(g.h.i)perylene		<0.010 (LQ)	µg/L
Benzo(k)fluoranthene		<0.010 (LQ)	µg/L
Chrysene		<0.010 (LQ)	µg/L
Dibenz(a.h)anthracene		<0.010 (LQ)	µg/L
Fluoranthene		<0.030 (LQ)	µg/L
Fluorene		<0.020 (LQ)	µg/L
Indeno(1.2.3.cd)pyrene		<0.010 (LQ)	µg/L
Naphthalene		<0.100 (LQ)	µg/L
Phenanthrene		<0.030 (LQ)	µg/L
Pyrene		<0.060 (LQ)	µg/L
Sum of 16 PAH		<0.370 (LQ)	µg/L
Sum of 4 PAH		<0.040 (LQ)	µg/L

Eugénia Silva

Técnica Superior de Laboratório
Eugénia Silva

Analysis n.º:	QH / 15728 / 19
Collection Date:	-
Reception Date:	23-10-2019
Start Date:	24-10-2019
End Date:	29-11-2019
Client nº:	7401

Dear Sir
Nemus – Gestão e Req.Ambiental, Lda.
EST. DO PAÇO DO LUMIAR CAMPUS DO LUMIAR ED. D
LISBOA
1649-038 LISBOA

Unit: Nemus – Gestão e Requalificação Ambiental, Lda.

Sample Identification **178538 / 19**

Product: Natural Water
Reference: Sample 11
Packaging: bottle
Work Order: 1806/2019
The sample collection was not performed by Controlvet.
The results of this test report apply to the sample as received.

In this report change the report of Organochlorine Pesticides. Motive: laboratory change.

Equivalent internal method is one that has the same area of application (parameters and matrices) and that meets the performance characteristics, obtaining results comparable to the standard method (s)

Eugénia Silva

Técnica Superior de Laboratório
Eugénia Silva

Analysis n.º:	QH / 15728 / 19
Collection Date:	-
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Start Date:	24-10-2019
End Date:	29-11-2019
Client nº:	7401

Dear Sir
Nemus – Gestão e Req.Ambiental, Lda.
EST. DO PAÇO DO LUMIAR CAMPUS DO LUMIAR ED. D
LISBOA
1649-038 LISBOA

Unit: Nemus – Gestão e Requalificação Ambiental, Lda.

Sample Identification **178538 / 19**

Product: Natural Water
Reference: Sample 11
Packaging: bottle
Work Order: 1806/2019
The sample collection was not performed by Controlvet.
The results of this test report apply to the sample as received.

Notes

List of Abbreviations: EN-Estimated number; CFU-colony forming units; LQ - Limit of quantification; LD - limit of detection; LV - Limit Value; RV - Recommended Value, Pv - Parametric Value; C - According, A - Acceptable, NC - Nonconforming; Unit. - Unit, OD - Optical Density
The test marked with (s) was subcontracted and not accredited.
The test marked with (a) was subcontracted and is accredited.
In the results marked with (k) the microorganisms are present, but less than 3x dilution(if applicable).
In the results marked with (y) the microorganisms are present, but less than 4x dilution.
For the tests indicated by calculation techniques, the methodology followed can be made available on request.

This Test Report refers only to samples analyzed.
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Eugénia Silva

Técnica Superior de Laboratório
Eugénia Silva

ALS Controlvet

Correction of Previous Reports
Issue Date 29-11-2019

Analysis n.º:	QH / 15729 / 19
Collection Date:	-
Reception Date:	23-10-2019
Start Date:	24-10-2019
End Date:	29-11-2019
Client nº:	7401

Dear Sir
Nemus – Gestão e Req.Ambiental, Lda.
EST. DO PAÇO DO LUMIAR CAMPUS DO LUMIAR ED. D
LISBOA
1649-038 LISBOA

Unit: Nemus – Gestão e Requalificação Ambiental, Lda.

Sample Identification **178539 / 19**

Product: Natural Water **Packaging:** bottle
Reference: Sample 12 **Work Order:** 1806/2019
The sample collection was not performed by Controlvet.
The results of this test report apply to the sample as received.

Test	Method	Result	Unit
(a) Organochlorine Pesticides (OCP) for GC-ECD	CZ_SOP_D06_03_169 (CSN EN ISO 6468, US EPA 8081, DIN 38407-3, samples prepared as per CZ_SOP_D06_03_P01 chap. 9.1, CZ_SOP_D06_03_P02 chap. 9.1)		
Hexachlorobenzene		<0.350	µg/L
2,4'-DDT		<0.010	µg/L
4,4'-DDT		<0.010	µg/L
Hexachloroethane		<0.010	µg/L
Hexachlorobutadiene		<0.010	µg/L
1.2.3.5- & 1.2.4.5-Tetrachlorobenzene		<0.020	µg/L
1.2.3.4-Tetrachlorobenzene		<0.010	µg/L
Pentachlorobenzene		<0.010	µg/L
Trifluralin		<0.010	µg/L
Hexachlorocyclohexane Alpha		<0.010	µg/L
Hexachlorocyclohexane Beta		<0.010	µg/L
Hexachlorocyclohexane Gamma		<0.010	µg/L
Hexachlorocyclohexane Delta		<0.010	µg/L
Hexachlorocyclohexane Epsilon		<0.010	µg/L
Alachlor		<0.010	µg/L
Heptachlor		<0.010	µg/L
Aldrin		<0.0050	µg/L
Telodrin		<0.010	µg/L
Isodrin		<0.010	µg/L
Heptachloroepoxide-cis		<0.010	µg/L
Heptachloroepoxide-trans		<0.010	µg/L
2.4-DDE		<0.010	µg/L
alpha-Endosulfan		<0.010	µg/L
4.4`- DDE		<0.010	µg/L
Dieldrin		<0.010	µg/L
2.4-DDD		<0.010	µg/L
Endrin		<0.010	µg/L
beta-Endosulfan		<0.010	µg/L

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Eugénia Silva

Técnica Superior de Laboratório
Eugénia Silva

Analysis n.º:	QH / 15729 / 19
Collection Date:	-
Reception Date:	23-10-2019
Start Date:	24-10-2019
End Date:	29-11-2019
Client nº:	7401

Dear Sir
Nemus – Gestão e Req.Ambiental, Lda.
EST. DO PAÇO DO LUMIAR CAMPUS DO LUMIAR ED. D
LISBOA
1649-038 LISBOA

Unit: Nemus – Gestão e Requalificação Ambiental, Lda.

Sample Identification **178539 / 19**

Product: Natural Water
Reference: Sample 12
Packaging: bottle
Work Order: 1806/2019
The sample collection was not performed by Controlvet.
The results of this test report apply to the sample as received.

Test	Method	Result	Unit
4.4`-DDD		<0.010	µg/L
Methoxychlor		<0.010	µg/L
Dichlobenil		<0.050	µg/L
Sum of 3 tetrachlorobenzenes		<0.030	µg/L
Sum of 4 hexachlorcyclohexanes		<0.040	µg/L
Sum of 4 isomers DDT		<0.040	µg/L
Sum of 6 isomers DDT		0.060	µg/L
Sum of endosulfanes		<0.020	µg/L
Sum of 5 hexachlorocyclohexanes		<0.050	µg/L
Sum of 27 OCPs + 3 CBs		<0.290	µg/L
Sum of 29 OCPs + 3 CBs		<0.350	µg/L
(a) PAH for GCMS	CZ_SOP_D06_03_161 (US EPA 8270, CSN EN ISO 6468, US EPA 8000D, samples preparation according to CZ_SOP_D06_03_P01 chap. 9.1, 9.4.1)		
Acenaphthene		<0.010 (LQ)	µg/L
Acenaphthylene		<0.010 (LQ)	µg/L
Anthracene		<0.020 (LQ)	µg/L
Benz(a)anthracene		<0.010 (LQ)	µg/L
Benzo(a)pyrene		<0.020 (LQ)	µg/L
Benzo(b)fluoranthene		<0.010 (LQ)	µg/L
Benzo(g.h.i)perylene		<0.010 (LQ)	µg/L
Benzo(k)fluoranthene		<0.010 (LQ)	µg/L
Chrysene		<0.010 (LQ)	µg/L
Dibenz(a.h)anthracene		<0.010 (LQ)	µg/L
Fluoranthene		<0.030 (LQ)	µg/L
Fluorene		<0.020 (LQ)	µg/L
Indeno(1.2.3.cd)pyrene		<0.010 (LQ)	µg/L
Naphthalene		<0.100 (LQ)	µg/L
Phenanthrene		<0.030 (LQ)	µg/L
Pyrene		<0.060 (LQ)	µg/L
Sum of 16 PAH		<0.370 (LQ)	µg/L
Sum of 4 PAH		<0.040 (LQ)	µg/L

Tondela
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Eugénia Silva

Técnica Superior de Laboratório
Eugénia Silva

Analysis n.º:	QH / 15729 / 19
Collection Date:	-
Reception Date:	23-10-2019
Start Date:	24-10-2019
End Date:	29-11-2019
Client nº:	7401

Dear Sir
Nemus – Gestão e Req.Ambiental, Lda.
EST. DO PAÇO DO LUMIAR CAMPUS DO LUMIAR ED. D
LISBOA
1649-038 LISBOA

Unit: Nemus – Gestão e Requalificação Ambiental, Lda.

Sample Identification **178539 / 19**

Product: Natural Water
Reference: Sample 12
Packaging: bottle
Work Order: 1806/2019
The sample collection was not performed by Controlvet.
The results of this test report apply to the sample as received.

In this report change the report of Organochlorine Pesticides. Motive: laboratory change.

Equivalent internal method is one that has the same area of application (parameters and matrices) and that meets the performance characteristics, obtaining results comparable to the standard method (s)

Técnica Superior de Laboratório
Eugénia Silva

Analysis n.º:	QH / 15729 / 19
Collection Date:	-
Reception Date:	23-10-2019
Start Date:	24-10-2019
End Date:	29-11-2019
Client nº:	7401

Dear Sir
Nemus – Gestão e Req.Ambiental, Lda.
EST. DO PAÇO DO LUMIAR CAMPUS DO LUMIAR ED. D
LISBOA
1649-038 LISBOA

Unit: Nemus – Gestão e Requalificação Ambiental, Lda.

Sample Identification **178539 / 19**

Product: Natural Water
Reference: Sample 12
Packaging: bottle
Work Order: 1806/2019
The sample collection was not performed by Controlvet.
The results of this test report apply to the sample as received.

Notes

List of Abbreviations: EN-Estimated number; CFU-colony forming units; LQ - Limit of quantification; LD - limit of detection; LV - Limit Value; RV - Recommended Value, Pv - Parametric Value; C - According, A - Acceptable, NC - Nonconforming; Unit. - Unit, OD - Optical Density
The test marked with (s) was subcontracted and not accredited.
The test marked with (a) was subcontracted and is accredited.
In the results marked with (k) the microorganisms are present, but less than 3x dilution(if applicable).
In the results marked with (y) the microorganisms are present, but less than 4x dilution.
For the tests indicated by calculation techniques, the methodology followed can be made available on request.

This Test Report refers only to samples analyzed.
Prohibited the partial reproduction of this

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Técnica Superior de Laboratório
Eugénia Silva

ALS Controlvet

Correction of Previous Reports
Issue Date 29-11-2019

Analysis n.º:	QH / 15730 / 19
Collection Date:	-
Reception Date:	23-10-2019
Start Date:	24-10-2019
End Date:	29-11-2019
Client nº:	7401

Dear Sir
Nemus – Gestão e Req.Ambiental, Lda.
EST. DO PAÇO DO LUMIAR CAMPUS DO LUMIAR ED. D
LISBOA
1649-038 LISBOA

Unit: Nemus – Gestão e Requalificação Ambiental, Lda.

Sample Identification **178540 / 19**

Product: Natural Water **Packaging:** bottle
Reference: Sample 13 **Work Order:** 1806/2019
The sample collection was not performed by Controlvet.
The results of this test report apply to the sample as received.

Test	Method	Result	Unit
(a) Organochlorine Pesticides (OCP) for GC-ECD	CZ_SOP_D06_03_169 (CSN EN ISO 6468, US EPA 8081, DIN 38407-3, samples prepared as per CZ_SOP_D06_03_P01 chap. 9.1, CZ_SOP_D06_03_P02 chap. 9.1)		
Hexachlorobenzene		<0.0050	µg/L
2,4'-DDT		<0.010	µg/L
4,4'-DDT		<0.010	µg/L
Hexachloroethane		<0.010	µg/L
Hexachlorobutadiene		<0.010	µg/L
1.2.3.5- & 1.2.4.5-Tetrachlorobenzene		<0.020	µg/L
1.2.3.4-Tetrachlorobenzene		<0.010	µg/L
Pentachlorobenzene		<0.010	µg/L
Trifluralin		<0.010	µg/L
Hexachlorocyclohexane Alpha		<0.010	µg/L
Hexachlorocyclohexane Beta		<0.010	µg/L
Hexachlorocyclohexane Gamma		<0.010	µg/L
Hexachlorocyclohexane Delta		<0.010	µg/L
Hexachlorocyclohexane Epsilon		<0.010	µg/L
Alachlor		<0.010	µg/L
Heptachlor		<0.010	µg/L
Aldrin		<0.0050	µg/L
Telodrin		<0.010	µg/L
Isodrin		<0.010	µg/L
Heptachloroepoxide-cis		<0.010	µg/L
Heptachloroepoxide-trans		<0.010	µg/L
2.4-DDE		<0.010	µg/L
alpha-Endosulfan		<0.010	µg/L
4.4`- DDE		<0.010	µg/L
Dieldrin		<0.010	µg/L
2.4-DDD		<0.010	µg/L
Endrin		<0.010	µg/L
beta-Endosulfan		<0.010	µg/L

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Eugénia Silva

Técnica Superior de Laboratório
Eugénia Silva

Analysis n.º:	QH / 15730 / 19
Collection Date:	-
Reception Date:	23-10-2019
Start Date:	24-10-2019
End Date:	29-11-2019
Client nº:	7401

Dear Sir
Nemus – Gestão e Req.Ambiental, Lda.
EST. DO PAÇO DO LUMIAR CAMPUS DO LUMIAR ED. D
LISBOA
1649-038 LISBOA

Unit: Nemus – Gestão e Requalificação Ambiental, Lda.

Sample Identification **178540 / 19**

Product: Natural Water
Reference: Sample 13
Packaging: bottle
Work Order: 1806/2019
The sample collection was not performed by Controlvet.
The results of this test report apply to the sample as received.

Test	Method	Result	Unit
4.4`-DDD		<0.010	µg/L
Methoxychlor		<0.010	µg/L
Dichlobenil		<0.050	µg/L
Sum of 3 tetrachlorobenzenes		<0.030	µg/L
Sum of 4 hexachlorcyclohexanes		<0.040	µg/L
Sum of 4 isomers DDT		<0.040	µg/L
Sum of 6 isomers DDT		<0.060	µg/L
Sum of endosulfanes		<0.020	µg/L
Sum of 5 hexachlorocyclohexanes		<0.050	µg/L
Sum of 27 OCPs + 3 CBs		<0.290	µg/L
Sum of 29 OCPs + 3 CBs		<0.350	µg/L
(a) PAH for GCMS	CZ_SOP_D06_03_161 (US EPA 8270, CSN EN ISO 6468, US EPA 8000D, samples preparation according to CZ_SOP_D06_03_P01 chap. 9.1, 9.4.1)		
Acenaphthene		<0.010 (LQ)	µg/L
Acenaphthylene		<0.010 (LQ)	µg/L
Anthracene		<0.020 (LQ)	µg/L
Benz(a)anthracene		<0.010 (LQ)	µg/L
Benzo(a)pyrene		<0.020 (LQ)	µg/L
Benzo(b)fluoranthene		<0.010 (LQ)	µg/L
Benzo(g.h.i)perylene		<0.010 (LQ)	µg/L
Benzo(k)fluoranthene		<0.010 (LQ)	µg/L
Chrysene		<0.010 (LQ)	µg/L
Dibenz(a.h)anthracene		<0.010 (LQ)	µg/L
Fluoranthene		<0.030 (LQ)	µg/L
Fluorene		<0.020 (LQ)	µg/L
Indeno(1.2.3.cd)pyrene		<0.010 (LQ)	µg/L
Naphthalene		<0.100 (LQ)	µg/L
Phenanthrene		<0.030 (LQ)	µg/L
Pyrene		<0.060 (LQ)	µg/L
Sum of 16 PAH		<0.370 (LQ)	µg/L
Sum of 4 PAH		<0.040 (LQ)	µg/L

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Eugénia Silva

Técnica Superior de Laboratório
Eugénia Silva

Analysis n.º:	QH / 15730 / 19
Collection Date:	-
Reception Date:	23-10-2019
Start Date:	24-10-2019
End Date:	29-11-2019
Client nº:	7401

Dear Sir
Nemus – Gestão e Req.Ambiental, Lda.
EST. DO PAÇO DO LUMIAR CAMPUS DO LUMIAR ED. D
LISBOA
1649-038 LISBOA

Unit: Nemus – Gestão e Requalificação Ambiental, Lda.

Sample Identification **178540 / 19**

Product: Natural Water
Reference: Sample 13
Packaging: bottle
Work Order: 1806/2019
The sample collection was not performed by Controlvet.
The results of this test report apply to the sample as received.

In this report change the report of Organochlorine Pesticides. Motive: laboratory change.

Equivalent internal method is one that has the same area of application (parameters and matrices) and that meets the performance characteristics, obtaining results comparable to the standard method (s)

Eugénia Silva

Técnica Superior de Laboratório
Eugénia Silva

Analysis n.º:	QH / 15730 / 19
Collection Date:	-
Reception Date:	23-10-2019
Start Date:	24-10-2019
End Date:	29-11-2019
Client nº:	7401

Dear Sir
Nemus – Gestão e Req.Ambiental, Lda.
EST. DO PAÇO DO LUMIAR CAMPUS DO LUMIAR ED. D
LISBOA
1649-038 LISBOA

Unit: Nemus – Gestão e Requalificação Ambiental, Lda.

Sample Identification **178540 / 19**

Product: Natural Water
Reference: Sample 13
Packaging: bottle
Work Order: 1806/2019
The sample collection was not performed by Controlvet.
The results of this test report apply to the sample as received.

Notes

List of Abbreviations: EN-Estimated number; CFU-colony forming units; LQ - Limit of quantification; LD - limit of detection; LV - Limit Value; RV - Recommended Value, Pv - Parametric Value; C - According, A - Acceptable, NC - Nonconforming; Unit. - Unit, OD - Optical Density
The test marked with (s) was subcontracted and not accredited.
The test marked with (a) was subcontracted and is accredited.
In the results marked with (k) the microorganisms are present, but less than 3x dilution(if applicable).
In the results marked with (y) the microorganisms are present, but less than 4x dilution.
For the tests indicated by calculation techniques, the methodology followed can be made available on request.

This Test Report refers only to samples analyzed.
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Eugénia Silva

ALS Controlvet

Correction of Previous Reports
Issue Date 29-11-2019

Analysis n.º:	QH / 15731 / 19
Collection Date:	-
Reception Date:	23-10-2019
Start Date:	24-10-2019
End Date:	29-11-2019
Client nº:	7401

Dear Sir
Nemus – Gestão e Req.Ambiental, Lda.
EST. DO PAÇO DO LUMIAR CAMPUS DO LUMIAR ED. D
LISBOA
1649-038 LISBOA

Unit: Nemus – Gestão e Requalificação Ambiental, Lda.

Sample Identification **178541 / 19**

Product: Natural Water
Reference: Sample 14
Packaging: bottle
Work Order: 1806/2019
The sample collection was not performed by Controlvet.
The results of this test report apply to the sample as received.

Test	Method	Result	Unit
(a) Organochlorine Pesticides (OCP) for GC-ECD	CZ_SOP_D06_03_169 (CSN EN ISO 6468, US EPA 8081, DIN 38407-3, samples prepared as per CZ_SOP_D06_03_P01 chap. 9.1, CZ_SOP_D06_03_P02 chap. 9.1)		
Hexachlorobenzene		<0.0050	µg/L
2,4'-DDT		<0.010	µg/L
4,4'-DDT		<0.010	µg/L
Hexachloroethane		<0.010	µg/L
Hexachlorobutadiene		<0.010	µg/L
1.2.3.5- & 1.2.4.5-Tetrachlorobenzene		<0.020	µg/L
1.2.3.4-Tetrachlorobenzene		<0.010	µg/L
Pentachlorobenzene		<0.010	µg/L
Trifluralin		<0.010	µg/L
Hexachlorocyclohexane Alpha		<0.010	µg/L
Hexachlorocyclohexane Beta		<0.010	µg/L
Hexachlorocyclohexane Gamma		<0.010	µg/L
Hexachlorocyclohexane Delta		<0.010	µg/L
Hexachlorocyclohexane Epsilon		<0.010	µg/L
Alachlor		<0.010	µg/L
Heptachlor		<0.010	µg/L
Aldrin		<0.0050	µg/L
Telodrin		<0.010	µg/L
Isodrin		<0.010	µg/L
Heptachloroepoxide-cis		<0.010	µg/L
Heptachloroepoxide-trans		<0.010	µg/L
2.4-DDE		<0.010	µg/L
alpha-Endosulfan		<0.010	µg/L
4.4`- DDE		<0.010	µg/L
Dieldrin		<0.010	µg/L
2.4-DDD		<0.010	µg/L
Endrin		<0.010	µg/L
beta-Endosulfan		<0.010	µg/L

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Eugénia Silva

Técnica Superior de Laboratório
Eugénia Silva

Analysis n.º:	QH / 15731 / 19
Collection Date:	-
Reception Date:	23-10-2019
Start Date:	24-10-2019
End Date:	29-11-2019
Client nº:	7401

Dear Sir
Nemus – Gestão e Req.Ambiental, Lda.
EST. DO PAÇO DO LUMIAR CAMPUS DO LUMIAR ED. D
LISBOA
1649-038 LISBOA

Unit: Nemus – Gestão e Requalificação Ambiental, Lda.

Sample Identification **178541 / 19**

Product: Natural Water
Reference: Sample 14
The sample collection was not performed by Controlvet.
The results of this test report apply to the sample as received.

Packaging: bottle
Work Order: 1806/2019

Test	Method	Result	Unit
4.4`-DDD		<0.010	µg/L
Methoxychlor		<0.010	µg/L
Dichlobenil		<0.050	µg/L
Sum of 3 tetrachlorobenzenes		<0.030	µg/L
Sum of 4 hexachlorcyclohexanes		<0.040	µg/L
Sum of 4 isomers DDT		<0.040	µg/L
Sum of 6 isomers DDT		<0.060	µg/L
Sum of endosulfanes		<0.020	µg/L
Sum of 5 hexachlorocyclohexanes		<0.050	µg/L
Sum of 27 OCPs + 3 CBs		<0.290	µg/L
Sum of 29 OCPs + 3 CBs		<0.350	µg/L
(a) PAH for GCMS	CZ_SOP_D06_03_161 (US EPA 8270, CSN EN ISO 6468, US EPA 8000D, samples preparation according to CZ_SOP_D06_03_P01 chap. 9.1, 9.4.1)		
Acenaphthene		<0.010 (LQ)	µg/L
Acenaphthylene		<0.010 (LQ)	µg/L
Anthracene		<0.020 (LQ)	µg/L
Benz(a)anthracene		<0.010 (LQ)	µg/L
Benzo(a)pyrene		<0.020 (LQ)	µg/L
Benzo(b)fluoranthene		<0.010 (LQ)	µg/L
Benzo(g.h.i)perylene		<0.010 (LQ)	µg/L
Benzo(k)fluoranthene		<0.010 (LQ)	µg/L
Chrysene		<0.010 (LQ)	µg/L
Dibenz(a.h)anthracene		<0.010 (LQ)	µg/L
Fluoranthene		<0.030 (LQ)	µg/L
Fluorene		<0.020 (LQ)	µg/L
Indeno(1.2.3.cd)pyrene		<0.010 (LQ)	µg/L
Naphthalene		<0.100 (LQ)	µg/L
Phenanthrene		<0.030 (LQ)	µg/L
Pyrene		<0.060 (LQ)	µg/L
Sum of 16 PAH		<0.370 (LQ)	µg/L
Sum of 4 PAH		<0.040 (LQ)	µg/L

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3460-070 Tondela
Telef.: 232817817
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Eugénia Silva

Técnica Superior de Laboratório
Eugénia Silva

Analysis n.º:	QH / 15731 / 19
Collection Date:	-
Reception Date:	23-10-2019
Start Date:	24-10-2019
End Date:	29-11-2019
Client nº:	7401

Dear Sir
Nemus – Gestão e Req.Ambiental, Lda.
EST. DO PAÇO DO LUMIAR CAMPUS DO LUMIAR ED. D
LISBOA
1649-038 LISBOA

Unit: Nemus – Gestão e Requalificação Ambiental, Lda.

Sample Identification **178541 / 19**

Product: Natural Water
Reference: Sample 14
Packaging: bottle
Work Order: 1806/2019
The sample collection was not performed by Controlvet.
The results of this test report apply to the sample as received.

In this report change the report of Organochlorine Pesticides. Motive: laboratory change.

Equivalent internal method is one that has the same area of application (parameters and matrices) and that meets the performance characteristics, obtaining results comparable to the standard method (s)

Eugénia Silva

Técnica Superior de Laboratório
Eugénia Silva

Analysis n.º:	QH / 15731 / 19
Collection Date:	-
Reception Date:	23-10-2019
Start Date:	24-10-2019
End Date:	29-11-2019
Client nº:	7401

Dear Sir
Nemus – Gestão e Req.Ambiental, Lda.
EST. DO PAÇO DO LUMIAR CAMPUS DO LUMIAR ED. D
LISBOA
1649-038 LISBOA

Unit: Nemus – Gestão e Requalificação Ambiental, Lda.

Sample Identification **178541 / 19**

Product: Natural Water
Reference: Sample 14
Packaging: bottle
Work Order: 1806/2019
The sample collection was not performed by Controlvet.
The results of this test report apply to the sample as received.

Notes

List of Abbreviations: EN-Estimated number; CFU-colony forming units; LQ - Limit of quantification; LD - limit of detection; LV - Limit Value; RV - Recommended Value, Pv - Parametric Value; C - According, A - Acceptable, NC - Nonconforming; Unit. - Unit, OD - Optical Density
The test marked with (s) was subcontracted and not accredited.
The test marked with (a) was subcontracted and is accredited.
In the results marked with (k) the microorganisms are present, but less than 3x dilution(if applicable).
In the results marked with (y) the microorganisms are present, but less than 4x dilution.
For the tests indicated by calculation techniques, the methodology followed can be made available on request.

This Test Report refers only to samples analyzed.
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Eugénia Silva

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ALS Controlvet

Correction of Previous Reports
Issue Date 29-11-2019

Analysis n.º:	QH / 15732 / 19
Collection Date:	-
Reception Date:	23-10-2019
Start Date:	24-10-2019
End Date:	29-11-2019
Client nº:	7401

Dear Sir
Nemus – Gestão e Req.Ambiental, Lda.
EST. DO PAÇO DO LUMIAR CAMPUS DO LUMIAR ED. D
LISBOA
1649-038 LISBOA

Unit: Nemus – Gestão e Requalificação Ambiental, Lda.

Sample Identification **178542 / 19**

Product: Natural Water
Reference: Sample 18
Packaging: bottle
Work Order: 1806/2019
The sample collection was not performed by Controlvet.
The results of this test report apply to the sample as received.

Test	Method	Result	Unit
(a) Organochlorine Pesticides (OCP) for GC-ECD	CZ_SOP_D06_03_169 (CSN EN ISO 6468, US EPA 8081, DIN 38407-3, samples prepared as per CZ_SOP_D06_03_P01 chap. 9.1, CZ_SOP_D06_03_P02 chap. 9.1)		
Hexachlorobenzene		<0.0050	µg/L
2,4'-DDT		<0.010	µg/L
4,4'-DDT		<0.010	µg/L
Hexachloroethane		<0.010	µg/L
Hexachlorobutadiene		<0.010	µg/L
1.2.3.5- & 1.2.4.5-Tetrachlorobenzene		<0.020	µg/L
1.2.3.4-Tetrachlorobenzene		<0.010	µg/L
Pentachlorobenzene		<0.010	µg/L
Trifluralin		<0.010	µg/L
Hexachlorocyclohexane Alpha		<0.010	µg/L
Hexachlorocyclohexane Beta		<0.010	µg/L
Hexachlorocyclohexane Gamma		<0.010	µg/L
Hexachlorocyclohexane Delta		<0.010	µg/L
Hexachlorocyclohexane Epsilon		<0.010	µg/L
Alachlor		<0.010	µg/L
Heptachlor		<0.010	µg/L
Aldrin		<0.0050	µg/L
Telodrin		<0.010	µg/L
Isodrin		<0.010	µg/L
Heptachloroepoxide-cis		<0.010	µg/L
Heptachloroepoxide-trans		<0.010	µg/L
2.4-DDE		<0.010	µg/L
alpha-Endosulfan		<0.010	µg/L
4.4`- DDE		<0.010	µg/L
Dieldrin		<0.010	µg/L
2.4-DDD		<0.010	µg/L
Endrin		<0.010	µg/L
beta-Endosulfan		<0.010	µg/L

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Eugénia Silva

Técnica Superior de Laboratório
Eugénia Silva

Analysis n.º:	QH / 15732 / 19
Collection Date:	-
Reception Date:	23-10-2019
Start Date:	24-10-2019
End Date:	29-11-2019
Client nº:	7401

Dear Sir
Nemus – Gestão e Req.Ambiental, Lda.
EST. DO PAÇO DO LUMIAR CAMPUS DO LUMIAR ED. D
LISBOA
1649-038 LISBOA

Unit: Nemus – Gestão e Requalificação Ambiental, Lda.

Sample Identification **178542 / 19**

Product: Natural Water
Reference: Sample 18
Packaging: bottle
Work Order: 1806/2019
The sample collection was not performed by Controlvet.
The results of this test report apply to the sample as received.

Test	Method	Result	Unit
4.4`-DDD		<0.010	µg/L
Methoxychlor		<0.010	µg/L
Dichlobenil		<0.050	µg/L
Sum of 3 tetrachlorobenzenes		<0.050	µg/L
Sum of 4 hexachlorcyclohexanes		<0.040	µg/L
Sum of 4 isomers DDT		<0.040	µg/L
Sum of 6 isomers DDT		<0.060	µg/L
Sum of endosulfanes		<0.020	µg/L
Sum of 5 hexachlorocyclohexanes		<0.050	µg/L
Sum of 27 OCPs + 3 CBs		<0.290	µg/L
Sum of 29 OCPs + 3 CBs		<0.350	µg/L
(a) PAH for GCMS	CZ_SOP_D06_03_161 (US EPA 8270, CSN EN ISO 6468, US EPA 8000D, samples preparation according to CZ_SOP_D06_03_P01 chap. 9.1, 9.4.1)		
Acenaphthene		<0.010 (LQ)	µg/L
Acenaphthylene		<0.010 (LQ)	µg/L
Anthracene		<0.020 (LQ)	µg/L
Benz(a)anthracene		<0.010 (LQ)	µg/L
Benzo(a)pyrene		<0.020 (LQ)	µg/L
Benzo(b)fluoranthene		<0.010 (LQ)	µg/L
Benzo(g.h.i)perylene		<0.010 (LQ)	µg/L
Benzo(k)fluoranthene		<0.010 (LQ)	µg/L
Chrysene		<0.010 (LQ)	µg/L
Dibenz(a.h)anthracene		<0.010 (LQ)	µg/L
Fluoranthene		<0.030 (LQ)	µg/L
Fluorene		<0.020 (LQ)	µg/L
Indeno(1.2.3.cd)pyrene		<0.010 (LQ)	µg/L
Naphthalene		<0.100 (LQ)	µg/L
Phenanthrene		<0.030 (LQ)	µg/L
Pyrene		<0.060 (LQ)	µg/L
Sum of 16 PAH		<0.370 (LQ)	µg/L
Sum of 4 PAH		<0.040 (LQ)	µg/L

Tondela
Zona Industrial Tondela - ZIM II Lote 2 e 6
3460-070 Tondela
Telef.: 232817817
Fax: 232817819

Eugénia Silva

Técnica Superior de Laboratório
Eugénia Silva

Analysis n.º:	QH / 15732 / 19
Collection Date:	-
Reception Date:	23-10-2019
Start Date:	24-10-2019
End Date:	29-11-2019
Client nº:	7401

Dear Sir
Nemus – Gestão e Req.Ambiental, Lda.
EST. DO PAÇO DO LUMIAR CAMPUS DO LUMIAR ED. D
LISBOA
1649-038 LISBOA

Unit: Nemus – Gestão e Requalificação Ambiental, Lda.

Sample Identification **178542 / 19**

Product: Natural Water
Reference: Sample 18
Packaging: bottle
Work Order: 1806/2019
The sample collection was not performed by Controlvet.
The results of this test report apply to the sample as received.

In this report change the report of organochlorine pesticides. Motive: laboratory source.

Equivalent internal method is one that has the same area of application (parameters and matrices) and that meets the performance characteristics, obtaining results comparable to the standard method (s)

Técnica Superior de Laboratório
Eugénia Silva

Analysis n.º:	QH / 15732 / 19
Collection Date:	-
Reception Date:	23-10-2019
Start Date:	24-10-2019
End Date:	29-11-2019
Client nº:	7401

Dear Sir
Nemus – Gestão e Req.Ambiental, Lda.
EST. DO PAÇO DO LUMIAR CAMPUS DO LUMIAR ED. D
LISBOA
1649-038 LISBOA

Unit: Nemus – Gestão e Requalificação Ambiental, Lda.

Sample Identification **178542 / 19**

Product: Natural Water
Reference: Sample 18
Packaging: bottle
Work Order: 1806/2019
The sample collection was not performed by Controlvet.
The results of this test report apply to the sample as received.

Notes

List of Abbreviations: EN-Estimated number; CFU-colony forming units; LQ - Limit of quantification; LD - limit of detection; LV - Limit Value; RV - Recommended Value, Pv - Parametric Value; C - According, A - Acceptable, NC - Nonconforming; Unit. - Unit, OD - Optical Density
The test marked with (s) was subcontracted and not accredited.
The test marked with (a) was subcontracted and is accredited.
In the results marked with (k) the microorganisms are present, but less than 3x dilution(if applicable).
In the results marked with (y) the microorganisms are present, but less than 4x dilution.
For the tests indicated by calculation techniques, the methodology followed can be made available on request.

This Test Report refers only to samples analyzed.
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Eugénia Silva

Técnica Superior de Laboratório
Eugénia Silva

ALS Controlvet

Correction of Previous Reports
Issue Date 29-11-2019

Analysis n.º:	QH / 15733 / 19
Collection Date:	-
Reception Date:	23-10-2019
Start Date:	24-10-2019
End Date:	29-11-2019
Client nº:	7401

Dear Sir
Nemus – Gestão e Req.Ambiental, Lda.
EST. DO PAÇO DO LUMIAR CAMPUS DO LUMIAR ED. D
LISBOA
1649-038 LISBOA

Unit: Nemus – Gestão e Requalificação Ambiental, Lda.

Sample Identification **178543 / 19**

Product: Natural Water
Reference: Sample 22
Packaging: bottle
Work Order: 1806/2019
The sample collection was not performed by Controlvet.
The results of this test report apply to the sample as received.

Test	Method	Result	Unit
(a) Organochlorine Pesticides (OCP) for GC-ECD	CZ_SOP_D06_03_169 (CSN EN ISO 6468, US EPA 8081, DIN 38407-3, samples prepared as per CZ_SOP_D06_03_P01 chap. 9.1, CZ_SOP_D06_03_P02 chap. 9.1)		
Hexachlorobenzene		<0.0050	µg/L
2,4'-DDT		<0.010	µg/L
4,4'-DDT		<0.010	µg/L
Hexachloroethane		<0.010	µg/L
Hexachlorobutadiene		<0.010	µg/L
1.2.3.5- & 1.2.4.5-Tetrachlorobenzene		<0.020	µg/L
1.2.3.4-Tetrachlorobenzene		<0.010	µg/L
Pentachlorobenzene		<0.010	µg/L
Trifluralin		<0.010	µg/L
Hexachlorocyclohexane Alpha		<0.010	µg/L
Hexachlorocyclohexane Beta		<0.010	µg/L
Hexachlorocyclohexane Gamma		<0.010	µg/L
Hexachlorocyclohexane Delta		<0.010	µg/L
Hexachlorocyclohexane Epsilon		<0.010	µg/L
Alachlor		<0.010	µg/L
Heptachlor		<0.010	µg/L
Aldrin		<0.0050	µg/L
Telodrin		<0.010	µg/L
Isodrin		<0.010	µg/L
Heptachloroepoxide-cis		<0.010	µg/L
Heptachloroepoxide-trans		<0.010	µg/L
2.4-DDE		<0.010	µg/L
alpha-Endosulfan		<0.010	µg/L
4.4`- DDE		<0.010	µg/L
Dieldrin		<0.010	µg/L
2.4-DDD		<0.010	µg/L
Endrin		<0.010	µg/L
beta-Endosulfan		<0.010	µg/L

Tondela
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Técnica Superior de Laboratório
Eugénia Silva

Analysis n.º:	QH / 15733 / 19
Collection Date:	-
Reception Date:	23-10-2019
Start Date:	24-10-2019
End Date:	29-11-2019
Client nº:	7401

Dear Sir
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EST. DO PAÇO DO LUMIAR CAMPUS DO LUMIAR ED. D
LISBOA
1649-038 LISBOA

Unit: Nemus – Gestão e Requalificação Ambiental, Lda.

Sample Identification **178543 / 19**

Product: Natural Water
Reference: Sample 22
Packaging: bottle
Work Order: 1806/2019
The sample collection was not performed by Controlvet.
The results of this test report apply to the sample as received.

Test	Method	Result	Unit
4.4`-DDD		<0.010	µg/L
Methoxychlor		<0.010	µg/L
Dichlobenil		<0.050	µg/L
Sum of 3 tetrachlorobenzenes		<0.030	µg/L
Sum of 4 hexachlorcyclohexanes		<0.040	µg/L
Sum of 4 isomers DDT		<0.040	µg/L
Sum of 6 isomers DDT		<0.060	µg/L
Sum of endosulfanes		<0.020	µg/L
Sum of 5 hexachlorocyclohexanes		<0.050	µg/L
Sum of 27 OCPs + 3 CBs		<0.290	µg/L
Sum of 29 OCPs + 3 CBs		<0.350	µg/L
(a) PAH for GCMS	CZ_SOP_D06_03_161 (US EPA 8270, CSN EN ISO 6468, US EPA 8000D, samples preparation according to CZ_SOP_D06_03_P01 chap. 9.1, 9.4.1)		
Acenaphthene		<0.010 (LQ)	µg/L
Acenaphthylene		<0.010 (LQ)	µg/L
Anthracene		<0.020 (LQ)	µg/L
Benz(a)anthracene		<0.010 (LQ)	µg/L
Benzo(a)pyrene		<0.020 (LQ)	µg/L
Benzo(b)fluoranthene		<0.010 (LQ)	µg/L
Benzo(g.h.i)perylene		<0.010 (LQ)	µg/L
Benzo(k)fluoranthene		<0.010 (LQ)	µg/L
Chrysene		<0.010 (LQ)	µg/L
Dibenz(a.h)anthracene		<0.010 (LQ)	µg/L
Fluoranthene		<0.030 (LQ)	µg/L
Fluorene		<0.020 (LQ)	µg/L
Indeno(1.2.3.cd)pyrene		<0.010 (LQ)	µg/L
Naphthalene		<0.100 (LQ)	µg/L
Phenanthrene		<0.030 (LQ)	µg/L
Pyrene		<0.060 (LQ)	µg/L
Sum of 16 PAH		<0.370 (LQ)	µg/L
Sum of 4 PAH		<0.040 (LQ)	µg/L

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Eugénia Silva

Técnica Superior de Laboratório
Eugénia Silva

Analysis n.º:	QH / 15733 / 19
Collection Date:	-
Reception Date:	23-10-2019
Start Date:	24-10-2019
End Date:	29-11-2019
Client nº:	7401

Dear Sir
Nemus – Gestão e Req.Ambiental, Lda.
EST. DO PAÇO DO LUMIAR CAMPUS DO LUMIAR ED. D
LISBOA
1649-038 LISBOA

Unit: Nemus – Gestão e Requalificação Ambiental, Lda.

Sample Identification **178543 / 19**

Product: Natural Water
Reference: Sample 22
Packaging: bottle
Work Order: 1806/2019
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Técnica Superior de Laboratório
Eugénia Silva

Analysis n.º:	QH / 15733 / 19
Collection Date:	-
Reception Date:	23-10-2019
Start Date:	24-10-2019
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Client nº:	7401

Dear Sir
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EST. DO PAÇO DO LUMIAR CAMPUS DO LUMIAR ED. D
LISBOA
1649-038 LISBOA

Unit: Nemus – Gestão e Requalificação Ambiental, Lda.

Sample Identification **178543 / 19**

Product: Natural Water
Reference: Sample 22
Packaging: bottle
Work Order: 1806/2019
The sample collection was not performed by Controlvet.
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Notes

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Técnica Superior de Laboratório
Eugénia Silva

SYNLAB Analytics & Services B.V.
Correspondentieadres
Steenhouwerstraat 15 · 3194 AG Rotterdam
Tel.: +34 93 363 6000
www.synlab.nl

Analytical report

NEMUS - Gestão e Requalificação Ambiental Lda
César Jesus
Estrada do Paço do Lumiar
Campus do Lumiar,Edifício D, R/Chão
PT-1649-038 LISBOA

Your Project name	: Conservation_Plan_Lukanga_Swamp
Your Project number	: t19024
SYNLAB report number	: 13113941, version: 1
Certificate code	: PIVUHPHL

Rotterdam, 14.11.2019

Dear Mr./Mrs,

Attached you find the results of the laboratory tests carried out for your project t19024. The tests were carried out according to your order. The reported results refer only to the tested samples. The sample description, sample date (if provided) and project description were adopted from your order.

All tests were carried out by SYNLAB Analytics & Services B.V., Steenhouwerstraat 15, Rotterdam, Netherlands. Tests outsourced or carried out by the SYNLAB laboratory in France (99-101 Avenue Louis Roche, Gennevilliers) are marked in the report.

This certificate contains inclusive attachments 14 pages. In case of a version number of '2' or higher all former versions of the certificate are invalid. All attachments are inextricably part of this certificate. Only reproduction of the whole report is allowed.

In case of questions and/or remarks related to this certificate, for example in case of information required about measurement uncertainty of the analytical methods, please contact our Customer Support department.

Yours faithfully,

Jaap-Willem Hutter
Technical Director

SYNLAB Analytics & Services B.V. is accredited under nr. L028 by the Raad voor Accreditatie, according to the criteria for testing laboratories ISO/IEC 17025:2005.

All our work is carried out under the General Conditions, kept at the Kamer van Koophandel (Chamber of Commerce) in Rotterdam, Netherlands:Trade record: KVK Rotterdam 24265286.

Analytical report

Project name	Conservation_Plan_Lukanga_Swamp	Order date	27.09.2019
Project number	t19024	Starting date	27.09.2019
Report number	13113941 - 1	Report date	09.10.2019

Code	Sample type	Sample description
001	Sediment	1
002	Sediment	2
003	Sediment	3
004	Sediment	4
005	Sediment	5

Analysis	Unit	Q	001	002	003	004	005
dry weight	wght.-%	Q	51.4	70.8	59.2	85.3	73.0
sample pretreatment (sieving <2mm)			yes	yes	yes	yes	yes
TOC	mg/kgdm	Q	33000	7800	30000	<2000	<2000
PARTICAL SIZE							
min. parts <2um	% of DM	Q	43	5.8	<1	<1	2.8
min. parts <20um	% of DM		56	8.6	2.1	1.6	22
min. parts <63um	% of DM	Q	70	21	16	4.8	62
min. parts <2 mm	% of DM	Q	96	97	89	98	87
min. parts >2 mm	% of DM	Q	<1	<1	<1	<1	<1
METALS							
aluminium	mg/kgdm	Q	27000	4600	1500	9600	29000
arsenic	mg/kgdm	Q	<4	<4	<4	57	8.8
cadmium	mg/kgdm	Q	<0.2	<0.2	<0.2	<0.2	<0.2
chromium	mg/kgdm	Q	29	23	<10	170	140
cobalt	mg/kgdm	Q	19	4.7	<1.5	20	570
copper	mg/kgdm	Q	190	6.8	<5	49	2600
mercury	mg/kgdm	Q	<0.05	<0.05	<0.05	<0.05	<0.05
lead	mg/kgdm	Q	<10	<10	<10	<10	<10
nickel	mg/kgdm	Q	18	4.5	<3	31	24
iron	mg/kgdm	Q	14000	19000	1700	85000	64000
zinc	mg/kgdm	Q	<20	<20	27	26	51
POLYCYCLIC AROMATIC HYDROCARBONS							
phenanthrene	mg/kgdm	Q	<0.02	<0.02	<0.02	<0.02	0.02
anthracene	mg/kgdm	Q	<0.02	<0.02	<0.02	<0.02	<0.02
fluoranthene	mg/kgdm	Q	<0.02	<0.02	<0.02	<0.02	0.06
pyrene	mg/kgdm	Q	<0.02	<0.02	<0.02	<0.02	0.05
benzo(a)anthracene	mg/kgdm	Q	<0.02	<0.02	<0.02	<0.02	0.03
chrysene	mg/kgdm	Q	<0.02	<0.02	<0.02	<0.02	0.02
benzo(a)pyrene	mg/kgdm	Q	<0.02	<0.02	<0.02	<0.02	0.03
benzo(ghi)perylene	mg/kgdm	Q	<0.02	<0.02	<0.02	<0.02	0.02
indeno(1,2,3-cd)pyrene	mg/kgdm	Q	<0.02	<0.02	<0.02	<0.02	<0.02
sum PAHs (9 OSPAR)	mg/kgdm		<0.18	<0.18	<0.18	<0.18	0.23
CHLOROBENZENES							
hexachlorobenzene	µg/kgdm		<0.5	<0.5	<0.5	<0.5	<0.5
POLYCHLORINATED BIPHENYLS							

Analysis marked with Q are accredited by the RvA

Initials :

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Analytical report

Project name	Conservation_Plan_Lukanga_Swamp	Order date	27.09.2019
Project number	t19024	Starting date	27.09.2019
Report number	13113941 - 1	Report date	09.10.2019

Code	Sample type	Sample description
001	Sediment	1
002	Sediment	2
003	Sediment	3
004	Sediment	4
005	Sediment	5

Analysis	Unit	Q	001	002	003	004	005
PCB 28	µg/kgdm	Q	<1	<1	<1	<1	<1
PCB 52	µg/kgdm	Q	<1	<1	<1	<1	<1
PCB 101	µg/kgdm	Q	<1	<1	<1	<1	<1
PCB 118	µg/kgdm	Q	<1	<1	<1	<1	<1
PCB 138	µg/kgdm	Q	<1	<1	<1	<1	<1
PCB 153	µg/kgdm	Q	<1	<1	<1	<1	<1
PCB 180	µg/kgdm	Q	<1	<1	<1	<1	<1
total (7) PCB	µg/kgdm		4.9	4.9	4.9	4.9	4.9
SEVERAL CHEMICAL ANALYSIS							
specific weight	g/l		2179	2565	2190	2556	2716

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Analytical report

Project name	Conservation_Plan_Lukanga_Swamp	Order date	27.09.2019
Project number	t19024	Starting date	27.09.2019
Report number	13113941 - 1	Report date	09.10.2019

Code	Sample type	Sample description
006	Sediment	6
007	Sediment	7
008	Sediment	8
009	Sediment	9
010	Sediment	10

Analysis	Unit	Q	006	007	008	009	010
dry weight	wght.-%	Q	55.4	76.6	58.0	74.4	51.4
sample pretreatment (sieving <2mm)			yes		yes	yes	yes
TOC	mg/kgdm	Q	35000	12000	<2000	<2000	50000
PARTICAL SIZE							
min. parts <2um	% of DM	Q	50	29	8.0	<1	49
min. parts <20um	% of DM		58	33	47	<1	62
min. parts <63um	% of DM	Q	65	36	63	13	68
min. parts <2 mm	% of DM	Q	89	81	74	93	89
min. parts >2 mm	% of DM	Q	<1	<1	<1	<1	<1
METALS							
aluminium	mg/kgdm	Q	28000	43000	13000	12000	45000
arsenic	mg/kgdm	Q	<4	<4	5.5	4.0	<4
cadmium	mg/kgdm	Q	<0.2	<0.2	<0.2	<0.2	<0.2
chromium	mg/kgdm	Q	29	55	19	14	20
cobalt	mg/kgdm	Q	6.0	30	180	140	10
copper	mg/kgdm	Q	39	180	3700	5000	55
mercury	mg/kgdm	Q	<0.05	<0.05	<0.05	<0.05	<0.05
lead	mg/kgdm	Q	<10	10	10	<10	14
nickel	mg/kgdm	Q	19	32	17	13	14
iron	mg/kgdm	Q	8300	14000	21000	14000	9300
zinc	mg/kgdm	Q	<20	45	40	38	<20
POLYCYCLIC AROMATIC HYDROCARBONS							
phenanthrene	mg/kgdm	Q	<0.02	<0.02	<0.02	<0.02	<0.03 [1)]
anthracene	mg/kgdm	Q	<0.02	<0.02	<0.02	<0.02	<0.03 [1)]
fluoranthene	mg/kgdm	Q	<0.02	<0.02	<0.02	<0.02	<0.03 [1)]
pyrene	mg/kgdm	Q	<0.02	<0.02	<0.02	<0.02	<0.03 [1)]
benzo(a)anthracene	mg/kgdm	Q	<0.02	<0.02	<0.02	<0.02	<0.03 [1)]
chrysene	mg/kgdm	Q	<0.02	<0.02	<0.02	<0.02	<0.03 [1)]
benzo(a)pyrene	mg/kgdm	Q	<0.02	<0.02	<0.02	<0.02	<0.03 [1)]
benzo(ghi)perylene	mg/kgdm	Q	<0.02	<0.02	<0.02	<0.02	<0.03 [1)]
indeno(1,2,3-cd)pyrene	mg/kgdm	Q	<0.02	<0.02	<0.02	<0.02	<0.03 [1)]
sum PAHs (9 OSPAR)	mg/kgdm		<0.18	<0.18	<0.18	<0.18	<0.27
CHLOROBENZENES							
hexachlorobenzene	µg/kgdm		<0.5	<0.5	<0.5	<0.5	<0.54 [1)]
POLYCHLORINATED BIPHENYLS							

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Analytical report

Project name	Conservation_Plan_Lukanga_Swamp	Order date	27.09.2019
Project number	t19024	Starting date	27.09.2019
Report number	13113941 - 1	Report date	09.10.2019

Code	Sample type	Sample description
006	Sediment	6
007	Sediment	7
008	Sediment	8
009	Sediment	9
010	Sediment	10

Analysis	Unit	Q	006	007	008	009	010
PCB 28	µg/kgdm	Q	<1	<1	<1	<1	<1
PCB 52	µg/kgdm	Q	<1	<1	<1	<1	<1
PCB 101	µg/kgdm	Q	<1	<1	<1	<1	<1
PCB 118	µg/kgdm	Q	<1	<1	<1	<1	<1
PCB 138	µg/kgdm	Q	<1	<1	<1	<1	<1
PCB 153	µg/kgdm	Q	<1	<1	<1	<1	<1
PCB 180	µg/kgdm	Q	<1	<1	<1	<1	<1
total (7) PCB	µg/kgdm		4.9	4.9	4.9	4.9	4.9
SEVERAL CHEMICAL ANALYSIS							
specific weight	g/l		2147	2338	2419	2570	2141

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Analytical report

Project name	Conservation_Plan_Lukanga_Swamp	Order date	27.09.2019
Project number	t19024	Starting date	27.09.2019
Report number	13113941 - 1	Report date	09.10.2019

Remarks

1	Increased detectionlimit due to a high moisture content.

Initials :

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Analytical report

Project name	Conservation_Plan_Lukanga_Swamp	Order date	27.09.2019
Project number	t19024	Starting date	27.09.2019
Report number	13113941 - 1	Report date	09.10.2019

Code	Sample type	Sample description
011	Sediment	11
012	Sediment	12
013	Sediment	13
014	Sediment	14
015	Sediment	15

Analysis	Unit	Q	011	012	013	014	015
dry weight	wght.-%	Q	84.2	26.2	74.2	77.4	77.1
sample pretreatment (sieving <2mm)			yes	yes	yes	yes	yes
TOC	mg/kgdm	Q	<2000	57000	11000	<2000	3100
PARTICAL SIZE							
min. parts <2um	% of DM	Q	<1	14	15	1.9	<1
min. parts <20um	% of DM		<1	30	26	2.4	3.9
min. parts <63um	% of DM	Q	6.5	40	36	5.7	5.2
min. parts <2 mm	% of DM	Q	97	56	100	98	99
min. parts >2 mm	% of DM	Q	<1	<1	<1	<1	<1
METALS							
aluminium	mg/kgdm	Q	1700	35000	16000	2200	2800
arsenic	mg/kgdm	Q	<4	<4	<4	<4	<4
cadmium	mg/kgdm	Q	<0.2	<0.2	<0.2	<0.2	<0.2
chromium	mg/kgdm	Q	12	30	24	<10	18
cobalt	mg/kgdm	Q	4.1	13	86	7.7	160
copper	mg/kgdm	Q	8.7	42	1300	92	800
mercury	mg/kgdm	Q	<0.05	<0.05	<0.05	<0.05	<0.05
lead	mg/kgdm	Q	13	<10	10	<10	<10
nickel	mg/kgdm	Q	<3	28	15	<3	6.0
iron	mg/kgdm	Q	6500	5900	16000	2800	7200
zinc	mg/kgdm	Q	<20	<20	24	<20	<20
POLYCYCLIC AROMATIC HYDROCARBONS							
phenanthrene	mg/kgdm	Q	<0.02	<0.05 [1)]	0.05	<0.02	<0.02
anthracene	mg/kgdm	Q	<0.02	<0.05 [1)]	<0.02	<0.02	<0.02
fluoranthene	mg/kgdm	Q	<0.02	<0.05 [1)]	0.10	<0.02	0.05
pyrene	mg/kgdm	Q	<0.02	<0.05 [1)]	0.08	<0.02	0.04
benzo(a)anthracene	mg/kgdm	Q	<0.02	<0.05 [1)]	0.05	<0.02	<0.02
chrysene	mg/kgdm	Q	<0.02	<0.05 [1)]	0.04	<0.02	<0.02
benzo(a)pyrene	mg/kgdm	Q	<0.02	<0.05 [1)]	0.04	<0.02	<0.02
benzo(ghi)perylene	mg/kgdm	Q	<0.02	<0.05 [1)]	0.03	<0.02	<0.02
indeno(1,2,3-cd)pyrene	mg/kgdm	Q	<0.02	<0.05 [1)]	0.03	<0.02	<0.02
sum PAHs (9 OSPAR)	mg/kgdm		<0.18	<0.45	0.42	<0.18	<0.18
CHLOROBENZENES							
hexachlorobenzene	µg/kgdm		<0.5	<1.0 [1)]	<0.5	<0.5	<0.5
POLYCHLORINATED BIPHENYLS							

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Analytical report

Project name	Conservation_Plan_Lukanga_Swamp	Order date	27.09.2019
Project number	t19024	Starting date	27.09.2019
Report number	13113941 - 1	Report date	09.10.2019

Code	Sample type	Sample description
011	Sediment	11
012	Sediment	12
013	Sediment	13
014	Sediment	14
015	Sediment	15

Analysis	Unit	Q	011	012	013	014	015
PCB 28	µg/kgdm	Q	<1	<1	<1	<1	<1
PCB 52	µg/kgdm	Q	<1	<1	<1	<1	<1
PCB 101	µg/kgdm	Q	<1	<1	<1	<1	<1
PCB 118	µg/kgdm	Q	<1	<1	<1	<1	<1
PCB 138	µg/kgdm	Q	<1	<1	<1	<1	<1
PCB 153	µg/kgdm	Q	<1	<1	<1	<1	<1
PCB 180	µg/kgdm	Q	<1	<1	<1	<1	<1
total (7) PCB	µg/kgdm		4.9	4.9	4.9	4.9	4.9
SEVERAL CHEMICAL ANALYSIS							
specific weight	g/l		2546	2071	2487	2514	2514

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Analytical report

Project name	Conservation_Plan_Lukanga_Swamp	Order date	27.09.2019
Project number	t19024	Starting date	27.09.2019
Report number	13113941 - 1	Report date	09.10.2019

Remarks

1	Increased detectionlimit due to a high moisture content.

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Analytical report

Project name	Conservation_Plan_Lukanga_Swamp	Order date	27.09.2019
Project number	t19024	Starting date	27.09.2019
Report number	13113941 - 1	Report date	09.10.2019

Code	Sample type	Sample description
016	Sediment	16
017	Sediment	17
018	Sediment	18
019	Sediment	8a

Analysis	Unit	Q	016	017	018	019
dry weight	wght.-%	Q	68.8	79.9	68.8	61.3
sample pretreatment (sieving <2mm)				yes	yes	yes
TOC	mg/kgdm	Q	33000	4600	14000	21000
PARTICAL SIZE						
min. parts <2um	% of DM	Q	34	8.5	24	30
min. parts <20um	% of DM		51	24	33	37
min. parts <63um	% of DM	Q	76	28	46	51
min. parts <2 mm	% of DM	Q	90	95	92	89
min. parts >2 mm	% of DM	Q	<1	<1	<1	1.1
METALS						
aluminium	mg/kgdm	Q	31000	8900	13000	24000
arsenic	mg/kgdm	Q	7.6	6.1	5.5	7.5
cadmium	mg/kgdm	Q	0.53	<0.2	<0.2	<0.2
chromium	mg/kgdm	Q	43	63	24	50
cobalt	mg/kgdm	Q	450	160	8.4	16
copper	mg/kgdm	Q	3300	1100	13	28
mercury	mg/kgdm	Q	0.24	<0.05	<0.05	<0.05
lead	mg/kgdm	Q	60	<10	<10	<10
nickel	mg/kgdm	Q	34	8.8	9.9	19
iron	mg/kgdm	Q	32000	32000	14000	25000
zinc	mg/kgdm	Q	250	<20	<20	<20
POLYCYCLIC AROMATIC HYDROCARBONS						
phenanthrene	mg/kgdm	Q	0.06 [2)]	<0.02	<0.02	<0.02
anthracene	mg/kgdm	Q	0.02	<0.02	<0.02	<0.02
fluoranthene	mg/kgdm	Q	0.12	<0.02	<0.02	<0.02
pyrene	mg/kgdm	Q	0.10	<0.02	<0.02	<0.02
benzo(a)anthracene	mg/kgdm	Q	0.05	<0.02	<0.02	<0.02
chrysene	mg/kgdm	Q	0.04	<0.02	<0.02	<0.02
benzo(a)pyrene	mg/kgdm	Q	0.05	<0.02	<0.02	<0.02
benzo(ghi)perylene	mg/kgdm	Q	0.08	<0.02	<0.02	<0.02
indeno(1,2,3-cd)pyrene	mg/kgdm	Q	0.06	<0.02	<0.02	<0.02
sum PAHs (9 OSPAR)	mg/kgdm		0.58	<0.18	<0.18	<0.18
CHLOROBENZENES						
hexachlorobenzene	µg/kgdm		<0.5	<0.5	<0.5	<0.5
POLYCHLORINATED BIPHENYLS						
PCB 28	µg/kgdm	Q	1.7 [3)]	<1	<1	<1

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Analytical report

Project name	Conservation_Plan_Lukanga_Swamp	Order date	27.09.2019
Project number	t19024	Starting date	27.09.2019
Report number	13113941 - 1	Report date	09.10.2019

Code	Sample type	Sample description
016	Sediment	16
017	Sediment	17
018	Sediment	18
019	Sediment	8a

Analysis	Unit	Q	016	017	018	019
PCB 52	µg/kgdm	Q	<1	<1	<1	<1
PCB 101	µg/kgdm	Q	1.3	<1	<1	<1
PCB 118	µg/kgdm	Q	1.2 [2)]	<1	<1	<1
PCB 138	µg/kgdm	Q	2.1	<1	<1	<1
PCB 153	µg/kgdm	Q	1.7 [2)]	<1	<1	<1
PCB 180	µg/kgdm	Q	<1	<1	<1	<1
total (7) PCB	µg/kgdm		9.4	4.9	4.9	4.9
SEVERAL CHEMICAL ANALYSIS						
specific weight	g/l		2246	2505	2432	2300

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Analytical report

Project name	Conservation_Plan_Lukanga_Swamp	Order date	27.09.2019
Project number	t19024	Starting date	27.09.2019
Report number	13113941 - 1	Report date	09.10.2019

Remarks

2	The result is idicative due to the presence of interfering compounds
3	The result for PCB 28 is possibly overestimated because of the presence of PCB 31.

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Analytical report

Project name	Conservation_Plan_Lukanga_Swamp	Order date	27.09.2019
Project number	t19024	Starting date	27.09.2019
Report number	13113941 - 1	Report date	09.10.2019

Analyses	Sample type	Relation to standard
dry weight	Sediment	Sediment: In house method (analysis equivalent to ISO 11465 and equivalent to NEN-EN 15934). Sediment (AS3000): in accordance with AS3210-1 and in accordance with NEN-EN 15934
sample pretreatment (sieving <2mm)	Sediment	In house method (seaving method)
TOC	Sediment	In accordance with NEN-EN 13137
min. parts <2um	Sediment	Gathered from NEN 5753
min. parts <20um	Sediment	Ditto
min. parts <63um	Sediment	In house method (seaving method)
min. parts <2 mm	Sediment	Ditto
min. parts >2 mm	Sediment	Ditto
aluminium	Sediment	digestion in accordance with NEN 6961, measurement in accordance with NEN-EN-ISO 17294-2
arsenic	Sediment	Ditto
cadmium	Sediment	Ditto
chromium	Sediment	Ditto
cobalt	Sediment	Ditto
copper	Sediment	Ditto
mercury	Sediment	Ditto
lead	Sediment	Ditto
nickel	Sediment	Ditto
iron	Sediment	Ditto
zinc	Sediment	Ditto
phenanthrene	Sediment	Own method, extraction with acetone-hexane, analysis with GC-MS
anthracene	Sediment	Ditto
fluoranthene	Sediment	Ditto
pyrene	Sediment	Ditto
benzo(a)anthracene	Sediment	Ditto
chrysene	Sediment	Ditto
benzo(a)pyrene	Sediment	Ditto
benzo(ghi)perylene	Sediment	Ditto
indeno(1,2,3-cd)pyrene	Sediment	Ditto
hexachlorobenzene	Sediment	Own method, analysis with GC-MS
PCB 28	Sediment	In-house method, acetone/hexane-extraction, analysis with GC-MS.
PCB 52	Sediment	Ditto
PCB 101	Sediment	Ditto
PCB 118	Sediment	Ditto
PCB 138	Sediment	Ditto
PCB 153	Sediment	Ditto
PCB 180	Sediment	Ditto
total (7) PCB	Sediment	Ditto
specific weight	Sediment	In house method

Sample	Barcode	Reception date	Sampling date	Container
001	Y5756355	25.09.2019	14.09.2019	ALC201
001	Y5756298	25.09.2019	14.09.2019	ALC201

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Analytical report

Project name	Conservation_Plan_Lukanga_Swamp	Order date	27.09.2019
Project number	t19024	Starting date	27.09.2019
Report number	13113941 - 1	Report date	09.10.2019

Sample	Barcode	Reception date	Sampling date	Container
001	Y5756381	25.09.2019	14.09.2019	ALC201
002	Y5756392	25.09.2019	14.09.2019	ALC201
002	Y5756386	25.09.2019	14.09.2019	ALC201
003	Y5756394	25.09.2019	14.09.2019	ALC201
003	Y5756390	25.09.2019	14.09.2019	ALC201
003	Y5756387	25.09.2019	14.09.2019	ALC201
004	Y5756382	25.09.2019	14.09.2019	ALC201
004	Y5756393	25.09.2019	14.09.2019	ALC201
005	Y5755340	25.09.2019	14.09.2019	ALC201
005	Y5755360	25.09.2019	14.09.2019	ALC201
006	Y5756397	25.09.2019	14.09.2019	ALC201
006	Y5756396	25.09.2019	14.09.2019	ALC201
007	Y5755346	25.09.2019	14.09.2019	ALC201
007	Y5755349	25.09.2019	14.09.2019	ALC201
008	Y5755352	25.09.2019	14.09.2019	ALC201
008	Y5755241	25.09.2019	14.09.2019	ALC201
009	Y5755247	25.09.2019	14.09.2019	ALC201
009	Y5755290	25.09.2019	14.09.2019	ALC201
010	V6957993	25.09.2019	14.09.2019	ALC201
010	V6958001	25.09.2019	14.09.2019	ALC201
011	V6958023	25.09.2019	14.09.2019	ALC201
011	V6958005	25.09.2019	14.09.2019	ALC201
012	V6958004	25.09.2019	14.09.2019	ALC201
012	V6958015	25.09.2019	14.09.2019	ALC201
012	V6957999	25.09.2019	14.09.2019	ALC201
013	Y5755339	25.09.2019	14.09.2019	ALC201
013	Y5755341	25.09.2019	14.09.2019	ALC201
014	V6957988	25.09.2019	14.09.2019	ALC201
014	V6957998	25.09.2019	14.09.2019	ALC201
015	Y5755336	25.09.2019	14.09.2019	ALC201
015	Y5756311	25.09.2019	14.09.2019	ALC201
016	Y5756391	25.09.2019	14.09.2019	ALC201
016	Y5756384	25.09.2019	14.09.2019	ALC201
017	Y5756360	25.09.2019	14.09.2019	ALC201
017	Y5756388	25.09.2019	14.09.2019	ALC201
018	V6957987	25.09.2019	14.09.2019	ALC201
018	V6958003	25.09.2019	14.09.2019	ALC201
018	V6958000	25.09.2019	14.09.2019	ALC201
019	Y5756389	25.09.2019	14.09.2019	ALC201
019	Y5756385	25.09.2019	14.09.2019	ALC201
019	Y5756383	25.09.2019	14.09.2019	ALC201

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SYNLAB Analytics & Services B.V.
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Tel.: +34 93 363 6000
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Analytical report

NEMUS - Gestão e Requalificação Ambiental Lda
César Jesus
Estrada do Paço do Lumiar
Campus do Lumiar,Edifício D, R/Chão
PT-1649-038 LISBOA

Your Project name	: Conservation_Plan_Lukanga_Swamp - 2
Your Project number	: t19024
SYNLAB report number	: 13137776, version: 2
Certificate code	: VTQP3E4D

Rotterdam, 15.11.2019

Dear Mr./Mrs,

Attached you find the results of the laboratory tests carried out for your project t19024. The tests were carried out according to your order. The reported results refer only to the tested samples. The sample description, sample date (if provided) and project description were adopted from your order.

All tests were carried out by SYNLAB Analytics & Services B.V., Steenhouwerstraat 15, Rotterdam, Netherlands. Tests outsourced or carried out by the SYNLAB laboratory in France (99-101 Avenue Louis Roche, Gennevilliers) are marked in the report.

This certificate contains inclusive attachments 12 pages. In case of a version number of '2' or higher all former versions of the certificate are invalid. All attachments are inextricably part of this certificate. Only reproduction of the whole report is allowed.

In case of questions and/or remarks related to this certificate, for example in case of information required about measurement uncertainty of the analytical methods, please contact our Customer Support department.

Yours faithfully,

Jaap-Willem Hutter
Technical Director

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Analytical report

Project name	Conservation_Plan_Lukanga_Swamp - 2	Order date	31.10.2019
Project number	t19024	Starting date	05.11.2019
Report number	13137776 - 2	Report date	15.11.2019

Code	Sample type	Sample description
001	div. (solid)	sample nº 28 - Leaves
002	div. (solid)	sample nº 29 - Leaves
003	div. (solid)	sample nº 27 - Leaves
004	div. (solid)	sample nº 25 - Leaves
005	div. (solid)	sample nº 16 - Leaves

Analysis	Unit	Q	001	002	003	004	005
ANALYSES OUTSOURCED							
9 metals in vegetal leaves			see appendix	see appendix	see appendix	see appendix	see appendix

Initials :

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Analytical report

Project name	Conservation_Plan_Lukanga_Swamp - 2	Order date	31.10.2019
Project number	t19024	Starting date	05.11.2019
Report number	13137776 - 2	Report date	15.11.2019

Code	Sample type	Sample description
006	div. (solid)	sample nº 2 - Leaves
007	div. (solid)	sample nº 26 - Leaves
008	div. (solid)	sample nº 11 - Leaves
009	div. (solid)	sample nº 15 - Leaves
010	div. (solid)	sample nº 17 - Leaves

Analysis	Unit	Q	006	007	008	009	010
ANALYSES OUTSOURCED							
9 metals in vegetal leaves			see appendix	see appendix	see appendix	see appendix	see appendix

Initials :

TESTEN RvA L 028

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Analytical report

Project name	Conservation_Plan_Lukanga_Swamp - 2	Order date	31.10.2019
Project number	t19024	Starting date	05.11.2019
Report number	13137776 - 2	Report date	15.11.2019

Code	Sample type	Sample description
011	Sediment	sample nº 26 - Sediment
012	Sediment	sample nº 27 - Sediment

Analysis	Unit	Q	011	012
dry weight	wght.-%	Q	34.4	45.5
sample pretreatment (sieving <2mm)			yes	yes
TOC	mg/kgdm	Q	91000	38000
PARTICAL SIZE				
min. parts <2um	% of DM	Q	26	11
min. parts <20um	% of DM		34	21
min. parts <63um	% of DM	Q	36	25
min. parts <2 mm	% of DM	Q	53	64
min. parts >2 mm	% of DM	Q	1.2	<1
METALS				
aluminium	mg/kgdm	Q	23000	14000
arsenic	mg/kgdm	Q	<4	<4
cadmium	mg/kgdm	Q	<0.2	<0.2
chromium	mg/kgdm	Q	34	15
cobalt	mg/kgdm	Q	11	4.9
copper	mg/kgdm	Q	30	15
mercury	mg/kgdm	Q	<0.05	<0.05
lead	mg/kgdm	Q	15	<10
nickel	mg/kgdm	Q	19	11
iron	mg/kgdm	Q	11000	6200
zinc	mg/kgdm	Q	<20	<20
POLYCYCLIC AROMATIC HYDROCARBONS				
phenanthrene	mg/kgdm	Q	<0.04 [1)]	<0.03 [1)]
anthracene	mg/kgdm	Q	<0.04 [1)]	<0.03 [1)]
fluoranthene	mg/kgdm	Q	<0.04 [1)]	<0.03 [1)]
pyrene	mg/kgdm	Q	<0.04 [1)]	<0.03 [1)]
benzo(a)anthracene	mg/kgdm	Q	<0.04 [1)]	<0.03 [1)]
chrysene	mg/kgdm	Q	<0.04 [1)]	<0.03 [1)]
benzo(a)pyrene	mg/kgdm	Q	<0.04 [1)]	<0.03 [1)]
benzo(ghi)perylene	mg/kgdm	Q	<0.04 [1)]	<0.03 [1)]
indeno(1,2,3-cd)pyrene	mg/kgdm	Q	<0.04 [1)]	<0.03 [1)]
sum PAHs (9 OSPAR)	mg/kgdm		<0.36	<0.27
CHLOROBENZENES				
hexachlorobenzene	µg/kgdm		<0.74 [1)]	<0.51 [1)]
POLYCHLORINATED BIPHENYLS				
PCB 28	µg/kgdm	Q	<1	<1
PCB 52	µg/kgdm	Q	<1	<1
PCB 101	µg/kgdm	Q	<1	<1

Analysis marked with Q are accredited by the RvA

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Analytical report

Project name	Conservation_Plan_Lukanga_Swamp - 2	Order date	31.10.2019
Project number	t19024	Starting date	05.11.2019
Report number	13137776 - 2	Report date	15.11.2019

Code	Sample type	Sample description
011	Sediment	sample nº 26 - Sediment
012	Sediment	sample nº 27 - Sediment

Analysis	Unit	Q	011	012
PCB 118	µg/kgdm	Q	<1	<1
PCB 138	µg/kgdm	Q	<1	<1
PCB 153	µg/kgdm	Q	<1	<1
PCB 180	µg/kgdm	Q	<1	<1
total (7) PCB	µg/kgdm		4.9	4.9
SEVERAL CHEMICAL ANALYSIS				
specific weight	g/l		1821	2114

Analysis marked with Q are accredited by the RvA

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Analytical report

Project name	Conservation_Plan_Lukanga_Swamp - 2	Order date	31.10.2019
Project number	t19024	Starting date	05.11.2019
Report number	13137776 - 2	Report date	15.11.2019

Remarks

1	Increased detectionlimit due to a high moisture content.

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Analytical report

Project name	Conservation_Plan_Lukanga_Swamp - 2	Order date	31.10.2019
Project number	t19024	Starting date	05.11.2019
Report number	13137776 - 2	Report date	15.11.2019

Analyses	Sample type	Relation to standard
dry weight	Sediment	Sediment: In house method (analysis equivalent to ISO 11465 and equivalent to NEN-EN 15934). Sediment (AS3000): in accordance with AS3210-1 and in accordance with NEN-EN 15934
sample pretreatment (sieving <2mm)	Sediment	In house method (seaving method)
TOC	Sediment	In accordance with NEN-EN 13137
min. parts <2um	Sediment	Gathered from NEN 5753
min. parts <20um	Sediment	Ditto
min. parts <63um	Sediment	In house method (seaving method)
min. parts <2 mm	Sediment	Ditto
min. parts >2 mm	Sediment	Ditto
aluminium	Sediment	digestion in accordance with NEN 6961, measurement in accordance with NEN-EN-ISO 17294-2
arsenic	Sediment	Ditto
cadmium	Sediment	Ditto
chromium	Sediment	Ditto
cobalt	Sediment	Ditto
copper	Sediment	Ditto
mercury	Sediment	Ditto
lead	Sediment	Ditto
nickel	Sediment	Ditto
iron	Sediment	Ditto
zinc	Sediment	Ditto
phenanthrene	Sediment	Own method, extraction with acetone-hexane, analysis with GC-MS
anthracene	Sediment	Ditto
fluoranthene	Sediment	Ditto
pyrene	Sediment	Ditto
benzo(a)anthracene	Sediment	Ditto
chrysene	Sediment	Ditto
benzo(a)pyrene	Sediment	Ditto
benzo(ghi)perylene	Sediment	Ditto
indeno(1,2,3-cd)pyrene	Sediment	Ditto
hexachlorobenzene	Sediment	Own method, analysis with GC-MS
PCB 28	Sediment	In-house method, acetone/hexane-extraction, analysis with GC-MS.
PCB 52	Sediment	Ditto
PCB 101	Sediment	Ditto
PCB 118	Sediment	Ditto
PCB 138	Sediment	Ditto
PCB 153	Sediment	Ditto
PCB 180	Sediment	Ditto
total (7) PCB	Sediment	Ditto
specific weight	Sediment	In house method
9 metals in vegetal leaves	div. (solid)	Subcontracted analysis

Sample	Barcode	Reception date	Sampling date	Container
001	X1295191	05.11.2019	10.10.2019	ALC201

Initials :

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Analytical report

Project name	Conservation_Plan_Lukanga_Swamp - 2	Order date	31.10.2019
Project number	t19024	Starting date	05.11.2019
Report number	13137776 - 2	Report date	15.11.2019

Sample	Barcode	Reception date	Sampling date	Container
002	X1295198	05.11.2019	10.10.2019	ALC201
003	X1295193	05.11.2019	10.10.2019	ALC201
004	X1295197	05.11.2019	10.10.2019	ALC201
005	X1295194	05.11.2019	10.10.2019	ALC201
006	X1295195	05.11.2019	10.10.2019	ALC201
007	X1295196	05.11.2019	10.10.2019	ALC201
008	X1295192	05.11.2019	10.10.2019	ALC201
009	X1295199	05.11.2019	10.10.2019	ALC201
010	X1295190	05.11.2019	10.10.2019	ALC201
011	V6957994	05.11.2019	21.10.2019	ALC201
011	V6957991	05.11.2019	21.10.2019	ALC201
011	V6957995	05.11.2019	21.10.2019	ALC201
012	V6957992	05.11.2019	21.10.2019	ALC201
012	V6957989	05.11.2019	21.10.2019	ALC201
012	V6957986	05.11.2019	21.10.2019	ALC201

Initials :

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Your contact:
Waldemar Demidow
Scientific Staff
Division Residues and Contaminants
Phone +49(0)3641 / 3096 - 345
waldemar.demidow@synlab.com
www.synlab.de

Test report for order no. F 23709 - 19

document no. F2019-023709-0

customer:	SYNLAB Analytics & Services B.V. C/ Verge de Guadalupe, 18, 08950 Esplugues, Barcelona
no. of samples:	10 samples
sample type:	plant material (10x)
sampling:	customer, 05-11-2019
date of sample receipt:	08-11-2019
test period:	08-11-2019 to 11-11-2019

remark: The test results relate only to the items tested. This report shall not be reproduced, except in full, without written consent of SYNLAB Analytics & Services Germany GmbH. This test report has been validated and cleared by the person mentioned below. All tests were conducted at the SYNLAB site in Jena unless stated otherwise.

Samples marked with "Sampling: Client" have been taken within the responsibility of the customer. The details of the sampling and all associated data (information on the sample, on-site values, volume information, etc.) were provided by the customer. They were taken over as transmitted. All results apply to the sample as received.

abbreviations, symbols: --: not determined, not applicable, (S) subcontraction to an accredited laboratory, (SY) conducted at different SYNLAB site; (N) non-accredited test method, loq: limit of quantification, n.determ.: not determined, n.a.: not applicable, n.d.: not detected, n.av.: not available, DM: dry mass, DS: dry substance, FS: fresh substance, OS: original substance, SF: surface, ‡: information provided by the customer

Jena, 11-11-2019

Waldemar Demidow
Scientific Staff
Division Residues and Contaminants

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07743 Jena
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Test report for order no. F 23709 - 19
document no. F2019-023709-0

product::	plant material
sampling:	customer, 05-11-2019‡
sample transport:	courier
sample container:	plastic container
sample state:	flawless
date of sample receipt:	08-11-2019
sample temperature on arrival:	unchilled
purchase order no.:	P92108‡

lab no.			L1	L2	L3	L4	L5
labelling of sample(s):			Sample 28 - Leaves†	Sample 29 - Leaves†	Sample 27 - Leaves†	Sample 25 - Leaves†	Sample 16 - Leaves†
sample No.:			13137776-001‡	13137776-002‡	13137776-003‡	13137776-004‡	13137776-005‡
parameter	**analytical method**	**unit**					
sample preparation HNO3-pressure digestion	ASU § 64 LFGB L00.00-19/1 and DIN EN 13805:2014-12		--	--	--	--	--
As	DIN EN ISO 17294: 2017-01	mg/kg	0,0089	0,036	0,12	0,11	0,33
Pb	DIN EN ISO 17294: 2017-01	mg/kg	0,17	0,098	0,29	0,049	0,16
Cd	DIN EN ISO 17294: 2017-01	mg/kg	0,0034	0,0010	0,0017	0,0013	0,0036
Cr	DIN EN ISO 17294: 2017-01	mg/kg	0,40	1,1	0,40	0,13	1,1

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Test report for order no. F 23709 - 19
document no. F2019-023709-0

	lab no.		L1	L2	L3	L4	L5
	labelling of sample(s):		Sample 28 - Leaves‡	Sample 29 - Leaves‡	Sample 27 - Leaves‡	Sample 25 - Leaves‡	Sample 16 - Leaves‡
	sample No.:		13137776-001‡	13137776-002‡	13137776-003‡	13137776-004‡	13137776-005‡
parameter	**analytical method**	**unit**					
Co	DIN EN ISO 17294: 2017-01	mg/kg	0,024	0,18	0,023	0,013	0,46
Cu	DIN EN ISO 17294: 2017-01	mg/kg	1,5	6,6	3,9	1,0	12
Ni	DIN EN ISO 17294: 2017-01	mg/kg	0,23	0,65	0,36	0,10	0,47
Zn	DIN EN ISO 17294: 2017-01	mg/kg	30	26	16	21	7,9
Hg	DIN EN 15763:2010-04	mg/kg	0,0032	0,0045	0,0035	0,0040	0,0036

	lab no.		L6	L7	L8	L9	L10
	labelling of sample(s):		Sample 2 - Leaves‡	Sample 26 - Leaves‡	Sample 11 - Leaves‡	Sample 15 - Leaves‡	Sample 17 - Leaves‡
	sample No.:		13137776-006‡	13137776-007‡	13137776-008‡	13137776-009‡	13137776-010‡
parameter	**analytical method**	**unit**					
sample preparation HNO3-pressure digestion	ASU § 64 LFGB L00.00-19/1 and DIN EN 13805:2014-12		--	--	--	--	--
As	DIN EN ISO 17294: 2017-01	mg/kg	0,011	0,031	0,14	0,084	0,048

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Test report for order no. F 23709 - 19
document no. F2019-023709-0

lab no.			L6	L7	L8	L9	L10
labelling of sample(s):			Sample 2 - Leaves‡	Sample 26 - Leaves‡	Sample 11 - Leaves‡	Sample 15 - Leaves‡	Sample 17 - Leaves‡
sample No.:			13137776-006‡	13137776-007‡	13137776-008‡	13137776-009‡	13137776-010‡
parameter	**analytical method**	**unit**					
Pb	DIN EN ISO 17294: 2017-01	mg/kg	0,028	0,30	0,063	0,10	0,072
Cd	DIN EN ISO 17294: 2017-01	mg/kg	0,00090	0,0020	0,0022	0,0030	0,0021
Cr	DIN EN ISO 17294: 2017-01	mg/kg	1,1	0,24	1,1	0,75	0,58
Co	DIN EN ISO 17294: 2017-01	mg/kg	0,049	0,022	1,1	0,41	0,99
Cu	DIN EN ISO 17294: 2017-01	mg/kg	5,4	3,6	19	12	11
Ni	DIN EN ISO 17294: 2017-01	mg/kg	1,0	0,18	0,87	0,44	0,34
Zn	DIN EN ISO 17294: 2017-01	mg/kg	11	15	7,5	11	14
Hg	DIN EN 15763:2010-04	mg/kg	0,0026	0,0028	0,0030	0,0049	0,0043

Appendix D – Spatial distribution of the parameters determined in the sampled media

A) Distribution of parameters determined in surface water samples

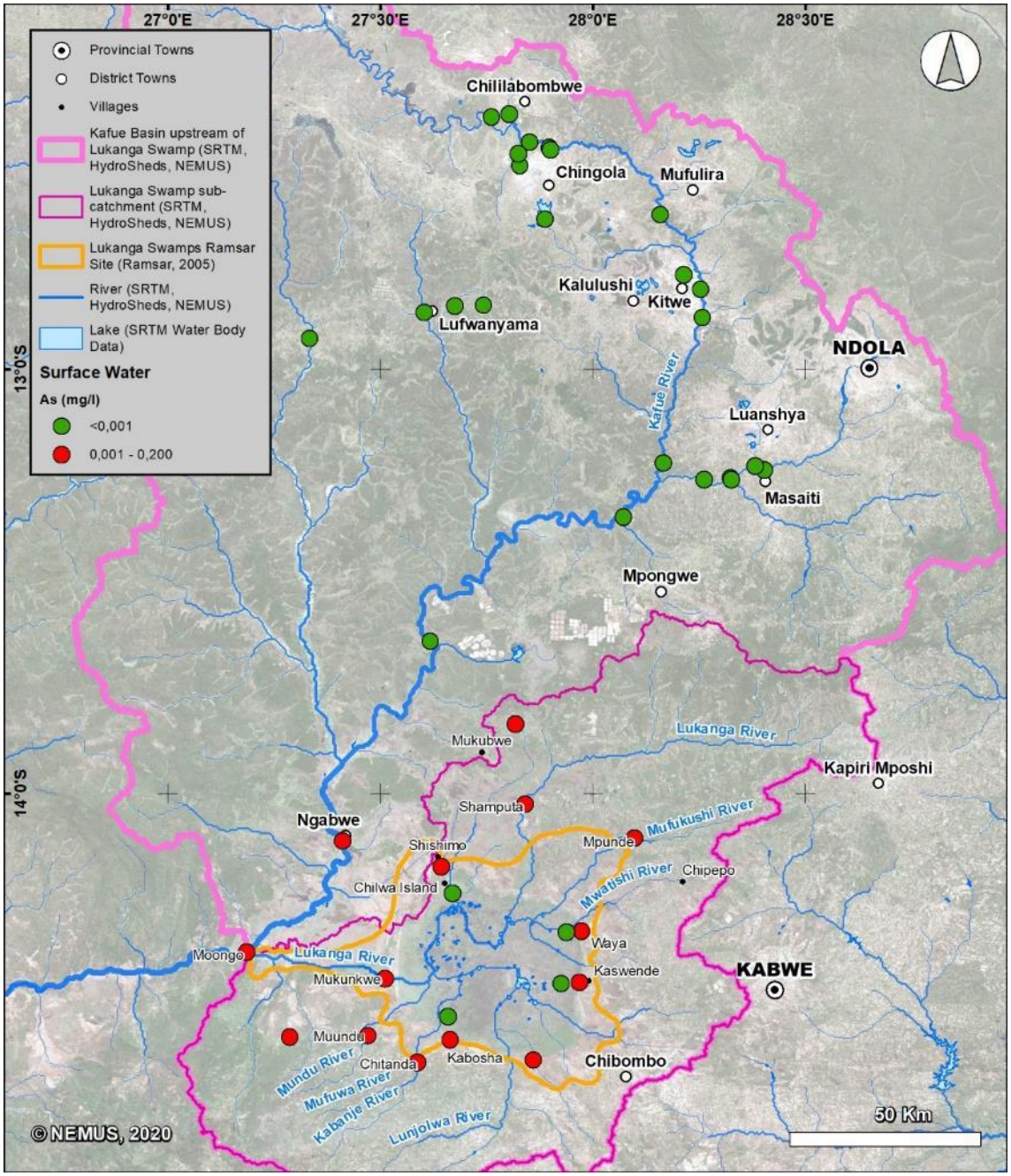


Figure 34 – Distribution of As in surface water samples in the Lukanga Swamp and Upper Kafue River Basin

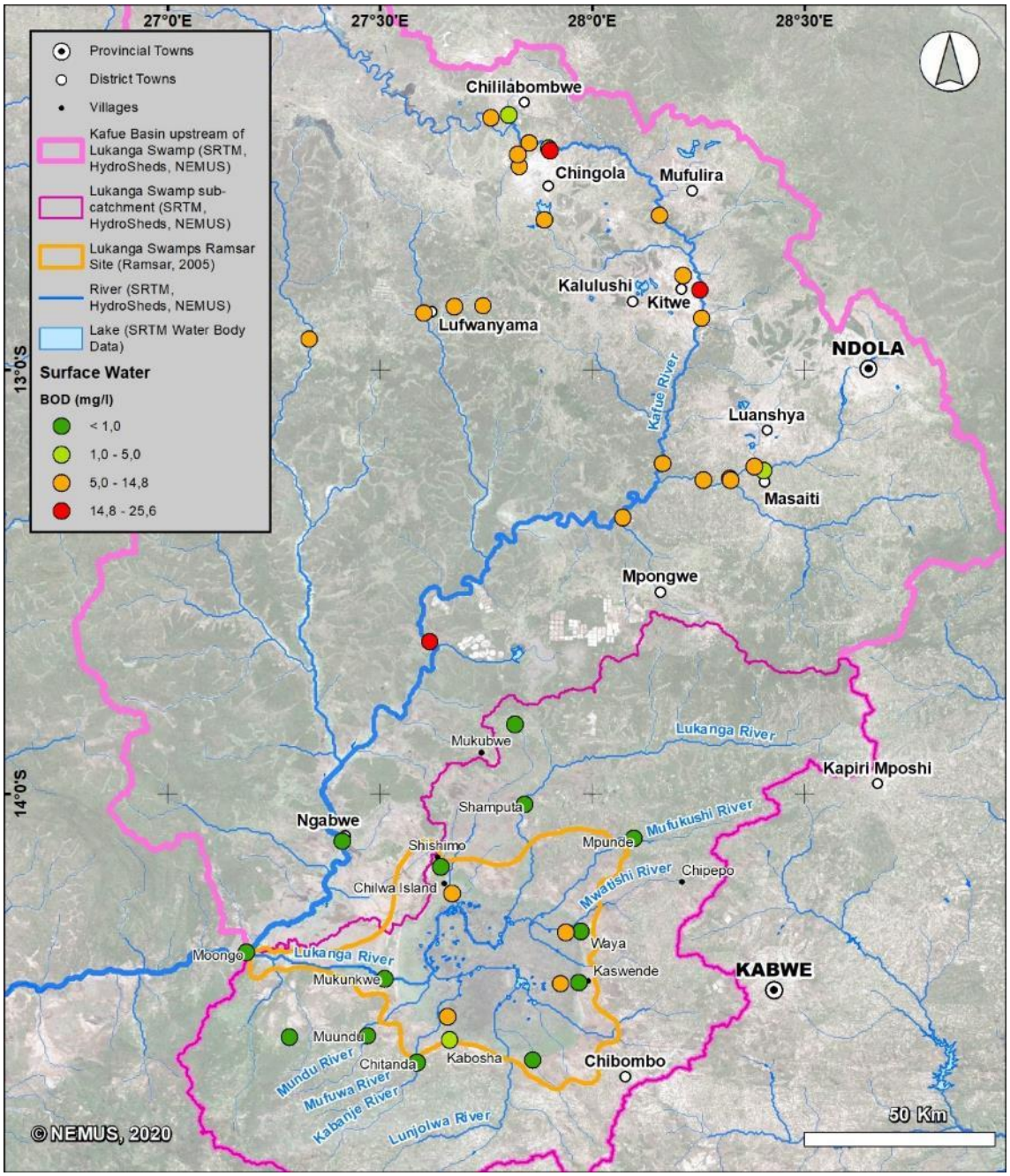


Figure 35 – Distribution of BOD in surface water samples in the Lukanga Swamp and Upper Kafue River Basin

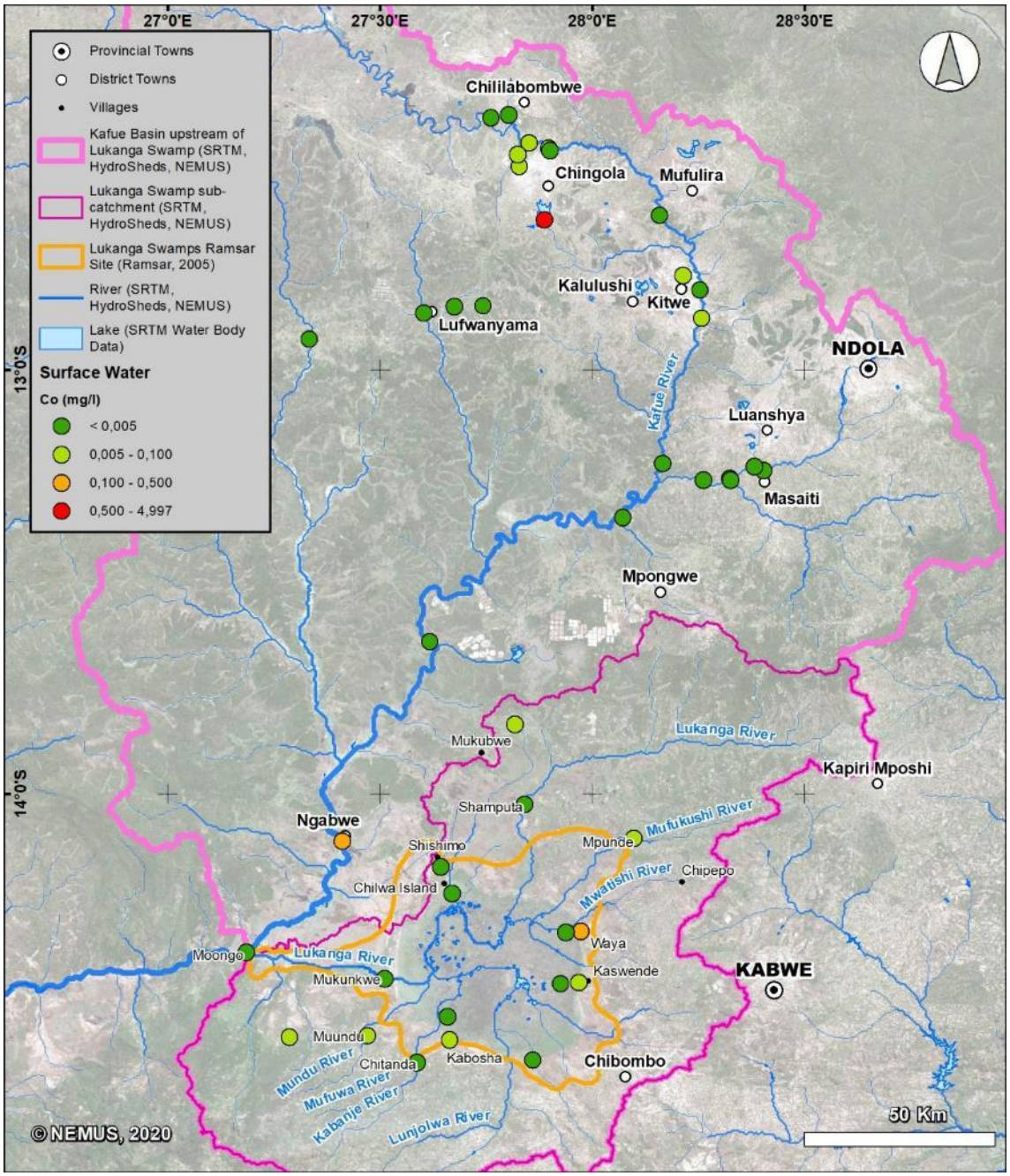


Figure 36 – Distribution of Co in surface water samples in the Lukanga Swamp and Upper Kafue River Basin

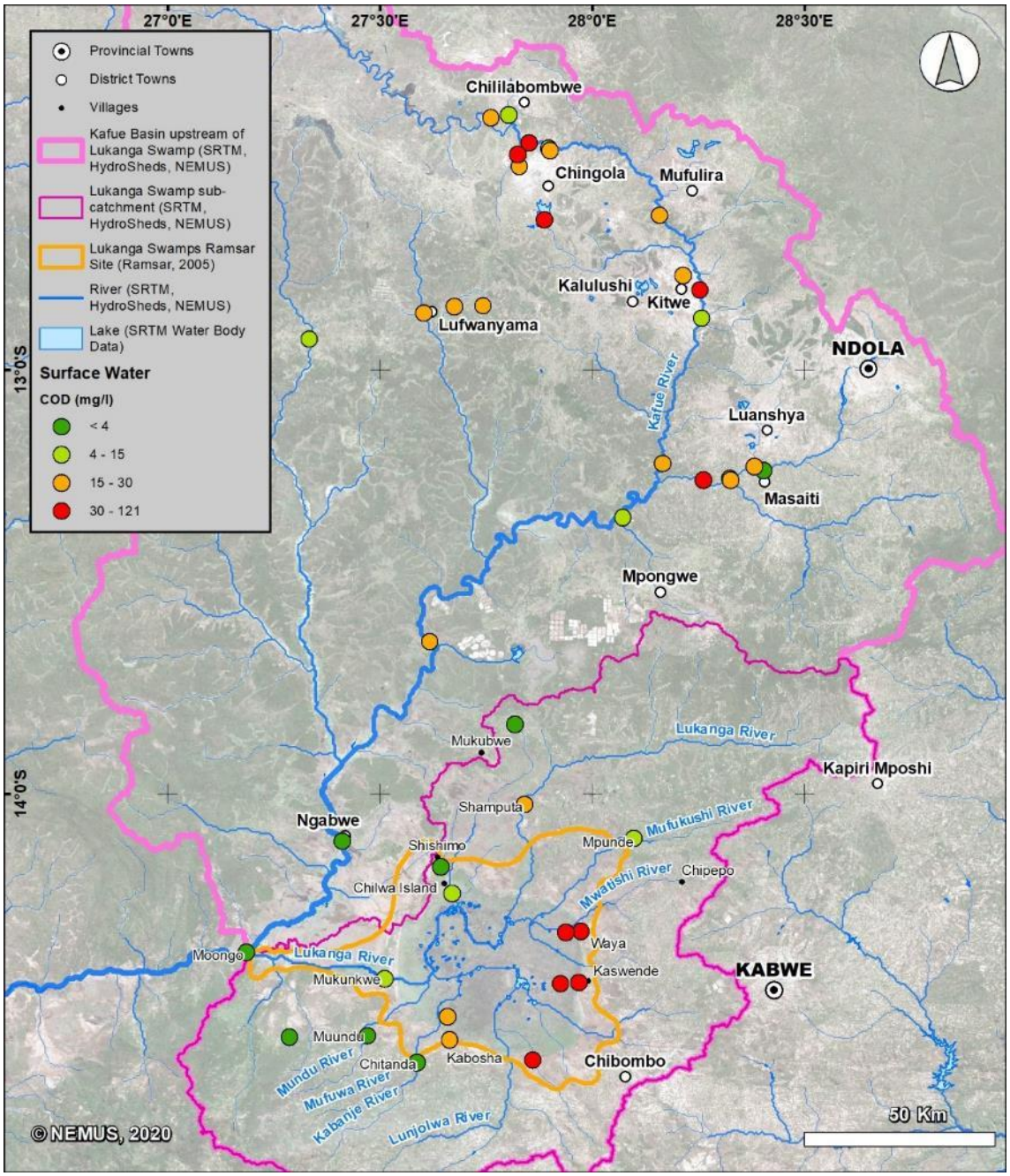


Figure 37 – Distribution of COD in surface water samples in the Lukanga Swamp and Upper Kafue River Basin

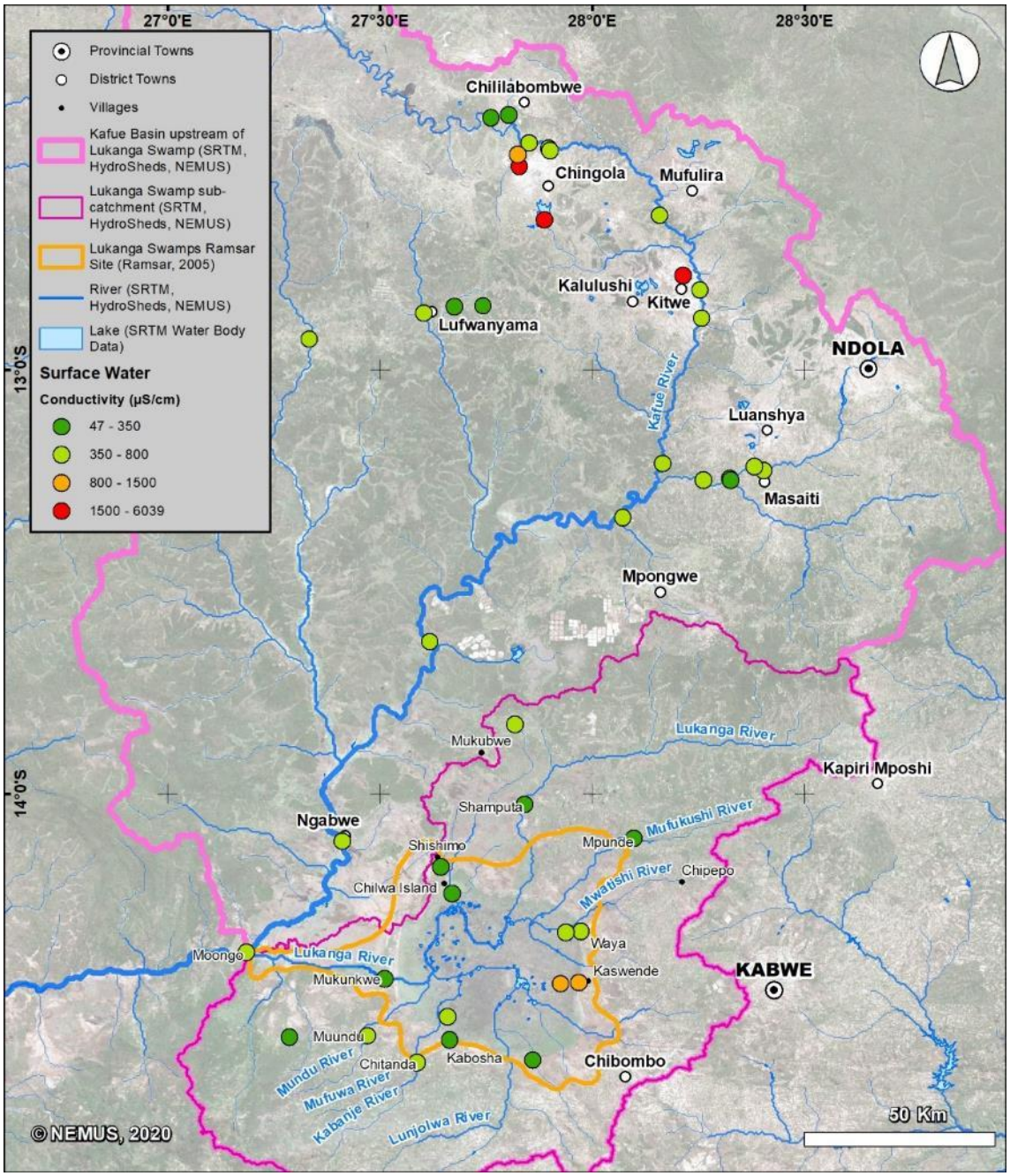


Figure 38 – Distribution of conductivity in surface water samples in the Lukanga Swamp and Upper Kafue River Basin

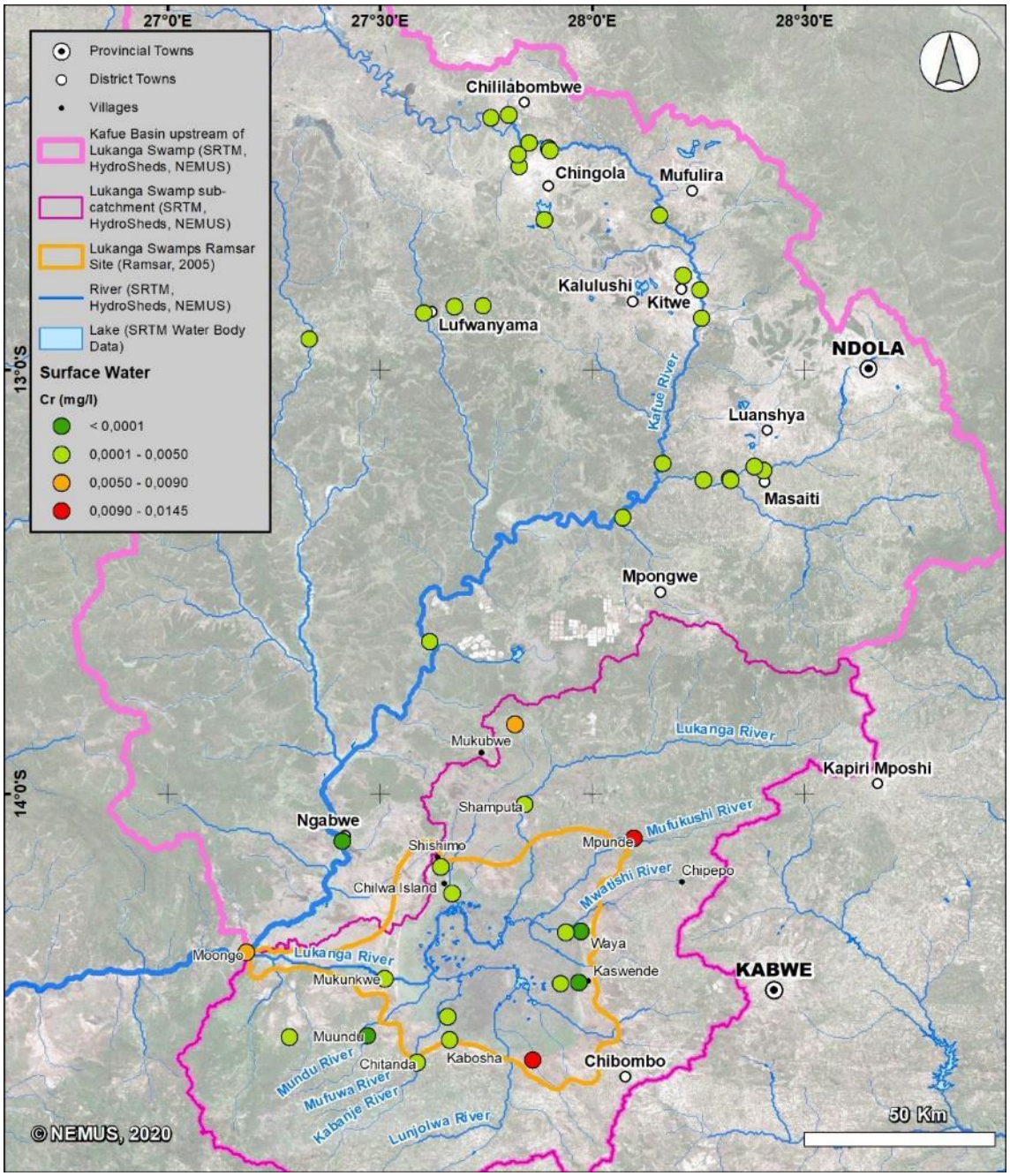


Figure 39 – Distribution of Cr in surface water samples in the Lukanga Swamp and Upper Kafue River Basin

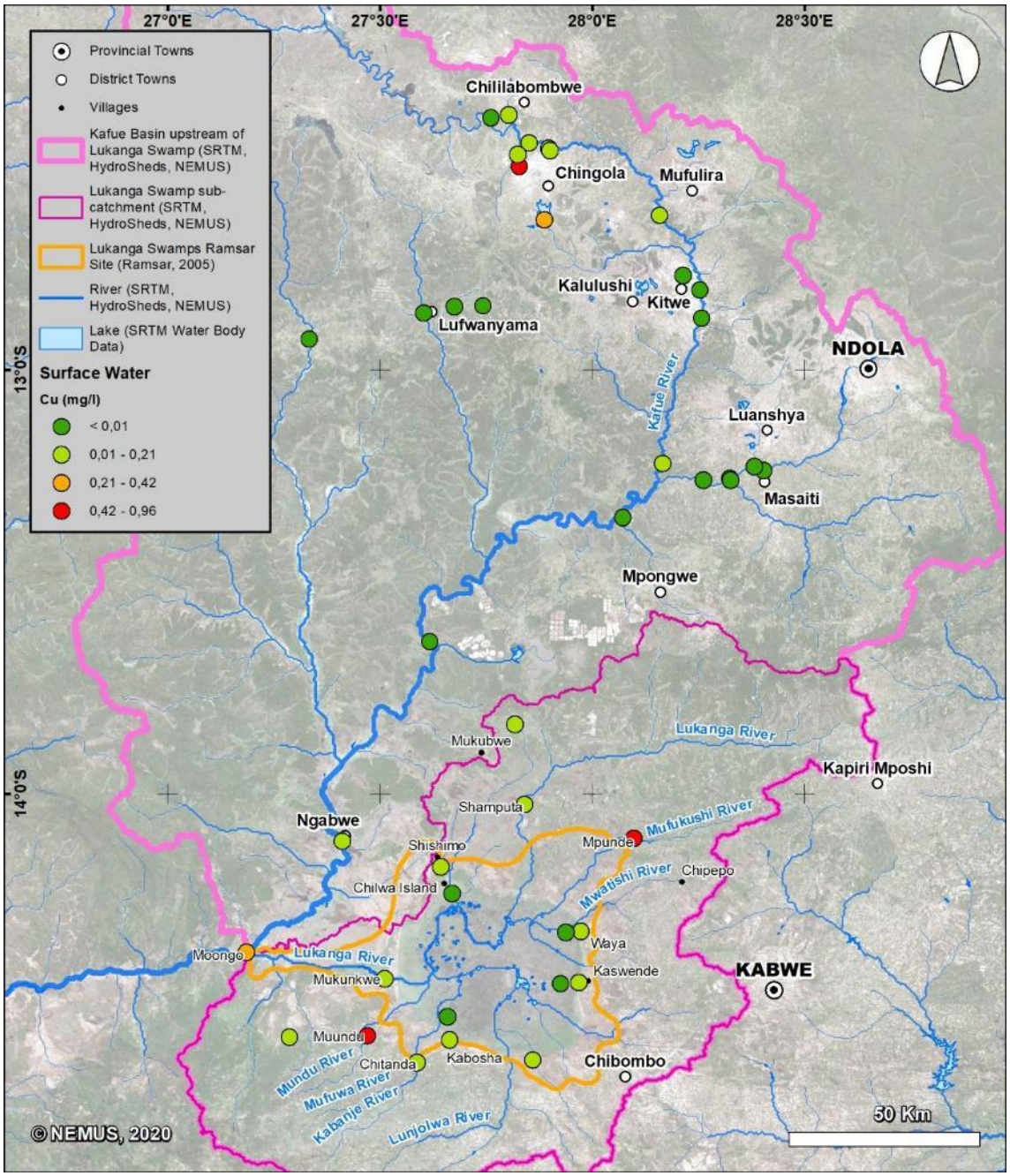


Figure 40 – Distribution of Cu in surface water samples in the Lukanga Swamp and Upper Kafue River Basin

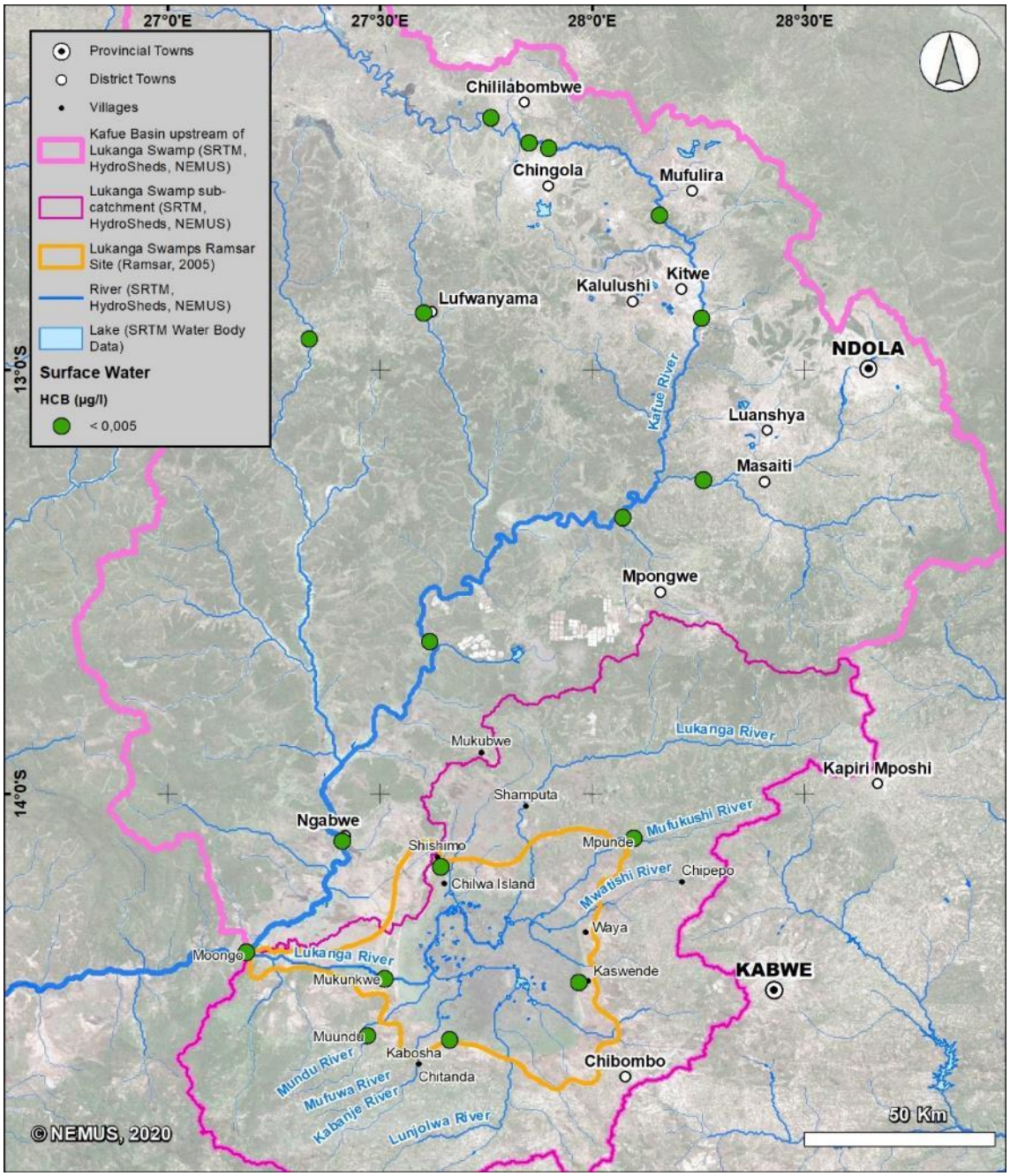


Figure 41 – Distribution of HCB in surface water samples in the Lukanga Swamp and Upper Kafue River Basin

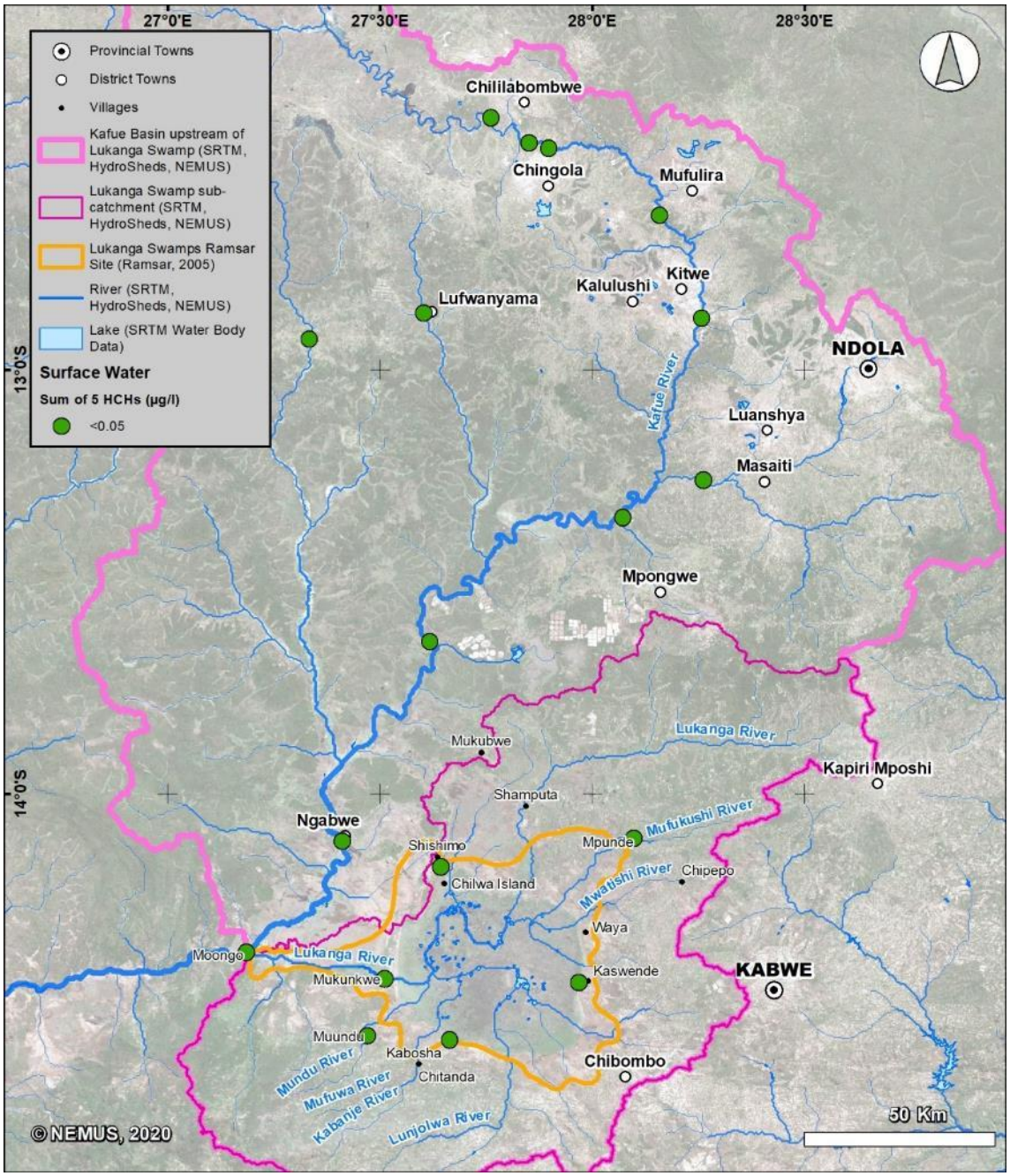


Figure 42 – Distribution of HCH in surface water samples in the Lukanga Swamp and Upper Kafue River Basin

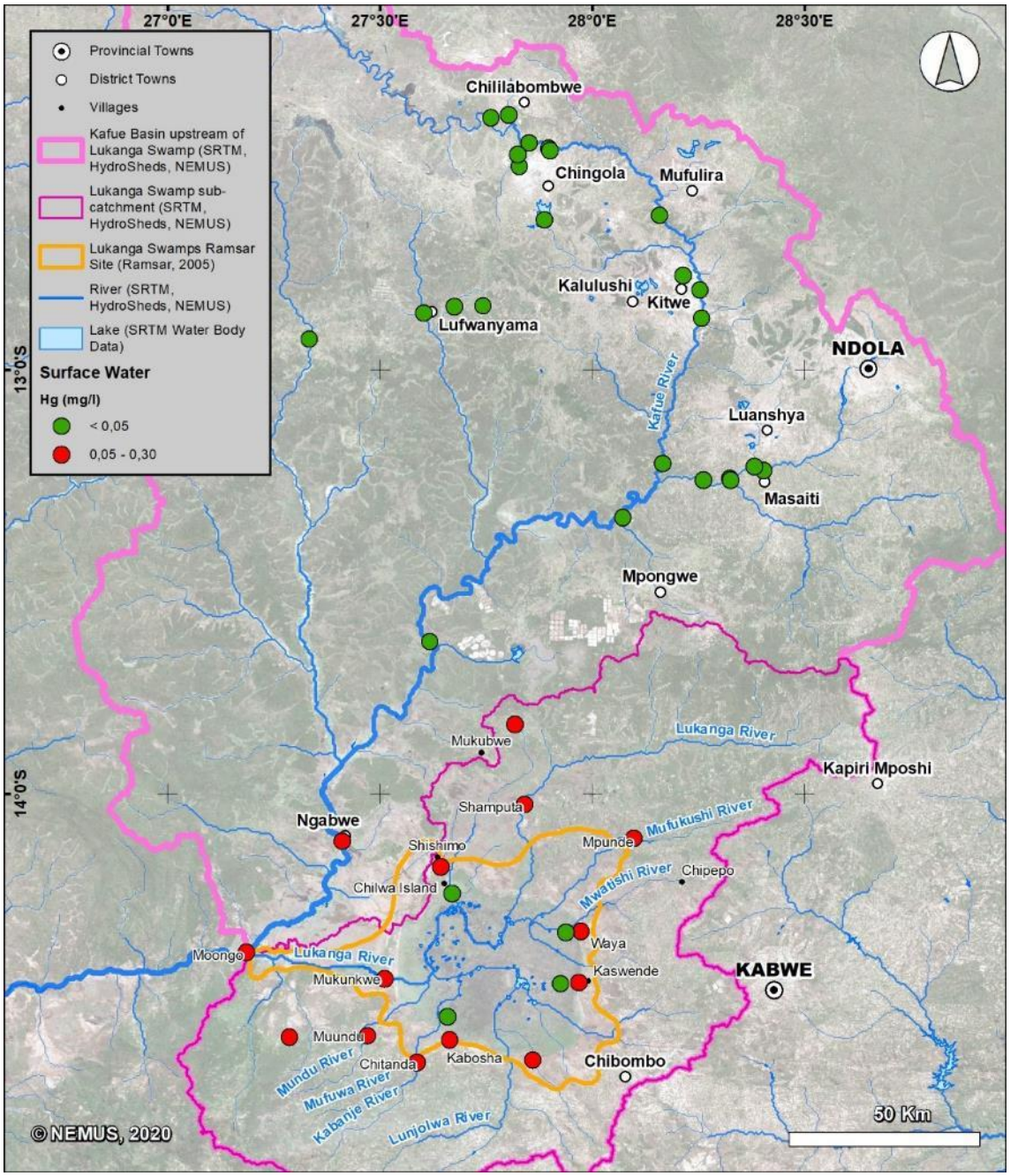


Figure 43 – Distribution of Hg in surface water samples in the Lukanga Swamp and Upper Kafue River Basin

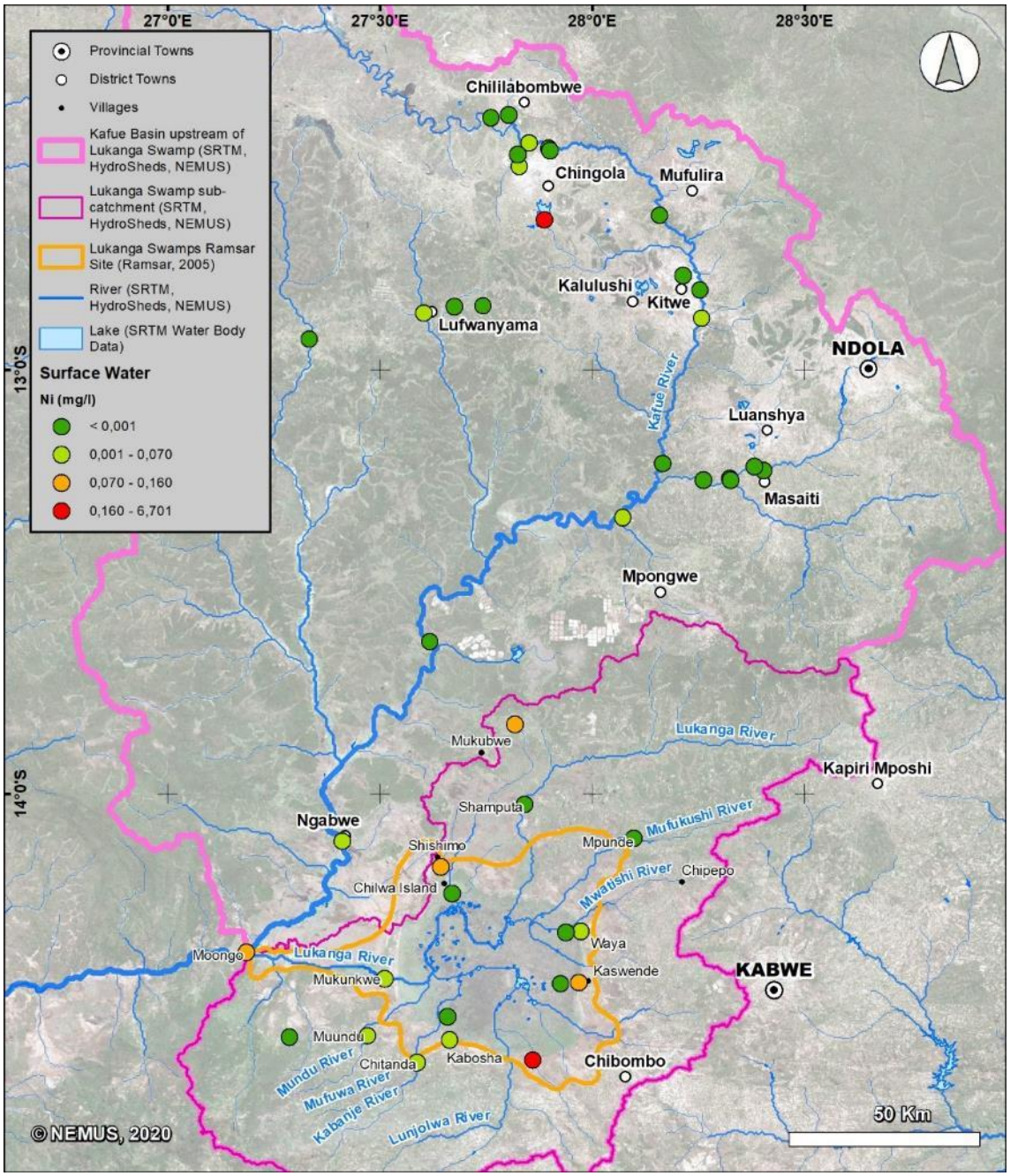


Figure 44 – Distribution of Ni in surface water samples in the Lukanga Swamp and Upper Kafue River Basin

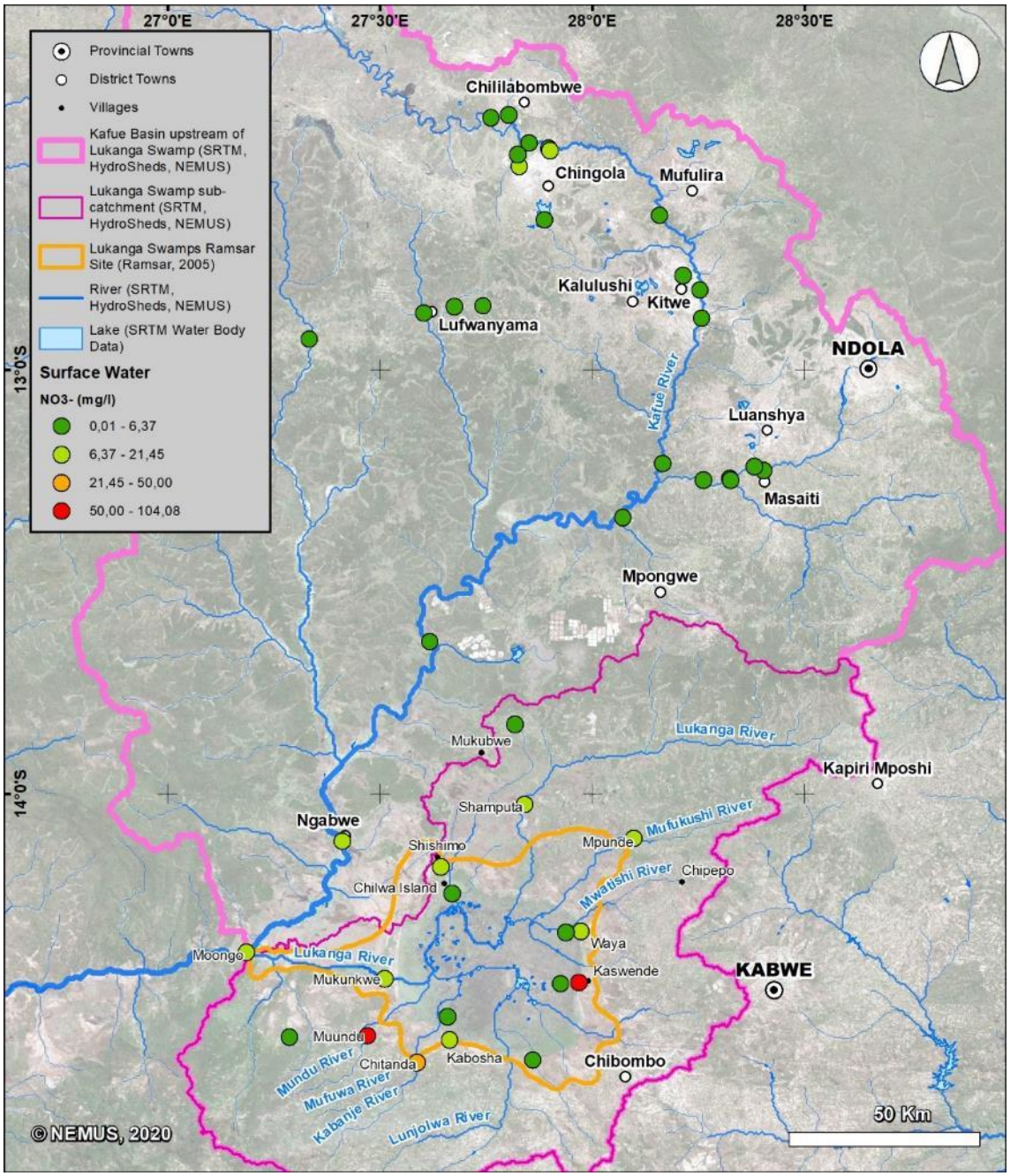


Figure 45 – Distribution of nitrates in surface water samples in the Lukanga Swamp and Upper Kafue River Basin

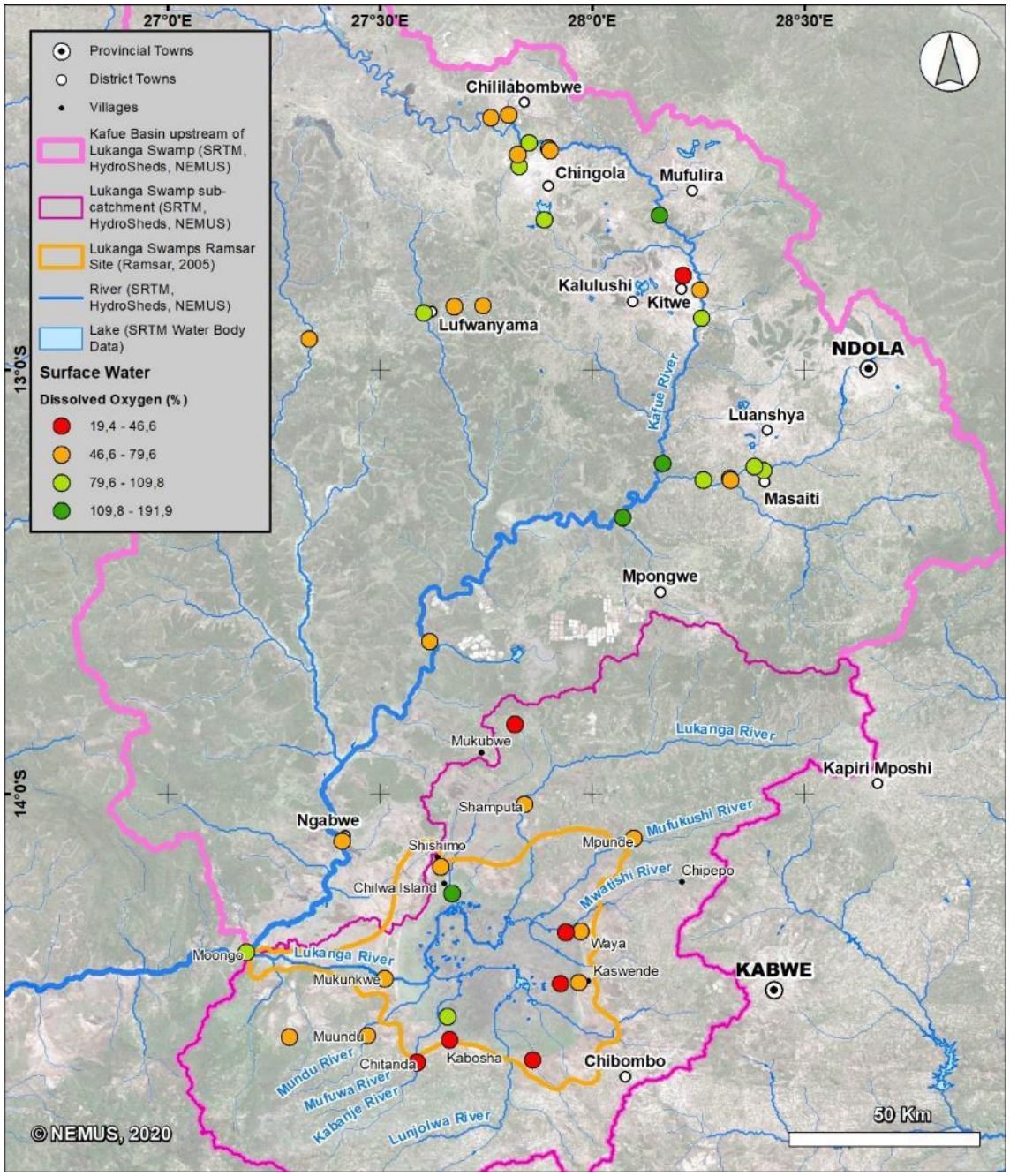


Figure 46 – Distribution of dissolved oxygen in surface water samples in the Lukanga Swamp and Upper Kafue River Basin

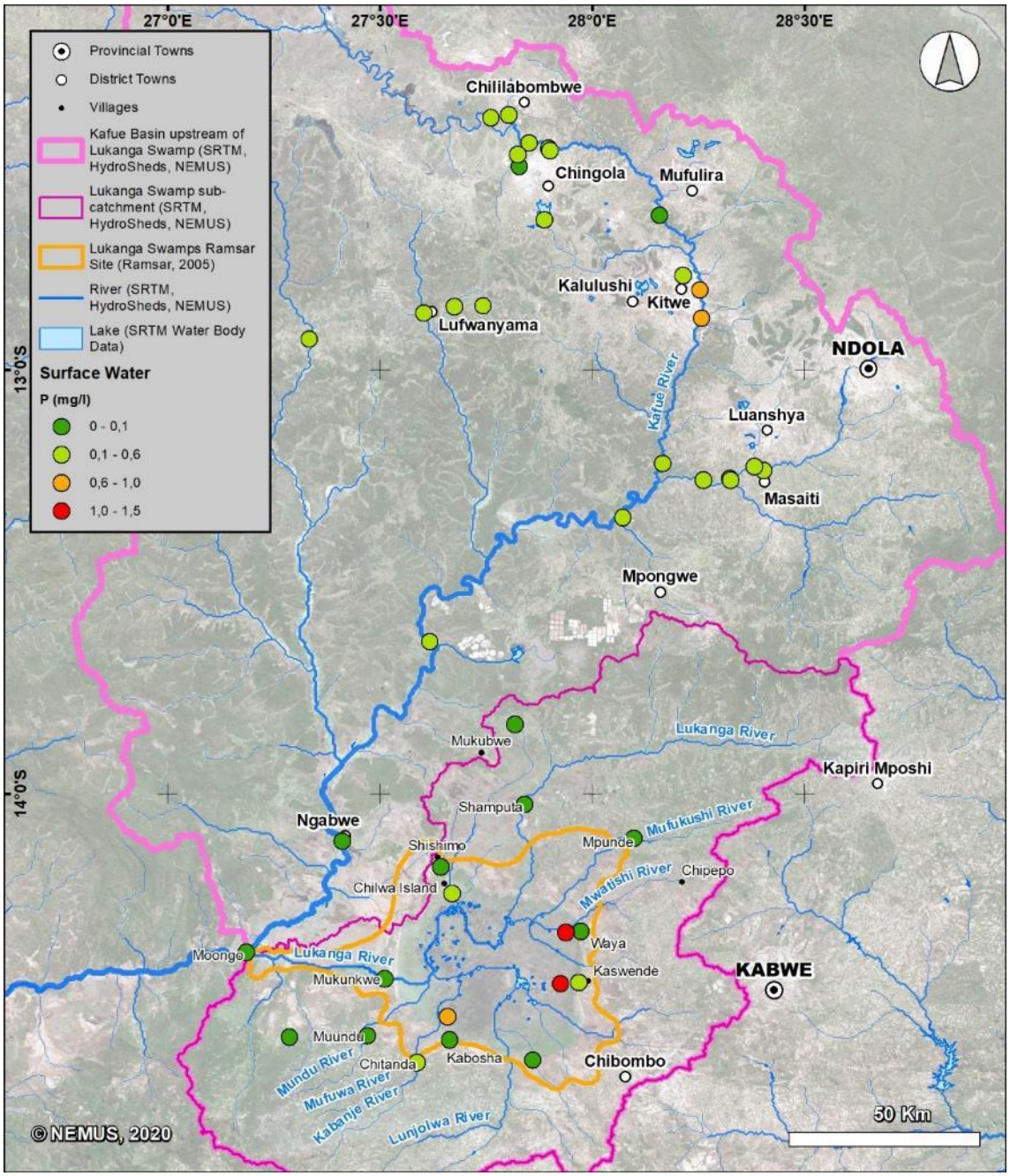


Figure 47 – Distribution of phosphorus in surface water samples in the Lukanga Swamp and Upper Kafue River Basin

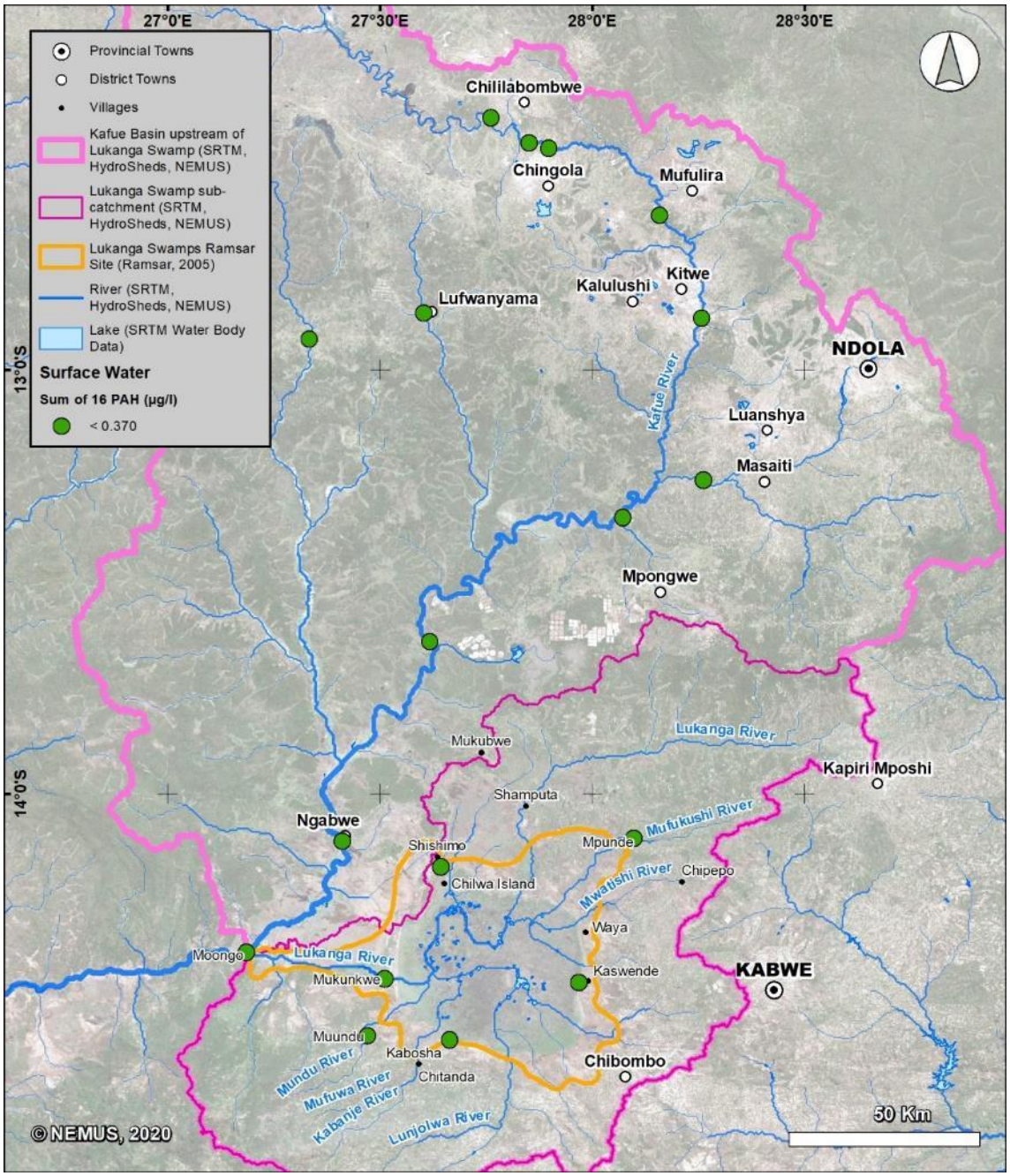


Figure 48 – Distribution of PAH in surface water samples in the Lukanga Swamp and Upper Kafue River Basin

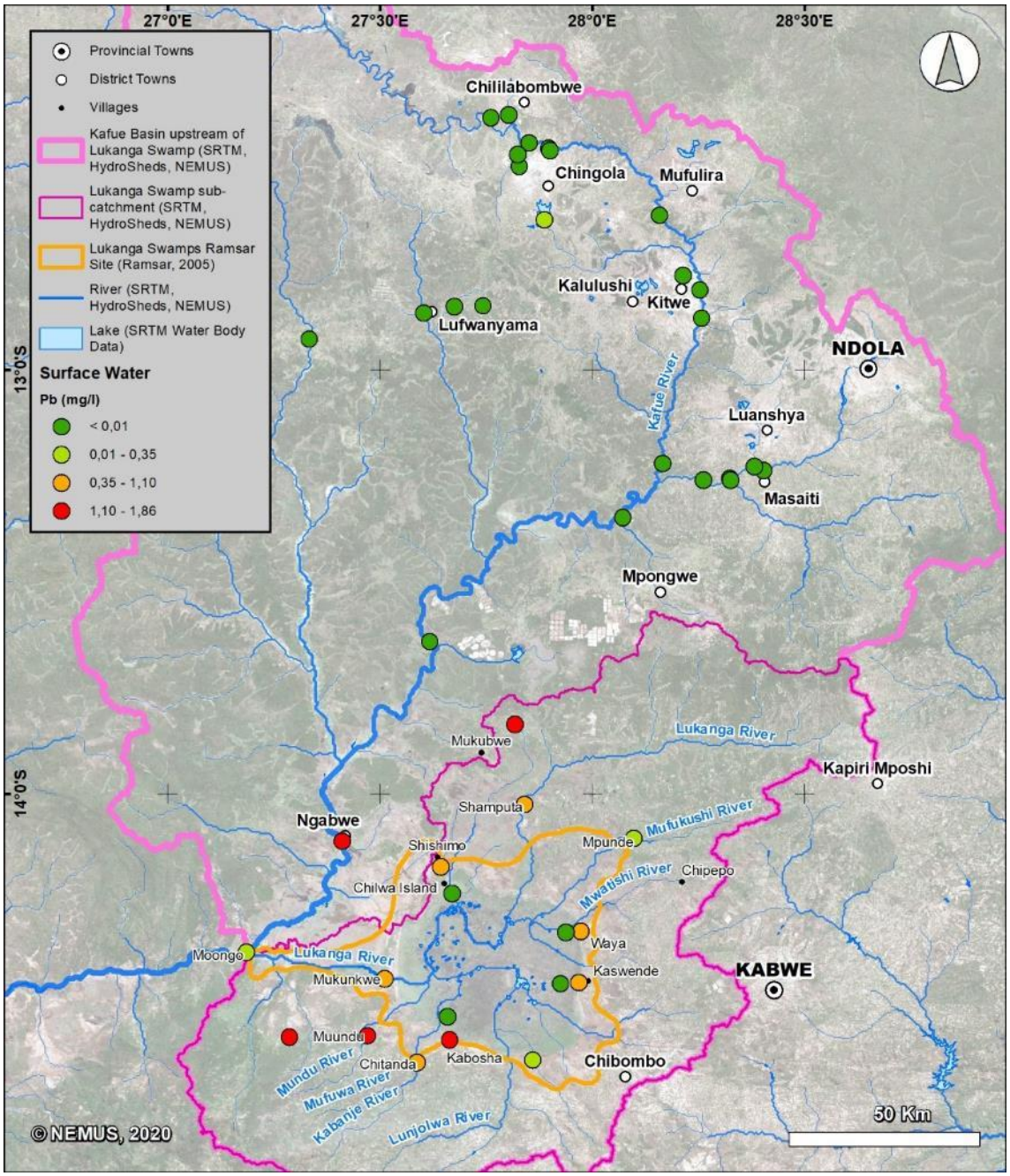


Figure 49 – Distribution of Pb in surface water samples in the Lukanga Swamp and Upper Kafue River Basin

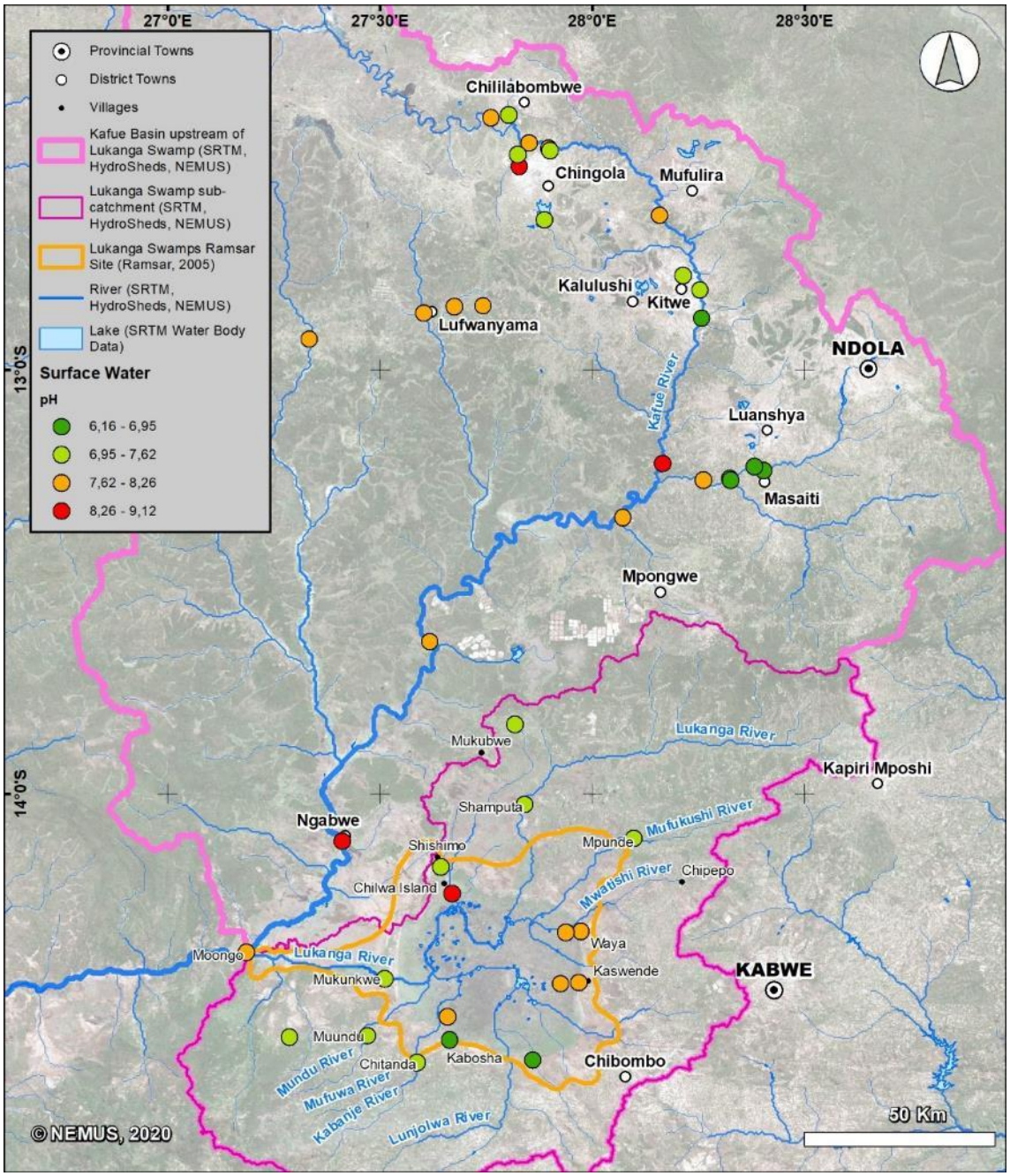


Figure 50 – Distribution of pH in surface water samples in the Lukanga Swamp and Upper Kafue River Basin

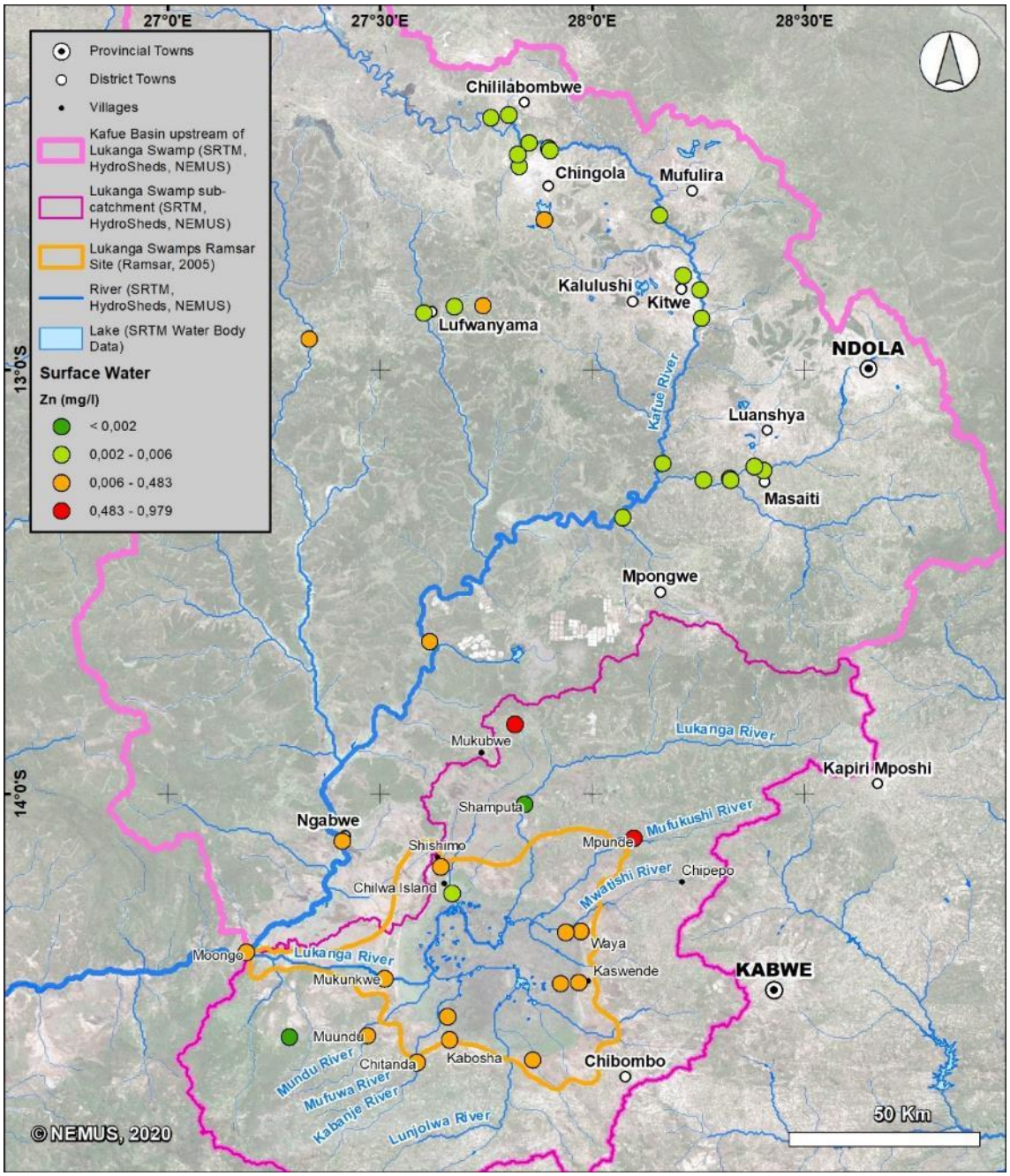


Figure 51 – Distribution of Zn in surface water samples in the Lukanga Swamp and Upper Kafue River Basin

B) Distribution of parameters determined in groundwater samples

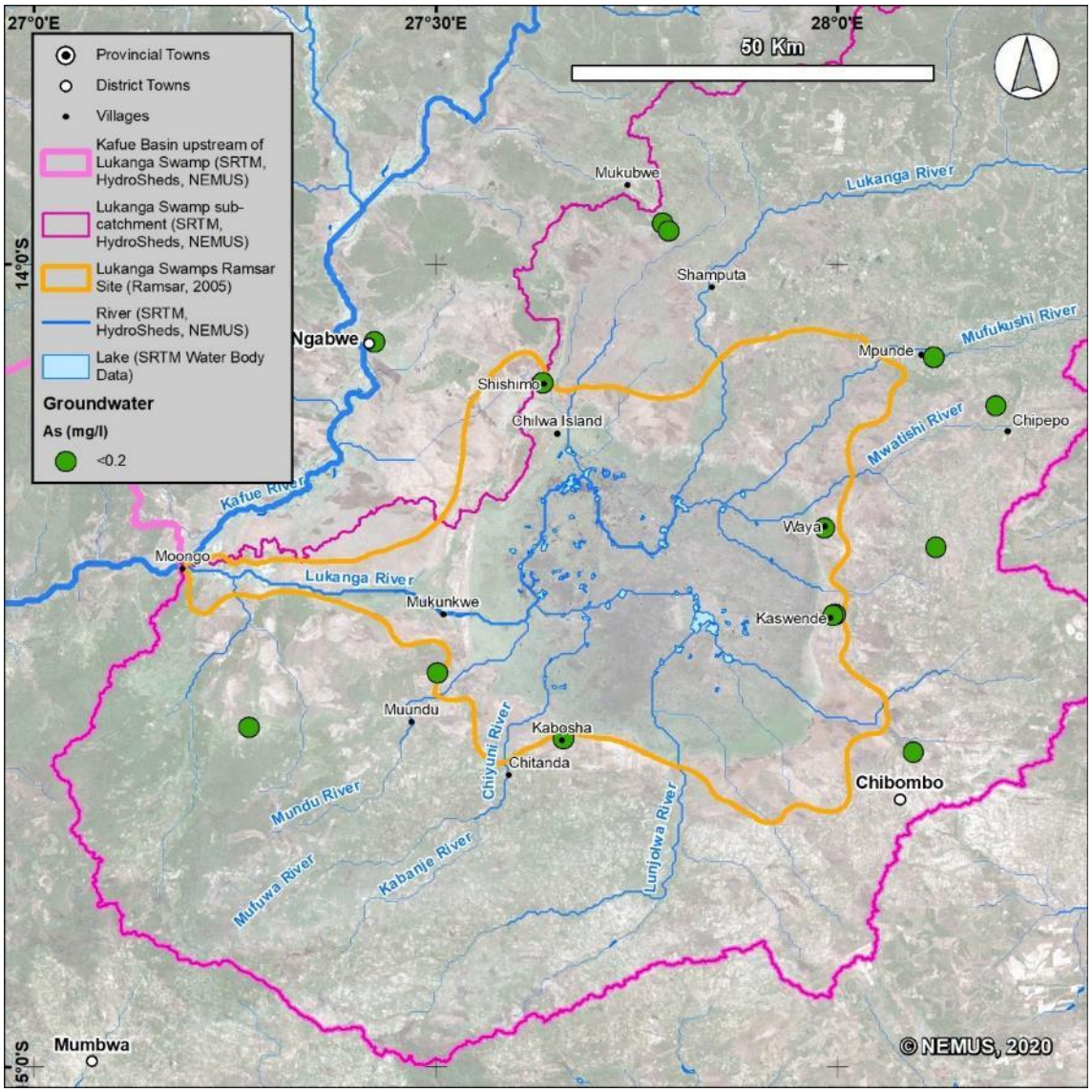


Figure 52 – Distribution of As in groundwater samples in the Lukanga Swamp area

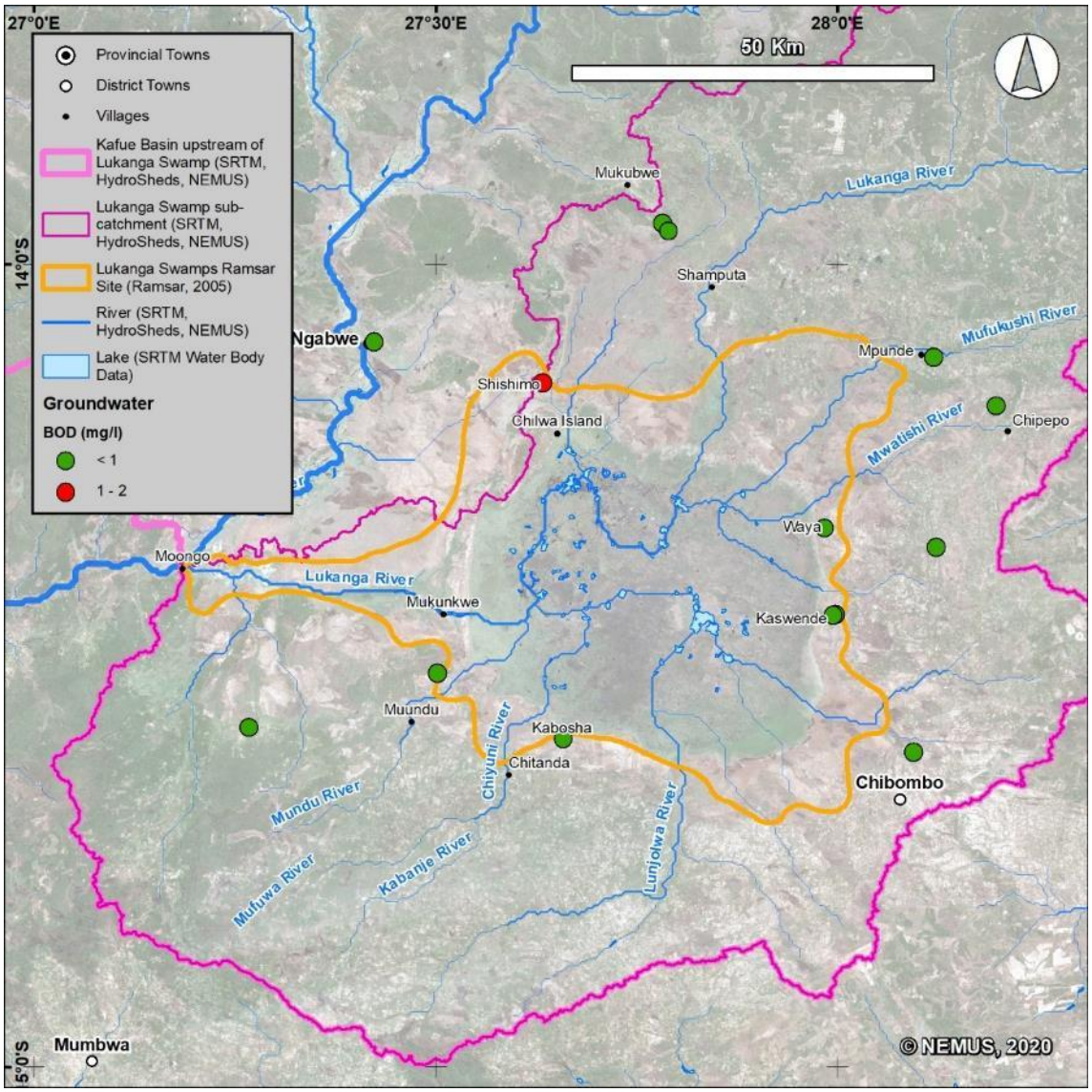


Figure 53 – Distribution of BOD in groundwater samples in the Lukanga Swamp area

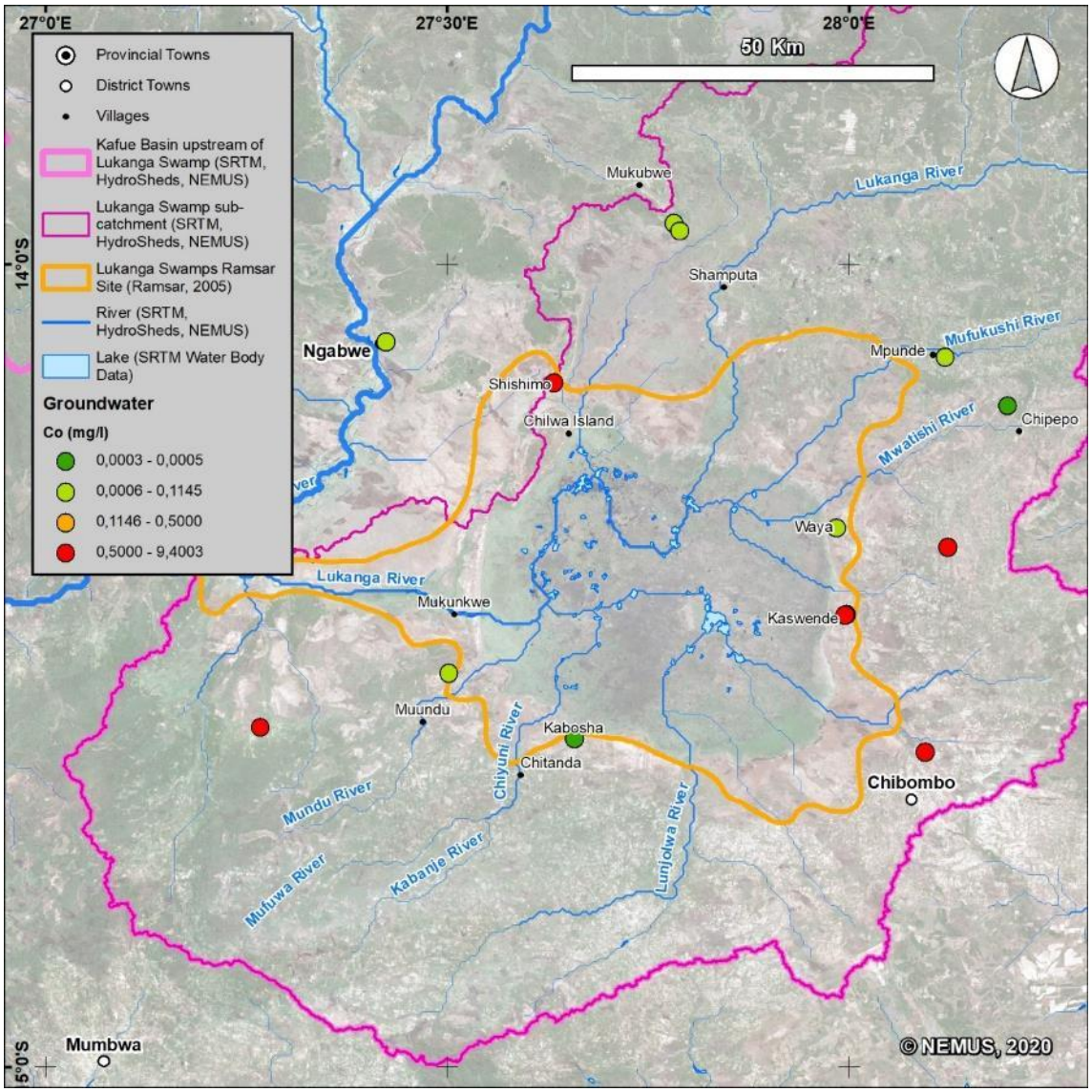


Figure 54 – Distribution of Co in groundwater samples in the Lukanga Swamp area

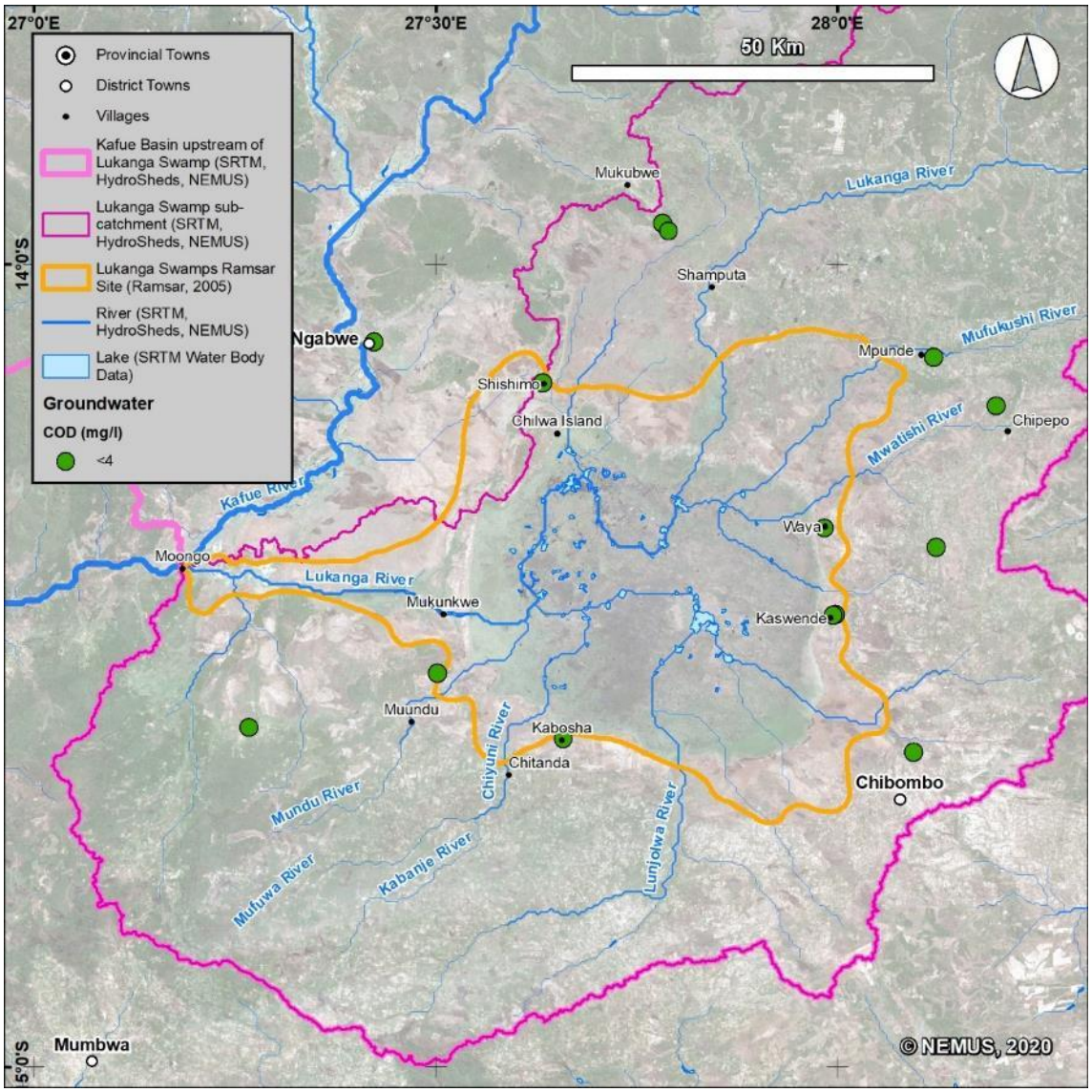


Figure 55 – Distribution of COD in groundwater samples in the Lukanga Swamp area

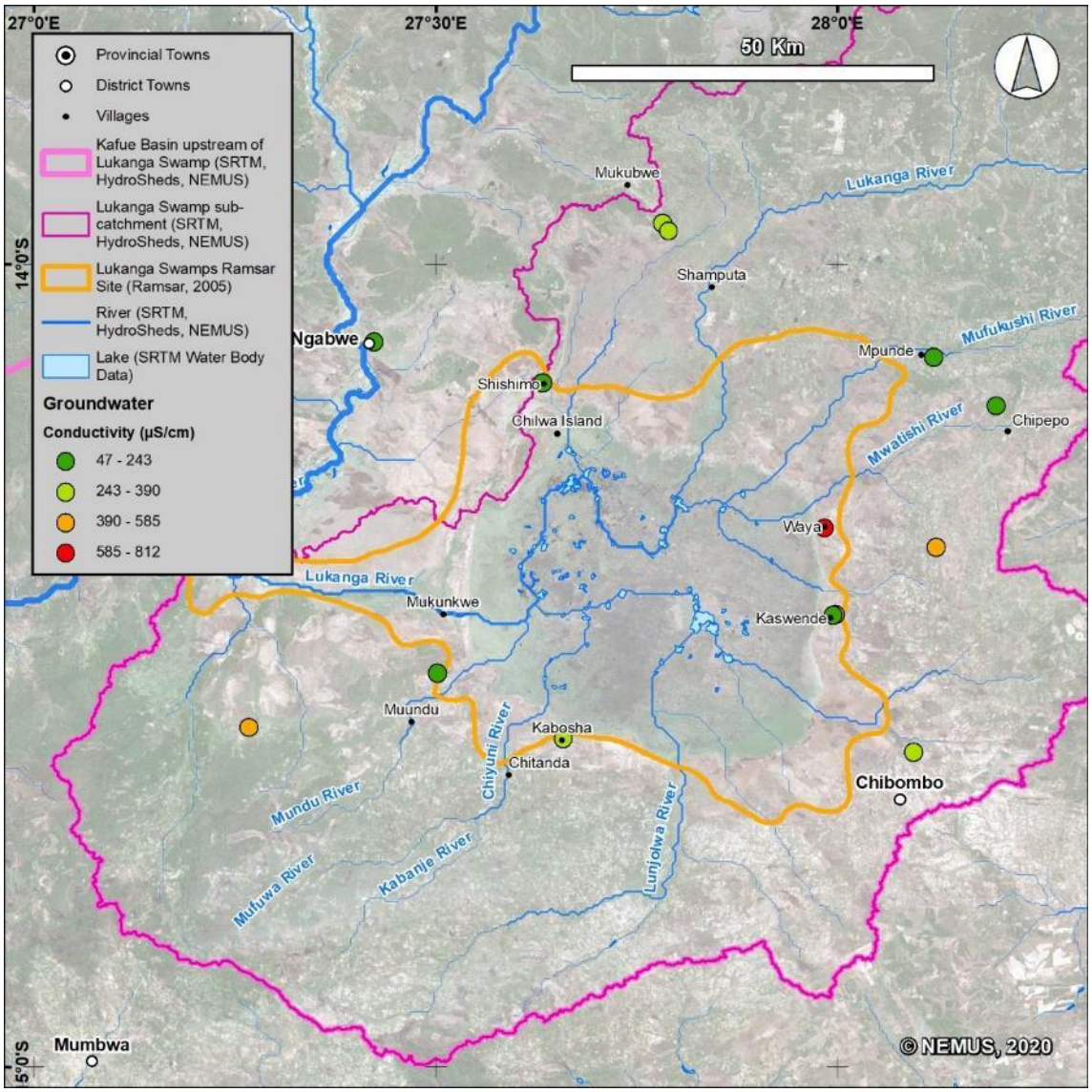


Figure 56 – Distribution of conductivity in groundwater samples in the Lukanga Swamp area

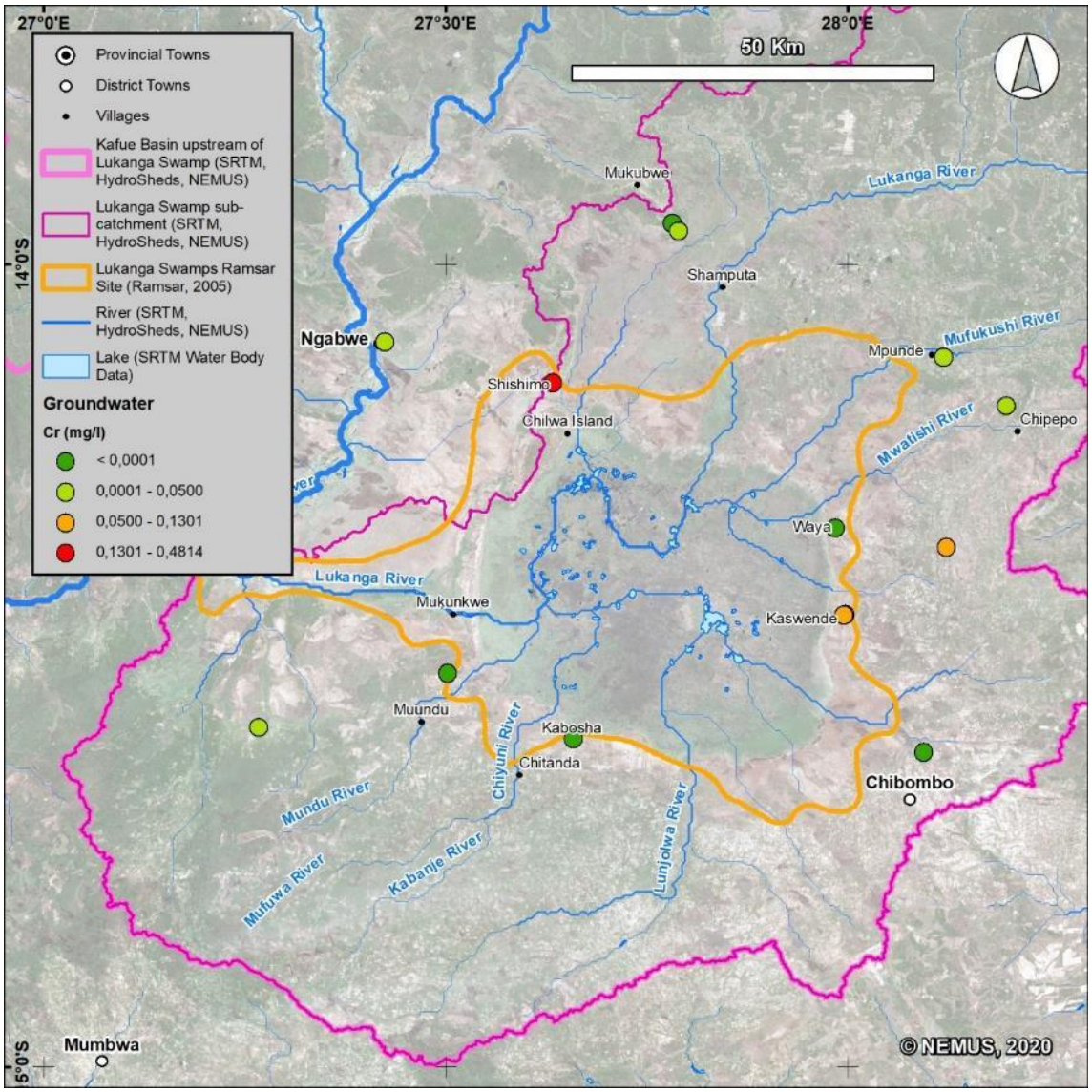


Figure 57 – Distribution of Cr in groundwater samples in the Lukanga Swamp area

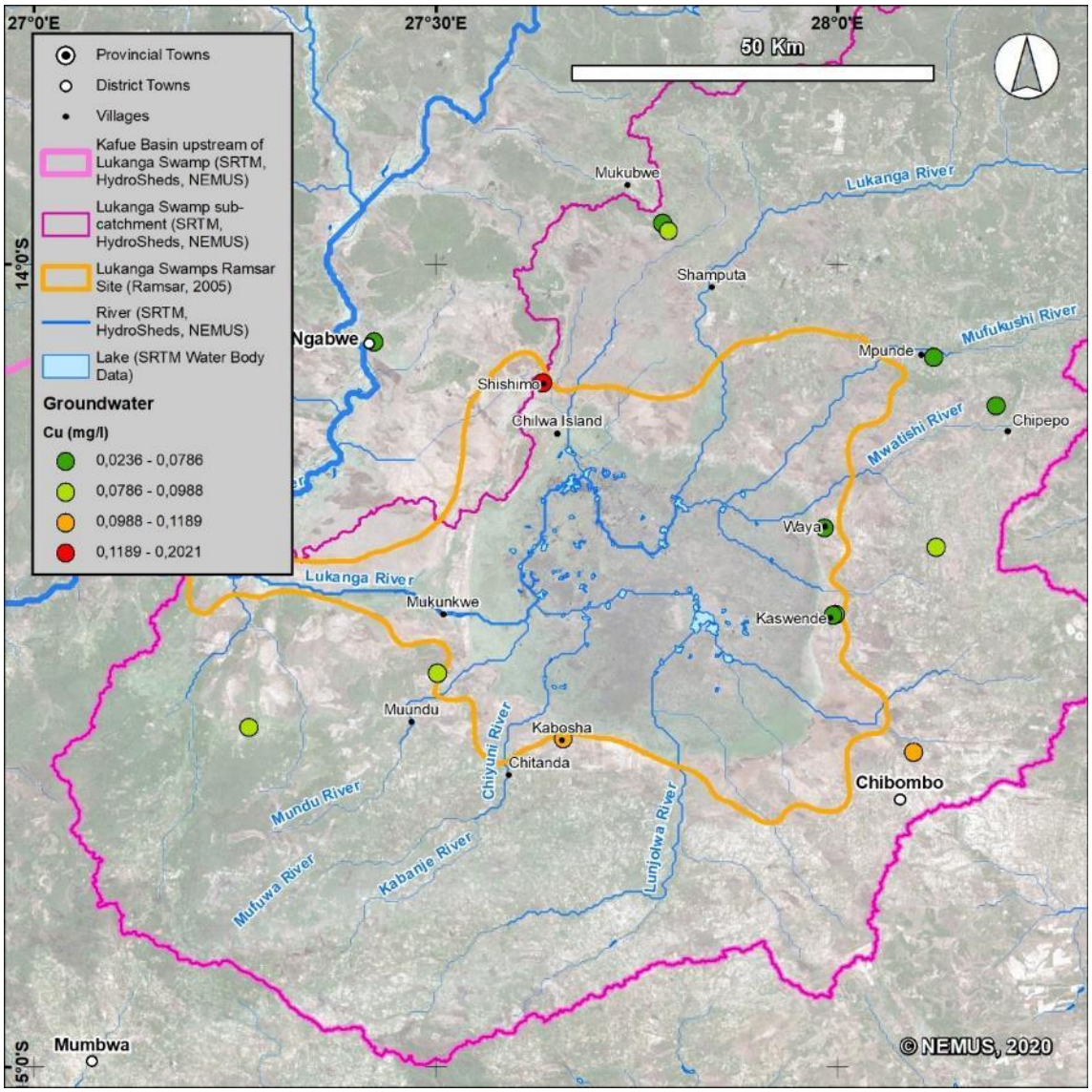


Figure 58 – Distribution of Cu in groundwater samples in the Lukanga Swamp area

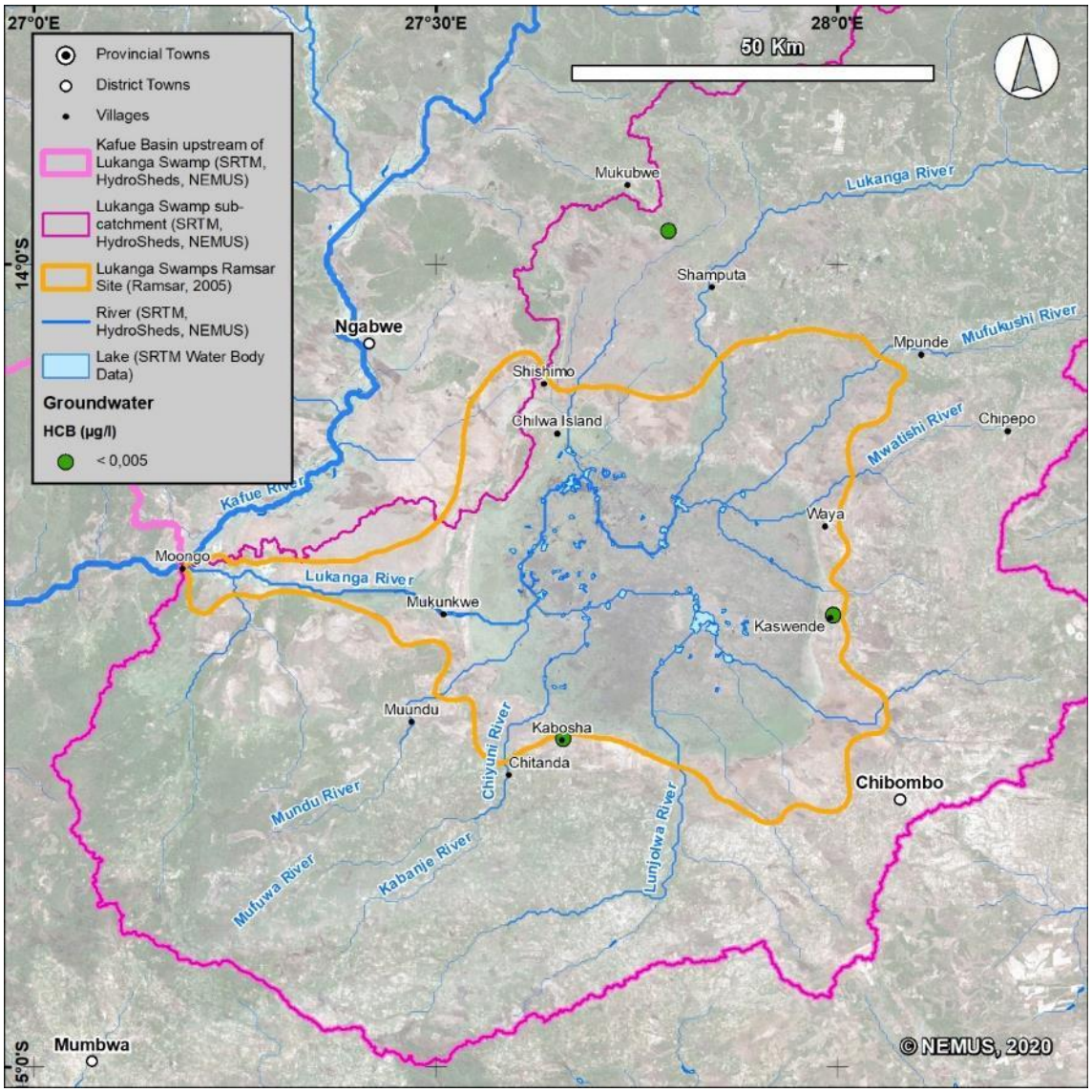


Figure 59 – Distribution of HCB in groundwater samples in the Lukanga Swamp area

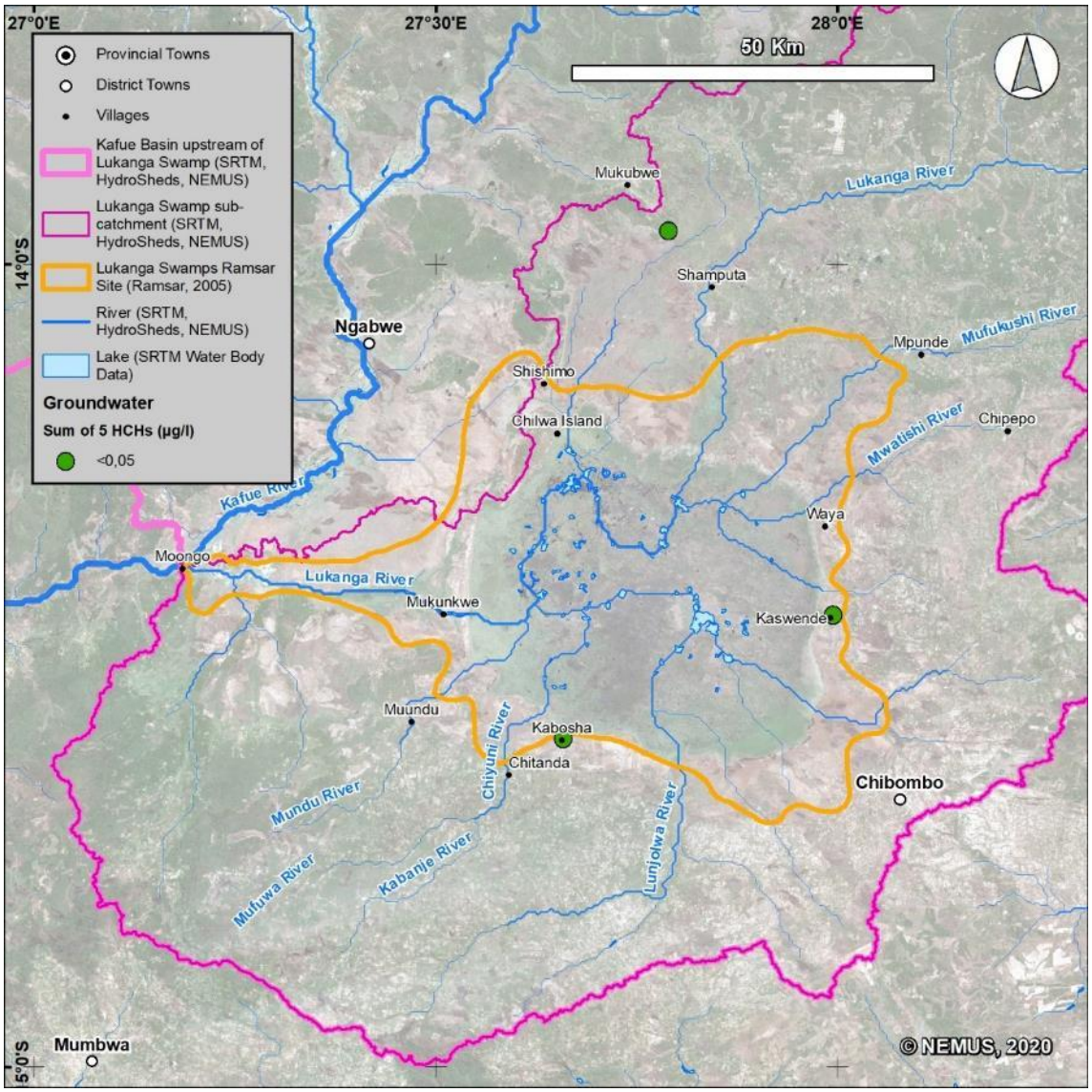


Figure 60 – Distribution of HCH in groundwater samples in the Lukanga Swamp area

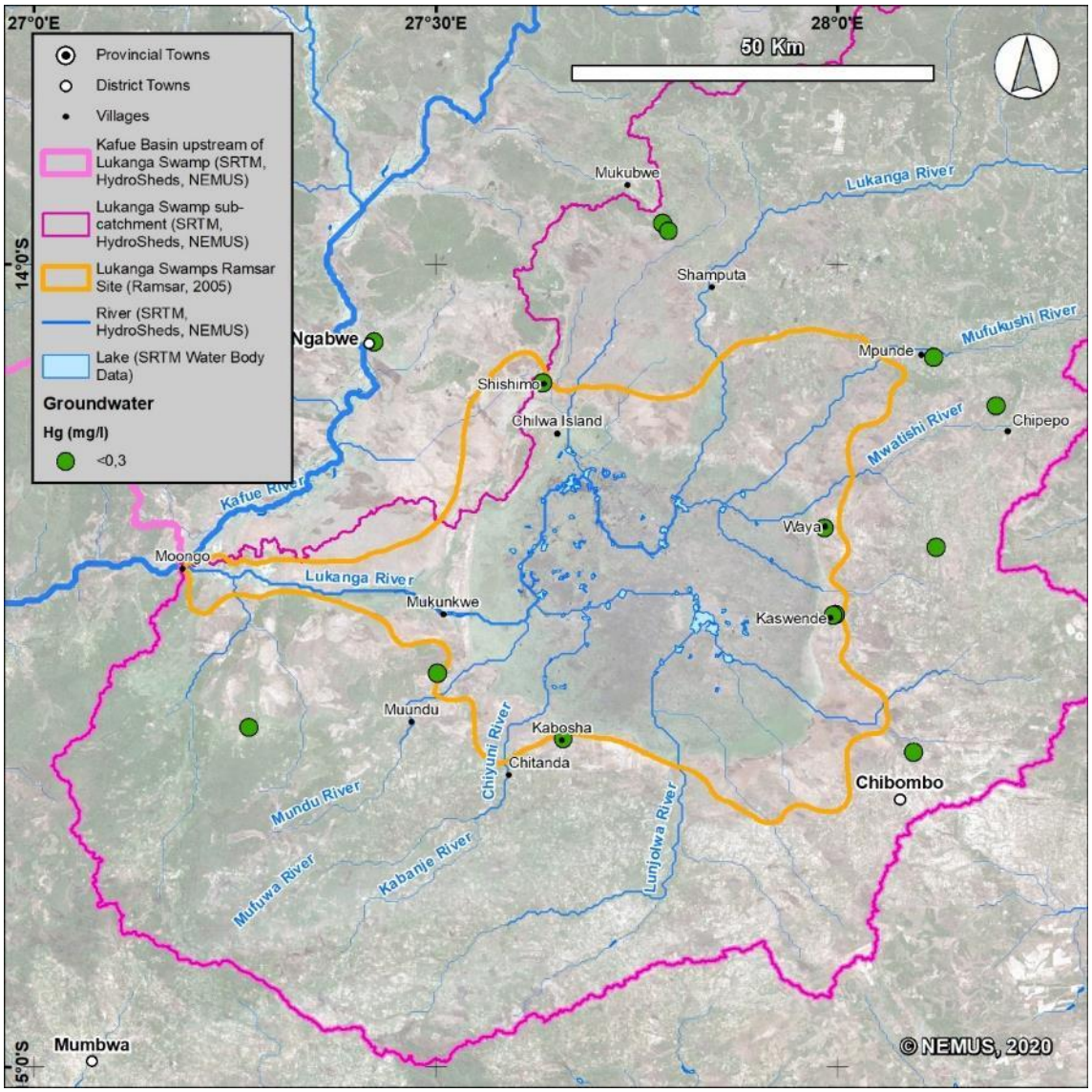


Figure 61 – Distribution of Hg in groundwater samples in the Lukanga Swamp area

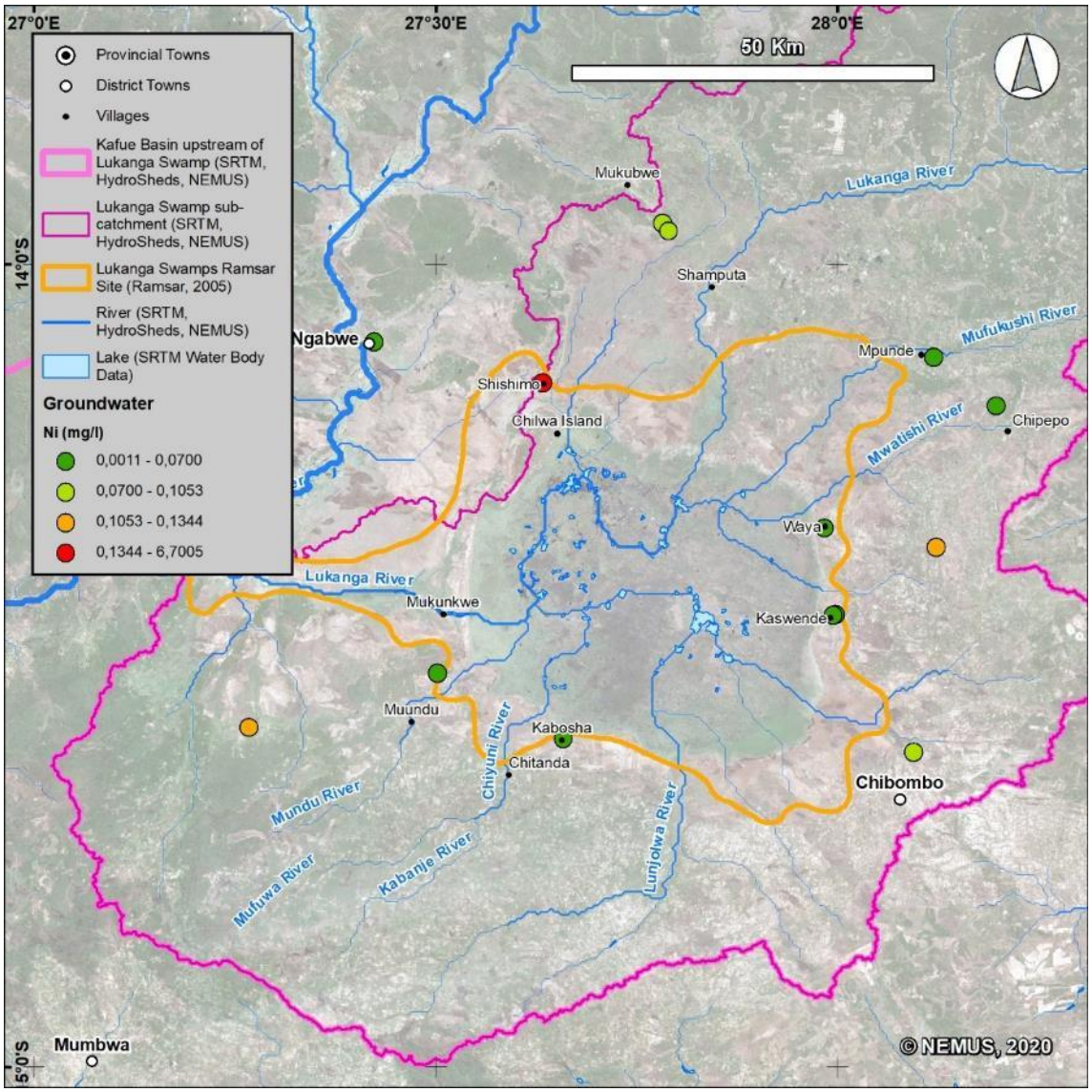


Figure 62 – Distribution of Ni in groundwater samples in the Lukanga Swamp area

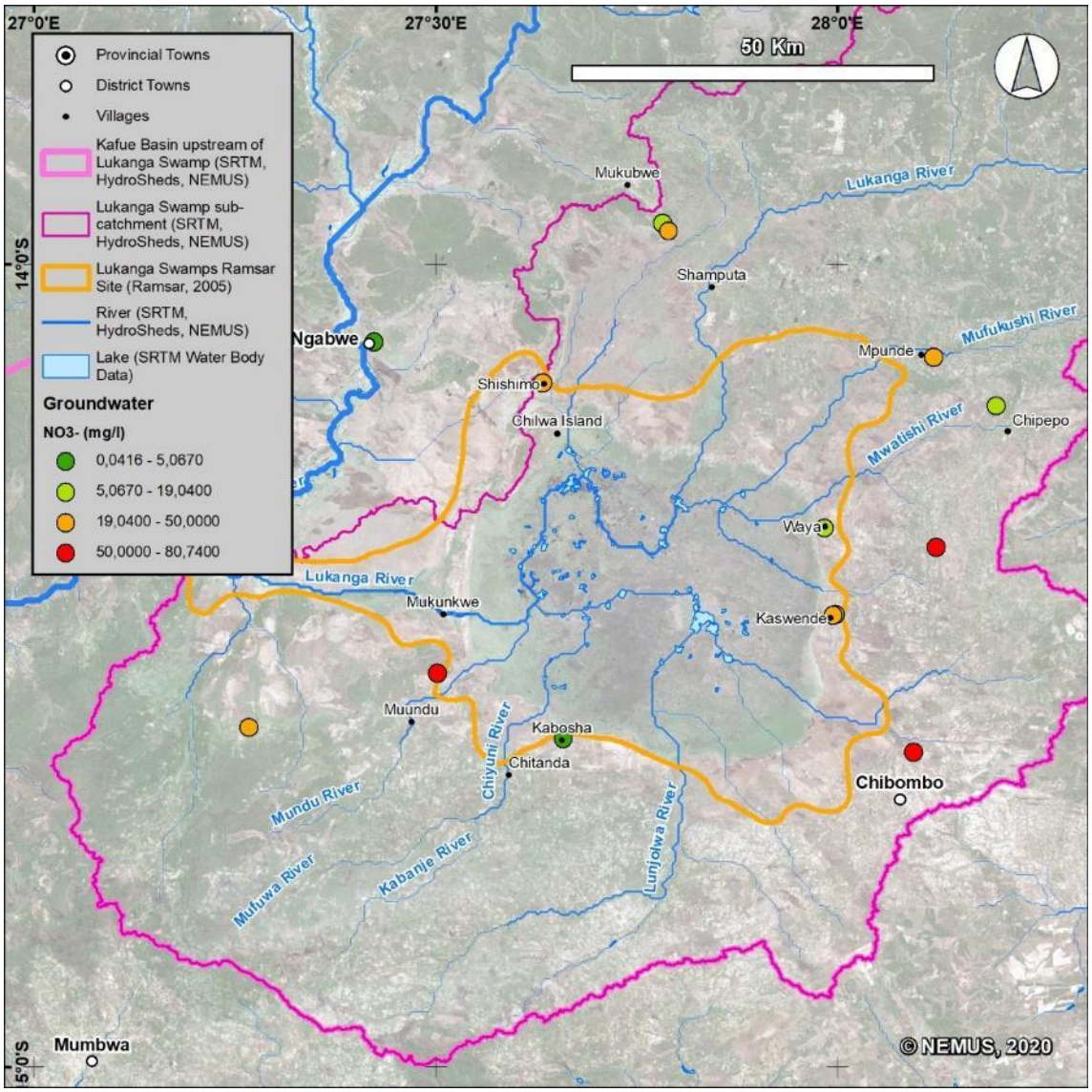


Figure 63 – Distribution of nitrates in groundwater samples in the Lukanga Swamp area

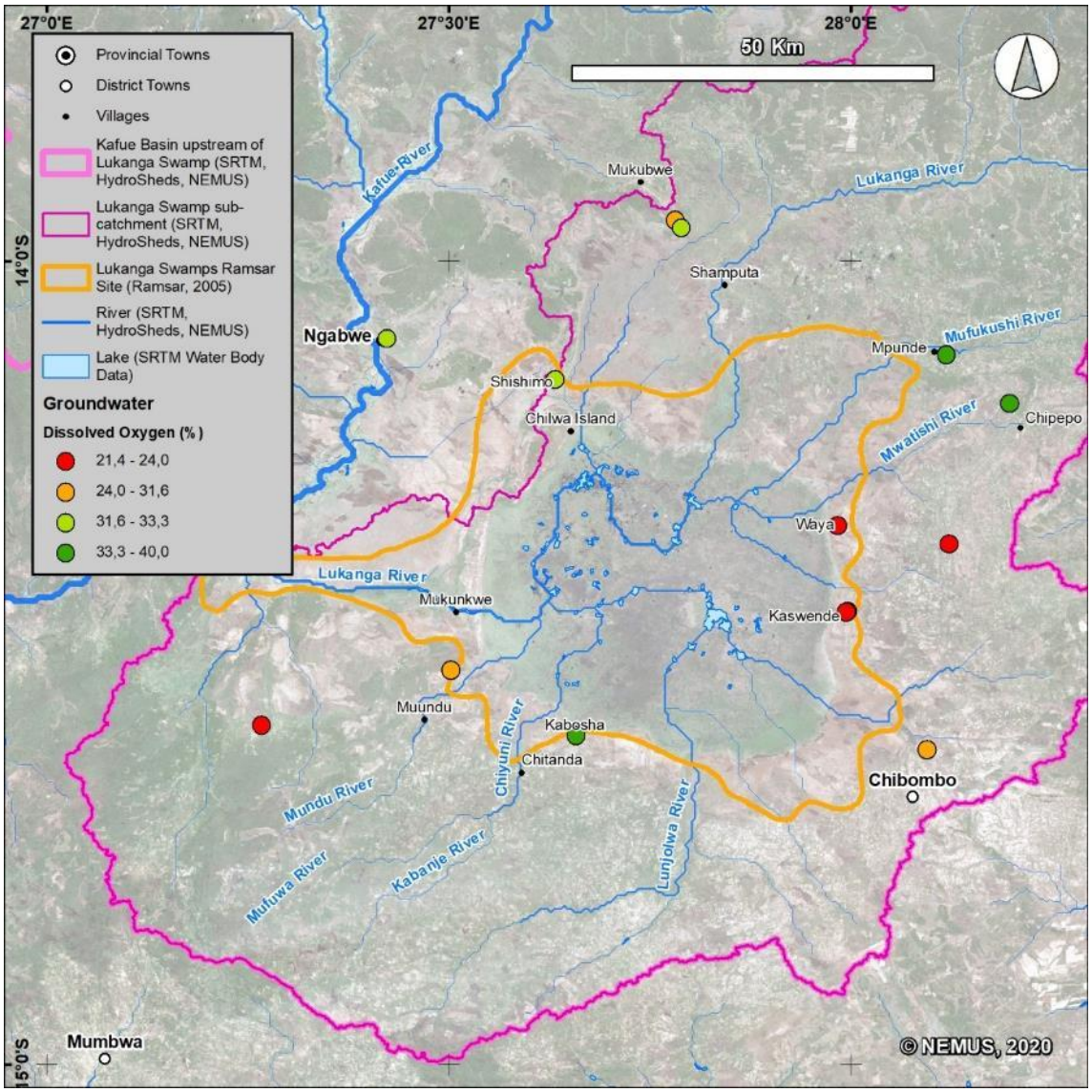


Figure 64 – Distribution of dissolved oxygen in groundwater samples in the Lukanga Swamp area

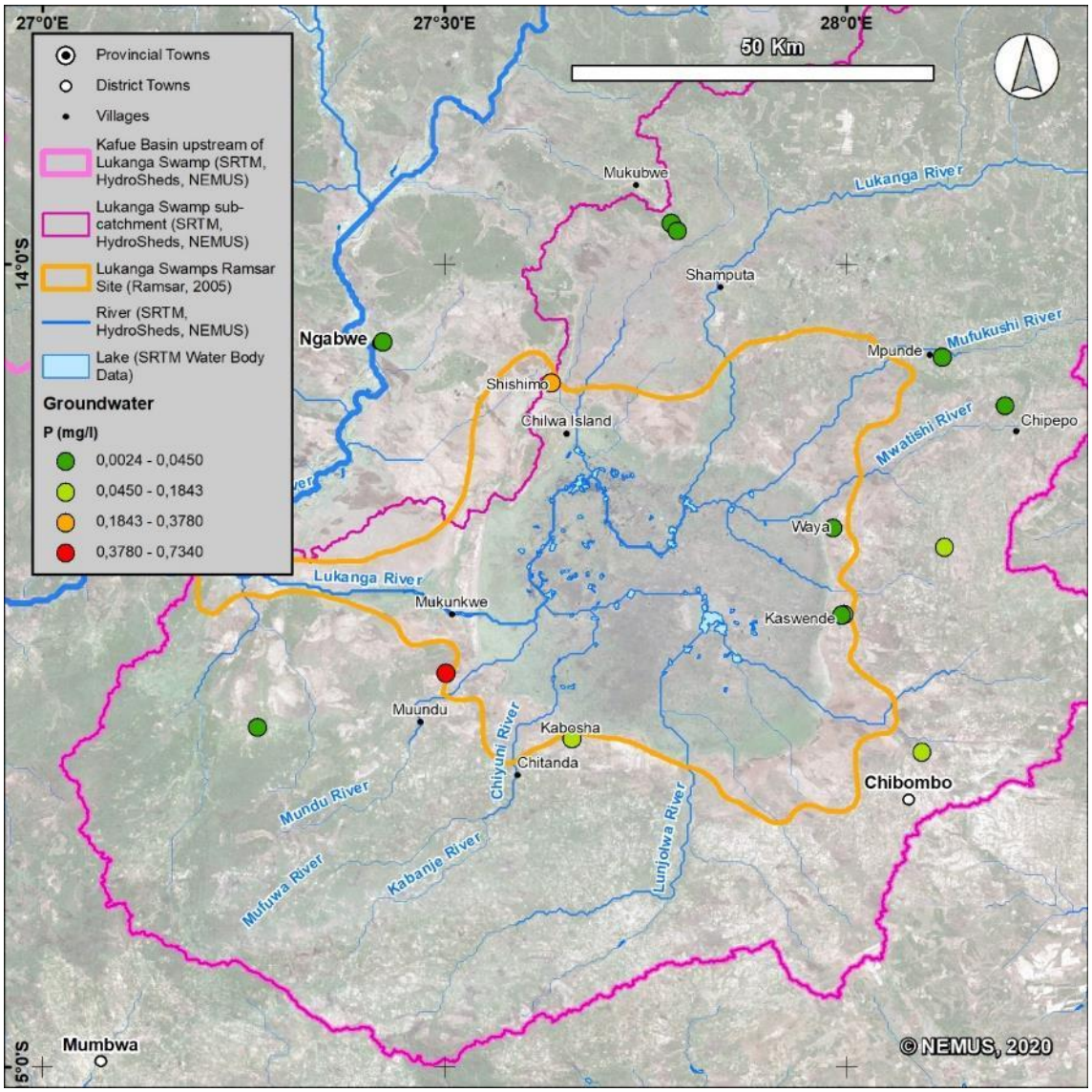


Figure 65 – Distribution of P in groundwater samples in the Lukanga Swamp area

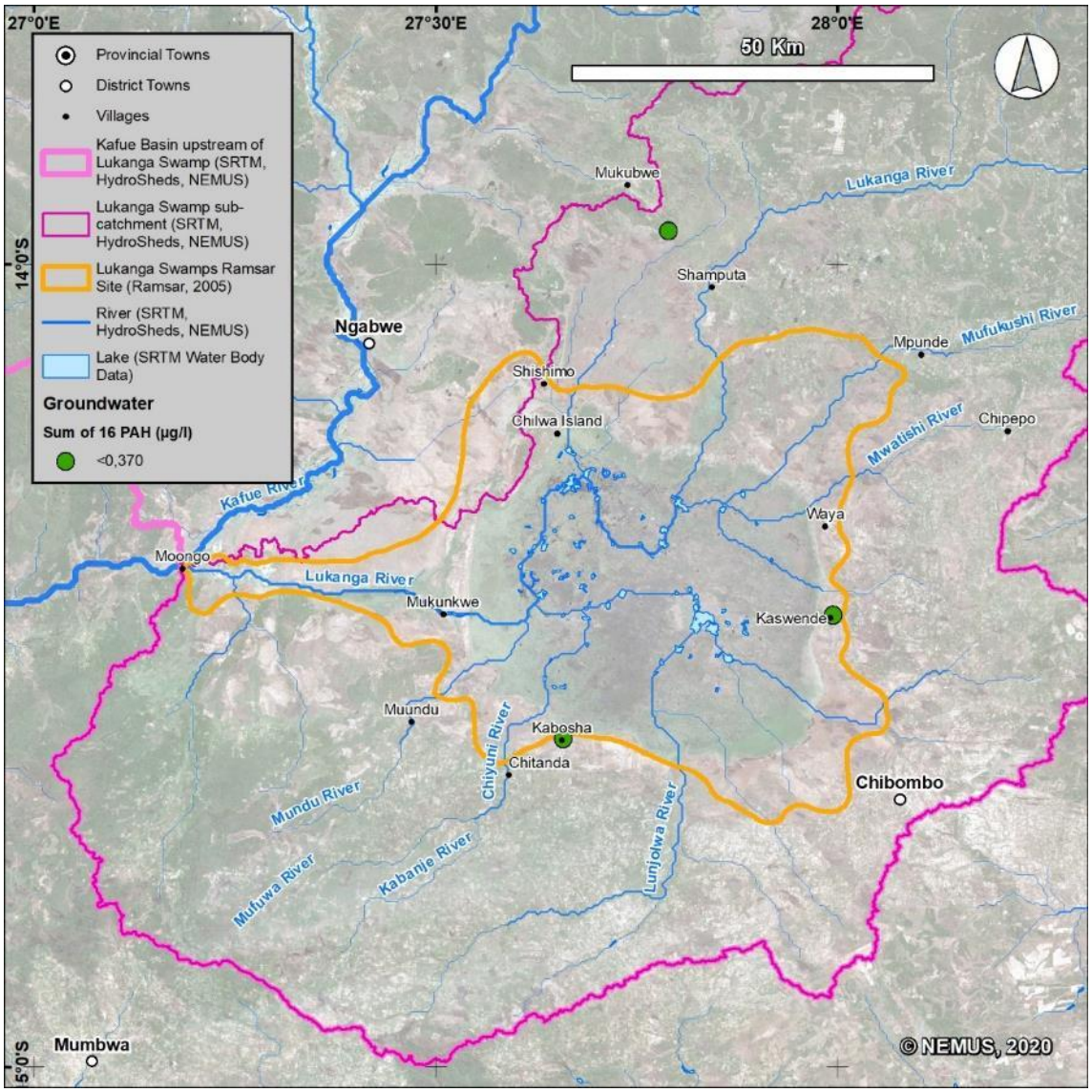


Figure 66 – Distribution of PAH in groundwater samples in the Lukanga Swamp area

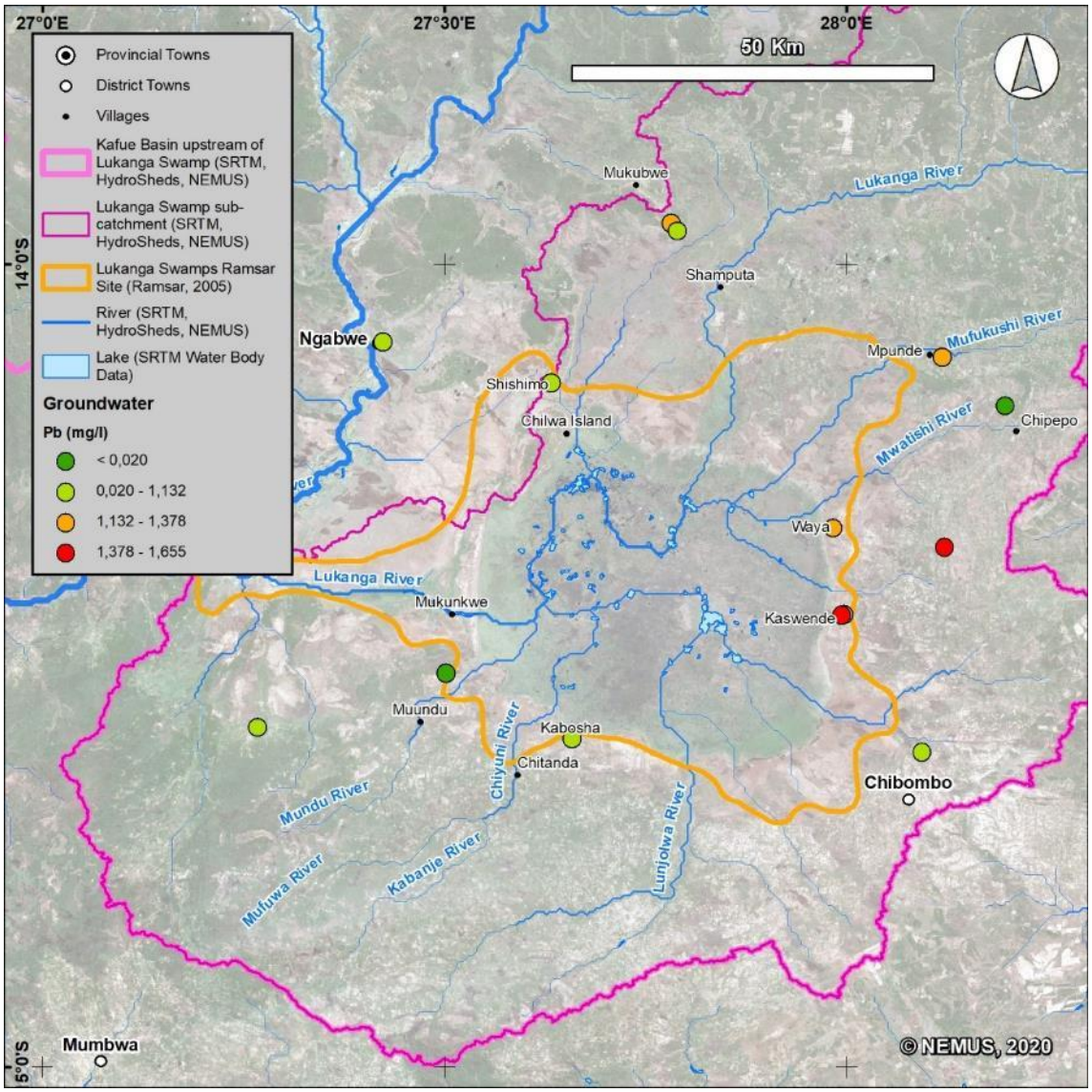


Figure 67 – Distribution of Pb in groundwater samples in the Lukanga Swamp area

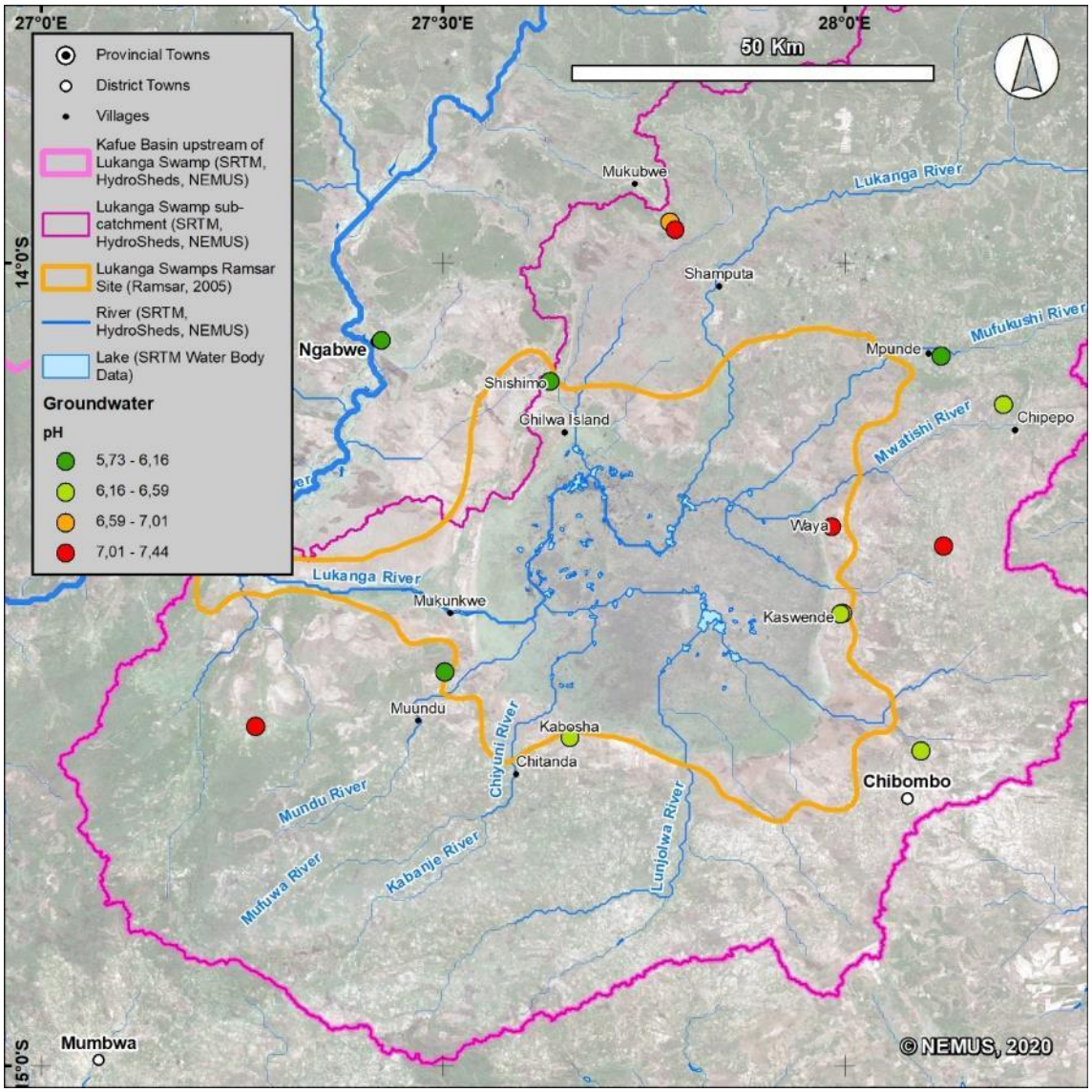


Figure 68 – Distribution of pH in groundwater samples in the Lukanga Swamp area

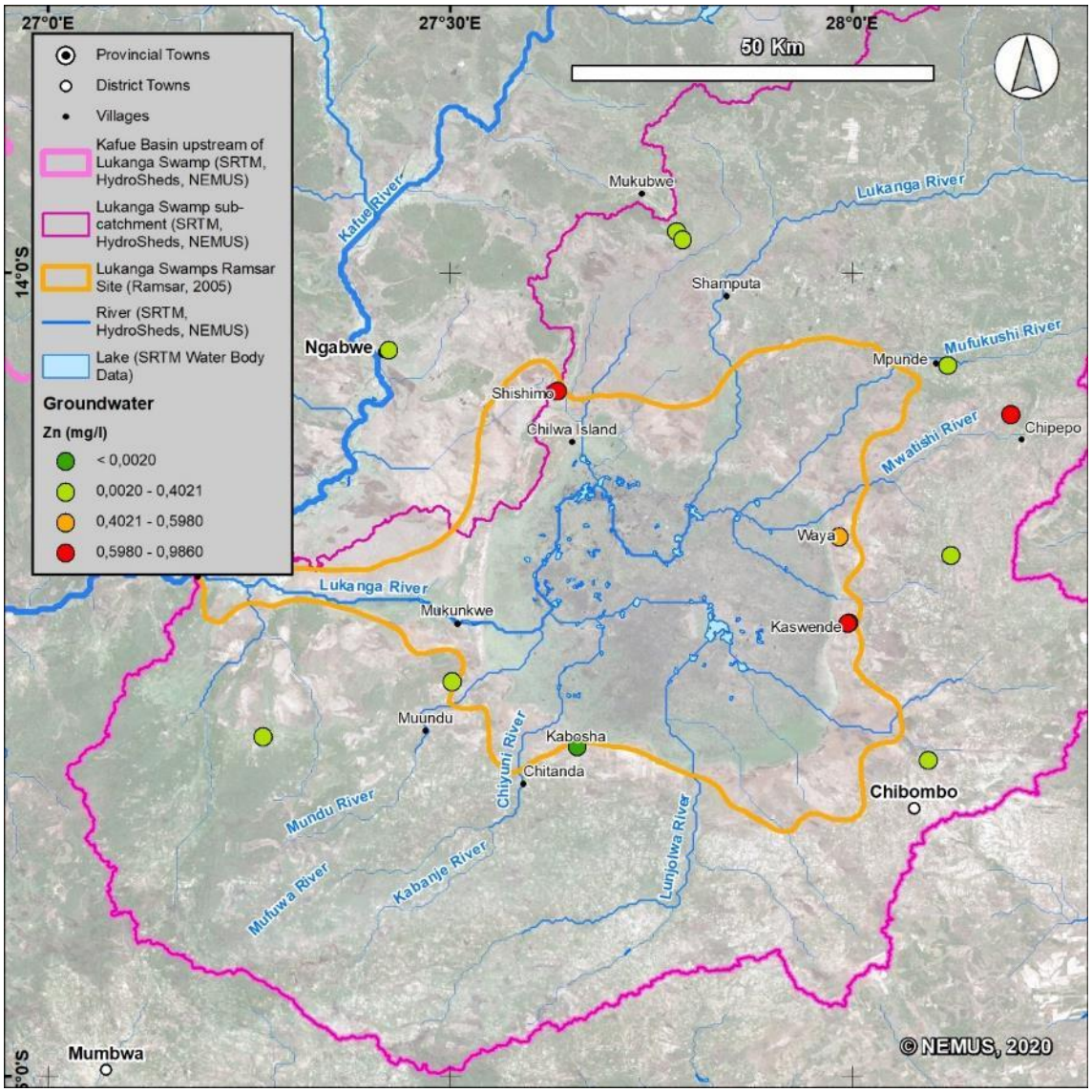


Figure 69 – Distribution of Zn in groundwater samples in the Lukanga Swamp area

C) Distribution of parameters determined in sediment samples and in composite leaf samples, if that is the case

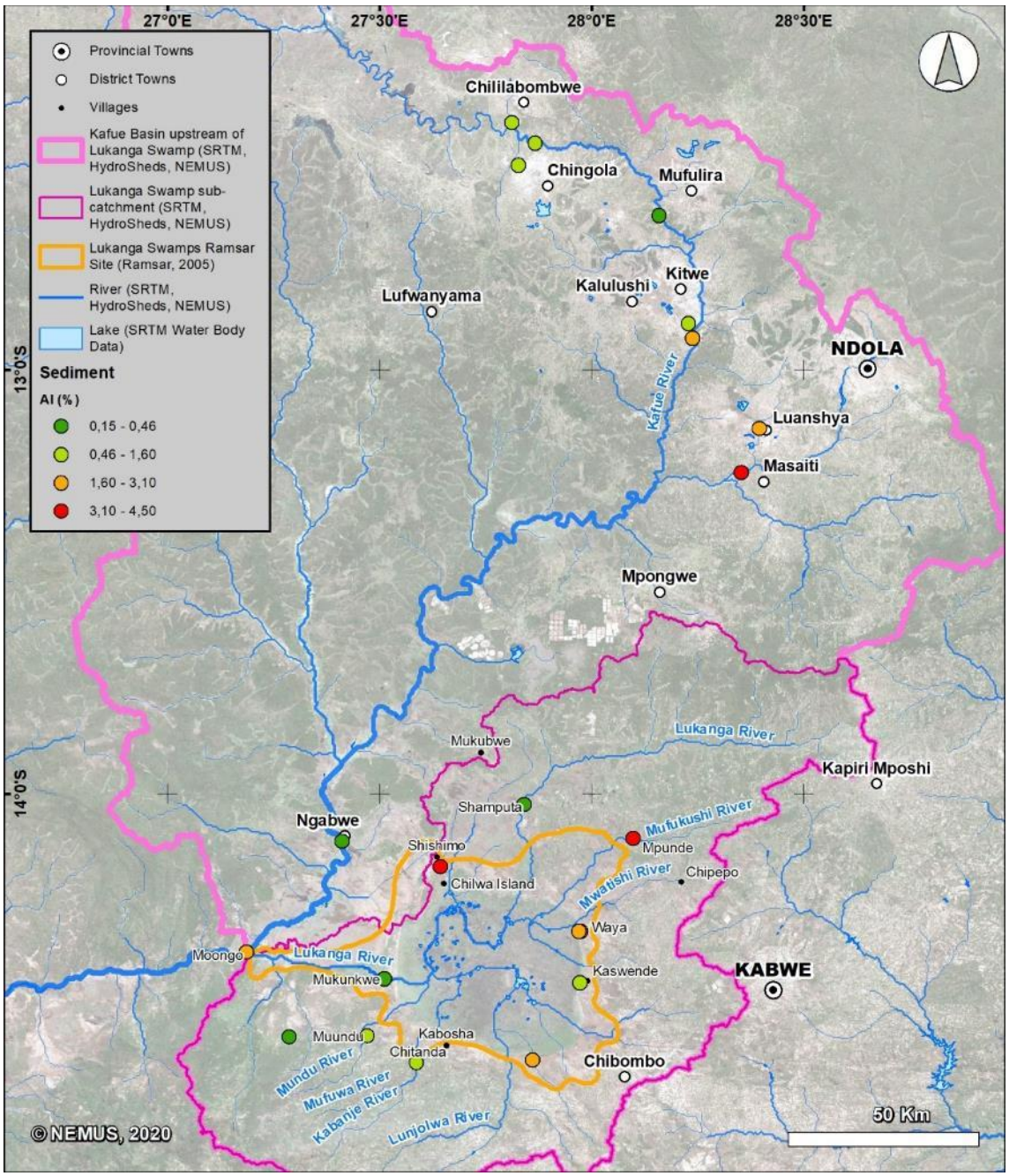


Figure 70 – Distribution of Al in sediment samples in the Lukanga Swamp and Upper Kafue River Basin

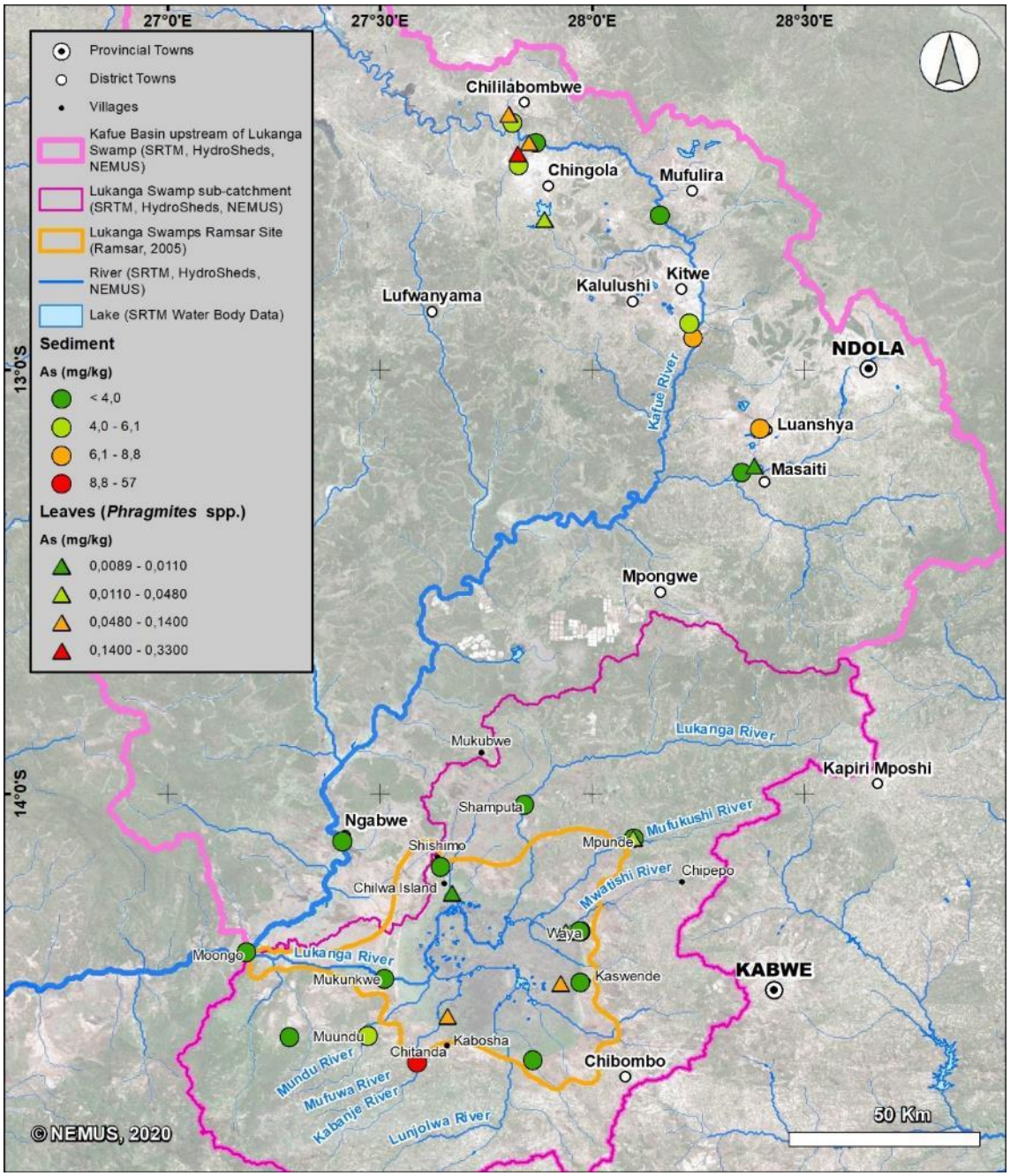


Figure 71 – Distribution of As in sediment samples and composite leaf samples in the Lukanga Swamp and Upper Kafue River Basin

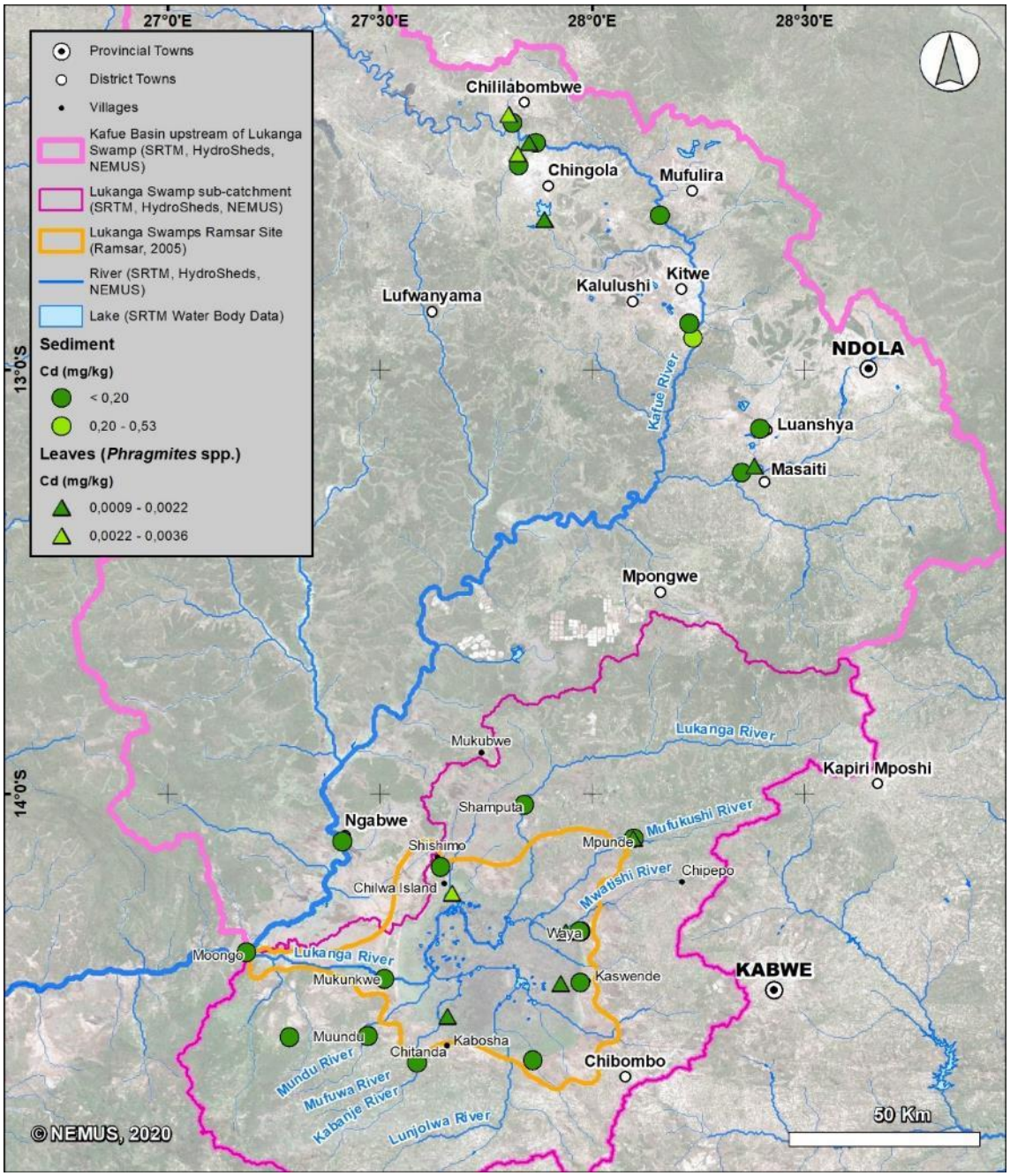


Figure 72 – Distribution of Cd in sediment samples and composite leaf samples in the Lukanga Swamp and Upper Kafue River Basin

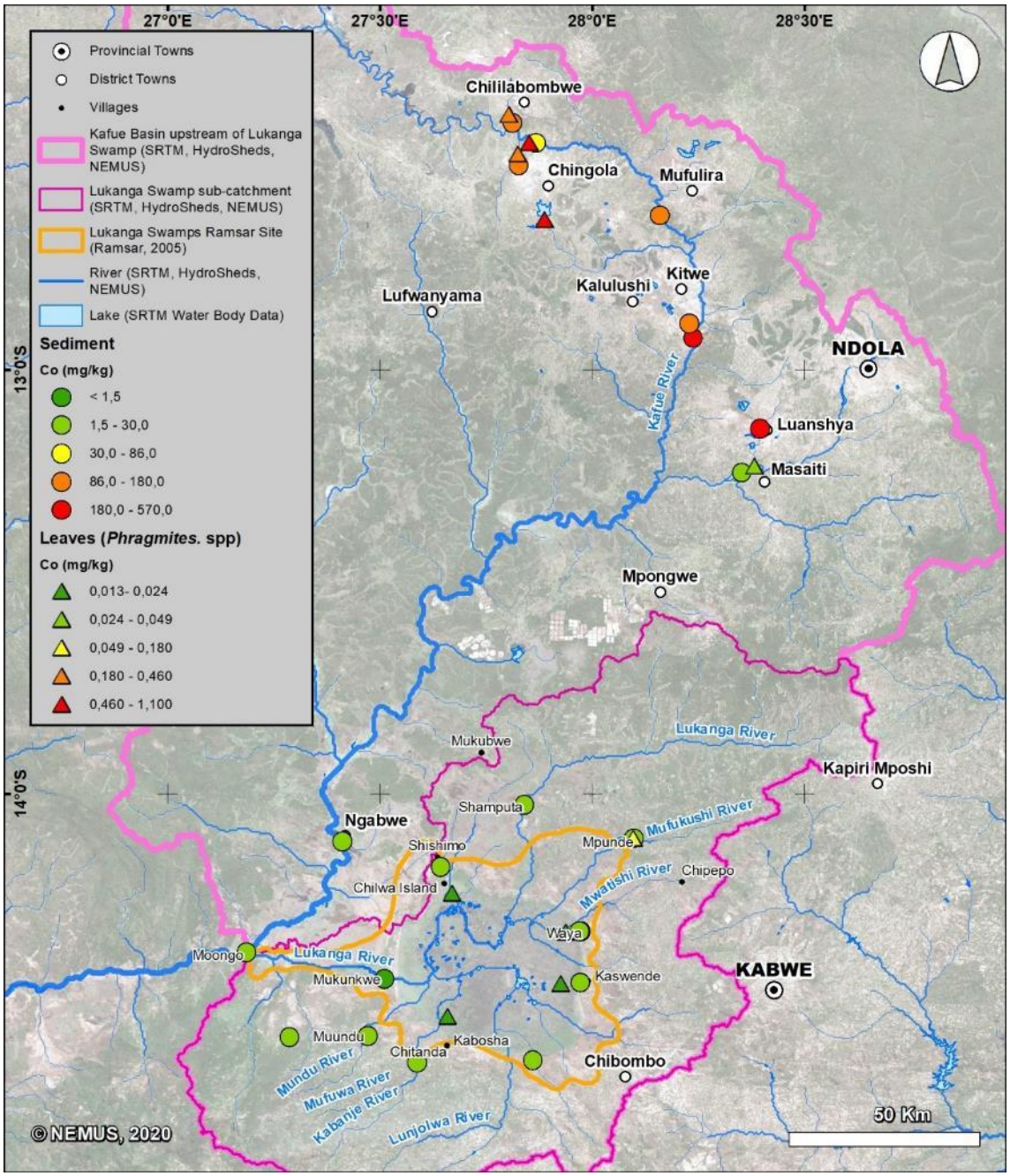


Figure 73 – Distribution of Co in sediment samples and composite leaf samples in the Lukanga Swamp and Upper Kafue River Basin

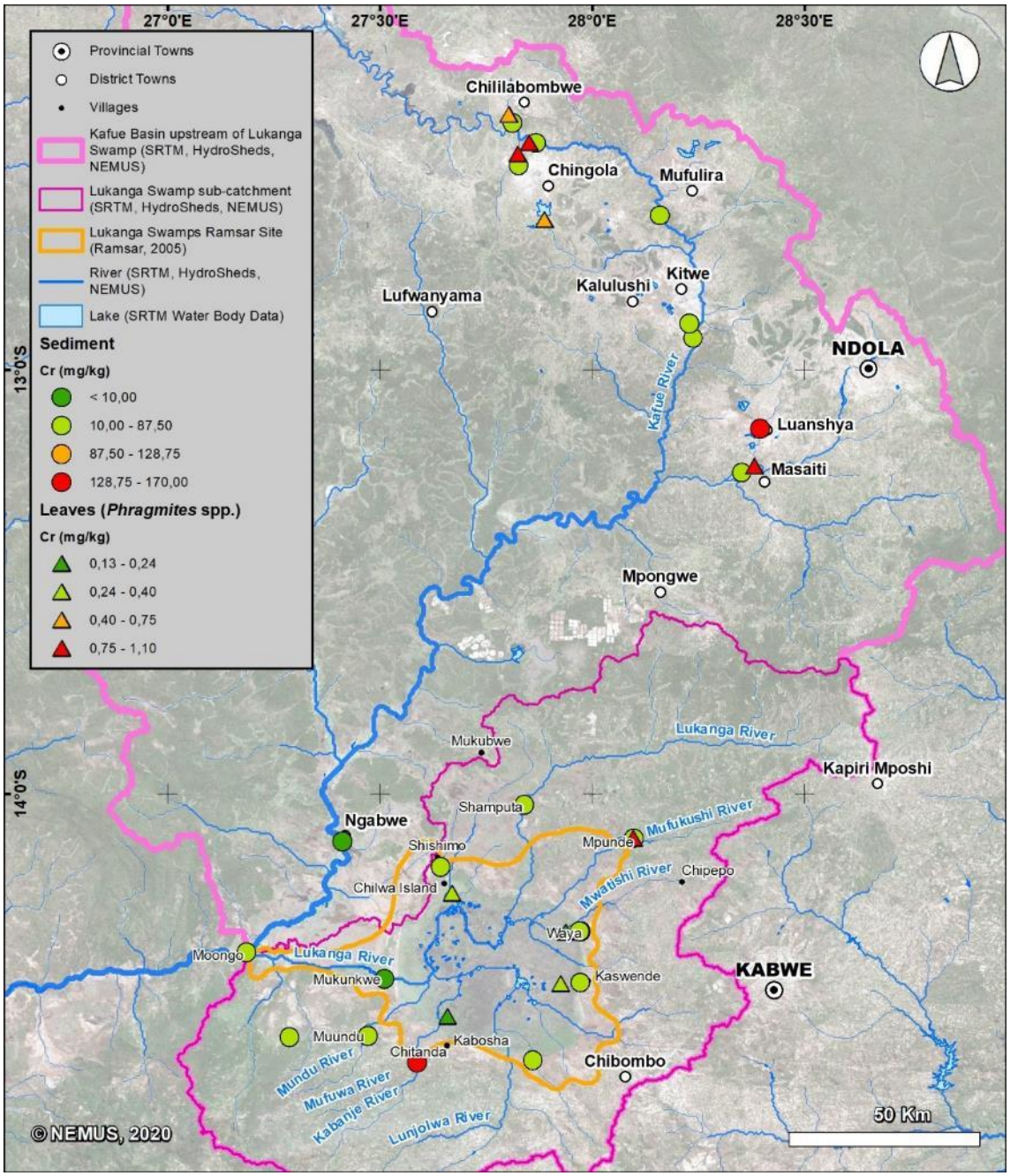


Figure 74 – Distribution of Cr in sediment samples and composite leaf samples in the Lukanga Swamp and Upper Kafue River Basin

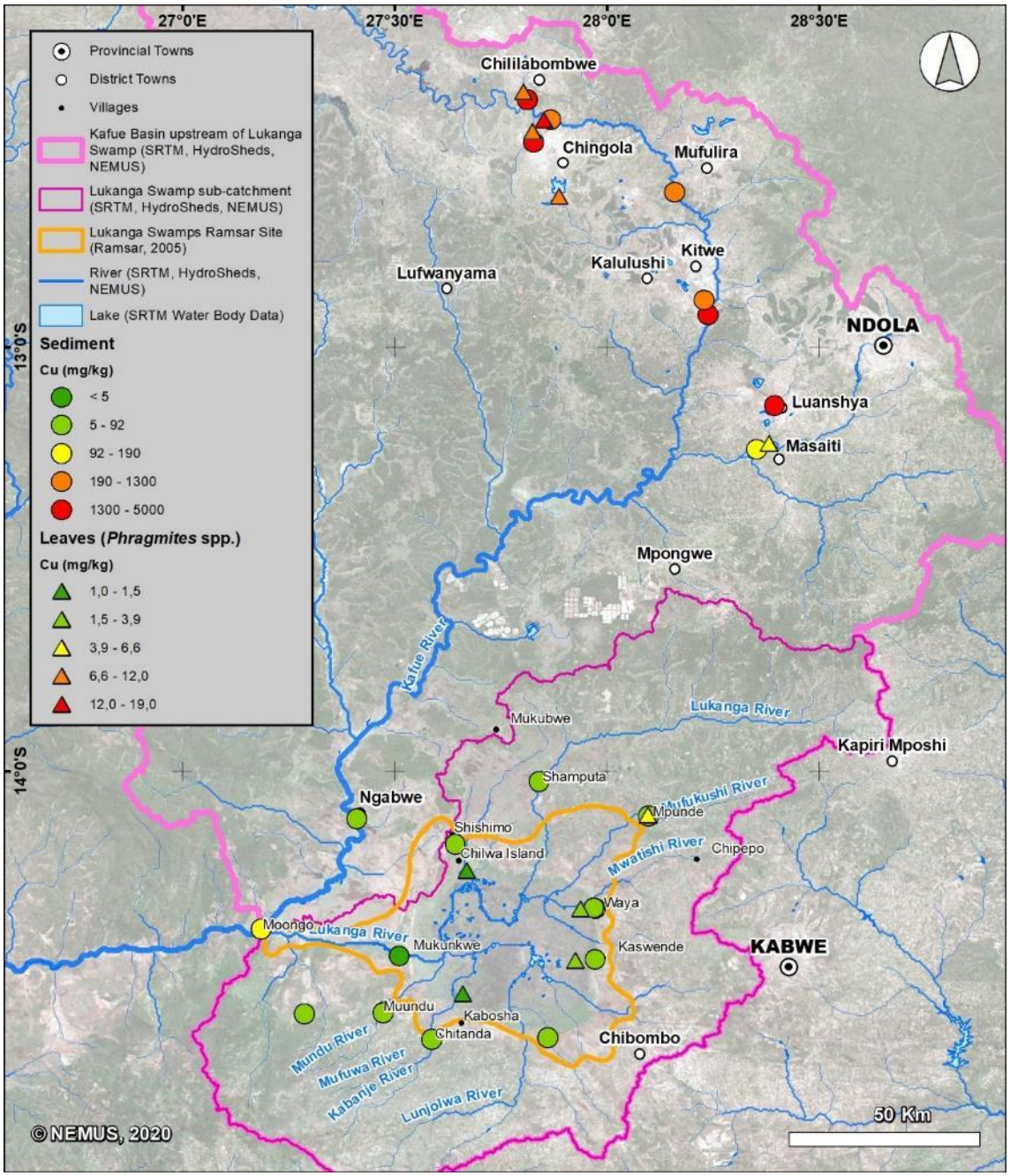


Figure 75 – Distribution of Cu in sediment samples and composite leaf samples in the Lukanga Swamp and Upper Kafue River Basin

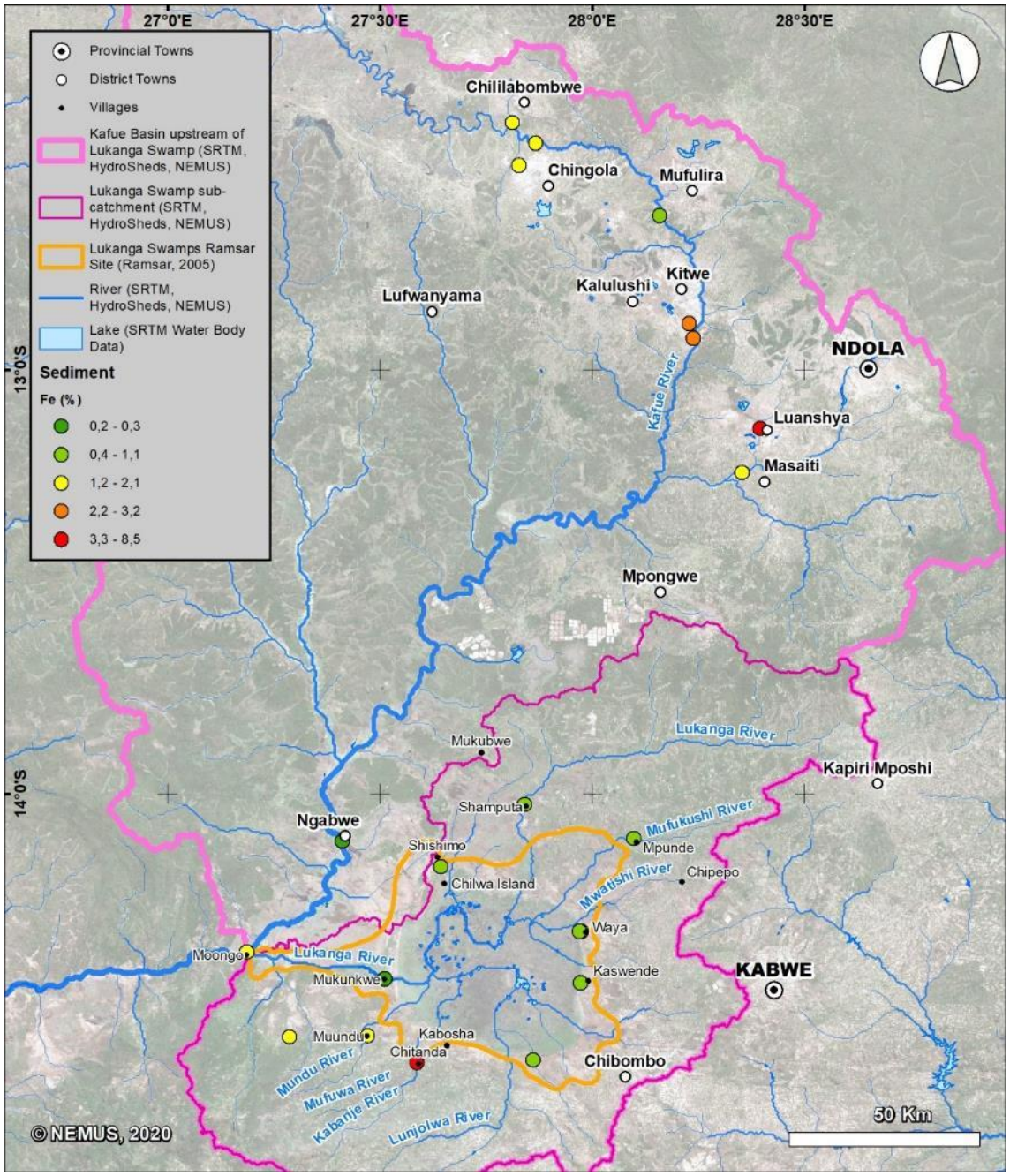


Figure 76 – Distribution of Fe in sediment samples in the Lukanga Swamp and Upper Kafue River Basin

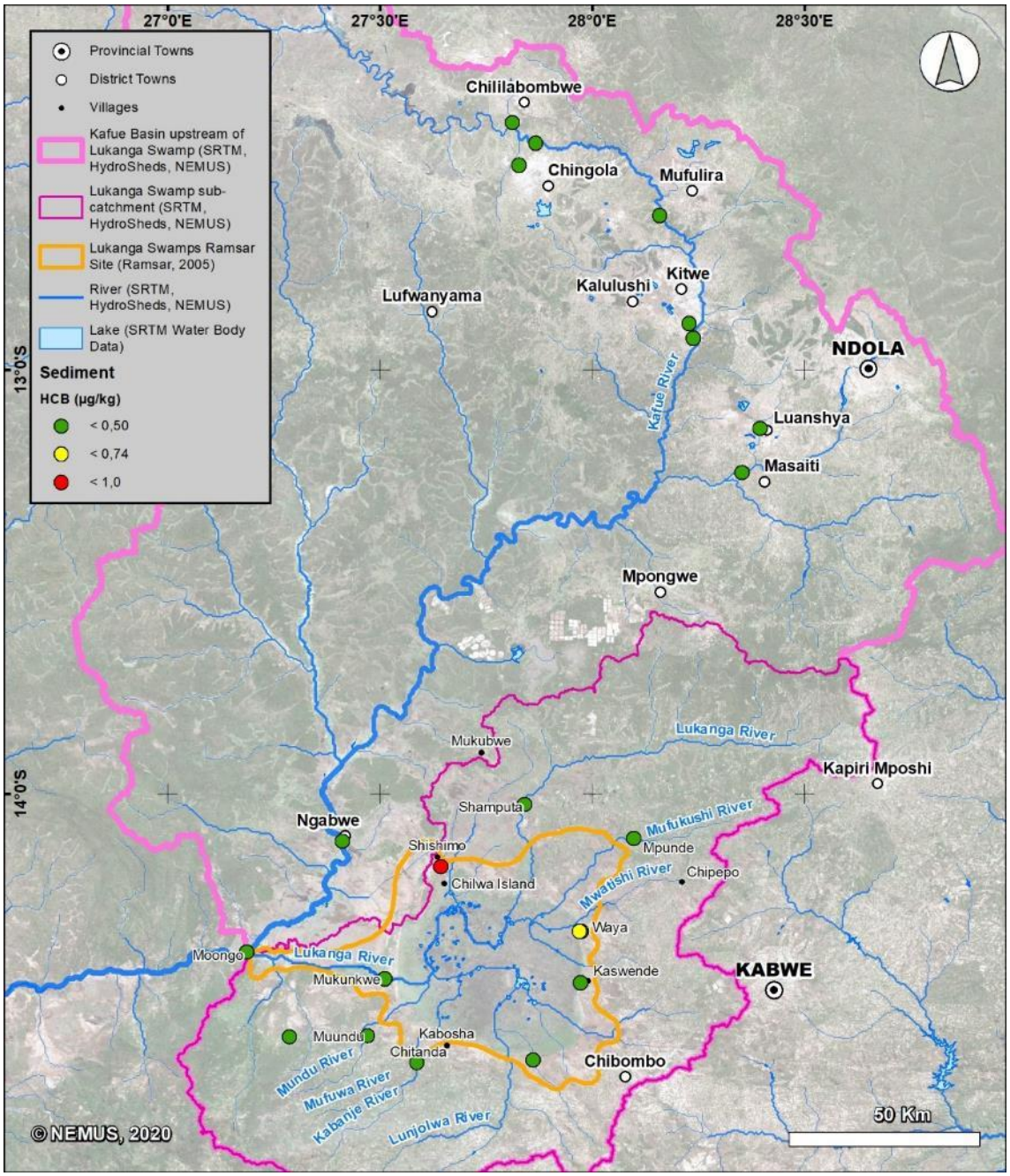


Figure 77 – Distribution of HCB in sediment samples in the Lukanga Swamp and Upper Kafue River Basin

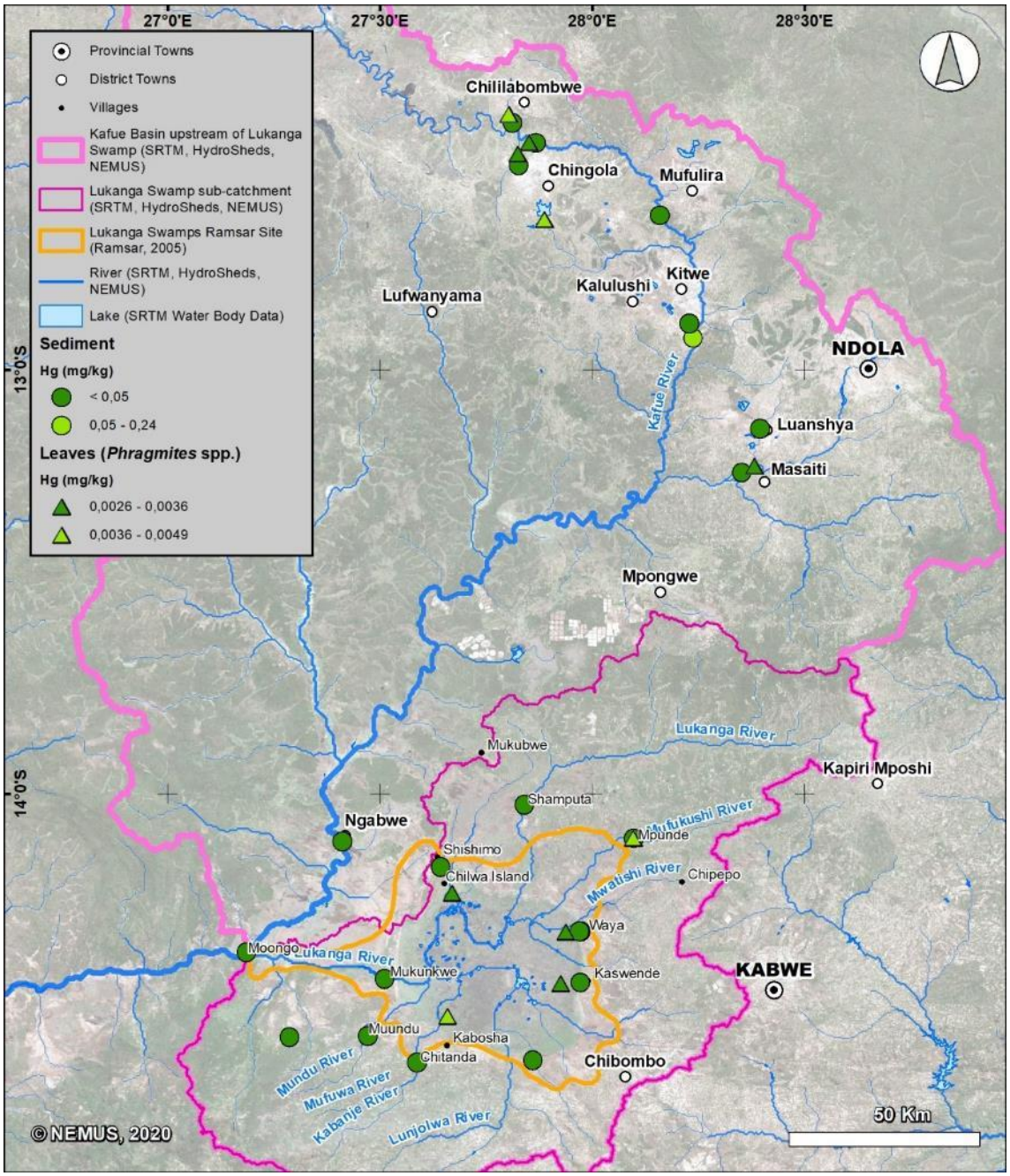


Figure 78 – Distribution of Hg in sediment samples and composite leaf samples in the Lukanga Swamp and Upper Kafue River Basin

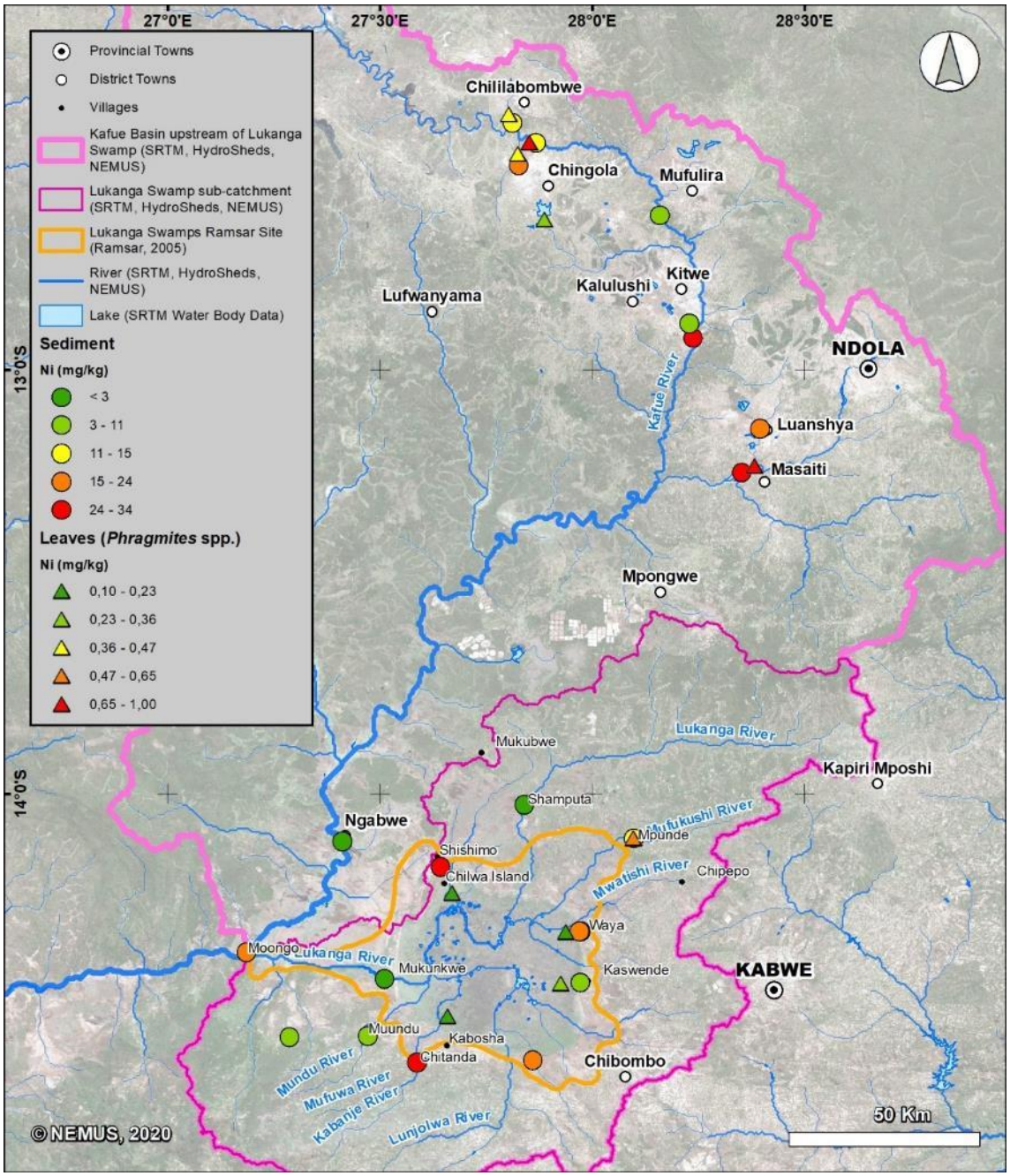


Figure 79 – Distribution of Ni in sediment samples and composite leaf samples in the Lukanga Swamp and Upper Kafue River Basin

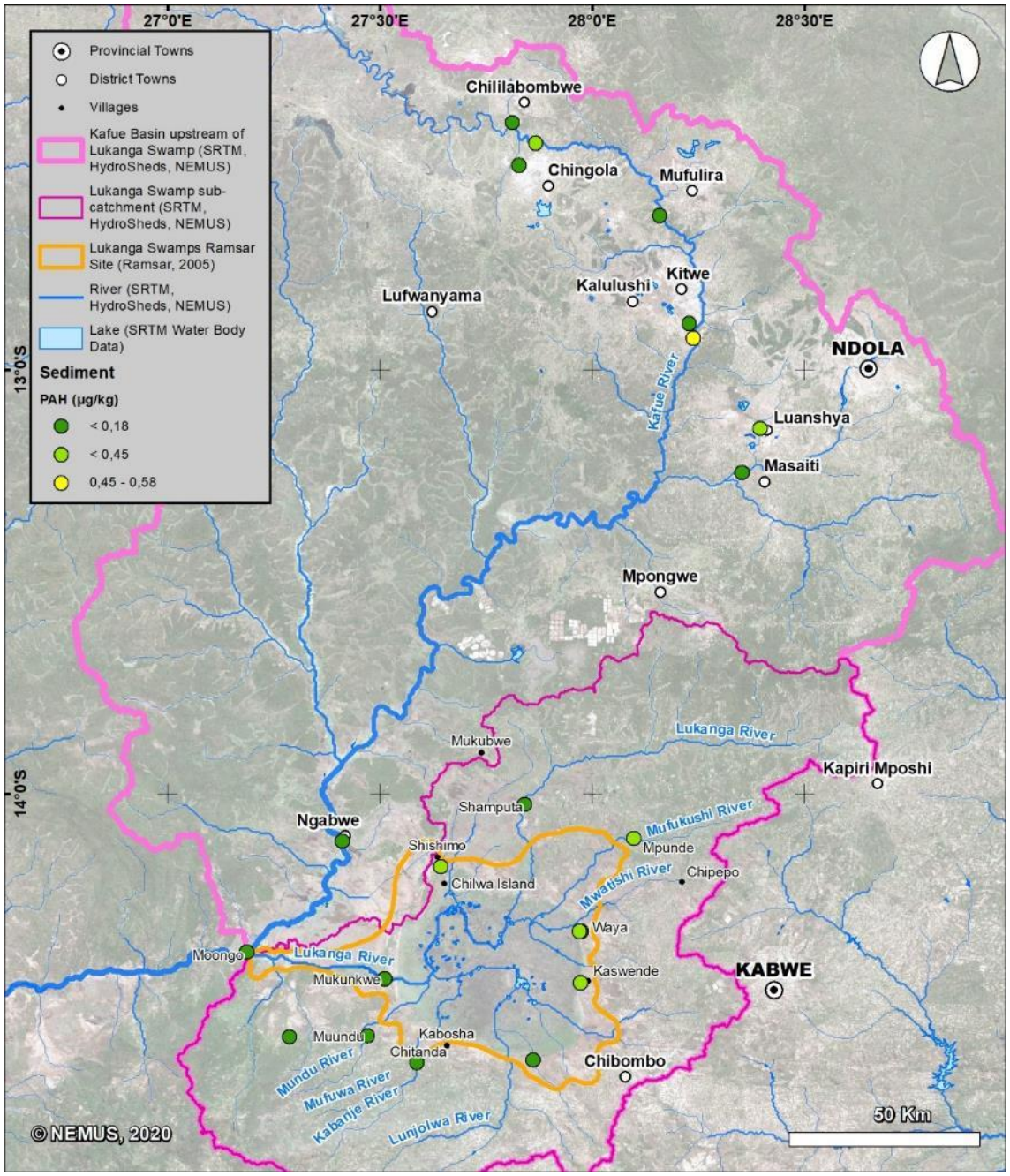


Figure 80 – Distribution of PAH in sediment samples in the Lukanga Swamp and Upper Kafue River Basin

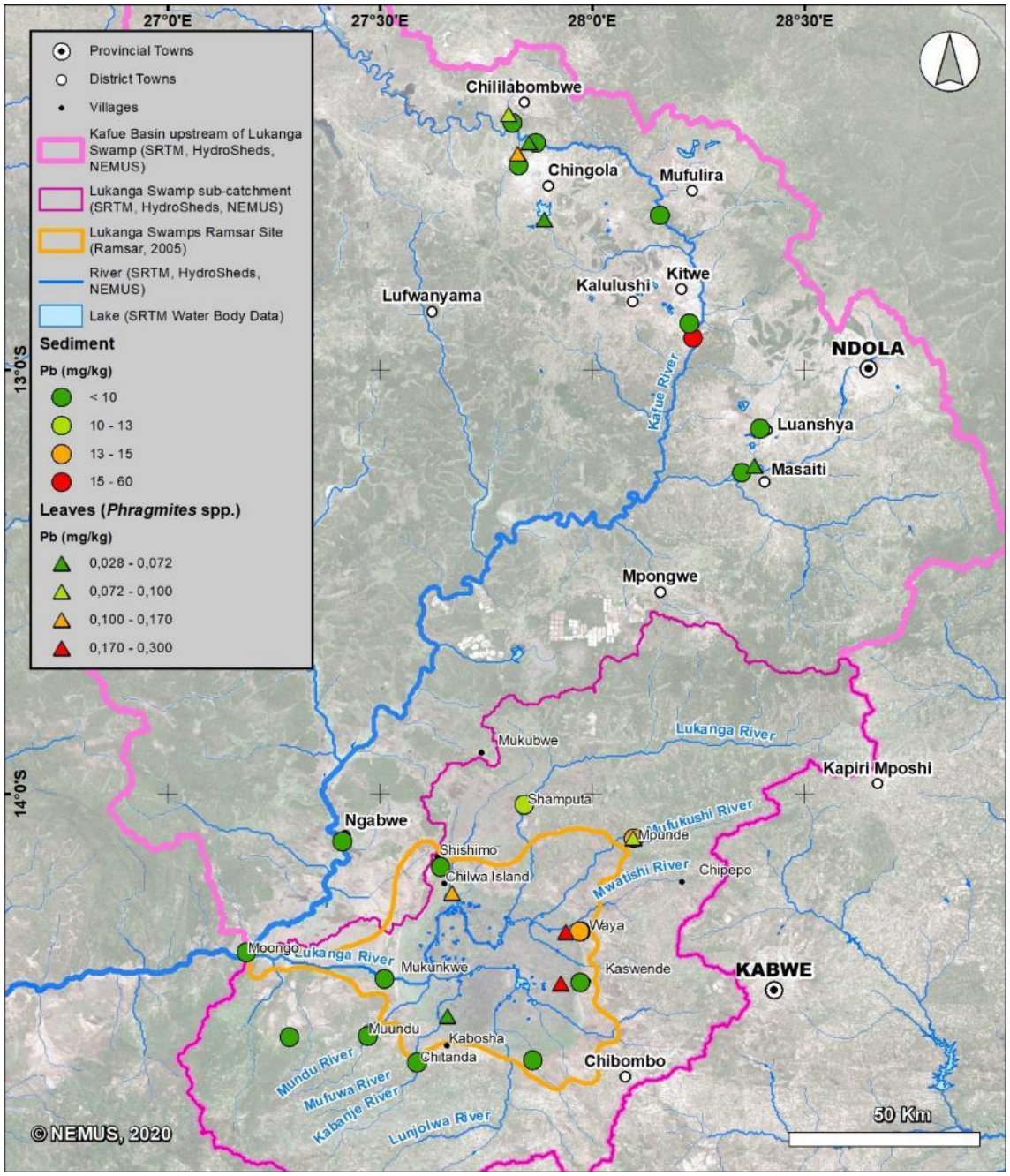


Figure 81 – Distribution of Pb in sediment samples and composite leaf samples in the Lukanga Swamp and Upper Kafue River Basin

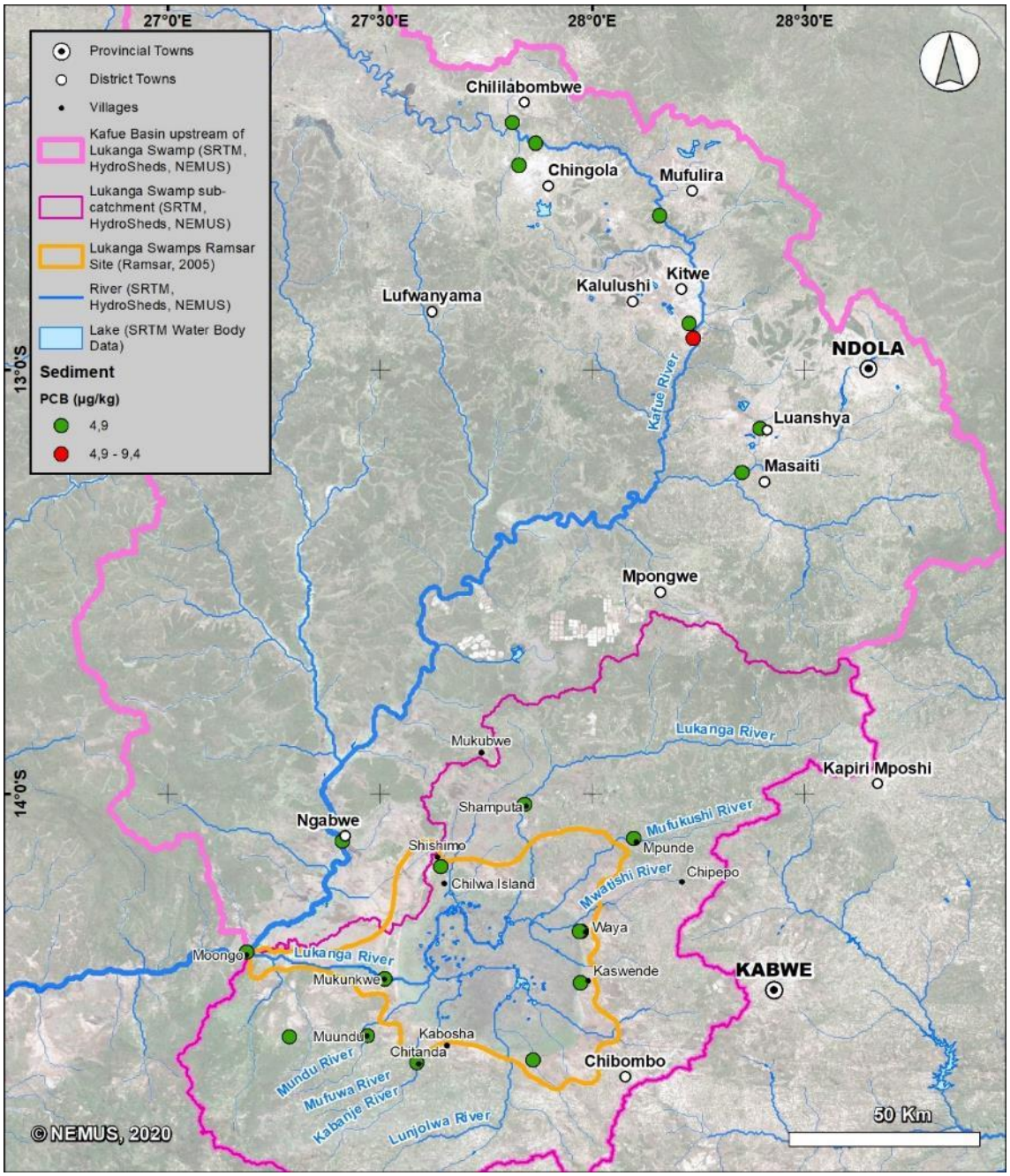


Figure 82 – Distribution of PCB in sediment samples in the Lukanga Swamp and Upper Kafue River Basin

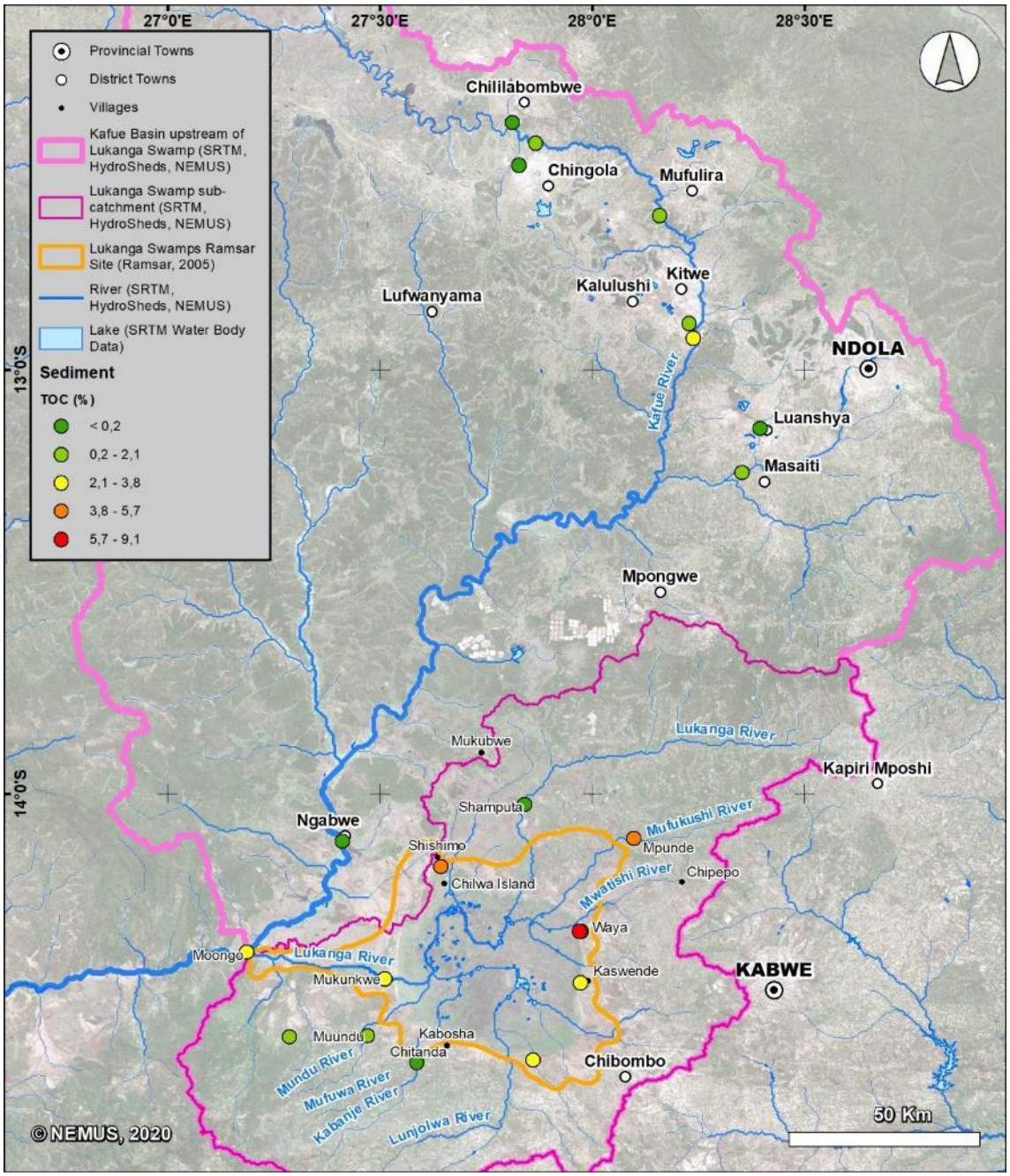


Figure 83 – Distribution of TOC in sediment samples in the Lukanga Swamp and Upper Kafue River Basin

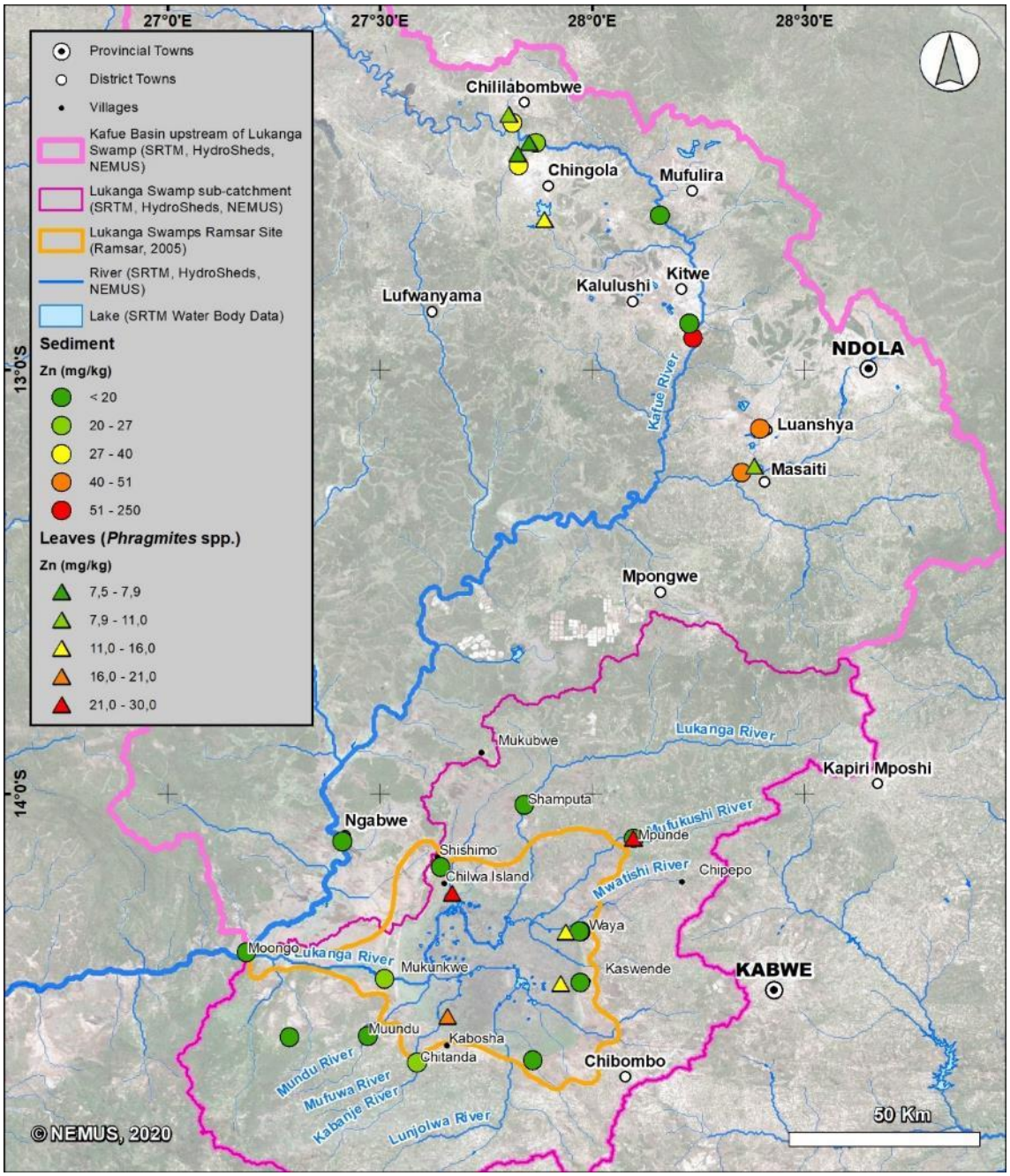


Figure 84 – Distribution of Zn in sediment samples and composite leaf samples in the Lukanga Swamp and Upper Kafue River Basin

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Appendix 3 – Ecological assessment

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CONSERVATION PLAN FOR LUKANGA SWAMP AND UPPER KAFUE BASIN

Ecological assessment

TABLE OF CONTENTS

1. Introduction; scope and methodology 1

2. Designated areas for the protection of biodiversity 7

3. Upper Kafue river basin 13

4. Lukanga swamp sub-catchment 17

5. Lukanga swamp 19

5.1. ILUA land cover 19

5.2. Habitats classification and mapping 21

5.3. Habitats mosaic 23

5.3.1. Permanent swamp 28

5.3.2. Edaphic grassland 40

5.3.3. Termitaria 49

5.3.4. Rivers and stream-associated wetland vegetation 55

5.3.5. Lakes 67

5.3.6. Forest land 72

5.3.7. Cultivated and managed land 85

5.4. Flora 90

5.4.1. Phytoplankton 90

5.4.2. Vascular flora 91

5.5. Fauna 96

5.5.1. Invertebrates 96

5.5.2. Ichthyofauna 99

5.5.3. Herpetofauna 101

5.5.4. Avifauna 103

5.5.5. Mamofauna 108

6. References 113

Appendix A – Habitats map 131

Appendix B – Flora species list 135

Appendix C – Fauna species list 175

LIST OF TABLES

Table 1 – Zambian land categories and vegetation classification 3
Table 2 – Macro-habitats of the Lukanga Ramsar site and surrounding area 27
Table 3 – Diversity of seed plants in Zambia by ecosystem 92
Table 4 – Summary of bird species with unfavorable conservation statuses and/or restricted distribution ranges 105
Table 5 – Flora species list for the Lukanga swamp and surrounding terrestrial macro-habitats 137
Table 6 – Fauna species list for the Lukanga swamp and surrounding terrestrial macro-habitats 177

LIST OF FIGURES

Figure 1 – Sites visited in September and October 2019 for ground truthing of cartographic units 5
Figure 2 – Land cover maps for 1972 and 2016 6
Figure 3 – Contextualization of the Lukanga Swamp in Zambia's national network of protected areas 7
Figure 4 – Important Bird Areas of Zambia 8
Figure 5 – Upper Kafue basin land cover 15
Figure 6 – Lukanga swamp cub-catchment land cover 18
Figure 7 – Lukanga swamp land cover 20
Figure 8 –Natural land use area: terrain and satellite images (cf., Figure 1, site S10, 14° 3'36.87"S; 27°37'9.24"E) 23
Figure 9 – Semi-natural lad use area: terrain and satellite images (cf., Figure 1, site S12, 14°36'45.53"S; 28° 5'25.47"E) 24
Figure 10 – Artificial/humanized land use area: terrain and satellite images (cf., Figure 1, Kaswende) 25
Figure 11 – Distribution of the permanent swamp macro-habitat 28
Figure 12 – Permanent swamp macro-habitat: A. emergent macrophytes; B. floating aquatic macrophytes 31
Figure 13 – Floating mats of grasses, ferns and forbs 32
Figure 14 – Kariba weed, *Salvinia molesta*, in the swamp off the village of Kabosha 33
Figure 15 – Wetland classes obtained through the classification of Landsat 5 TM imagery from the 2005 dry season and the 2006 wet season, coupled with low-altitude aerial photographs from October 2006 34
Figure 16 – Yellow-billed duck, *Anas undulata* (left), and Purple Swamphen, *Porphyrio porphyrio* (right), in a channel within the permanent swamp off Chilwa island 39
Figure 17 – Distribution of the edaphic grassland habitat 41
Figure 18 – Edaphic grassland habitat at the end of the dry season 42
Figure 19 – Individual of the African Openbill, *Anastomus lamelligerus* (LC), and a flock of African Sacred Ibises, *Threskiornis aethiopicus* (LC), using the grassland and flooded channels north of Chilwa Island 47
Figure 20 – Distribution of the Termitaria macro-habitat 49
Figure 21 – Termitaria macro-habitat: on top, the extensive plain north of the Lukanga river and downstream of the swamp; on the bottom left, tall termitaria between Chitanda and Mukunkwe; on the bottom right, short termitaria close to Twenty village, southeast of the swamp 51
Figure 22 – Distribution of the river and stream-associated wetland vegetation macro-habitat 56
Figure 23 – Open water in the river macro-habitat: on top and bottom left, the Lukanga river downstream from the swamp, flowing towards the confluence with the Kafue; on the bottom right, the same river upstream from the swamp, flowing through Mpunde 57
Figure 24 – Emergent macrophyte cover of the river macro-habitat: on top, Lukanga river's meanders between the swamp and the confluence with the Kafue; bottom left, the same river upstream from the swamp, flowing through Mpunde; bottom right, the same river as it leaves the swamp, at Mukunkwe 58
Figure 25 – Different macrophyte stands in the rivers around the Lukanga Swamp 59
Figure 26 – Macrophyte species of the Lukanga Swamp's in- and outflowing rivers and streams 61
Figure 27 – Riparian community along the Chiyuni river, as it passes through Chitanda 62
Figure 28 – Traditional harvesting of *Cyperus papyrus* culms and stems as raw material for the fabrication of matts, in the banks of the Lukanga River, just before the confluence between this and Kafue river, near the settlement of Moongo 64
Figure 29 – An individual of Eastern White Pelican, *Pelecanus onocrotalus*, using the Lukanga River downstream of the swamp, off Moongo 66
Figure 30 – Distribution of the lakes macro-habitat 67
Figure 31 – Lake habitat: on top, lake off the village of Kabosha; on the bottom, different sites at Lake Suye, off Chilwa island 69
Figure 32 – Submerged macrophyte *Najas* sp. in Lake Suye, off Chilwa island 70
Figure 33 – Grey-headed Gulls, *Larus cirrocephalus,* observed in Lake Suye 71
Figure 34 – Distribution of the forest land macro-habitat 72
Figure 35 – General aspects of the forest land macro-habitat 74

Figure 36 – Different uses of surrounding woodlands' tree species: on top, tree trunks on the harbour off Waya for drying fish on; on the bottom, dugout canoes on the harbour off Kabosha 80
Figure 37 – Charcoal production from local woodland species through the traditional earth kiln method 82
Figure 38 – Distribution of the cultivated and managed land cover 85
Figure 39 – Anthropic landscapes surrounding the Lukanga Swamp 86
Figure 40 – Traditional practice of ash-fertilizing the field by stocking woody material and burning it 88
Figure 41 – Kariba weed, *Salvinia molesta*, invasion off Kabosha (on the left) and Waya (on the right) 95

ACRONYMS

CR – Critically Endangered
DNPW – Department of National Parks and Wildlife
DoF – Department of Fisheries
EN – Endangered
FAO – Food and Agriculture Organization
FRA – Forest Resource Assessment
GMA – Game Management Area
IBA – Important Bird Area
ILUA – Integrated Land-Use Assessment
IUCN – International Union for Conservation of Nature
LC – Least Concern
LCCS – Land Cover Classification System
MFL – Ministry of Fisheries and Livestock
MLNREP – Ministry of Lands and Natural Resources and Environmental Protection
NBSAP – National Biodiversity Strategy and Action Plan
NP – National Park
NT – Near Threatened
VU – Vulnerable
WWF – World Wildlife Fund for Nature

1. Introduction; scope and methodology

The geographical **scope** of the ecology component of the Conservation Plan, herein designated as Lukanga Conservation Plan area, comprises the following units of territorial analysis:

- *Upper Kafue river basin* – which was characterised according to the work developed under the **Zambian Integrated Land-Use Assessment** (ILUA) project, phases I and II.
- *Lukanga Swamp catchment – idem*.
- *Lukanga Swamp* – which was characterized more in-depth; this level is represented by the "Lukanga Swamps Ramsar Site" (Ramsar, 2005) and a 10 km buffer area to allow the coverage of broader wetland boundaries and to properly frame wetland ecosystems within the wider social and ecological settings; this will produce a more complete and exhaustive depiction of the current situation, including drivers of change, impacts, ecosystem services and management/conservation needs.

The ILUA project is composed of Phases I (2005-2008) and II (2010–2016), and classified the country's vegetation based on FAO's Forest Resource Assessment (FRA) classification system, having then mapped its land-cover through extensive field surveys, interviews, direct observations and interpretation of spectral imagery.

This project re-classified Zambian natural terrestrial vegetation into "major vegetation and other land" and "forests and land use classes" across the following FRA's four broad categories (FAO, 2000):

- Forest: >0.5 ha, >10% canopy cover, 5 m height at maturity; "may consist either of closed forest formations where trees of various storeys and undergrowth cover a high proportion of the ground; or open forest formations with a continuous vegetation cover in which tree crown cover exceeds 10%", such as African woodlands;
- Other Wooded Land: >0.5 ha, 5-10% canopy cover, or shrubs/bushes => 10% canopy cover;
- Other Land: <5% canopy cover or shrubs/bushes <10%; "land not classified as forest or other wooded land as defined above. Includes agricultural lands, meadows and pastures, built-on areas, barren lands, etc.";
- Inland water: "area occupied by major rivers, lakes and reservoirs".

ILUA's Phase II **land-cover** map (Forestry Department, 2016) further classified Zambia according to the six (6) classes of the Intergovernmental Panel on Climate Change (IPCC) scheme, through the supervised classification of LandSat 5 thematic mapper (TM) images with a spatial resolution of 30 m for the 2014 epoch (using the maximum likelihood method), namely:

- 1, **Forests**: "this is land covered both by natural and planted forest meeting the threshold of 10% canopy cover growing over a minimum area of 0.5 ha with trees growing above 5 m height";
- 2, **Grassland**: "land that includes wooded rangeland that may be covered mainly by grasslands, plains, *dambos*, pans found along major river basins and water channels";
- 3, **Cropland**: "land actively used to grow agriculture (annual and perennial) crops which may be irrigated or rain feed for commercial, peasant and small-scale farms around urban and rural settlements";
- 4, **Wetlands**: "land which is waterlogged, may be wooded such as marshland, perennial flooded plains and swampy areas (surface water bodies included)";
- 5, **Settlements**: "land covered mainly by densely populated and organized or irregular settlement patterns surrounding cities. towns, chiefdoms and rural centres commonly referred to as urban and rural built-up areas";
- 6, **Other land**: "barren land covered by natural bare earth/ soil such as sandy dunes, beach sand, rocky outcrops and may include old open quarry sites for mines and related infrastructure outside settlements".

Table 1 includes ILUA's vegetation classification for the Zambian territory across these three levels, i.e., "FRA (land) class", "major vegetation and other land", and "Forests and land use classes", as well as their correspondence to the IPCC land cover categories.

Table 1 – Zambian land categories and vegetation classification

FRA (land) class	Major vegetation and other land	Forests and land use classes	Phase II land-cover
Forest land	Dry evergreen forest	*Parinari* forest and Copperbelt chipya	1, Forests
		Marquesia forest	
		Lake basin chipya	
		Chryptosepalum forest	
		Kalahari sand forest	
	Dry deciduous forest	*Baikiaea* forest and deciduous thicket	
		Itigi forest	
	Moist evergreen forest	Montane forest	
		Swamp forest	
		Riparian forest	
	Forest woodlands	*Miombo* woodland on plateau	
		Miombo woodland on hills	
		Kalahari woodland on sands	
		Mopane woodland on clay	
		Munga woodland on heavy soils	
	Forest plantations	Broad leaved forest plantation (*Eucalyptus*)	
		Coniferous forest plantation (*Pine*)	
Other wooded land	Wooded grasslands (including pans and shrubs with some trees)	Termitary vegetation and bush groups	2, grassland
		Shrubs/ thickets	

FRA (land) class	Major vegetation and other land	Forests and land use classes	Phase II land-cover
Other land	Grasslands	Dambos and floodplains	2, grassland
		Marshland and swamps	4, wetlands
	Bare land	Barren land	6, other land
		Sandy dune	
		Bare rock / outcrop	
	Cultivated and managed land	Annual crop	3, cropland
		Perennial crop	
		Pasture land	
		Fallow	
	Built-up areas	Urban	5, settlements
		Rural	
	Inland water	Lakes, Rivers, Dams	4, wetlands

Source: Shakachite *et al*. (2016); Forestry Department (2016).

The third level, the swamp and surrounding area, benefited from a more in-depth characterisation, focusing on the description of vegetation cover from **secondary information** (compiled from available specialist and grey literature, geographical information and datasets), and the production of macro-habitats cartography, which was subsequently validated on-site through field work.

Field visits were conducted in September and October 2019 (Figure 1), at the end of the dry season, and included the following general tasks:

- Identification of main vegetation communities;
- Assessment of preliminary mapping of land use, main existing macro-habitats and related conservation status (identification of pressures, etc.);
- Informal register of faunal species sighted during site walk-overs.

During these field surveys, a total of 56 sites were assessed and classified according to major vegetation classes (level 1) and, when possible, to macro-habitat (level 2) (section 0). Land use and degradation information was also collected.

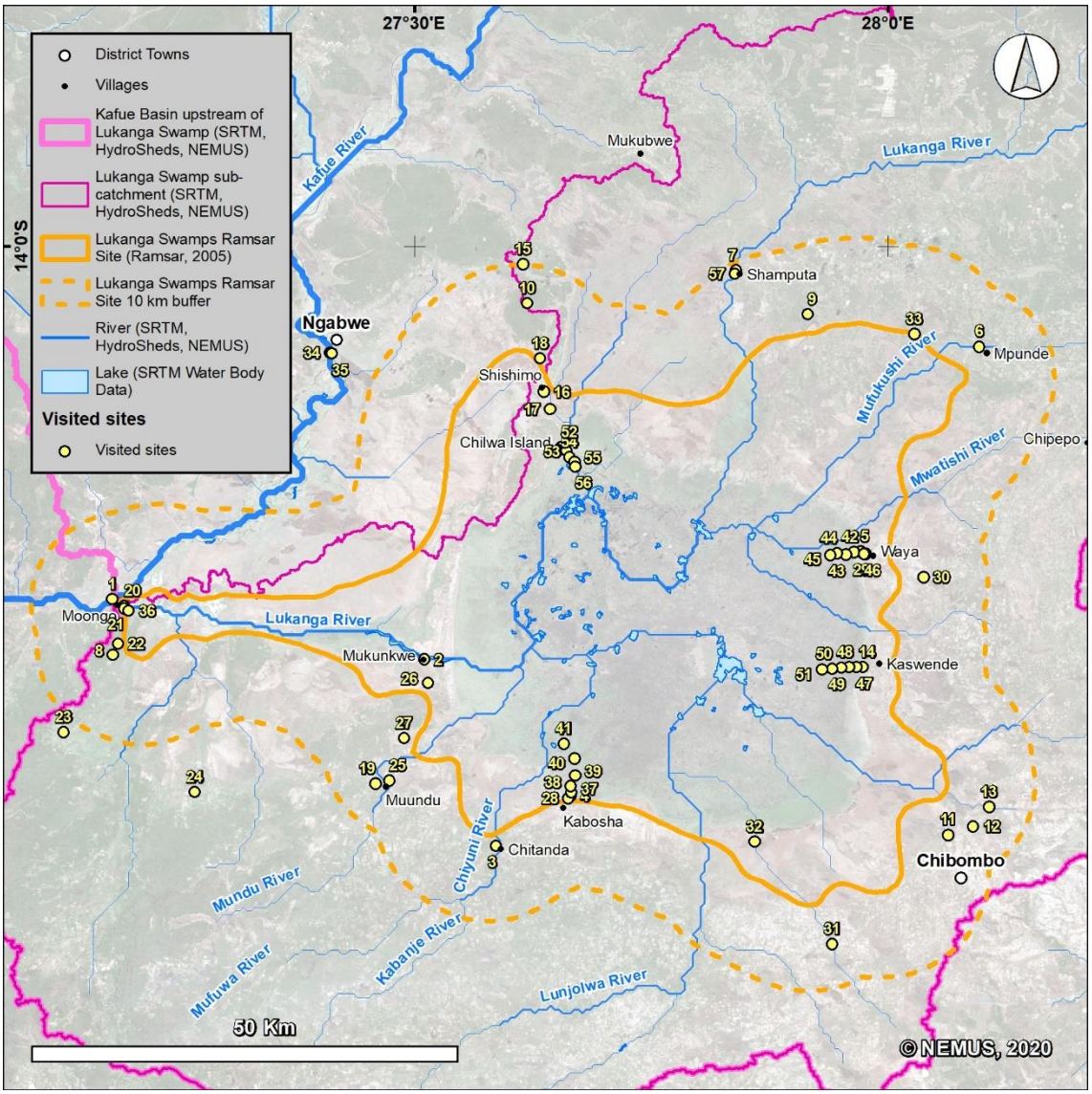
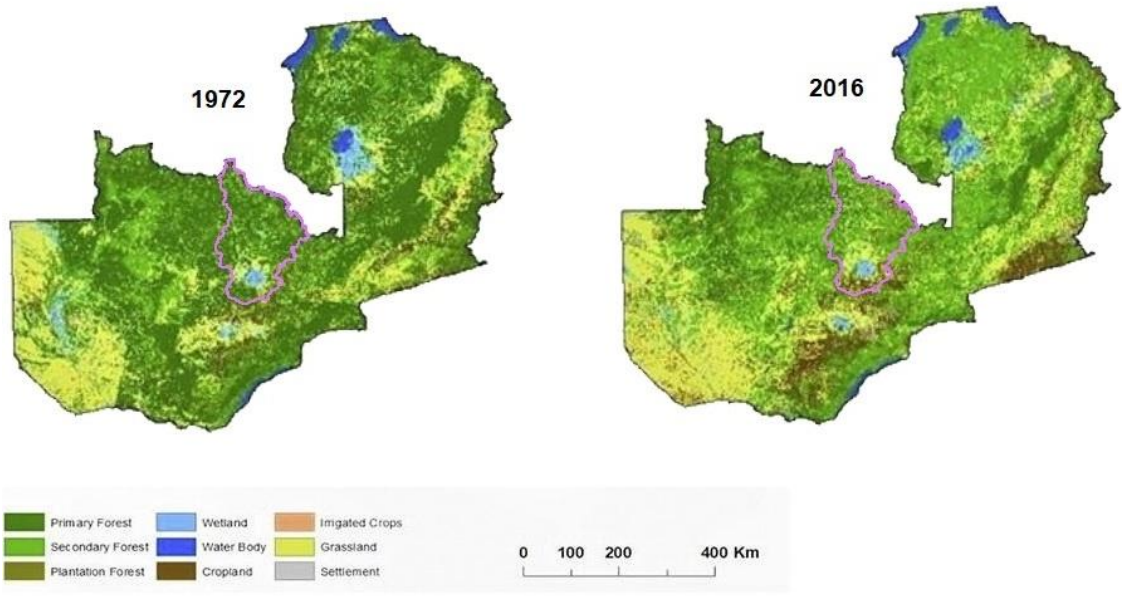


Figure 1 – Sites visited in September and October 2019 for ground truthing of cartographic units

Based on the information above, in the following sections an **ecological characterisation** covered the following topics:

- Designated areas for the protection of biodiversity (Chapter 2);
- Upper Kafue basin land cover (Chapter 3);
- Lukanga sub-catchment land cover (Chapter 4);
- Lukanga swamp land cover, habitats mosaic, flora and fauna (Chapter 5).

Figure 2 displays land cover maps for the years 1972 and 2016 obtained from remotely sensed data by Phiri, Morgenroth and Xu (2019a, b).



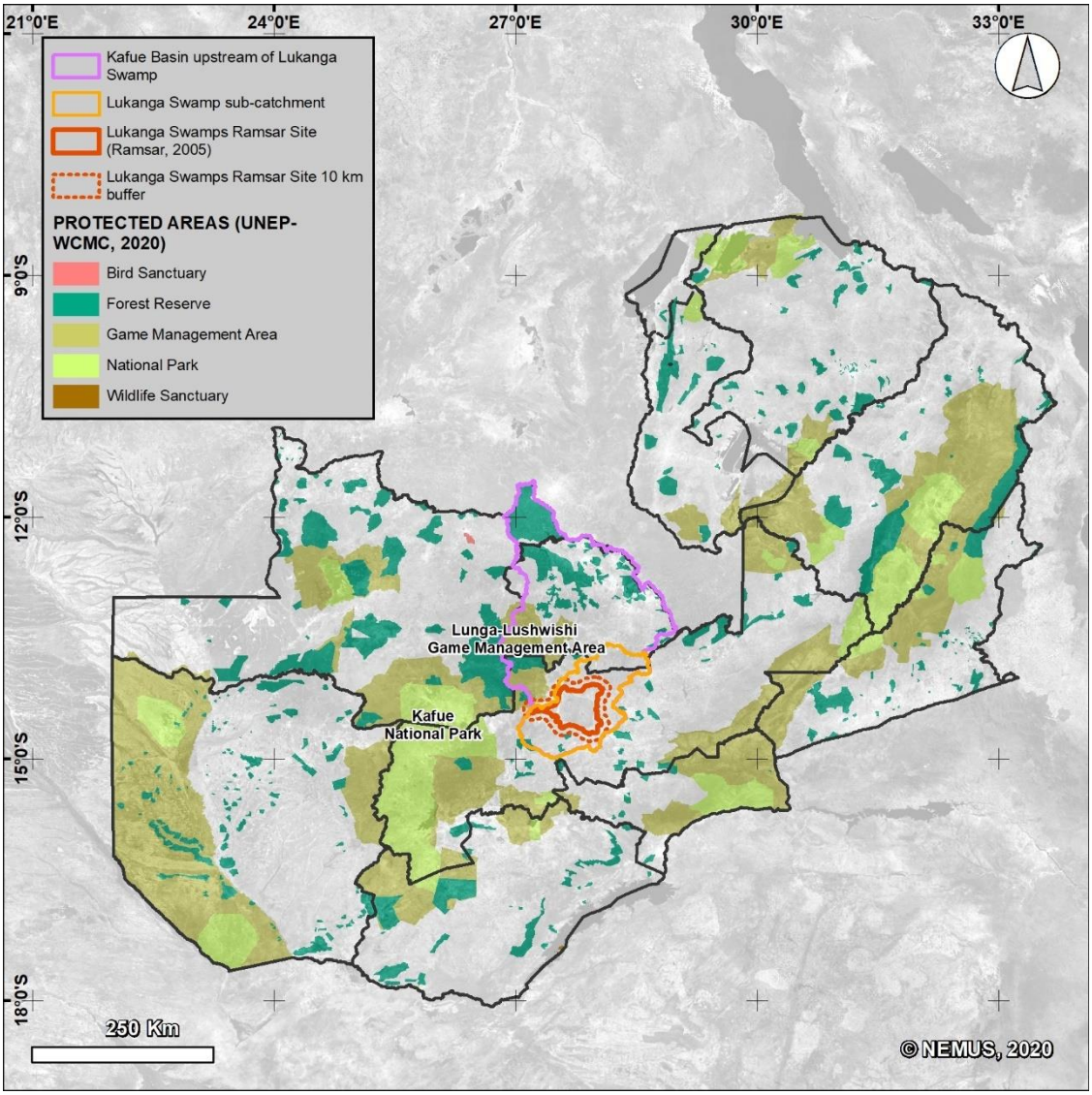
Source: adapted from Phiri, Morgenroth and Xu (2019b) (available at: https://www.sciencedirect.com/science/article/pii/S004896971934183X)

Figure 2 – Land cover maps for 1972 and 2016

As demonstrated by the figure above, over the period of 44 years, Zambia has suffered considerable land cover change. Primary forest cover, in particular, has seen an important decline in coverage, from 36,335.52x10^3 ha to 12,433.89x10^3 ha nationwide. Secondary forest (originated through the degradation of primary cover, for instance, by resource exploitation), grassland and cropland covers have all increased (Phiri, Morgenroth and Xu, 2019a).

2. Designated areas for the protection of biodiversity

The Lukanga swamp is set within a context of high importance for biodiversity. The ecological relevance of the site and its regional setting is demonstrated by the existence of two different typologies of protected areas specifically designated for the Lukanga's wetland ecosystems, and at least three more types of national designations in the upper Kafue basin and the swamp's sub-catchment (Figure 3).

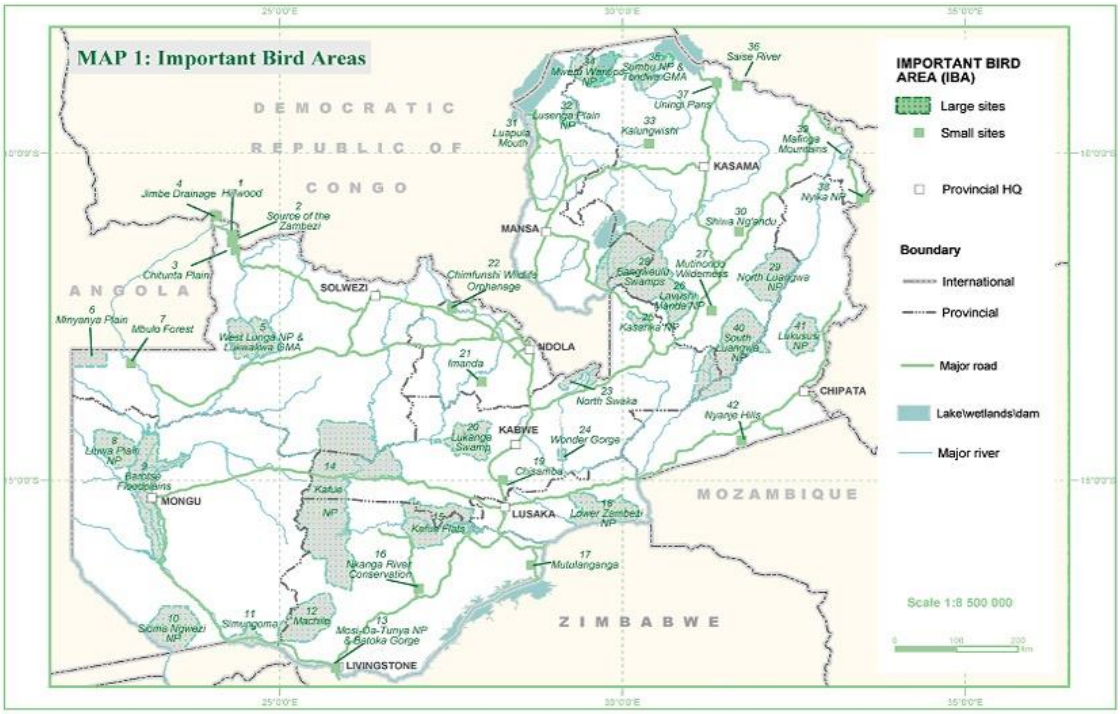


Source: adapted from UNEP-WCMC and IUCN (2020).

Figure 3 – Contextualization of the Lukanga Swamp in Zambia's national network of protected areas

In addition to the nationally classified areas, three additional categories occur in Zambia, of international significance, including eight Ramsar Site designations, 42 Important Bird

Area (IBA) designations (Figure 4) and one World Heritage Site (UNEP-WCMC and IUCN, 2020).



Source: Birdwatch Zambia (2019).

Figure 4 – Important Bird Areas of Zambia

The Lukanga Conservation Plan area intersects several nationally and internationally classified areas (UNEP-WCMC and IUCN, 2020), namely:

- **Important Bird Areas**:
  - Lukanga Swamp (ZM020);
  - Chimfunshi Wildlife Orphanage (ZM022) (upper Kafue);
  - Imanda (ZM021) (upper Kafue);
- **Ramsar sites**:
  - Lukanga Swamp Ramsar Site;
- **Game Management Areas**:
  - Lunga-Luswishi (upper Kafue);
  - Machiya Fungulwe (upper Kafue);
- **Forest Reserves**:
  - In the upper Kafue basin, there are three large national reserves, the Kafue head waters National Forest, the East Lunga National Forest and the Lamba Headwaters National Forest, together with several

other smaller National forests, such as Kabwima, Misaka, Monkey Fountain, and Luano, as well as local forests, such as Luena;
    - In the Lukanga's sub-catchment, there are mainly smaller local reserves, such as the Mumbwa Local Forest, the Mushingashi Local Forest, the Kalulu Local Forest or the Lukulaisho Local Forest;
- **Bird sanctuaries**:
    - Chembe Bird Sanctuary (upper Kafue).

The **Lukanga Swamp Ramsar Site** (N.1580) was designated in 2005, under Article 2.1 of the Convention on Wetlands (Ramsar, Iran, 1971), covering an area of 2.600 km^2 in the Central Province. It was designated under criteria 2, 3, and 8, which refer to the hosting of several endangered species, the support of animal species important for the conservation of Southern African biodiversity, and to the swamp's potential for fishing, respectively.

The Ramsar designation is an international one, binding the contracting parties to integrate in their territorial planning the conservation of designated sites and associated waterfowl, as well as to promote research and capacity building within the wetland research, management and wardening areas. Zambia has already designated eight sites. The implementation of the Ramsar Convention in Zambia is under the responsibility of the Department of National Parks and Wildlife (DNPW[1]) (of the Ministry of Tourism and Arts, MTA), while wetland management falls under the Ministry of Lands and Natural Resources. In Zambia's Ramsar National Report to Cop13 (Ramsar, 2018), the DNPW appoints the updating of information on sites, the improvement of natural flow regimes for wetlands impacted by industrial development and the control of invasive species as priorities in the implementation of the convention. In the COP13 assessment, it becomes clear the site lacks detailed baseline studies for effective management (Ramsar, 2018). Convention IOP's (International Organization Partners) that have or are assisting in the implementation of the convention, specifically targeting the Lukanga Swamp, include the World Wildlife Fund (WWF) and BirdLife International (Ramsar, 2018).

The **Lukanga Swamp IBA** (**ZM020**) was designated in 2001, by BirdLife International with an area of 3.300 km^2 (BirdLife International, 2020). This designation identifies sites

[1] The Department of National Parks and Wildlife (DNPW) (of the Ministry of Tourism and Arts) replaced the former Zambia Wildlife Authority (ZAWA) upon publication of the Wildlife Act (2015).

internationally significant for the conservation of bird populations, aiming to create a network of sites that safeguards their sustainability. To ensure the effective implementation of conservation strategies across this network, BirdLife International provides guidance on the management of sites, promotes community engagement, and promotes connections between knowledge holders and institutions for the production/compilation of ornithological and other relevant data.

In Zambia, BirdLife International's presence is ensured by BirdWatch Zambia, located in Lusaka. There is a programme currently underway at the Lukanga Swamps IBA for the control of the invasive floating fern *Salvinia molesta* (Kariba weed), having started in 2017 and being predicted to end in 2021. The Lukanga Swamp IBA was last assessed in 2017 and was awarded a "very high" threat score (a score that assesses pressure), a "very unfavourable" condition score (which assesses the current state), and a "low" action score (in the assessment of management response). It is further listed as "an IBA in danger!" (2018), an initiative dating to 2013 that singles out «sites in dire need of urgent conservation action to save them» (BirdLife International, 2020).

Regarding Zambia's national network of designated sites, there are two **Game Management Areas** (GMA) (IUCN category VI[2]) in the proximity of the wetland, managed by the DNPW under the legal framework of the Wildlife Act No. 14 of August 2015.

GMAs consist of buffer zones created around National Parks «for the sustainable utilisation of wildlife» (Wildlife Act, 2015), areas generally deemed better suited for the support of wildlife when compared to commercial livestock rearing or agriculture (Barnes *et al.*, 2011). The GMA designation is compatible with resource use, so that these areas support human settlements, hunting activities (subject to licensing), and a variety of traditional land-uses such as chitemene agriculture (Barnes *et al.*, 2011). Tourism is an important sector within GMAs and includes recreational hunting. Watson *et al.* (2014) reported important encroachment levels of Zabian GMAs, hindering the effectivness of

[2] IUCN Category **IV Habitat/Species management Area**: «[these] areas aim to protect particular species or habitats and management reflects this priority. Many […] will need regular, active interventions to address the requirements of particular species or to maintain habitats, but this is not a requirement of the category» (Dudley, 2008).

the country's protected area network, as buffer areas and potential wildlife corridors are eliminated.

The Lunga-Luswishi GMA was designated in 1971, with an area of 13,340 km^2. It buffers the Kafue National Park to the Northeast, and has as eastern border the Kafue river, thus overlapping with the 10 km buffer zone around the Lukanga Ramsar site, northwest of the Lukanga River. This GMA was classified has having a *low* management effectiveness (class 2 out of 7) (Mwima, 2007), and being threatened primarily by poaching and fire.

The Machiya Fungulwe GMA was designated in 1971, with an area of 1,557 km^2. It buffers the Lunga-Lushwishi GMA and was classified as having a *very low* management effectiveness (class 1 of 7), being threatened by poaching, subsistence agriculture, human encroachment and deforestation (Mwima, 2007).

The region also includes several **Forest Reserves** managed by the Forestry Department (of the Ministry of Lands and Natural resources) under the Forest Act No. 4 of 2015. These have been designated between the1960's and 1980's, with areas varying from 62.85 km^2 and 4,780.34 km^2 (UNEP-WCMC and IUCN, 2020).

These are classified as either Local Forests or National Forests in relation to the importance of their resources. National Forest designations aim at securing areas of national importance, conserving ecosystems and biodiversity, promoting improved forest resource management and sustainable use, as well as water catchment and head waters management (Forest Act, 2015). Here, entry is restricted outside public roads and footpaths. Local forest designations aim at promoting the security of forest resources - in particular of land and water resources of local strategic importance -, promoting the utilisation of forest resources at local level and meeting social, cultural and economic needs of local communities (Forest Act, 2015). The Forest Reserve designation restricts the extracting of forest resources, residence, grazing, etc., to license holders. The Lukulaisho Local Forest Reserve, designated in 1968, is the most closely located reserve to the Lukanga Swamp, and occurs to the south of the study area.

There is a clear difference between the upper Kafue basin, to the north, and the sub-catchment, to the south, when it comes to forest reserves. While the sub-catchment has but a few local and national forests, the upper Kafue basin has an abundance of these designations, including two large National Forests explicitly aimed at the protection of the basin's headwaters.

Finally, the **Kafue National Park** (KNP) (IUCN Category II[3]) is not intersected by any of the areas in focus, however, its relevance in the country's national network of protected areas and its importance for Zambian wildlife warrants a mention. Moreover, the park is buffered by the Lunga-Luswishi GMA in the north, which potentially represents a wildlife corridor leading to the Lukanga swamp

The KNP was the first formally designated national park in Zambia, in 1950 (then, Northern Rhodesia) and remains the largest, covering an area of 22,400 km^2. National Parks are characterised by their restrictive nature, whereby entry and traffic are controlled/regulated, human settlement and land ownership are prohibited, as well as hunting and introducing fauna and flora species. Mining rights may be granted upon impact assessment, and tourism is the main economic activity in this setting.

[3] IUCN Category **II National park**: «large natural or near natural areas set aside to protect large-scale ecological processes, along with the complement of species and ecosystems characteristic of the area, which also provide a foundation for environmentally and culturally compatible, spiritual, scientific, educational, recreation, and visitor opportunities» (Dudley, 2008).

3. Upper Kafue river basin

The upper Kafue basin is set in the Great African Plateau, touching on the ecoregions of the Central Zambezian Miombo Woodland to the north, and both Kalahari Acacia Woodland and Southern Miombo Woodland ecoregions to the south (Burgess *et al*., 2006).

It is located at the heart of the Zambezian regional centre of endemism (White,1983), the second largest phytochorion in Africa, showcasing a wide range of vegetation types and with a tropical climate characterized by a long dry season (which can be further divided into warm and cold seasons) and intense summer rainfall (from November to April).

Typical woodland habitats of the Zambezian region dominate the terrestrial landscape, which is interrupted by Zambezian seasonally flooded grasslands, permanent swamps and rivers, of the Kafue Freshwater and Zambezian Headwaters ecoregions.

The major vegetation type of the Zambezian region is the **woodland**, consisting of open stands of trees of at least 8 m height, with a canopy cover of 40% or more, but never with inter-locking crowns and usually with a field layer of heliophilous grasses. While it is generally interpreted as the climatic climax vegetation, some of the historical distribution is thought to be secondary, deriving from the replacement of dry forest by historical disturbance, and an increasing proportion of current woodland is secondary, having been altered by anthropogenic activities such as cultivation and fire (Phiri, Morgenroth and Xu, 2019a; White, 1983; Forestry Department, 2016).

The main woodland type in the upper Kafue basin is the miombo, an open woodland dominated by three genera on the canopy, *Brachystegia*, *Julbernardia* or *Isoberlinia*, with a field layer of herbaceous species, usually sparse. It develops on freely drained and acid soils. Being largely secondary, the miombo of this region typically presents reduced floristic and structural complexities. White (1983) classifies the miombo as either wetter or drier, and the upper Kafue falls entirely within the wetter region, which is characterized by more than 1 000 mm of annual rainfall. According to Wild and Barbosa (1967), the region's miombo takes up two major presentations, one dominated by *Brachystegia floribunda* together with *Julbernardia globiflora*, and a second one where *Brachystegia floribunda* is accompanied by *Julbernarida paniculata* instead, the former towards west and the latter, east.

Other woodland types are referenced as occurring in the region, such as the Chipya, which shares its distribution with the wetter miombo, according to White (1983). The designation of chipya originated from the Bemba term cipya, by Trapnell (1950, *in* White, 1983), who assigned it to formations of trees, also lacking the miombo dominants, mixed in well-developed grass (White, 1983). It consists of a predominately savanna-like formation, typically induced by fire, possibly a degradation stage of climax forested habitats such as dry evergreen forest and transition woodland (Kindt *et al*., 2011a). More details on this vegetation can be found in a later section (5.3.6 Forest land).

Grasslands (structurally simple formations dominated by an herbaceous field layer) are usually present as the edaphic climax vegetation of seasonally and permanently waterlogged soils, such as in river floodplains and depressions with increased water retention ability. Secondary grassland also occurs, but is maintained by fire and usually contains trees (White, 1983).

The majority of the upper Kafue river basin is located in agro-ecological zone IV, the northern and north-western high rainfall zone (between 1,000 and 1,500 mm annual rainfall), with low pH leached soils and of “moderate potential for agriculture” (Mukosha and Siambale, 2008).

The upper Kafue basin is predominantely covered by forest, grassland, wetland and cropland (Figure 5).

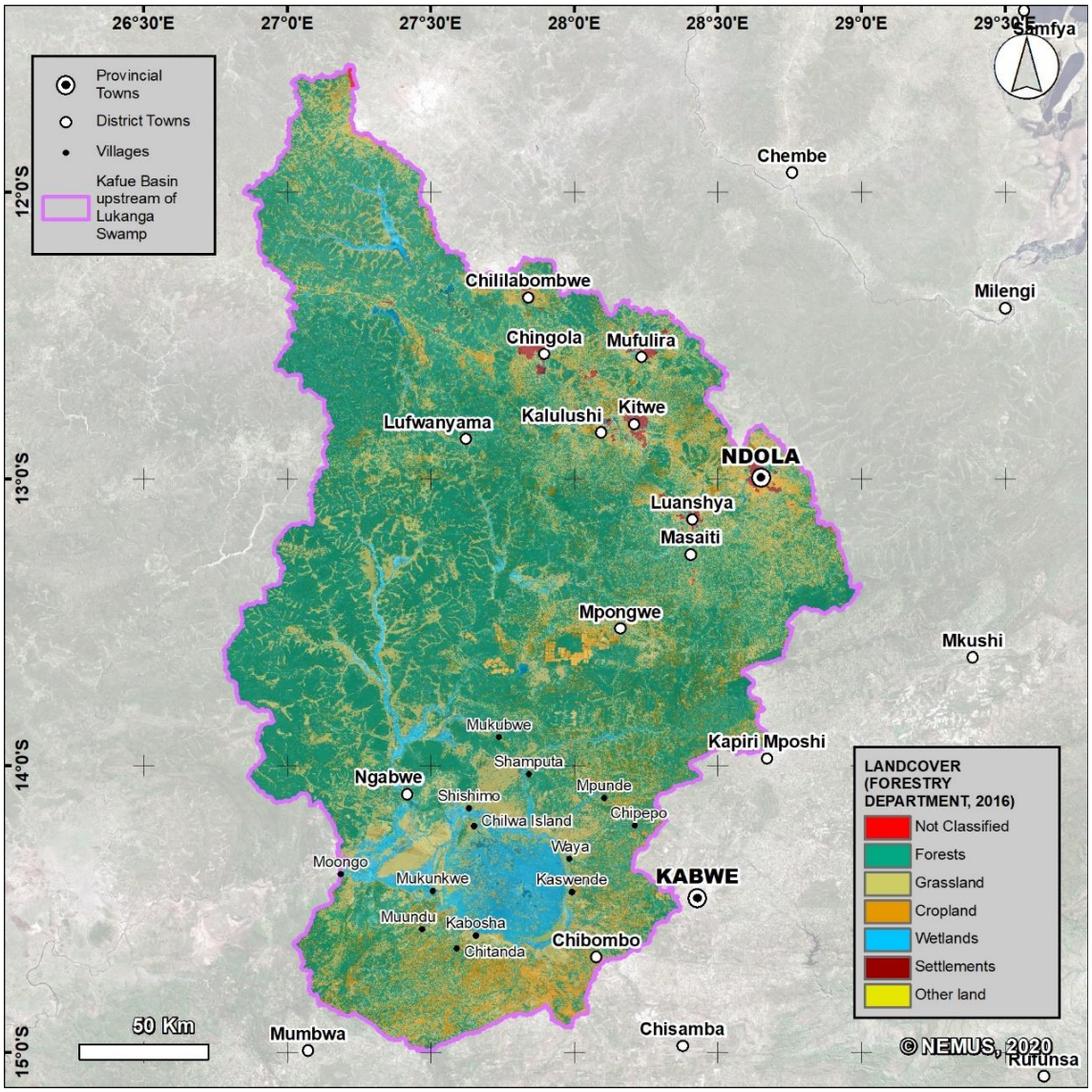


Figure 5 – Upper Kafue basin land cover

Hotspots of higher cropland density can be obsevred south of the Lukanga and around the urban centers of the Copperbelt Province (Ndola, Kitwe and Chingola), while intensive cultivation projects are mainly located in the middle region.

Extensive forested areas occupy the north and central western portion of the basin. According to Phiri, Morgenroth and Xu (2019a) (Figure 2), these are essentially secondary.

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4. Lukanga swamp sub-catchment

The same general description applies for the Lukanga's sub-catchment. In addition to miombo woodland, chipya and edaphic grassland, this region includes the potential distribution area of the North Zambezian undifferentiated woodland. An open savanna formation without the miombo's canopy dominants, this vegetation holds a high floristic variability overall and between different sites/stands (Kindt *et al*., 2011a).

Also known as munga or *Acacia-combretum*, according to dominant species, it is typically found in areas with seasonally-high water tables, being composed of flood-intolerant species that thrive in deficiently drained soils, such as *Acacia* spp. and *Combretum* spp., where miombo dominants do not develop so easily (Beilfuss *et al.*, 2001).

The sub-catchment of the Lukanga stands right at the southern edge of the wetter miombo potential distribution, after which it is replaced by drier miombo. It sits right at the transition between these two rainfall-defined regions and the local vegetation should reflect this.

The swamp's sub-catchment, in contrast to the upper Kafue, is located in agro-ecological zone IIb (annual rainfall between 800 and 1,000 mm on Kalahari Sand soils), with moderately leached clayey to loamy soils, and of "high agricultural potential" (Mukosha and Siambale, 2008).

Correspondingly, and as mentioned above, the sub-catchment is a cropland hotspot (Figure 6).

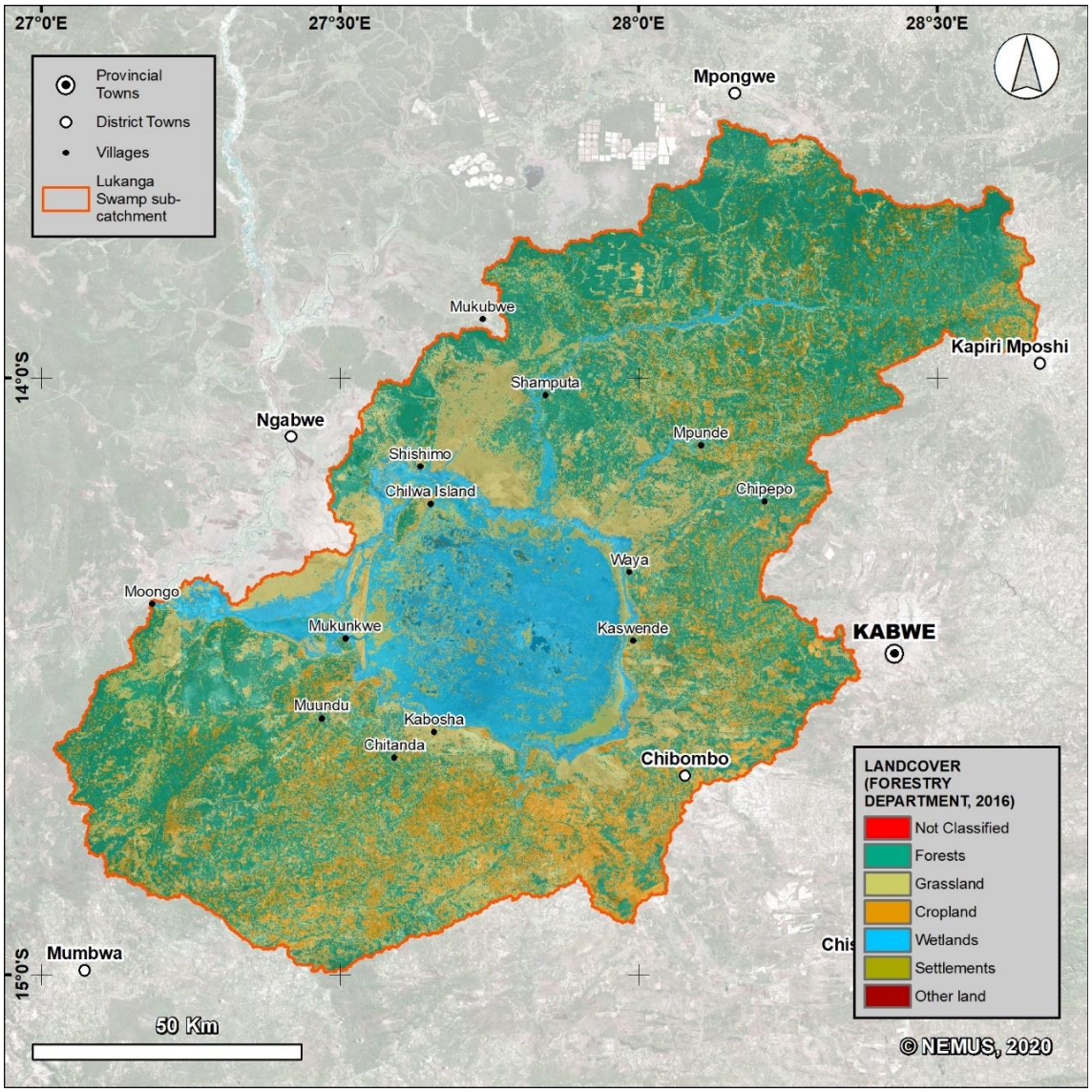


Figure 6 – Lukanga swamp cub-catchment land cover

5. Lukanga swamp

In addition to the land cover classification of the area according to ILUA's mapping, the swamp and surrounding environment were further described in terms of their ecological components (habitats, fauna and flora), complemented with additional elements such as pressures and resource uses, for the production of an in-depth diagnosis of the site.

The objective of this baseline is to enable the assessment of the area's current state and values, directing the analysis towards the aspects deemed more relevant to the conservation plan and to the assessment of ecosystem services.

5.1. ILUA land cover

The swamp is predominantly covered by agro-ecological zone IIb, but also reaches into zone III (higher rainfall) in the north.

Regarding land cover, the wetland dominates, with grassland and cropland following (Figure 7)

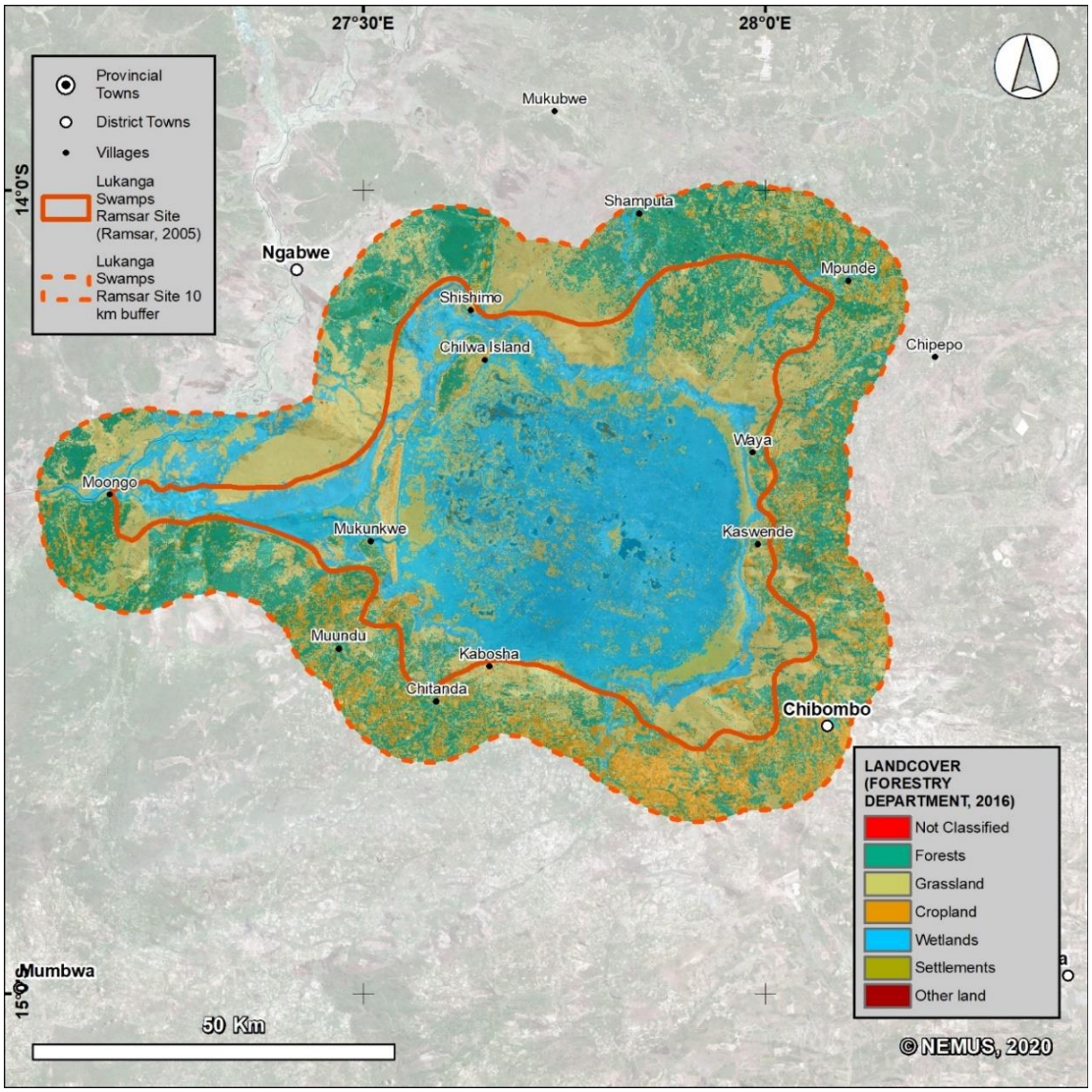


Figure 7 – Lukanga swamp land cover

5.2. Habitats classification and mapping

A habitat is defined as a territory unit which, given physical conditions, supports the development of a specific biological community (Alves *et al.*, 1998; Potschin-Young *et al.*, 2018). The development of vegetation (plant communities) into structural units of known composition serves as an indicator of the abiotic conditions of a particular area, as well as of its potential use by fauna and by human communities (Timberlake, 2000), thus providing an appropriate proxy for habitat classification. Hence, for the purpose of mapping the ecological components of the swamp area, it was considered that the adoption of macro-habitat classes as cartographic units is representative of land cover and ecosystem units, both broader in nature, and was based primarily in the classification of the area's vegetation cover.

The habitats map produced (cf., Habitats Map, Appendix A) combines the classification of structural elements of the vegetation through aerial photography, field observations aiming to confirm the physiognomic aspect of habitat classes, and additional elements such as the degree of human influence (naturality) and hydrological regime, and draws on existing accounts of these criteria in published reports, maps and literature. It compiles the maximum amount of available information regarding vegetation cover and other land cover data into visually interpretable cartographic units, and follows the Zambian Integrated Land-Use Assessment (ILUA)'s vegetation classification system (Shakachite *et al*., 2016).

Cartographic units were digitized to polygons in a Geographic Information System's environment from aerial photography superimposed with the ground truthing data and the following visual aids:

- Global Land Cover classification (10 m resolution) from Sentinel 2 spectral images dating to 2015 (which uses the UN FAO Land Cover Classification System (LCCS)) (CGLS, 2015);
- Zambia Land Cover raster data from the ILUA project Phase II, dating to 2014 (Forestry Department, 2016);
- Existing vegetation maps (Wild and Barbosa, 1967; Edmonds, 1976; Aubréville, Hoyle & Duvigneaud, 1987; Chabwela *et al*., 2010);
- Potential Natural Vegetation Map for Eastern Africa, Version 2.0 (van Breugel *et al.*, 2015).

Based on FAO's Forest Resource Assessment (FRA) classes and ILUA's major vegetation classes, existing information and field observations, and in accordance with the plan's objectives – conservation planning and ecosystem services assessment – five major classes were devised in the area: forest land; wooded grassland; grassland; anthropic landscapes and inland water.

These were further subdivided into 12 macro-habitat classes in accordance to ILUA's "Forests and land use classes", as follows:

- 1- Forest land:
  - 11: Miombo woodland;
  - 12: Baikiaea forest and deciduous thicket;
  - 13: Lake Basin Chipya;
  - 14: Munga or Miombo woodland;
- 2- Wooded grassland:
  - 21: Termitaria;
- 3- Grassland:
  - 31: Edaphic grassland;
  - 32: Permanent swamp;
  - 33: Stream-associated wetland vegetation;
- 4- Anthropic landscapes:
  - 41: Cultivated and managed land;
  - 42: Rural built-up land;
- 5- Inland water:
  - 51: Lakes;
  - 52: Rivers.

It should be noted that the cartography was updated between Progress Report No. 1 and Progress Report No. 2, based on new information on the area's ecological specificities. The main revision was the addition of a 12th class – **33: Stream-associated wetland vegetation** – to replace the inflowing streams previously classified as **32: Permanent swamp**, given the differences in their ecology and colonization by vegetation. These classes are further described and characterized in the next sections.

5.3. Habitats mosaic

The ecology of a given geographical area can be analysed according to occurring habitats, which are distributed amongst three main typologies of land-use, defined by the degree of distance or approximation to pristine vegetation characteristics: natural areas, semi-natural areas (modified) and artificial/humanized areas (heavily modified). Land-use refers to “the human use of a piece of land for a certain purpose such as irrigated agriculture or recreation”, and is influenced by, while also influencing, land-cover (Potschin-Young *et al.*, 2018).

Natural areas are those that maintain original conditions, and therefore vegetation types (referring to composition, structure and abundance) and associated faunal resources represent in majority or totality, the original values. These can be further divided between two main classes, aquatic and terrestrial (Figure 8). In and around the Lukanga, “natural areas” have actually been shaped by a long history of sustainable human uses such as cattle grazing or resource harvesting.



Source: Nemus (2019).

Figure 8 –Natural land use area: terrain and satellite images (cf., Figure 1, site S10, 14° 3'36.87"S; 27°37'9.24"E)

The intensification and settlement of some of these activities, significantly altering the vegetation, define where “semi-natural” areas begin. Hence, **semi-natural areas** are characterized by vegetation composed of different species than those that composed the original assemblages (Figure 9); there is a predominance of introduced vegetation, as these are managed by humans. These include managed land, such as cultivated and fallow areas, small to large-scale, and tree plantations.



Source: Nemus (2019).

Figure 9 – Semi-natural lad use area: terrain and satellite images (cf., Figure 1, site S12, 14°36'45.53"S; 28° 5'25.47"E)

Artificial/humanized areas display a profound degree of alteration: natural conditions and faunal values are totally distant from original values, and vegetation, when present, is anthropic and mainly opportunistic; in these areas, the degree of soil impermeabilization is usually high, and land use is associated with human presence. Being an exclusively rural area, without significant urban centres, this typology appears only as those settlements with higher population densities (Figure 10). Several more settlements exist than those that were mapped as cartographic units; however, these do not represent significant discontinuities of land-cover at the scale of analysis.



Source: Nemus (2019).

Figure 10 – Artificial/humanized land use area: terrain and satellite images (cf., Figure 1, Kaswende)

These three typologies are distributed unevenly across the swamp and surrounding area. The central portion, composed of the wetland system, is dominated by natural land cover and sustainable land uses.

The disc-shaped centre is surrounded to the **south and east** by a patchwork of semi-natural cropland and fallow land, natural woodland, and scattered artificial human settlements.

To the **north and west**, natural land dominates again, mainly composed of the flooding-prone Termitaria and upland woodland vegetation.

As expected, inside the boundaries of the Ramsar Site natural land use dominates, although some encroachment can be observed along the edges, to the south and west, in the form of cropland and rural settlements (cf., Habitats Map, Appendix A).

The characterisation of the area's most relevant macro-habitats focuses on the main natural values that compose them – deemed relevant in terms of conservation planning

–, on the description of their ecological functions, and available faunal niches. This information constitutes the basis for the subsequent ecological analysis, or diagnosis.

Several different natural macro-habitats occur, distinct in their floristic and faunistic composition, as well as in the ecological functions they perform and the kind of support they offer to existing resource uses.

The observed macro-habitat pattern is caused by topographic discontinuities of the territory which impose local hydrological regimes where azonal vegetation forms, interrupting the Great African Plateau's typical woodland landscape.

As such, there is a clear evolution of the macro-habitats' structural and composition complexity from the central depression pan outwards, along the environmental gradients of edaphic water content and depth. The central permanent swamp vegetation is replaced by seasonally flooded grasslands, that turn into a transition belt of grassland permeated by woodland and shrub vegetation on islands of higher ground (the termitaria), before actual woodland habitats develop on the upland. Both wetland and terrestrial habitats are further shaped by current and historical human activity. A patchwork of small-scale agricultural landscape disrupts the woodland throughout virtually the whole area, which is advancing inward, increasingly encroaching the seasonally flooded grasslands to make use of the available water.

In summary, the following natural macro-habitats can be distinguished, in addition to semi-natural and artificial typologies (cultivated and managed land, and rural built-up areas):

- Aquatic and semi-aquatic, including permanently and seasonally wet areas:
  - Permanent swamp;
  - Edaphic grassland;
  - Lakes;
  - Rivers and stream-associated wetland vegetation;
  - Termitaria;
- Terrestrial:
  - Forest land (Woodland [Miombo, Baikiaea, Chipya and Munga]).

Table 2 presents the extent of each of these classes' coverage in the site.

Table 2 – Macro-habitats of the Lukanga Ramsar site and surrounding area

Macro-habitat		Ramsar		Total (Ramsar + buffer)	
		(ha)	(%)	(ha)	(%)
Forest land	Miombo	10,617.88	3.2	47,433.56	7.07
	Baikiaea	-	-	1,190.12	0.18
	Lake basin Chipya	4,471.84	1.35	5,184.30	0.77
	Munga or Miombo	87.29	0.03	12,587.33	1.88
Total		**15,177.02**	**4.589**	**66,395.31**	**9.9**
Wooded grassland	Termitaria	44,869.19	13,54	154,619.44	23.05
Total		**44,869.19**	**13,54**	**154,619.44**	**23.05**
Grassland	Edaphic grassland	78,436.29	23.67	112,951.26	16.83
	Permanent swamp	169,235.99	51.06	169,655.34	25.29
	Stream-associated wetland vegetation	958.80	0.29	3,035.99	0.45
Total		**248,631.09**	**75,02**	**285,642.59**	**42,57**
Inland water	Lakes	4,887.72	1.47	4,887.72	0.73
	Rivers	550.87	0.17	1,581.33	0.23
Total		**5,438.59**	**1.64**	**6469,05**	**0.96**
Anthropic landscapes	Cultivated and managed land	16,912.63	5.1	156,658.19	23.35
	Rural built-up land	398.29	0.12	1,149.95	0.17
Total		**17,310.92**	**5.22**	**157808,13**	**23.52**
Total		**331,426.81**	**100**	**670,934.52**	**100**

The description that follows includes a summary of each macro-habitat's vegetation structure, floristic composition, ecological conditions and existing faunal niches.

5.3.1. Permanent swamp

The permanent swamp macro-habitat forms part of the palustrine wetland, and consists of the vegetated and permanently flooded disc-shaped pan at the centre of the area (Figure 11), covering 169,236 ha, or 23.67%, of the Ramsar site.

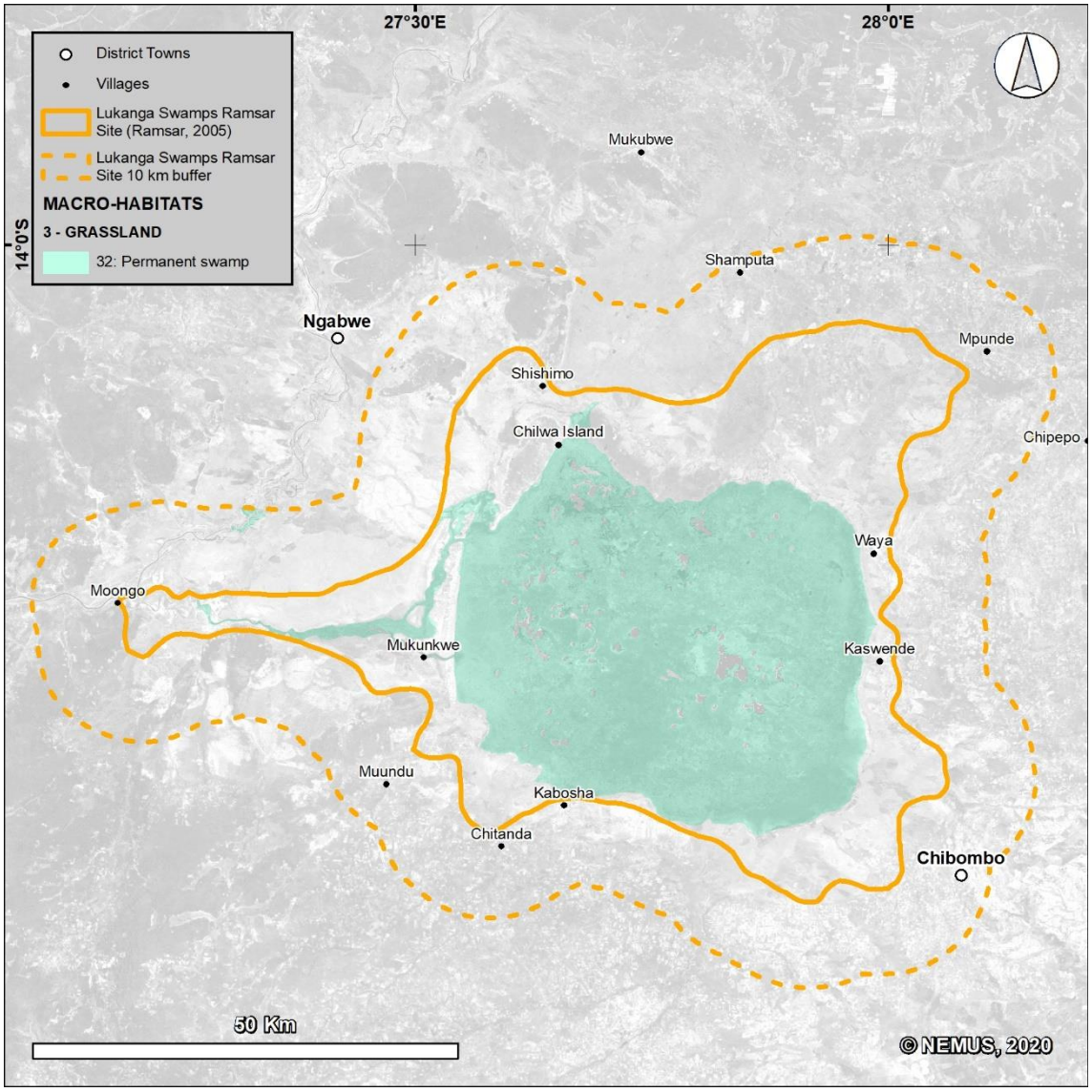


Figure 11 – Distribution of the permanent swamp macro-habitat

The swamp is an area of slow-flowing or stagnant water, flooded to varying depths, and colonized by hydrophytes with physical and physiological characteristics that confer them a range of tolerance to flooding. The permanent swamp has relatively stable hydrological conditions, remaining flooded throughout the year at an average depth of 1.5 m, and attaining higher depths during the rainy season and in the lakes (Chabwela

et al., 2010; Hunink *et al*., 2017; cf., 5.3.5 – Lakes). Severe droughts, although rare, may cause it to dry substantially, with water remaining only in lagoons, as happened between 1992 and 1996 (Kamweneshe and Beilfuss, 2002; Chabwela *et al*., 2010).

This habitat's composition and physiognomy (its vertical and horizontal structure) vary throughout the wetland as a result of multiple factors. It is a structurally complex aquatic habitat, being composed of an herbaceous emergent layer, a surface-floating layer and submerged communities. The controlling factors include variations in local topography and water balance, as well as in temperature, turbidity, conductivity, nutrient availability, carbon dioxide supply, salinity, alkalinity, pH, microclimate, competition and human-induced pressures (Denny, 1985a). Following the gradients in these different parameters, the distribution of hydrophytes typically presents in a continuum from land to underwater, until reaching the maximum depth of plant development (Denny, 1985a).

This zonation can be directly observed through the gradual, or sometimes abrupt, turnover of plant communities dominated by different life-forms – groups with different strategies related to flooded conditions - along the environmental continuum. In wetlands where there is not a marked gradient, the herbaceous layer can instead form complex mosaics of physiognomically different communities that translate local gradients, as is the case of the Lukanga.

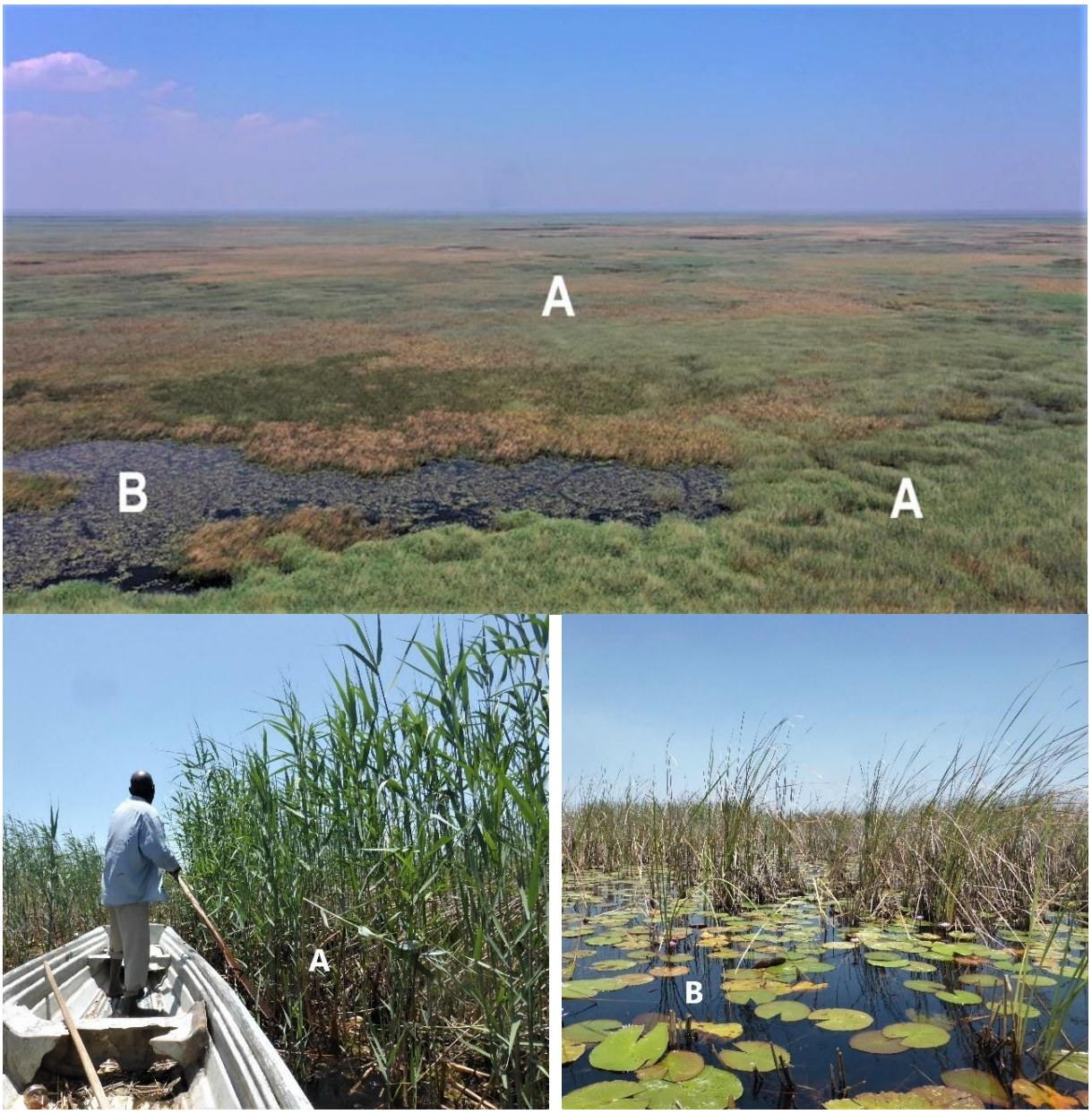
Swamp vegetation typically includes species from all the different hydrophyte life-forms, all of which present, namely (Denny, 1985a):

- **Emergent macrophytes** – plants that are anchored or rooted to the substrate, possess rhizomes adapted to permanently anaerobic sediments, and aerial reproductive organs; these tend to occur in the littoral zone of waterbodies, in up to 1-1.5 m depth; these can be erect emergent macrophytes, when their stems rise above the water, such as *Typha* and *Phragmites*, or creeping emergents, such as *Ludwigia*, when the stems grow horizontally, without however resting in the water; this is the dominant life-form of the Lukanga Swamp, occurring throughout the whole area and only absent from deeper lakes, ponds, man-maintained channels and shallower/drier islands (Figure 12, B);
- **Floating-leaved macrophytes** – plants that are also rooted in the substrate, possess coriaceous floating leaves adapted to mechanical stress, and either floating or emergent inflorescences and flowers; since they possess long petioles, these plants can colonize the wetland up to the 3 m depth zone;

these species, such as *Nymphaea* sp., occur throughout the whole swamp area as well, mainly in the channels and ponds (also occurring along the edges of lakes, cf., 5.3.5 – Lakes) (Figure 12, A);

- **Submerged macrophytes** – plants either rooted or unrooted with their vegetative parts completely submerged, but that can possess emergent reproductive organs, such as is the case of *Utricularia* spp.; this group includes organisms from other major taxonomic plant groups, such as algae and mosses; submerged macrophytes occur throughout the swamp, mainly in the channels and ponds where the cover of emergents is reduced (also occurring in lakes and rivers, cf., 5.3.4 – Rivers and stream-associated wetland vegetation; 5.3.5 – Lakes);
- **Free-floating macrophytes** (or surface floating) – unrooted plants with aerial and/or floating leaves and reproductive organs, such as the water fern *Salvinia molesta*; their distribution is primarily determined by wind and water movement, and their proliferation and compaction can form extensive rafts; several of these species are important invasive weeds worldwide, given their high mobility coupled with high growth rates.

The swamp is composed of dense stands of emergent vegetation rooted to the substrate, cut out by channels and pools that serve as refuge to submerged and floating-leaved macrophytes (Denny, 1985b; Figure 12). Cover density varies substantially, from undisturbed reed stands forming densities close to 100%, to lower densities in human-maintained channels and ponds. Height also varies considerably, from <10 cm for short emergent and floating macrophytes, on floating mats, channels and ponds, up to 2 m in the reed stands.



Source: Nemus (2019).

Figure 12 – Permanent swamp macro-habitat: A. emergent macrophytes; B. floating aquatic macrophytes

Regarding the swamp's floristic composition, only vascular plant communities have been documented. This is a floristically poor habitat, as usual for reed swamps, showcasing higher species diversity along the fringes (Thompson, 1985). Chabwela, Chomba and Thole (2017) performed transect surveys between Chilwa island and Waya, and identified six (6) different communities of aquatic macrophytes, from the termitaria down to the permanently flooded swamp area. The three major ones in the permanently

flooded area are the *Phragmites australis*, *Typha capensis* and *Nymphaea nouchali* var. *caerulea* communities.

Tall emergent vegetation (which tends to form dense stands at the edge of rivers or lakes) dominates throughout the whole area, as is typically the case with herbaceous African swamps, flat and permanently inundated to shallow depths (Howard-Williams and Gaudet, 1985). In the outer rim and drier zones within the permanent swamp, common reed (*P. australis*) dominated communities occur, with *Leersia hexandra* as co-dominant, and abundant *Aeschynomene fluitans*, *Ipomea aquatic*, *Ludwigia leptocarpa* and *Typha capensis*. Further within the swamp, monotypic formations of *Phragmites australis* cover large areas. In deeper zones, these are replaced by communities dominated by *T. capensis*, with the occurrence of *P. australis* and *Eleocharis dulcis*.

Shade-tolerant ferns occur within the emergent stands (Denny, 1985a), and in floating mats of grasses such as *Vossia cuspidata* (White, 1983), between the reed swamp and the truly aquatic vegetation (Figure 13).



Source: Nemus (2019).

Figure 13 – Floating mats of grasses, ferns and forbs

In shallow pools, channels and the edges of lakes, where the canopy of emergent communities breaks down, these are replaced by mixed communities of floating-leaved species (Denny, 1985a), dominated by *Nymphaea nouchali* var. *caerulea*, and with varying proportions of *T. capensis* and *P. australis* (Chabwela, Chomba and Thole, 2017) (Figure 12, A).

These floating-leaved dominated communities are also colonized by submerged plants, which typically continue until a maximum depth of 3 m (Denny, 1985a). Several of these were detected in October 2019, along the channels, shallow ponds and shallower edges of lakes, including the species *Ceratophyllum demersum* and species of the *Najas*, *Utricularia,* and *Potamogeton* genera. *Utricularia* spp. and *C. demersum* are typical of the channels that run along the permanent swamp, preferring low-flowing waters with shade and meso- to oligotrophic conditions (Denny, 1985b).

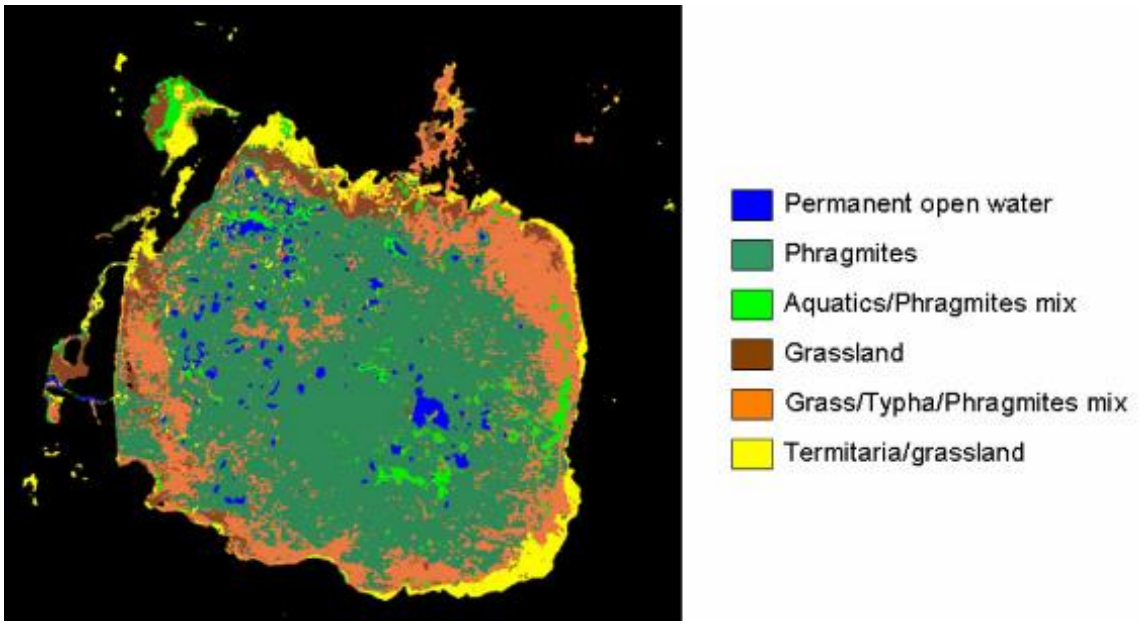
The only free-floating species observed during the September and October visits was the Kariba weed, *Salvinia molesta* (Figure 14), present in all of the visited sites.



Source: Nemus (2019).

Figure 14 – Kariba weed, *Salvinia molesta*, in the swamp off the village of Kabosha

Rebelo, McCartney, and Finlayson (2007) conducted a remote sensing mapping exercise of the swamp through supervised classification and expert assessment of satellite and aerial photography. This returned three broad landcover categories – burned, vegetation and open water. The vegetation class was further subdivided according to species dominance through a similar supervised classification procedure, having classified it into *Phragmites* dominated (i.e., emergent vegetation), mix of aquatics and *Phragmites* (i.e., emergent, floating-leaved and submerged vegetation), and mix of *Phragmites*, grass and *Typha* (i.e., emergent vegetation), surrounded by termitaria and grassland (Figure 15). Their analysis confirmed the dominance of *P. australis* as the rooted swamp-forming species.



Source: Rebelo, McCartney, and Finlayson (2007).

Figure 15 – Wetland classes obtained through the classification of Landsat 5 TM imagery from the 2005 dry season and the 2006 wet season, coupled with low-altitude aerial photographs from October 2006

Ecological conditions and functions

The bulk part of the Lukanga swamp is composed of rooted and tall herbaceous vegetation, *Phragmites australis* and *Typha capensis* in particular. These affect swamp conditions and processes in the following ways.

Because water movement is slowed by reed stands, oxygen (O_2) input to the water column (which happens through water turbulence – pulses of moving water, winds and rains – and aquatic photosynthetic organisms) is difficulted. Consumer organisms use up this O_2 rapidly through decomposition of plant biomass, so that, in closed canopy areas – such as dense stands of *Phragmites australis* – oxygen concentration is severely reduced (Howard-Williams and Gaudet, 1985). Here, decomposition of humic matter increases the concentration of carbon dioxide, lowering the pH. Indeed, higher dissolved oxygen concentrations and pH were found in open water lakes off Chilwa island and Kabosha, compared to the water of the channels, in October 2019 (cf. Conservation Plan Appendix 2, Environmental Quality Assessment).

Dense reed stands also influence the swamp's microclimatic conditions: they reduce light penetration into the water, generally down to below 10%; reduce temperature, as much as 3ºC; and reduce wind velocity, down to 18% (several studies in Howard-Williams and Gaudet, 1985). All of these effects result in **reduced evapotranspiration** compared to open water bodies. Compared to flowing water bodies such as rivers, on the contrary, because the water is halted upon arriving at the swamp, it becomes more subject to evapotranspiration where vegetation cover is not so dense.

The other important component of this ecosystem is the complex system of channels and pools that cuts out reed stands. As mentioned above, dense emergent vegetation areas tend to display anoxic and acidic conditions. The existence of interface areas with higher horizontal mixing, such as man-made channels and pools, reduces stagnation and increases dissolved oxygen concentrations.

This is where the submerged macrophyte community develops, which increases surface area and habitat complexity below water, therefore increasing the habitat's potential as **refuge** and increasing **food-supply for grazers** (Bird, Day and Malan, 2014). In addition to being fish breeding areas, these ponds and channels colonized by submerged macrophytes serve as refuge for fry, and habitat for invertebrates, which in turn represent important food-supplies for fish and birds. These are essential components for the maintenance of swamp fisheries.

Wetlands in general are very productive systems, and, in tropical Africa, these are characterized by sustaining plant growth and production in the dry season due to the edaphic water content. In tropical perennial swamps such as the Lukanga, the majority of the production can be attributed to the dominant emergent species, *Phragmites australis* and *Typha capensis*, with floating-leaved and submerged macrophytes contributing significantly less (Howard-Williams and Gaudet, 1985). Tropical freshwater swamps tend to have an aboveground productivity between 1,500 and 3,000 g m^{-2} y^{-1} (*in* Giesen, 2018). Murray-Hudson and Mmopelwa (2011) estimated an above-ground productivity between 2,000 and 3,000 g m^{-2} y^{-1} for subtropical *P. australis* reedbeds of the Okavango Delta, while net productivity of tropical *Typha* swamps was shown to vary between 2,500 and 3,000 g m^{-2} y^{-1} (*in* Howard-Williams and Gaudet, 1985). Given the massive rhizome development that characterizes *P. australis* and *Typha capensis*, a considerable proportion of the biomass will be below-ground.

Depending on their characteristics, wetlands will function as **carbon sinks** or **sources**. Atmospheric carbon is sequestered and stored as plant biomass through primary

production (i.e., fixation through photosynthesis), and is then deposited in the swamp's substrate as detrital matter, which can be oxidized back to the atmosphere, reduced to CH_4 by microbial action, or be buried and preserved long-term. The rates of these different pathways depend on acting biogeochemical processes. Storage happens in systems where high rates of primary production and organic input are met with low rates of decomposition.

Regarding the nutrient cycle, tropical freshwater swamps are *typically* low-nutrient environments (generally nitrogen(N)-limited), and are consequently known for their water purification capacity (Rejmánková, 2011). Nutrient uptake takes place in the dense root system, and nutrients are either leached back by rainwater, decomposed, settled in the bottom sludge, or kept in the reedbed biomass through an internal recycling system. The nutrient-recycling system is what allows these swamps to maintain high production rates in N-limited conditions (Howard-Williams and Gaudet, 1985).

Permanent herbaceous wetlands are often viewed as "**nutrient traps**" (Howard-Williams and Gaudet, 1985). The rhizosphere formed by the reedbeds that dominate the Lukanga offers extensive surface area for the fixation of microbes and for the slowing down of the water flow. These features, together with the naturally high rates of N-uptake by *Phragmites australis*, allow the entrapment and settlement of suspended particles, absorption and assimilation into plant tissues, and transformation by microbial activity of pollutants in the water (organic compounds, suspended solids, pathogens, metals, pesticides, nutrients, etc.) (García-Ávila *et al*., 2019). Throughflow water is filtered out of these compounds, its gas and nutrient dissolution is changed, and its clarity increases downstream (Howard-Williams and Gaudet, 1985; García-Ávila *et al*., 2019).

Clear-water swamps dominated by emergent and submerged macrophytes have low to medium trophic statuses, with low phytoplankton productivity, and a high capacity to trap nutrients (Howard-Williams and Gaudet, 1985). However, continued nutrient inflow may surpass the swamp's carrying capacity, inducing a shift from the balanced clear-water state to a turbid state, with a higher trophic status, as is happening to wetlands around the world. The proliferation of the Kariba weed, *Salvinia molesta*, for instance, could be an indication of a heightened nutrient status of the Lukanga wetland (*Personal Communication*, 2020). According to the water quality analyses undertaken in the scope of the plan (cf. Conservation Plan Appendix 2, Environmental Quality Assessment), at the end of the dry season, nitrate, phosphorus, chemical oxygen demand (COD) and

biological oxygen demand (BOD) values tendentially increase towards the inside of the swamp.

The accumulation of nutrient rich detritus in the sediment forms what is called the sludge, which can be washed out of the swamp to downstream environments. Hence, through the decomposition of plant biomass, the swamp's sediment, or sludge, represents an important source of nutrients to the water column as well as to downstream ecosystems, functioning as a "nutrient pump" (Howard-Williams and Gaudet, 1985), especially during high-flow periods such as the rainy season.

The erect emergent macrophytes – predominantly *Phragmites australis* and *Typha capensis*, but also *Cyperus papyrus* in the Lukanga river outflow from the swamp – are important sources of raw material, or fibre, for local communities. These harvest them for construction materials, for fabricating mats, baskets and poles for traversing the swamp's channels in shallow water (field observation, 2019; McCartney *et al*., 2011).

Faunal niches

In this section, a brief account of this macro-habitat's relevance for faunal communities is given, highlighting any vulnerable, indicator or otherwise relevant species. The conservation status[4] of the mentioned species for which this is available from the IUCN Red List of Threatened Species (IUCN, 2020) is given in parenthesis after the species name.

Although highly productive, the swamp is a stressful environment for fauna, in particular for aquatic fauna, who needs to cope with low oxygen concentrations. Several obligate wetland dwellers can colonize perennial swamps, such as aquatic invertebrates, ichthyofauna, avifauna, herpetofauna and mammals (Howard-Williams and Thompson, 1985). For those species capable of colonizing this environment, the emergent and submerged hydrophytes in particular offer a wealth of habitat.

Aquatic macroinvertebrates benefit from vegetated biotopes on wetlands as sources of habitat, food, and refuge from predators, and submerged vegetation is often preferred in comparison to emergent communities (Bird, Day and Malan, 2014). Common freshwater

[4] IUCN, 2020: NE: Not evaluated; DD: Data deficient; LC: Least concern; NT: Near threatened; VU: Vulnerable; EN: Endangered; CR: Critically endangered; EW: Extinct in the wild; EX: Extinct.

macroinvertebrates include insects (the most diverse group), annelids, crustaceans, molluscs, acarine and turbellarians. Most common insect orders, in turn, are Diptera (flies), Hemiptera (water bugs), Coleoptera (water beetles), Odonata (damselflies and Dragonflies), Ephemeroptera (mayflies) and Trichopteran (caddis flies) (Dallas *et al.*, 2018; Batzer and Boix, 2016). Microinvertebrates include nematodes (dominant), tardigrades, flatworms and gastrotricha in the benthos, and rotifers and microcrustaceans in the water column (Batzer and Boix, 2016).

The permanent swamp supports important fisheries as well. Channels and shallow pools are particularly important for the wetland's ichthyofauna, since most fish breed and take refuge (especially fry) in submerged macrophyte vegetation. Currently available information on the swamp's fisheries suggest it is dominated by *Oreochromis andersonii* (Three-spotted Tilapia, VU), *O. machrochir* (Green-headed Tilapia, VU), *Tilapia rendalii* (Red-breasted Tilapia, LC), *T. sparrmanii* (banded Tilapia, LC), *Serranochromis angusticeps* (Thin-faced Largemouth, LC) and *S. robustus* (Nembwe, CR) (Mudenda, 1998, in Kamweneshe and Beilfuss, 2002; Central Statistical Office, 2018), together with several barbel and catfish species (Marshall, 2000; Kachali *et al*., 2008).

The permanent swamp habitat can be colonized both by truly aquatic herpetofauna (such as crocodiles, snakes, terrapins, clawed frogs or platanas) and reed swamp associated species, typically more diverse (Broadley, 2000), feeding on herpetofauna, fish and invertebrates. Fully aquatic species are few, and include the Nile crocodile, *Crocodylus niloticus* (LC), the African Rock-python, *Python sebae*, and the Nile monitor, *Varanus niloticus* (Chabwela *et al*., 2010).

This is an important region for resident and migratory avifauna, as is demonstrated by its IBA designation and associated 346 recorded species (Willems and Leonard, 2019). In the permanent swamp, several wetland bird species occur (waterfowl). These are species "ecologically dependent on water and/or marshy habitats, i.e., a wetland species that spends its life in and around these habitats for [feeding, breeding or both]" (Mundy, 2000). Swamp residents include the Eurasian bittern, *Botaurus stellaris* (LC), the Purple Heron, *Ardea purpurea* (LC), the Shoebill, *Balaeniceps rex* (VU), the Purple Swamphen *Porphyrio porphyrio* (LC), the Coppery-tailed Coucal, *Centropus cupreicaudus* (LC), the Little Rush-warbler, *Bradypterus baboecala* (LC) and the Lesser Swamp-warbler, *Acrocephalus gracilirostris* (LC) (Leonard, 2001). Floating-leaved species such as *Nymphaea nouchali* var. *caerulea* in the channels and ponds provide habitat for duck

and teal species such as the Yellow-billed duck, *Anas undulata* (LC) and the Purple Swamphen, *Porphyrio porphyrio* (LC), as was observed in October 2019 (Figure 16).



Source: Nemus (2019).

Figure 16 – Yellow-billed duck, *Anas undulata* (left), and Purple Swamphen, *Porphyrio porphyrio* (right), in a channel within the permanent swamp off Chilwa island

Finally, regarding mammal species, few large herbivores colonize the permanent swamp, along with small mammals (bats, insectivores and rodents), which are not dependent on swamps, but can exploit them (Cotterill, 2000a and b).

For herbivores, this is a particularly unfavourable habitat given its denseness, unstable substrate, permanent inundation and low palatability (Howard-Williams and Gaudet, 1985). The Sitatunga, *Tragelaphus spekii*, is a semi-aquatic antelope well adapted to the swamp environment, and grazes on *Phragmites australis*, *Vossia cuspidata* and *Typha capensis* shoots, for instance. This is a difficult species to detect, as it spends their days hiding in the dense reed stands, and Kamweneshe and Beilfuss (2002) estimated the population, in 2001, at less than 100 individuals.

The Hippopotamus (*Hippopotamus amphibius*) also used to colonize the perennial swamp habitat, making use of its channels and ponds, as well as surrounding grasslands (Kamweneshe and Beilfuss, 2002). Its population was severely affected by the droughts of the 90s, and, currently, there are no estimates of its size. During the October (2019) field works, a local fisherman commented on a possible sighting of hippopotamus activity signs (within the reeds, along a channel departing from Kabosha, cf., Figure 1).

Small semi-aquatic mammals such as otters, mongooses and civets are able to colonize such as the African Clawless Otter, *Aonyx capensis* (NT) and the Marsh Mongoose, *Atilax paludinosus* (LC) (Pacini and Harper, 2008).

5.3.2. Edaphic grassland

The edaphic grassland habitat forms part of the seasonally wet palustrine wetland (Figure 17), covering 112,951.26 ha, or 16.83%, of the area as a whole, and 78,436.ha, or 23.67%, of the Ramsar site. This term refers to herbaceous wetlands that are only seasonally waterlogged, and encompasses a plethora of areas with different flooding regimes, such as dambos[5], riverine floodplains and seasonal swamps (Thompson, 1985; Ellenbroek, 1987), occurring around the central pan and along the existing rivers. It also occurs extensively as the basal layer of Termitaria (cf., 5.3.3 – Termitaria).

[5] A *dambo* can defined as a "broad valley […] that is waterlogged for some months during the wet season" (Timberlake, 2000).

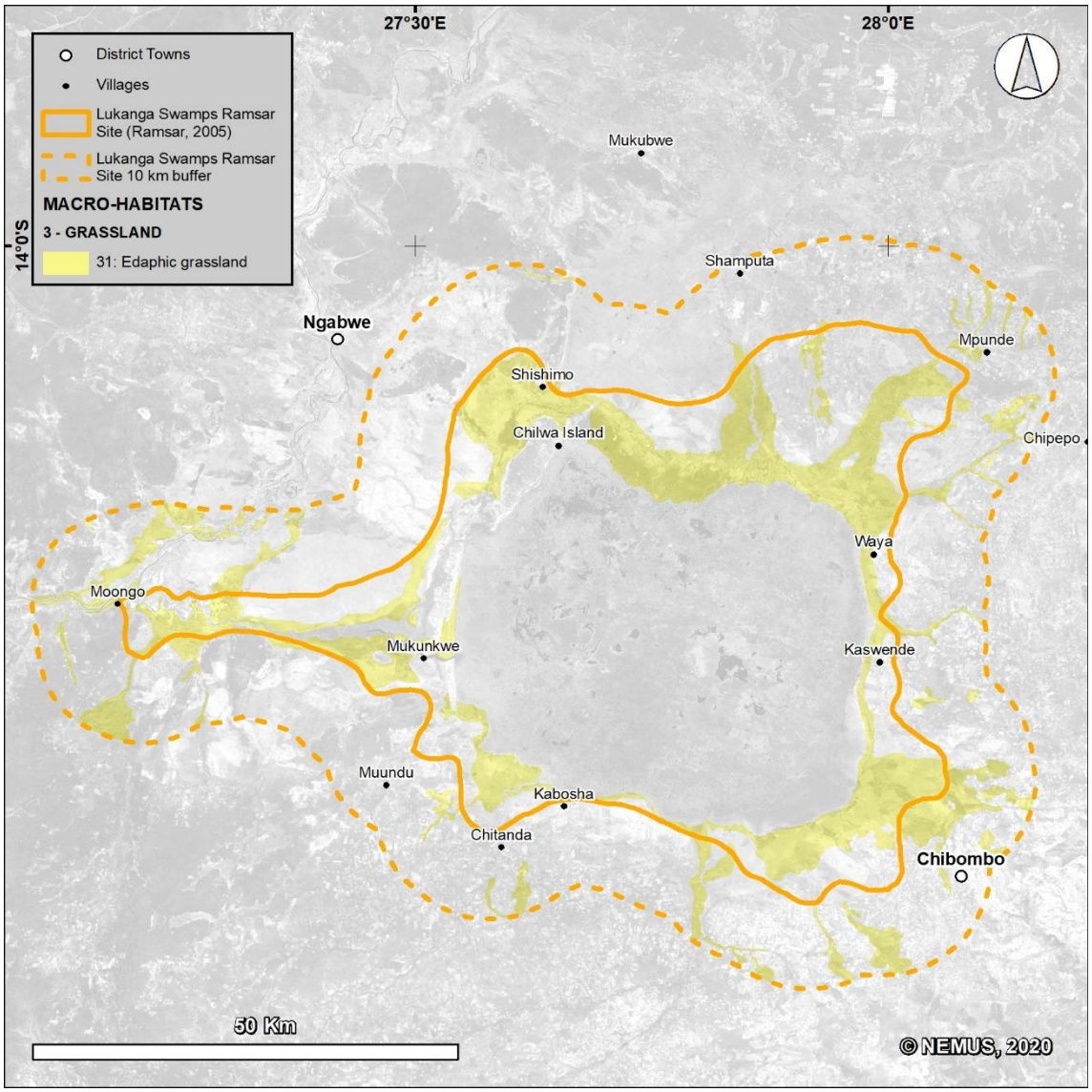


Figure 17 – Distribution of the edaphic grassland habitat

This seasonally-flooded habitat consists of the landward end of the wetland vegetation continuum, and is composed of species adapted to periodic saturation. The colonization by vegetation is almost entirely determined by the seasonal disturbance regime, which produces a mosaic of different grassland types that is dynamic and constantly changing (White, 1983). Local rainfall and runoff from seasonal streams start rising the Lukanga's water levels around January, typically peaking around April (Kamweneshe and Beilfuss, 2002; Hunink *et al.*, 2017). Floodwaters form a shallow inundation area around the swamp with an average depth of 1.5 m, that starts receding after April, defining the extent of this habitat.

Pure azonal grassland represents the edaphic climax vegetation of seasonally-flooded soils, as it is determined by soil properties (such was waterlogging) rather than climatic conditions (White, 1983). In addition to hydrological aspects (flooding regime and height of the water table), however, other disturbance regimes such as fire and grazing alter, or determine, this grassland so that it is not purely edaphic, but secondary to some extent (Thompson, 1985).

By definition, the grassland is a physiognomically or structurally simple habitat, as the herbaceous layer constitutes the main aspect of the landscape (Figure 18), and woody species may occur only at low densities, their presence being precluded by the high water table and poor drainage. When present, tree and shrub communities develop on higher ground, as is the case of Termitaria (5.3.3 – Termitaria). Basal cover is typically close to 100%, and height is generally shorter than the permanent swamp's emergent reed stands during the dry season.



Source: Nemus (2019).

Figure 18 – Edaphic grassland habitat at the end of the dry season

Regarding species composition, this is very variable, and is influenced primarily by timing and duration of flooding, acting in conjunction with several factors such as soil type, salinity, and competition (Thompson, 1985).

Edaphic grasslands typically hold a higher diversity compared to permanent swamps (White, 1983; Thompson, 1985; Beilfuss *et al.*, 2001). These are colonized by hydrophytic communities as well (here, flood tolerant species as opposite to obligate aquatics), and the boundaries between different communities are normally indistinct, depending on the interannual variability of flooding (Thompson, 1985).

A typical floodplain hydrosere of emergents in the region follows as such (from the water): *Vossia – Oryza – Echinochloa – Hyparrhenia* (Thompson, 1985). Many different combinations are possible, and examples of typical hydroseres occur for instance on the Kafue flats and Bangweulu floodplain wetlands of Zambia (Thompson, 1985). Local communities, however, tend to not strictly follow this series due to external pressures such as fire and grazing, more so with increasing distance from the central permanently flooded swamp.

Ellenbroek (1987) identified three main groups of periodically inundated grassland communities in the Kafue flats: zones of high seasonal flood, up to 1.50 m, closer to the permanent water bodies/wetlands; “water meadows”, higher on the floodplain, seasonally flooded up to 0.5 m; and vegetation of shallow flooded areas, less than 0.5 m, that can inclusively remain dry on drought years, on the outer rim of the wetland.

It was not possible to identify most of the species that compose this habitat in September and October 2019 due to the absence of reproductive structures, however, literature accounts suggest a similar composition of communities along the flooding regime’s gradient. Chabwela, Chomba and Thole (2017) described lower floodplain communities around the Lukanga as dominated by perennial rhizomatous grasses such as *Acroceras macrum*, *Leersia hexandra*, *Phragmites australis*, *Vossia cuspiidata* and herbaceous and woody dicotyledons such as *Aeschynomene fluitans*, *Ipomea aquatic*, *Sesbania* spp., *Amaranthus* spp., and *Polygonum senegalense*.

These medium to deep (mid to lower floodplain) grassland communities are characterised by long inundation periods, and often include other perennial rhizome forming species such as *Oryza longistaminata* and *Echinochloa* spp., representing important grazing grounds for herbivores (White, 1983; Thompson, 1985; Beilfuss *et al.*, 2001; Ellenbroek, 1987).

Higher floodplain areas – less frequently flooded or rarely flooded but with high water table – include both perennial and annual species, increasingly seed spreading (Thompson, 1985). Chabwela, Chomba and Thole (2017) reference *Panicum maximum*, *Digitaria milanjiana*, *Setaria anceps*, *Cymbopogon validus*, *Brachiaria brizantha* and *Sorghum verticilliflorum* as dominating these areas.

Ecological conditions and functions

The edaphic grassland is a cyclic, dynamic and predominantly herbaceous vegetation community determined by the flooding regime, together with fire and grazing pressures. As such, two alternating phases can be observed, inundation and drainage, with distinct ecological functions. Its most defining feature is the seasonal pattern of growth, with a growing period coinciding with the rains and a dormant period during drawback.

During the wet season, specifically from January to April, the lower grassland remains inundated to an average depth of 1.5 m. As water inundates the soils, terrestrial species die off, increasing litter and detrital matter which, together with ash from dry season fires, release nutrients. The first months of rising water levels are marked by intensive hydrophyte growth, mostly of perennial grasses, forming the water meadow. Below the water level, periphyton starts to cover the surface of vegetation structures, representing an important food source for invertebrates and fish grazers. Peak above-ground biomass is reached in the end of the wet season.

As floodwater recedes during the dry season, hydrophytes die off and terrestrial plants can colonize the area again. Grazers and fire are the main agents of the nutrient cycle. Throughout this season, controlled burning of the vegetation is undertaken by local people to induce the growth of fresh herb, more palatable to grazers. The plant biomass is then transformed into dung by cattle, accelerating the nutrient cycle and benefiting fish and plant biomass growth during the following flood (several studies in Howard-Williams and Thompson, 1985).

This is a “pulse stabilized ecosystem” (Beilfuss *et al.*, 2001), whereby the vegetation’s succession is cyclically halted by the different disturbance regimes (flooding, fire and grazing), i.e., its structure and composition are maintained in an intermediate state, resulting in a rapid nutrient cycle and high production rates (Marchand, 1987).

These grasslands' high primary production means an equally high rate of carbon sequestration from the atmosphere, which is predominantly stored as below-ground biomass (Gibson, 2009). Grasslands can rapidly turn into carbon sources, however, as opposed to sinks, through the unmanaged intensification/increased frequency of dry season fires and grazing pressure.

The nutrient cycle is enhanced by the seasonal cycle of nutrient import and retention from lateral sources (Davies *et al.*, 2008), and is accelerated by dry season fires and grazing. Decomposition rates tend to be low, while the soil's organic matter is high (Gibson, 2009).

Accompanying the rising water level, the spillage of rivers and swamp, and the formation of temporary streams and pools, adult fish migrate horizontally towards the floodplain, increasing secondary production. Here, they find shelter, food and breeding habitat, and become an important food source for bird and human populations.

African floodplain fisheries are very productive and resilient to change, and depend on the alternating phases of flooding and drawdown to be maintained (Howard-Williams and Thompson, 1985). During the floods, there is an increased availability of seeds, vegetative plant material, invertebrates and habitat, that sustain the breeding stock during reproduction (Welcomme, 1975). Because feeding, growth, reproduction and mortality rates vary from the dry to the wet season, fluctuations in the seasonal flooding pattern induce changes in fish populations. Most fish species go through high growth rates when in the floodplain, as opposed to the dry season, as demonstrated by Welcomme (1975), who references greater strength, growth and survival of populations from years of good-flooding.

This is therefore a highly productive system of local and regional importance to wildlife and human populations alike.

Faunal niches

Seasonally flooded grasslands that fringe swamp habitats are tendentially richer in terms of fauna diversity and biomass than permanently wet inner areas (Howard-Williams and Gaudet, 1985) (cf. section 5.3.1 – Permanent swamp). Because this habitat is subjected to periodic flooding, there are at least two distinct instances of colonization by fauna.

During the wet season, flooded grasslands provide important habitat for African inland freshwater fish. Fish migrations occur to and from floodplains, and timings are generally species specific (Welcomme, 1975). During the dry season, as water recedes, fish populations return to permanent waterbodies and wild herbivores and cattle recolonize the floodplain grassland (Marchand, 1987).

The hydroperiod is a fundamental factor of invertebrate community structure in these grasslands. Both terrestrial and aquatic habitat-specific invertebrate fauna occur, with assemblages composed of species with life history traits adapted to the alternating flood and drought conditions, such as short life cycles (Wantzen *et al.*, 2016; Batzer and Boix, 2016). Terrestrial assemblages include myriapods, spiders, mites and beetles, and termite and dung beetles are particularly relevant for the system's functioning (Gibson, 2009; Batzer and Boix, 2016). The high microbial action typical of African wetlands results in rapid changes of water conditions, which represents an additional challenge for these organisms.

Dambo and seasonally-flooded grassland amphibians possibly occurring in the area include the Shovel-footed Squeaker, *Arthroleptis stenodactylus* (LC), the Yellow Swamp Toad, *Sclerophrys lemairii* (LC), the Guinea Snout-burrower, *Hemisus guineensis* (LC), and the Small puddle frog, *Phrynobatrachus parvulus* (LC) (Bittencourt-Silva, 2019; IUCN SSC Amphibian Specialist Group, 2016).

Regarding avifauna, several bird species use the flooded grassland for breeding, refuge and feeding, some remaining in the dried-up grassland, such as the Cattle Egret, *Bubulcus ibis* (LC), and the White Stork, *Ciconia Ciconia* (LC). As floodwater recedes, bird flocks concentrate in the littoral zone, in the dry grassland near flooded channels and shallow ponds (Ellenbroek, 1987; Figure 19).



Source: Nemus (2019).

Figure 19 – Individual of the African Openbill, *Anastomus lamelligerus* (LC), and a flock of African Sacred Ibises, *Threskiornis aethiopicus* (LC), using the grassland and flooded channels north of Chilwa Island

The dry floodplain is inhabited by granivorous and insectivorous species such as Fülleborn's Longclaw, *Macronyx fuelleborni* (LC), the Collered Pratincole, *Glareola pratincola* (LC), the African Pipit, *Anthus cinnamomeus* (LC), and the African Quailfinch, *Ortygospiza atricollis* (LC) and other dry grassland characteristic species (Leonard, 2001). As the floods advance, the inundated grassland is occupied by Ardeidae (herons and egrets), Threskiornithidae (ibises and spoonbills), and Anatidae (Leonard, 2001).

The Wattled crane, *Bugeranus carunculatus* (VU), prefers this kind of habitats, having been registered to use the seasonally flooded dambos (occurring to the north) and floodplains of the Lukanga and Mushingashi rivers. The local population was surveyed in 2001 and 25 individuals were counted (Kamweneshe and Beilfuss, 2002).

Southern African floodplains fringing permanent swamps are important forage habitats for large and medium-sized mammal herbivores. Reduncine antelopes such as the Waterbuck, *Kobus ellipsiprymnus* (LC), the Southern Reedbuck, *Redunca arundinum* (LC), the Puku, *Kobus vardonii* (NT), and the Red Lechwe, *Kobus leche* subsp. *leche* (NT), together with other ungulates such as the Oribi, *Ourebia oribi* (LC), are typically associated to these floodplain and peripheral grasslands (Cotterill, 2000a; Bell and Grimsdell, 1973; Fynn *et al.*, 2015). Most of these are gregarious grazers displaying a high diversity in the Zambezi Basin, with populations gathering around important

Zambian wetland systems such as the Kafue flats and the Bangweulu Swamps (Cotterill, 2000a; Fynn *et al.*, 2015).

Despite the availability of reduncine habitat, the Lukanga Swamp contrasts to this tendency, mainly because of the history of human disturbance in northern, western and southern areas. Red lechwe and Oribi were detected in 2001, with population estimates of less than 100 and more than 60, respectively (Kamweneshe and Beilfuss, 2002).

The relatively undisturbed region to the northwest of the Lukanga river and up to the Kafue River, the Itundu Plain, is reported as supporting higher numbers of fauna, including, in addition to the aforementioned, other ungulates such as the Eland (*Taurotragus oryx*, LC), and other mammals like the Elephant (*Loxodonta africana*, VU). These populations are, however, said to have been depleted as well (key informant interviews, 2019; personal communication, Kabwe, 2019).

Small mammals – insectivores and rodents such as voles, mice, shrews, etc. – are abundant in these habitats (Gibson, 2009; Namukonde *et al*., 2017), and remain the predominant wildlife of the area (Chabwela *et al*., 2010).

5.3.3. Termitaria

The termitaria macro-habitat is also included in the palustrine portion of the Lukanga wetland, and occurs in seasonally flooded areas or where the water table is permanently high, covering 154,619.44 ha, or 23.04%, of the area as a whole, and 44,869.19 ha, or 13.54%, of the Ramsar site (Figure 20).

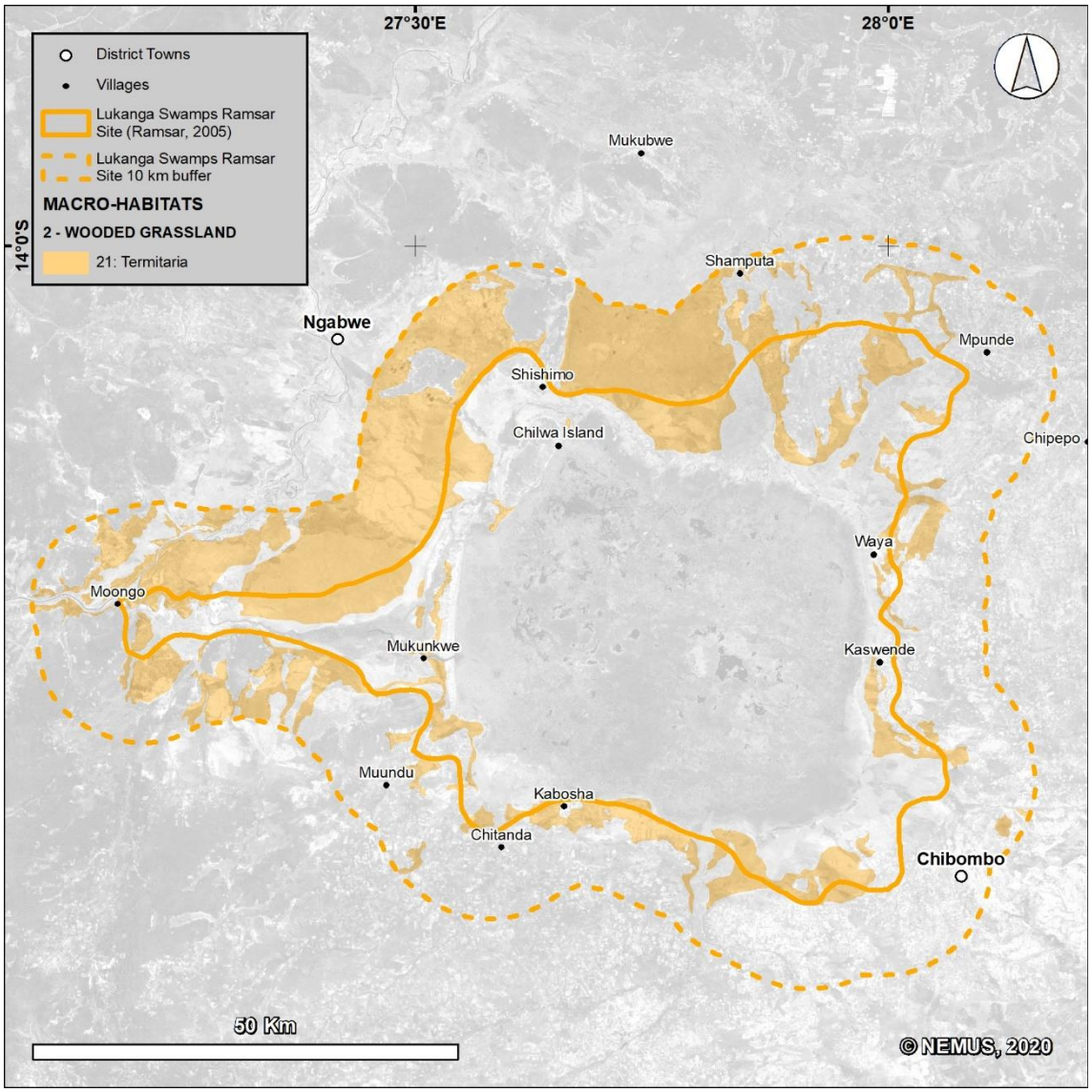


Figure 20 – Distribution of the Termitaria macro-habitat

What distinguishes this macro-habitat from the edaphic grassland is the existence of well-drained islands of higher ground, formed by termites, which allow the colonization by less flood-tolerant and woody species whose development is inhibited in the rest of the area (Chabwela, Chomba and Thole, 2017).

Termitaria are distributed universally throughout central Africa, and are not a habitat or vegetation type per se, displaying formations of “all the major physiognomic vegetation types” (Fanshawe, 1968). Around the Lukanga Swamp, however, in addition to occurring in forest land habitats (cf. section 5.3.6 – Forest land), they form a distinctive wetland-associated landscape that can be mapped and must be assessed as its own unit accordingly.

The distribution of termite mounds is determined by moisture, soil conditions and biotic conditions (Malaisse, 1978). Here, they form after the zone of low-flood (Chabwela *et al*., 2010), and dominate the north western region, including in the Itundu Plain up to the Kafue river (Figure 20), i.e., occupying the area between wetland and woodland habitats, as observed in the Kafue flats (Ellenbroek, 1987).

Structurally, this is a complex macro-habitat where the basal layer is composed of edaphically-determined grassland as described earlier (cf. section 5.3.2 – Edaphic grassland), and the canopy presents as clusters of different woody plant communities, from shrubs to trees, forming a wooded grassland, or savanna-type environment (White, 1983; Shakachite *et al.*, 2016).

The woody vegetation clusters on top of termite mounds can also be described along an edaphically controlled catenary sequence of forest vegetation through to grassland, with shrubland in between (Fanshawe, 1968). Large, aged and better-drained termite mounds (often further away from the flooded area), are normally covered by dense thicket with some trees (White, 1983; Ellenbroek, 1987) (Figure 21), while more recent and shorter/smaller mounds (typically closer to the swamp and hence subjected to higher floods), tend to be covered by shorter shrubs or herbaceous vegetation.



Source: Nemus (2019).

Figure 21 – Termitaria macro-habitat: on top, the extensive plain north of the Lukanga river and downstream of the swamp; on the bottom left, tall termitaria between Chitanda and Mukunkwe; on the bottom right, short termitaria close to Twenty village, southeast of the swamp

Zambezian termite mound vegetation is a very rich group floristically (White, 1983), being composed of communities from the different vegetation types of the region, and Termitaria grasslands are richer than floodplain grasslands (Ellenbroek, 1987). Local floristic compositions are correlated to local habitats, so that, in the current context, Miombo, Munga and grassland/riparian termitaria communities are expected to occur (Fanshawe, 1968).

In the short termite mounds closer to the permanent swamp, the hydrophytes *Aeschynomene fluitans*, *Ipomea aquatic*, *Phragmites australis*, *Sesbania rostrata*, *Vossia cuspidata*, *Leersia hexandra*, *Maranthus* spp. and *Persicaria senegalensis*

dominate, with *Heliotropium* sp., *Hibiscus* sp., and *Sida* sp. also abundant (Chabwela, Chomba and Thole, 2017). Other typical species include *Acroceras macrum*, *Setaria sphacelate*, *Setaria anceps*, *Chloris* sp., *Cynodon dactylon*, *Imperata cylindrica* and *Panicum repens* (Chabwela, 1998, in Chabwela *et al*., 2010).

According to Chabwela, Chomba and Thole (2017) woody species on the taller termitaria include *Piliostigma thonningii*, *Phyllanthus reticulatus* and *Securinega virosa*, as well as *Ziziphus mucronata*, *Lannea stuhlmannii*, *Albizia Harvey*, *Capparis tomentosa*, *Loncocarpus capassa*, *Phoenix reclinate*, *Boscia* sp. and *Acacia nilotica* (Chabwela *et al*., 2010), most being typical upper-, understorey and shrub species in Munga termitaria (Fanshawe, 1968). This is similar to what was encountered in the Kafue Flats by Ellenbroek (1987), who described woody termitaria as displaying vegetation communities closer to Fanshawe's Munga termitaria than to riparian termitaria, despite their occurrence in a seasonally inundated area.

The herbaceous field layer farthest from the permanently inundated swamp is composed of *Sorghum verticilliflorum*, *Setaria phragmitoides*, *Setaria sphacelate*, *Hyparrhennia rufia*, *Rottboellia exaltata*, *Chloris* sp., *Panicum maximum*, *Vetiveria nigritana*, *Digitaria milanjiana*, *Brachiaria brizantha* and *Andropogon gayanus* (Chabwela *et al*., 2010; Chabwela, Chomba and Thole, 2017), as well as *Hibiscus* sp. and *Setaria anceps* (Chabwela, Chomba and Thole, 2017).

Ecological conditions and functions

In terms of its conditions and functions, the termitaria macro-habitat occupies a transition landscape between wetland and terrestrial habitats, and displays spatially separated features of both: on the base, an edaphic grassland seasonally inundated by rainfall and runoff, and, scattered into clusters, grassland, shrubland or woodland vegetation that remains dry throughout the year.

The seasonally flooded grassland matrix will display similar conditions to those described for the edaphic grassland (cf. section 5.3.2 – Edaphic grassland), with areas inundated every rainy season to higher depths and others only occasionally inundated, but with high wate table. Throughout the dry season, this area becomes dehydrated. The grassland vegetation therefore also features a seasonal growth period coinciding with the rains, after which most species become dormant.

The termite mounds introduce additional levels of structure complexity and associated functionality, compared to the grassland matrix. During inundation, these are dry islands where animal species such as small mammals and birds can take refuge. Even the short mounds that are not colonized by woody vegetation, in the regularly inundated grassland, are important resting places for birds during flooding (Ellenbroek, 1987; Pullan, 1974). The surrounding flooded grassland is a rich feeding habitat at this point (cf. section 5.3.2 – Edaphic grassland).

Termites are important soil engineers as they can alter the soil's physical, chemical and microbiological properties; hence their presence constitutes a significant element of this macro-habitat's functioning. *Odontermes* spp. and *Macrotermes* spp. can modify the soil's cohesion and water permeability depending on their ecological requirements (Jouquet *et al.*, 2006). Because the composition of the soil's litter transformers is different from the surrounding soil, nutrient uptake and release will be modified, depending on the age of the structure and the degree of activity of the termites. In the edaphic grassland context, termitaria are characterized by higher soil pH and better drainage than surrounding soils, while also maintaining moisture at higher levels during the dry season (Malaisse, 1978; Ellenbroek, 1987; Khan *et al.*, 2018).

Termite species occupy three major feeding guilds, soil feeders (or humivorous, feeding directly on the soil's organic matter), wood feeders or mixed feeders (Khan *et al.*, 2018). The foraging activity of fungi-growing (develop a symbiotic relation with saprophytic termitophilous fungi who decompose the litter material collected by termites) and harvester termite species (that consume the plant material directly) increases the organic content of the soil (Pullan, 1974; Khan *et al.*, 2018). According to Pullan (1974) termite species of the plan area used to be predominantly fungi-growing and harvesters, so that their activity would represent a significant input of nutrients from external sources on the mounds.

These soils are also characterized by higher rates of microbial activity, in relation to surrounding woodland/dry habitats, so that the soils tend to be enriched in ammonium and nitrate, soil organic matter and ions (Jouquet *et al.*, 2006), which constitute improved conditions for plant development. Because of the higher ion concentration, antelopes are known to use termitaria as salt licks (Malaisse, 1978), which is also true for local cattle (personal communication, 2019).

Faunal niches

The existence of drier islands of woody vegetation in this macro-habitat increases both habitat structural heterogeneity and plant species diversity, offering a wider variety of feeding and sheltering habitat for fauna compared to the edaphic grassland (Namukonde, 2017; Ellenbroek, 1987; Pullan, 1974). The main groups occupying the termitaria macro-habitat are terrestrial invertebrates, avifauna and mammals.

Mounds formed in the Plateau are typically occupied by several termite species (Fanshawe, 1968). Chabwela, Chomba and Thole (2017) mentions, for the plan area, that higher mounds, in the seldom inundated zones, are built or occupied by *Macroterms* spp. and *Odontoterms* spp., whereas the shorter mounds, in regularly inundated zones, are occupied by *Cubitermes* spp. The activity of termites is influenced by the inundation level, increasing with restricted flooding (Ellenbroek, 1987), and being inhibited by extreme flood events, that force the termites up the mound, or even killing them.

During the dry season, these habitats are generally abandoned, being used mostly by small animals seeking for shelter. During the inundation period, termite mounds represent dry islands thought to provide refuge for mammal and bird species alike. These are used, in the Kafue Flats, by waterfowl and lechwe, which feed from the surrounding grassland (Ellenbroek, 1987).

Large mammals such as the Red Lechwe (*Kobus leche* subsp. *leche*, NT) and the Oribi (*Ourebia ourebi*, LC) have been reported to use the termitaria zones (Beilfuss *et al.*, 2001), together with the Reed buck (*Redunca arundinum*, LC), Marsh Mongoose (*Atilax paludinosus*, LC) and Serval Cat (*Leptailurus serval*, LC) (Chabwela *et al*., 2010). However, their populations are now depleted (cf. section 5.3.2 – Edaphic grassland), and the mammal biomass utilising the termitaria is assumed to be dominated by small mammals such as rodents and shrews (Chabwela *et al*., 2010; Namukonde, 2017). In accordance with the claim of higher structure and niche complexity provided by the termitaria, Namukonde (2017) recorded a significantly high number of species from the KNP termitaria compared to the numbers from woodland and grassland vegetation, given their relative coverage of the Park.

Notwithstanding, the Itundu Plain (dominated by termitaria vegetation) appears to hold a particular significance for large mammals, owing to its undisturbed condition compared to the rest of the areas surrounding the swamp, while the overall termitaria/grassland macro-habitat is important for livestock grazing (Chabwela *et al*., 2010).

According to Leonard (2001), bird species favoured by termitaria (areas dominated by these formations and supporting only scattered shrubs) include the Capped Wheatear, *Oenanthe pileata* (LC), and the Sooty Chat, *Myrmecocichla nigra* (LC), while Chabwela *et al.* (2010), references the utilization by the Yellow-throat Sand Grouse, *Pterocles gutturalis* (LC), Wattled Crane, *Grus carunculata* (VU), Blacksmith Lapwing, *Vanellus armatus* (LC), Wattled Lapwing, *Vanellus senegallus* (LC), and the Black Kite, *Milvus migrans*, (LC).

5.3.4. Rivers and stream-associated wetland vegetation

The river and stream-associated wetland vegetation encompass both open water and vegetated permanent streams, and exclude riverine floodplains only seasonally inundated (which are included in the edaphic grassland, cf. section 5.3.2 – Edaphic grassland). It covers 4,617 ha, or 0.69%, of the area as a whole, and 1,509.7 ha, or 0.46%, of the Ramsar site, and includes the courses of the Kafue, Lukanga, Mufukushi, Chiyuni and Lunjolwa rivers (Figure 22).

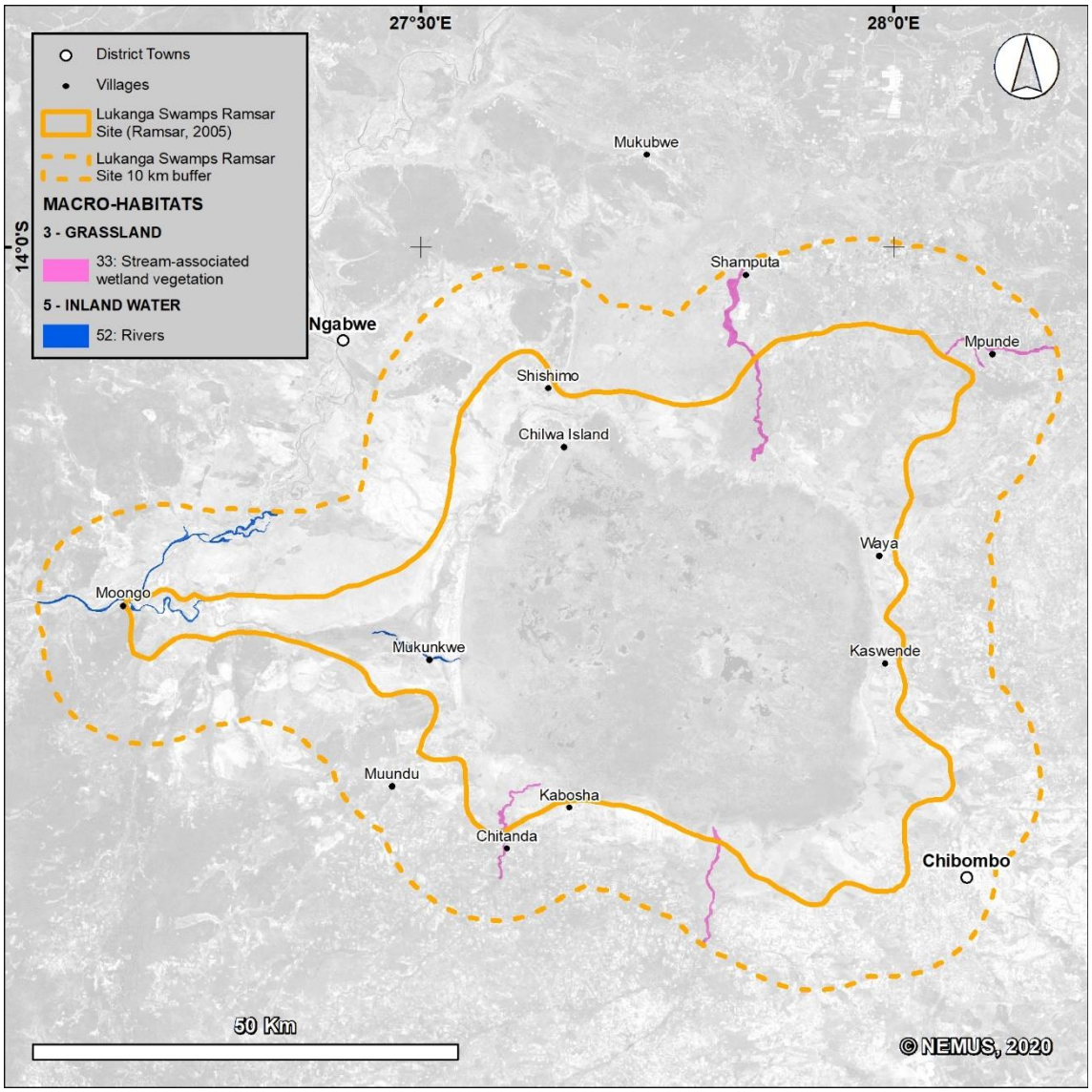


Figure 22 – Distribution of the river and stream-associated wetland vegetation macro-habitat

Structurally, permanently inundated streams and rivers include two major configurations, open water and emergent vegetation (i.e., inland waters and grassland), which were mapped separately but are here described together given their close association. The first consists of the flowing water body of major rivers, without emergent macrophyte stands and with varying development of submerged, floating-leaved and surface floating species inwards, depending on depth, flow and turbidity (Figure 23).



Source: Nemus (2019).

Figure 23 – Open water in the river macro-habitat: on top and bottom left, the Lukanga river downstream from the swamp, flowing towards the confluence with the Kafue; on the bottom right, the same river upstream from the swamp, flowing through Mpunde

The latter presents as emergent macrophyte stands similar to the permanent swamp's (cf. section 5.3.1 – Permanent swamp), developing along the banks of major rivers or occupying the entire waterbody of smaller streams (Figure 24). Both the Mufukushi and Lukanga rivers' surface flows are interrupted during the dry season, upstream of the swamp, and their courses become instead a series of open water patches with varying degrees of vegetation cover.



Source: Nemus (2019).

Figure 24 – Emergent macrophyte cover of the river macro-habitat: on top, Lukanga river's meanders between the swamp and the confluence with the Kafue; bottom left, the same river upstream from the swamp, flowing through Mpunde; bottom right, the same river as it leaves the swamp, at Mukunkwe

The structural and floristic complexity of the river's vegetation is varied and, similarly to the swamp and lakes, develops as a continuum from the shallow banks down to the faster flowing and deeper body of water, until reaching the maximum depth of plant development (Denny, 1985a).

The banks are usually colonized by a fringe of emergent macrophytes, which can overgrow the entire stream if it is sufficiently shallow and slow-flowing. Upstream of the swamp, the dominant species is *Phragmites mauritianus* (Figure 25a), while,

downstream, emergent macrophyte stands are dominated by *Cyperus papyrus* and/or *Typha capensis* (Figure 25b,c,d).



a. *Phragmites mauritianus*



b. *Cyperus papyrus*



c. *Typha capensis*



d. *Cyperus papyrus* and *Typha capensis* stand

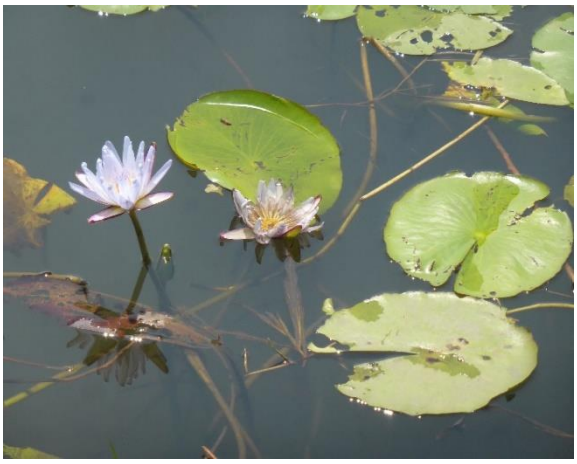
Source: Nemus (2019).

Figure 25 – Different macrophyte stands in the rivers around the Lukanga Swamp

Inward from the banks, towards deeper water, there is a turnover from emergents into different communities dominated by floating-leaved and submerged macrophytes, along depth, flow, and turbidity gradients (Denny, 1985a).

The emergent stands in the edge of the water can also be colonized by *Ludwigia leptocarpa*, *Cyperus latifolius*, *Cyperus difformis*, *Persicaria senegalensis* (syn. *Polygonum senegalinse*), *Cyperus digitatus* subsp. *auricomus*, among others, and are gradually replaced by floating-leaved, rooted, *Nymphaea nouchali* var. *caerulea* and *N. lotus*, mixed in with submerged, rooted or unrooted, *Ceratophyllum demersum*, *Najas* sp. and *Utricularia* sp. (Figure 26).

Free-floating invasive species such as *Salvinia molesta* and *Azolla filiculloides* are also present, mainly in slow-flowing areas and towards the edges of rivers, anchored by other vegetation. These were only detected in the Lukanga river downstream of the swamp, not in any of the upstream courses.



Nymphaea nouchali var. *caerulea*



Ludwigia leptocarpa



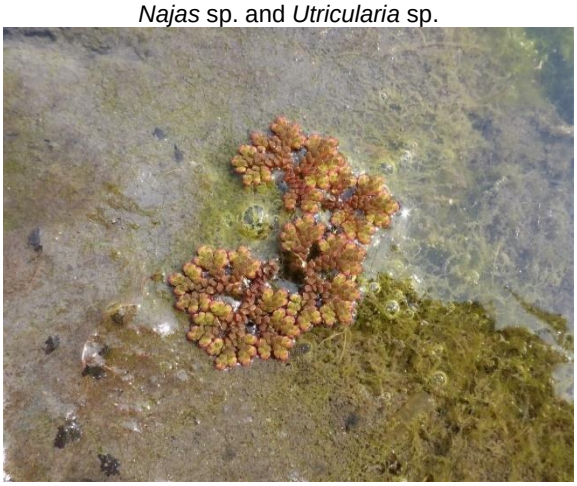
Ceratophyllum demersum



Najas sp. and *Utricularia* sp.



Salvinia molesta



Azola filliculoides

Source: Nemus (2019).

Figure 26 – Macrophyte species of the Lukanga Swamp's in- and outflowing rivers and streams

Some woody riparian communities can occur along river channels (Figure 27). According to Chabwela *et al.* (2010), these include *Syzygium guineense*, *Trichilia emetica*, *Phyllanthus reticulatus*, *Acacia albida*, *Combretum imberbe*, and *Diospyros mespiliformis* (Chabwela *et al*., 2010).

Riverine floodplain is composed of *Acroceras macrum*, *Brothriochloa radicans*, *Chloris gayana*, *Leersia hexandra*, *Phragmites mauritianus*, *Pennisetum purpureum, Echinochloa stagnina*, and *Vossia cuspidata* (Chabwela *et al*., 2010).



Source: Nemus (2019).

Figure 27 – Riparian community along the Chiyuni river, as it passes through Chitanda

Ecological conditions and functions

The functioning of tropical rivers and streams is primarily regulated by seasonal changes in flow regimes and hydrological connectivity, which, coupled with light availability, control the colonization by, and activity of, primary producers. These systems are characterized by year-round growth (Davies *et al.*, 2008), as opposed to seasonally wet habitats like the surrounding edaphic grassland, but rates in primary productivity vary considerably.

Dissolved nutrient concentration is typically low in undisturbed tropical streams and rivers, and consequently, so is primary productivity (Davies *et al.*, 2008). In small streams, which are normally not shaded by riparian vegetation in the area, and in the absence of pollution, nutrient limitation should be the factor influencing primary production the most.

The bulk of these systems' primary production is done by aquatic macrophytes, with a significantly lower portion being attributed to periphyton and phytoplankton, as is the case of the permanent swamp (Davies *et al.*, 2008). During the wet season, high flow causes increased turbidity, and in-stream primary production from algae is further reduced. Also controlling benthic algal biomass is top-down control by fish and invertebrate grazers.

Nutrients are imported through agricultural runoff from the floodplain and upland, and from the swamp, and are continually flushed downstream. Organic matter originates primarily from plant litter and from external sources such as herbivores on the floodplain, which here consist almost entirely of cattle.

Submerged macrophyte vegetation provides important habitat (for breeding and shelter) and food for fish, while emergent vegetation provides a number of products to local communities. Local communities harvest the *Cyperus papyrus* sedge for the construction of mats, and consider it to be more adequate to such uses than *Phragmites australis*, which currently dominates the swamp's emergent cover (field observation, 2019; key informant interviews, 2019) (Figure 28). The common reed *P. australis* is widespread and more abundant, and so it is also commonly harvested.



Source: Nemus (2019).

Figure 28 – Traditional harvesting of *Cyperus papyrus* culms and stems as raw material for the fabrication of matts, in the banks of the Lukanga River, just before the confluence between this and Kafue river, near the settlement of Moongo

Fish communities influence the river's functioning through their effect on primary production and nutrient cycling. As mentioned before, these systems are greatly determined by seasonal flood dynamics. Fish reproduction and growth in tropical southern African streams with floodplains peak during the floods, as fish migrate towards the plain to spawn. Small fishes (more vulnerable to predation) typically occupy densely vegetated areas, whereas bigger and predatory fish occupy the open water (Winemiller, Agostinho and Caramaschi, 2008).

Fish communities are composed of species displaying diverse feeding strategies, and occupy several niches/levels of the stream's food web, namely: there are algae/periphyton grazers, detritivores, invertebrate pickers, invertebrate feeding substrate sifters, piscivores, and generalized carnivores

Faunal niches

Seasonal flood pulses are the major determinants of animal aquatic communities in tropical streams (Pacini and Harper, 2008).

Ichthyofaunal communities are similar to those of the swamp, as these are closely linked, more so during the wet season. Cyprinid and cichlid species are particularly important (Winemiller, Agostinho and Caramaschi, 2008). According to Chabwela *et al.* (2010), inflowing streams to the swamp are important breeding areas for fish species.

Semi-aquatic reptiles include the Nile Crocodile, *Crocodylus niloticus* (LC), which is mentioned as occurring in the banks of the Kafue and Lukanga rivers, the latter downstream of the swamp (personal communication, October 2019). The African monitor lizard, *Varanus niloticus*, is referenced for the area (Chabwela *et al*., 2010), although no survey accounts were found in the literature. Other semi-aquatic reptiles possibly using the area's streams are freshwater turtles, who forage in slow-moving streams and are known to use floodplain wetlands especially during the breeding season (in Pacini and Harper, 2008).

All amphibians are semi-aquatic, depending on water bodies for the first stages of their development. Some remain closely associated to water courses or wetlands through adulthood, and possibly occur in the vegetated streams around the swamp, such as the Kachalola Reed Frog, *Hyperolius kachalolae* (LC) or the Pointed Long Reed Frog, *Hyperolius nasicus* (LC), which have been found using emergent vegetation near streams elsewhere in Zambia (Bittencourt-Silva, 2019; IUCN SSC Amphibian Specialist Group, 2016).

Resident and migrant waterfowls use the rivers and streams, however, given the higher degree of human disturbance, and the availability of better habitat in the proximity, most are expected to prefer the swamp and the Lukanga Rivers outflow (Figure 29).



Source: Nemus (2019).

Figure 29 – An individual of Eastern White Pelican, *Pelecanus onocrotalus*, using the Lukanga River downstream of the swamp, off Moongo

Semi-aquatic mammals include hippopotamuses, otters, mongooses, civets, etc., and other terrestrial groups are closely dependent on water courses.

It is possible that the hippopotamus, *Hippopotamus amphibius* (VU), occurs in the Kafue River, northwest of the Swamp (Figure 22) (Lewison and Pluháček, 2017). Despite a possible sighting of trampled vegetation by hippopotamuses within the swamp in October 2019, no accounts exist of its occurrence outside of the Kafue banks, in the plan area.

Insectivore shrews and bats use streams and rivers for foraging, while otter, mongooses and civets predate on crustaceans, fish and herpetofauna. The African clawless Otter, *Aonyx capensis* (NT) could be present in the area, given its resilience and ability to colonize altered habitats. The African Marsh mongoose, *Atilax paludinosus* (LC), should occur in the area, given it is not fully dependent on streams and can take advantage of the wider landscape's habitats (Pacini and Harper, 2008).

5.3.5. Lakes

The lake macro-habitat is the lacustrine portion of the Lukanga wetland (Figure 30), covering 4,887.72 ha, or 0.73%, of the plan area, all within the Ramsar site.

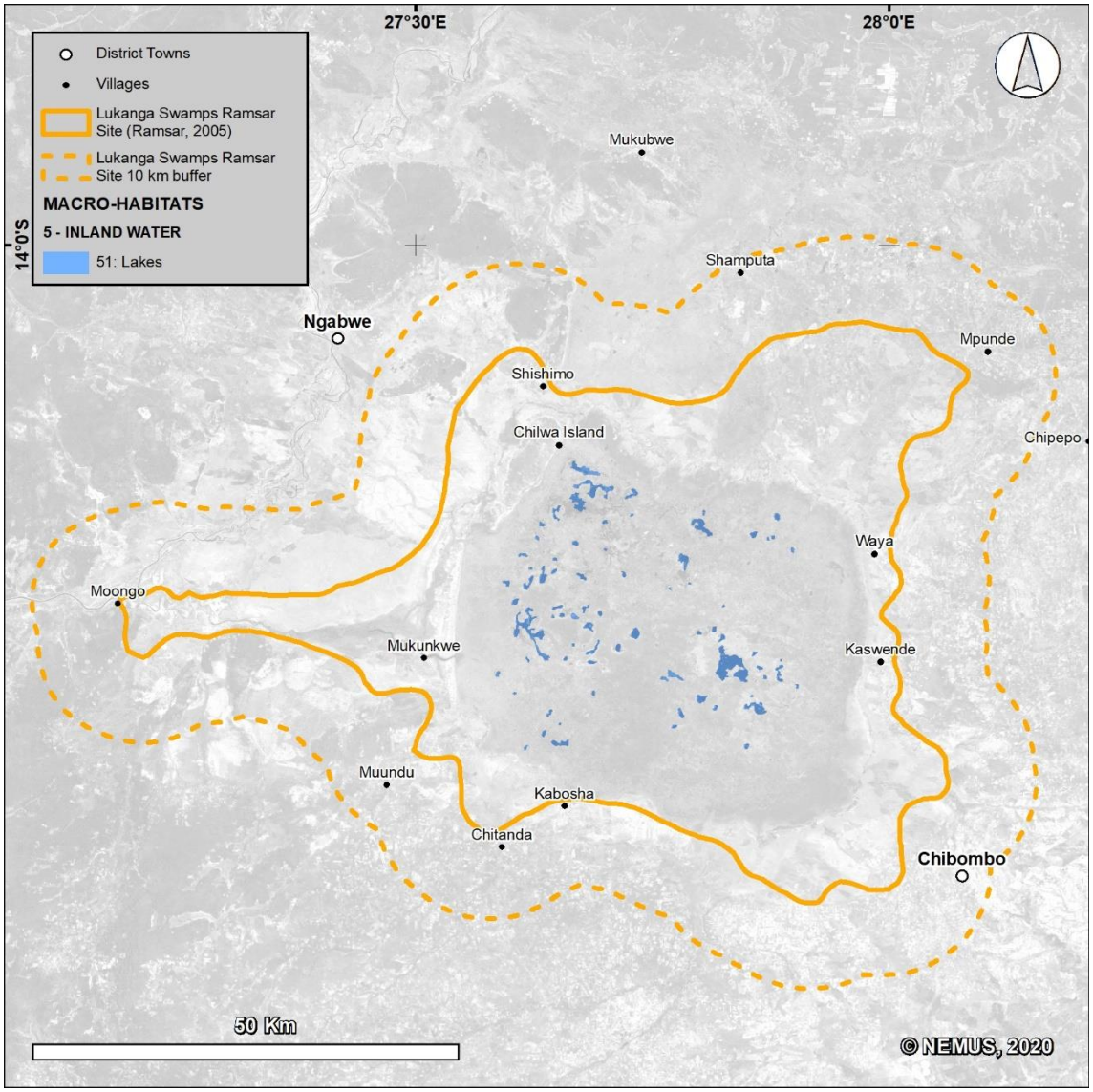


Figure 30 – Distribution of the lakes macro-habitat

This macro-habitat consists of the large bodies of open water scattered throughout the permanent swamp area. Its area varies seasonally according to flood levels and resulting growth of emergent vegetation, and can be significantly altered following events of severe drought (Chabwela *et al*., 2010; Hunink *et al.*, 2017).

In terms of vegetation structure, lakes are colonized by aquatic macrophytes according to depth. They are fringed by emergent reed stands, and shallower edges are occupied

by floating-leaved and submerged macrophytes (Figure 31). Because the lakes within the swamp vary considerably in size and depth, they can showcase a variety of vegetation patterns.

The colonization limits of floating-leaved species, rooted to the substrate, are determined by the overall depth of the water column, so that they tend to occur along the edges, and up to the 4 m depth mark (Denny, 1985b), depending on species' preferences. Truly submerged macrophytes are able to colonize further down, being limited only by the euphotic zone. Their development is determined by light availability, which depends on the water's turbidity.

While some lakes are deep enough to exclude the development of macrophytes altogether (Figure 31), others include large areas of deep enough water as to exclude the swamp's emergent and floating-leaved vegetation, but shallow enough to allow the development of extensive submerged meadows (Figure 31). The two biggest lakes, Suye and Chiposya surpass 10 ha, and depth varies at least between around 0.5 and 4 m according to available records (Mwambazi, 1998, in Chabwela *et al.*, 2010; Hunink *et al.*, 2017).



Source: Nemus (2019).

Figure 31 – Lake habitat: on top, lake off the village of Kabosha; on the bottom, different sites at Lake Suye, off Chilwa island

Regarding the floristic composition, inward from the permanent swamp area, this is where emergent vegetation grades into the truly aquatic and open water communities. The edges of lakes typically support communities of *Nymphaea nouchali* var. *caerulea* with *Ceratophyllum demersum* and *Utricularia* spp. in the understorey, grading into deeper exclusively submerged communities with *Potamogeton* sp. and *Najas* sp., as was described by Denny (1985b) and observed in October 2019 (Figure 32).



Source: Nemus (2019).

Figure 32 – Submerged macrophyte *Najas* sp. in Lake Suye, off Chilwa island

Ecological conditions and functions

The Lukanga's lakes represent a small portion of the wetland habitat, and their conditions are closely related to those of the swamp matrix they are inserted in. Lentic environments typically show thermal stratification of the water column in relation to the euphotic zones. Since the Lukanga's lakes are relatively shallow, light permeability should only be constrained by suspended solids.

Open water lakes are zones of increased wind influence, which induces vertical mixing within the lake environment and horizontal mixing with the adjacent swamp. Accordingly, and as observed for similar environments elsewhere, dissolved oxygen increases in the open lakes, as does pH (cf. Conservation Plan Appendix 2, Environmental Quality Assessment; Howard-Williams and Gaudet, 1985).

These areas also tend to have higher temperatures and evaporative losses compared to flowing rivers and adjacent swamps, given the lack of emergent vegetation cover. Evaporative losses have been estimated to drop down to 60-85% in the swamp, compared to adjacent lakes (in Howard-Williams and Gaudet, 1985).

Nutrients are introduced seasonally from runoff and flooded areas during the rainy season and from the surrounding swamp's sludge.

Faunal niches

Because of the relatively milder conditions of lakes compared to the vegetated swamp, these provide breeding, feeding and refuge for fish, and, subsequently, for the bird populations that predate on them. Large, shallower and vegetated lakes in particular, such as Lake Suye, are important fish breeding areas.

Deep open water does not support significant bird populations, whereas shallower open lakes are used by *Phalacrocorax* spp., *Pelecanus* spp. and *Chlidonias* spp. (Leonard, 2001). The Grey-headed Gull, *Larus cirrocephalus* (LC), prefers open water bodies with swampy or grassy islands of vegetation for breeding, for instance, and was observed in Lake Suye in October 2019 (Figure 33).



Source: Nemus (2019).

Figure 33 – Grey-headed Gulls, *Larus cirrocephalus,* observed in Lake Suye

5.3.6. Forest land

The forest land macro-habitat refers to the regional woodland vegetation, and was mapped as four distinct units: Miombo, Munga, Chipyia and Baikiaea (Figure 34). Forest land covers 66,395.31 ha, or 9.9%, of the plan area as a whole, and 15,177.02 ha, or 4.58%, of the Ramsar site. Of this, and within the Ramsar site, 10,617.88 ha were mapped as Miombo, 4,471.84 ha as Chipya, and 87.29 ha as Munga or Miombo woodland.

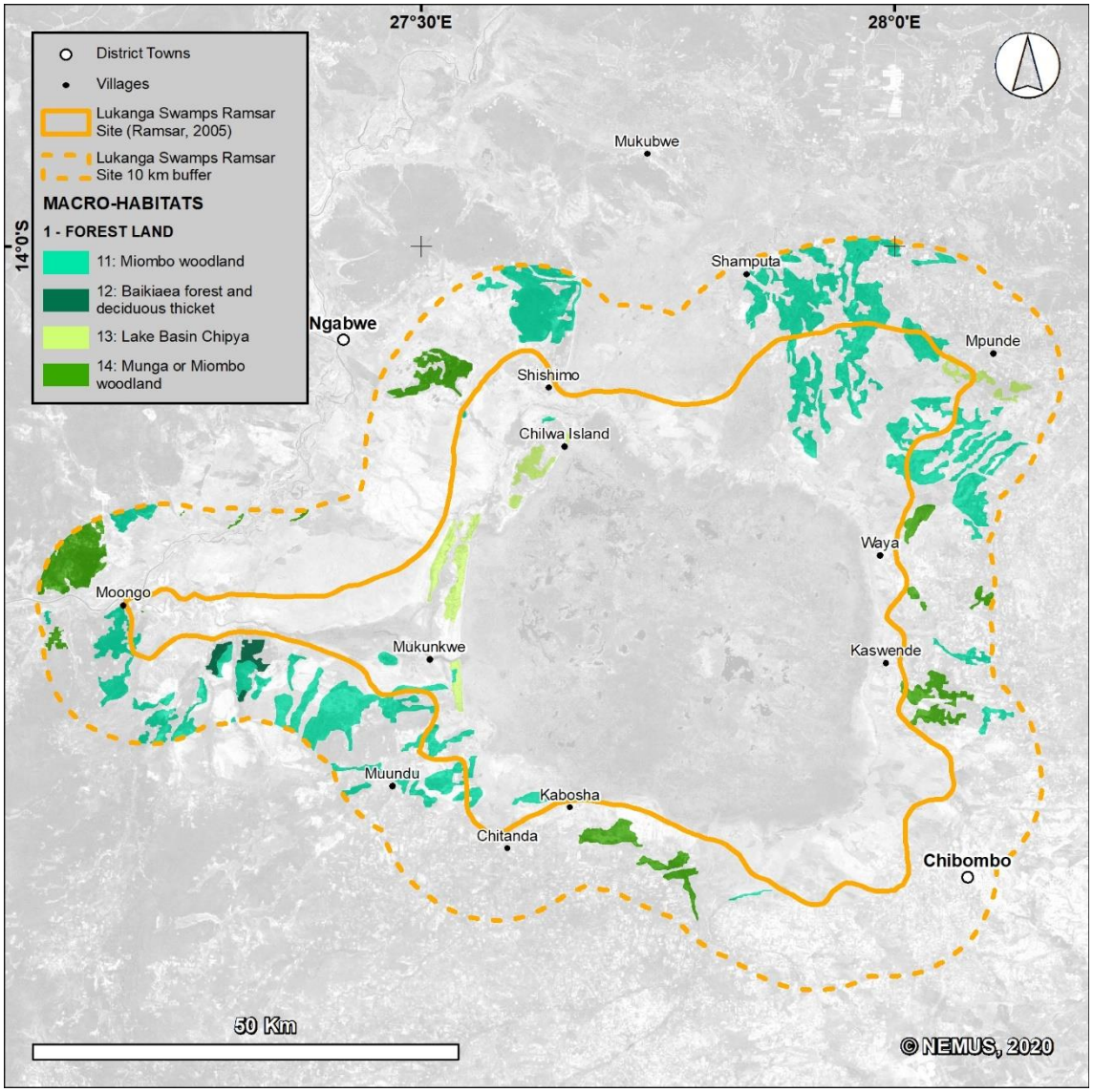


Figure 34 – Distribution of the forest land macro-habitat

This macro-habitat represents the typical dry land vegetation of the region, occupying the upland areas in relation to the Lukanga swamp, and therefore supporting the development of more structurally and species complex woody vegetation (Beilfuss *et al.*, 2001). Inside the swamp and seasonally flooded areas, two islands exist, Chilwa and Chiposha, of Kalahari sand (Chabwela *et al.*, 2010), that support upland vegetation.

Forest land is defined by FAO as land with a minimum area of 0.5 ha, with a canopy cover over 10% and trees higher that 5 m tall, and encompasses from closed and multi-storeyed forest vegetation down to open stands of trees with a field layer of heliophilous grasses only (FAO, 2000; White, 1983).

The latter type, the woodland, is widespread in the African continent and the major vegetation type of the Zambezian region, making up the wooded vegetation surrounding the wetland. While Zambezian woodlands are generally interpreted as the climatic climax vegetation, some are thought to be secondary, deriving from the replacement of dry forest or transition woodland by historical disturbance, and an increasing proportion is currently altered by anthropogenic activities such as cultivation and fire (White, 1983; Forestry Department, 2016).

Structure wise, it typically presents as an open stand of trees without interlocking crowns, of varying heights, and a field layer of herbaceous species with scattered shrubs (White, 1983; Chidumayo, 1987) (Figure 35). Under limiting conditions, dominant species may form scrub woodland, with reduced height.



Source: Nemus (2019).

Figure 35 – General aspects of the forest land macro-habitat

The physiognomy and composition of forest land varies throughout the plan area, but it is mainly open deciduous forest, of which two main types occur, the miombo and munga, along with other less well represented types scattered around (Chabwela *et al.*, 2010; Forestry Department, 2016). In White's UNESCO Vegetation Map of Africa (White,

1983), the central area of the Lukanga swamp is predominantly surrounded by unit 25 – *Zambezian woodland*, wetter miombo, and to the south, in a small portion, by unit 29 – *North Zambezian undifferentiated woodland and wooded grassland*.

The **miombo** is an open woodland (or light closed-canopy) that develops in freely drained and acidic soils, readily distinguished by its canopy composition dominated by three genera, *Brachystegia*, *Julbernardia* or *Isoberlinia*, which are rarely present in other vegetation types (White, 1983). Mostly semi-deciduous, the canopy's height typically varies between 10 and 20 m, but can be stunted down to 3 m in disturbed stands and when developing in less ideal conditions. The shrub and epiphyte layers are typically absent or scattered, and the field layer consists of sparse herbaceous vegetation, with a height varying up to 2 m (White, 1983).

In the region of the African Plateau, the miombo is often altered by agricultural practices such as the chitemene, so that it presents reduced floristic and structural complexities (White, 1983). In more disturbed stands, like stunted ones, other dominants can develop in the canopy, such as *Parinaria curatelifolia*, while *Uapaca* sp. tends to be more abundant in secondary miombo and in the transition with edaphic grassland vegetation (White, 1983).

White (1983) classifies the miombo as either wetter or drier, and the area falls within the wetter region, which is characterized by more than 1,000 mm of annual rainfall. Chidumayo (1987), on the other hand, classifies the area's miombo as Central Drier Miombo, having separated the different types at the 1,100 mm mean annual rainfall isohyet instead. He describes it as being dominated by three *Brachystegia* species and *Julbernardia globiflora* as co-dominants, with *Diplorhynchus condylocarpon*, *Lannea* spp., *Ochna* spp. and *Pseudolachnostylis maprouneifolia* in the understorey.

Around the Lukanga Swamp, the miombo is the most widespread type of forest vegetation, and occurs throughout the northern and southwestern parts (cf., Habitats Map). Chabwela, Chomba and Thole (2017) describes two different communities, namely:

- East of Waya harbour, woodlands are dominated by *Pseudolachnostylis maprouneifolia*, *Julbernardia paniculata*, *Albizia adianthifolia*, *Diplorhynchus condylocarpon* and *Craterosipjon quarrei*, and display the typical indicator species *Uapaca nitida*, *Combretum ghasalense*, *Lannea discolor*, and *Brachystegia boehmii*;

- In Maunde Forest, the vegetation is dominated by *Isoberlinia angolensis* and *Julbernardia globiflora*, with typical *Albizia adianthifolia*, *Brachystegia boehmi*, *B. taxifolia*, *Diplorhynchus condylocarpon*, and *Parinari curatellifolia*.

The **munga** woodland, also designated as North Zambezian undifferentiated woodland and wooded grassland (White, 1983), is a savanna-type open woodland, described by White as characteristically lacking the miombo and mopane dominants (*Colosphospermum mopane* in the latter), as it undergoes a rapid turnover of the floristic composition over short distances, being inclusively more biodiverse than these two (Kindt *et al.*, 2011a).

The term 'munga' was introduced either by Fanshawe (1971, in Forestry Department, 2016) or White (Kindt *et al.*, 2011a), after the Tonga word for savanna and for the vernacular name of straight-thorned acacias. Some communities are also referenced as *Acacia-Combretum*, based on dominant genera (Edmonds, 1976, in Chabwela, Chomba and Thole, 2017; Trapnell *et al.*, 1950, in Kindt *et al.*, 2011a).

The munga is typically found in areas with seasonally high-water tables, being composed of flood-intolerant species that thrive in deficiently drained soils, such as *Acacia* spp. and *Combretum* spp., where miombo dominants do not develop so easily (Beilfuss *et al.*, 2001). Accordingly, it occurs mainly in the north western part, between the swamp and the Kafue river, and to the south and southwest, in river-associated soils along streams (cf. Habitats Map, Appendix A; Edmonds, 1976, in Chabwela, Chomba and Thole, 2017; Chabwela *et al.*, 2010).

Chabwela, Chomba and Thole (2017) describes local munga woodland as *Acacia-Combretum*, dominated by *Combretum ghasalense*, *Julbernardia paniculata*, *Bauhinia petersiana*, *Brachystegia spiciformis*, *Acacia xantophloea*, *Acacia polyacantha*, and *Parinari curatellifolia*, with several other *Acacia* spp., *Albizia* spp., and Combretum spp., and typical miombo associates such as *Pericopsis angolensis*, and *Pseudolachnostylis maprouneifolia*.

Other woodland types are referenced as occurring in the region, such as the **chipya**, whose designation originated from the Bemba term cipya, by Trapnell (1950, in White, 1983) who assigned it to formations of trees lacking the miombo dominants, mixed in well-developed grass (White, 1983). This is a fire- or agriculture-induced (i.e., man-derived and degraded) type of savanna woodland, whereby fire-tolerant tree species are

maintained through seasonal intense fires of the grass layer (Forestry Department, 2016).

Structurally, the chipya varies greatly, from very open to closed woodland, being a «complex mosaic representing different stages of degradation and reestablishment of the original vegetation» (Kindt *et al.*, 2011a). It is typically described as consisting of a field layer of perennial grasses, forbs and bracken, up to 2 m or more, frequent small trees other than the miombo dominants (see above), and scattered tree clusters up to 15 m tall (Lawton, 1978). Scattered within the chipya vegetation, evergreen patches of thicket, the mateshi, can develop (White, 1983).

According to Chabwela *et al.* (2010) and Edmonds (1976, in Chabwela, Chomba and Thole, 2017), it occurs in patches in the plan area (cf., Habitats Map, Appendix A), namely, in Chilwa Island. Here, it is dominated in the north by *Albizia adianthifolia*, *Combretum elatroides* and *Markamia obtusifolia*, and to the south, by *Albizia adianthifolia*, *Strychnos pungens*, *Commiphora mollis*, *Diospyros senensis* and *Schrebera trichoclada* (Chabwela, Chomba and Thole, 2017).

Other referenced species for this type of woodland in the area include: *Albizia antunesiana*, *Burkea africana*, *Pericopsis angolensis*, *Afzelia quanzensis*, *Combretum mechowiananum*, *Erythrophleum africana*, *Sclerocarya caffra* and *Terminalia sericea*; with an understorey of *Combretum ghasalense*, *Diplorhynchus condylocarpon*, *Piliostigma thoniingii*, *Ziziphus macronata*, *Pseadolachnostylis maprouneifolia* and *Xyzygium guineense* (Chabwela, 1998, in Chabwela *et al.*, 2010).

Three herbaceous species are apparently widespread, *Aframomum alboviolaceum*, *Pteridium aquilinum* and *Smilax anceps*, while dominant grasses include *Hyparrhenia* sp. and *Andropogon gayanus* (White, 1983).

Forested habitats such as the **Baikiaea**, a subtype of the Zambezian dry deciduous forest and scrub forest distinguished by its almost pure canopy of *Baikiaea plurijuga* (Kindt *et al.*, 2011a), are the potential climatic vegetation of the region, typically occurring in areas that experience a long season of low atmospheric humidity. Other dominant and widespread species typically include *Pterocarpus anthunesii*, *Acacia giraffae* and *Combretum mechowianum*, and a shrub layer of *Baphia masaiensis*, *Bauhinia macrantha*, *Combretum celastroides* and *Monanthotaxis obovate* (Chabwela *et al.*, 2010).

It is in part characterized by its thicket understorey, the mutemwa (Fanshawe, 1971, in Forestry department, 2016). These are referenced as occurring only in small patches in the region of the Lukanga Swamp (cf., Habitats Map, Appendix A; Edmonds, 1976, in Chabwela, Chomba and Thole, 2017), having been replaced by other woodland vegetation due to human influence.

Finally, similarly to what is seen in the wetland, the woodland landscape is marked by the presence of termite mounds, by *Macrotermes* sp. and *Odonterms* sp. (Chabwela, Chomba and Thole, 2017), which provide an additional level of complexity to these habitats, of great importance to fauna, humans and the ecosystem's functioning. These tend to be colonized by specific plant species lacking the miombo dominants, thus providing islands of different vegetation (Fleming and Loveridge, 2003).

The Ramsar site is increasingly being encroached by small-scale agricultural activity, so that tree and shrub species from miombo, chipya and munga occur throughout the anthropic landscape area.

Ecological conditions and functions

Forest land, here almost exclusively constituted of open deciduous woodlands (Miombo, Munga and Chipya), is characterized by a complex structure dominated by woody species that provide a number of woody and non-woody products together with wider impacting services.

In addition to climate characteristics (long dry season and high rainfall wet season), influencing this macro-habitat's conditions and functions is a disturbance regime primarily characterised by frequent fires and product harvesting by human communities. Indeed, all the types of woodland present around the Lukanga are maintained by disturbance, to some extent.

The miombo's conditions and functions are inherently connected to its floristic distinctiveness, i.e., its *Caesalpinnioidae* dominated canopy, with its typical species being excluded from most other vegetation types. Other characteristic features include seasonal growth, low herbivore biomass, large termite biomass and seasonal rainfall, together with freely drained and acid soils with low organic matter content (Frost,1996).

This predominantly deciduous woodland shows a seasonal growth pattern, with new growth happening towards the end of the dry season. As old leaves are shed just before the onset of the rains, new ones unfold using nutrient and carbohydrate reserves from the previous growing season. Woody plants comprise 95-98% of the above ground biomass of undisturbed stands, while herbaceous species take the rest, and net primary production varies between 900 and 1,600 g $m^{-2}y^{-1}$ (Frost, 1996). The forest vegetation's productive functions – i.e., biomass production and the ability to sequester carbon – provide provisional and regulatory services with local and regional implications.

Wild fruit from miombo species such as *Parinari curatellifolia*, *Uapaca nitida*, *Uapaca kirkiana*, and *Pseudolachnostylis maprouneifolia* is also consumed, mainly in the end of the dry season and in the beginning of the wet season (key informant interviews, 2019; Clarke, Cavendish and Coote, 1996). The roots, leaves and bark are commonly harvested as traditional medicine, from species such as *Brachystegia boehmii*, *Swartzia madagascariens* (syn. *Bobgunia madagascariensis*), *Pseudolachnostylis maprouneifolia* and *Pterocarpus angolensis* (key informant interviews, 2019; Clarke, Cavendish and Coote, 1996).

The miombo is characterised by its poor nutritional quality of forage, both of the woody and herbaceous species, which constraints herbivory. In this low herbivore biomass context, the nutrient cycle is kept running through litter decomposition or fire (Frost, 1996). The soil's organic matter is maintained at low levels (despite the expected abundance of decaying litter, given the low herbivory) through removal by termites and oxidation by burning (Frost, 1996). There is some consumption of plant biomass by invertebrate grazers, such as caterpillars of the *Elaphrodes lactea* moth (Frost, 1996). This consumption is concentrated in the wet season and on locally available suitable plants, and can be highly variable interannually.

Ectomycorrhizal associations also characterise the miombo's dominant species, such as *Brachystegia* spp., *Julbernardia* spp., *Isoberlinia* spp., *Marquesia* spp. and *Uapaca* spp. (Frost, 1996). Several of the associated fungi species, in turn, produce mushrooms, some of which edible, such as *Amanita zambiana*, *Cantharellus* spp. and *Boletos* spp.

Tree species that are resistant to wood-eating insects and wood-decaying fungi such as *Parinari curatellifolia* and *Pericopsis angolensis*, are sources of construction materials, such as for building poles for houses and roofing (Kalaba, Quinn and Dougill, 2013a). In the case of the woodlands surrounding the Lukanga, an important fishery, some tree

species are used for the construction of dugout canoes and for the fish drying structures (Figure 36).



Source: Nemus (2019).

Figure 36 – Different uses of surrounding woodlands' tree species: on top, tree trunks on the harbour off Waya for drying fish on; on the bottom, dugout canoes on the harbour off Kabosha

Dry season fires are recurrent, either accidentally or intentionally started, and mainly consume the understorey of the miombo. This is undertaken as a traditional practice to clear pathways, to induce regrowth of herbaceous species for livestock grazing, and to ash-fertilize the soil for chitemene cultivation. Most of the miombo's dominants, such as *Julbernardia paniculata* and *Brachystegia spiciformis*, are not completely fire-tolerant, and decline under regular fire. Other species encountered in the area such as *Pseudolachnostylis maprouneifolia* are semi-tolerant, while *Pericopsis angolensis*, *Parinari curatellifolia*, *Uapaca nitida*, and *Diplorhynchus condylocarpon* are fire-tolerant (Trapnell, 1959, in Frost, 1996).

Termite mounds significantly enhance the miombo's heterogeneity, increasing the availability of niches and thus promoting species diversity, with repercussions on its functioning (Frost, 1996; Fleming and Loveridge, 2003). The presence and activity of termites themselves promote the redistributing of nutrients and organic matter within the woodland, creating eutrophic hot-spots with higher pH and moisture levels, hence supporting diversified vegetation assemblages compared to the woodland matrix.

Some miombo trees are palatable for herbivores, such as *Parinari curatellifolia*, and some can inclusively be used for fodder, such as *Julbernardia paniculata* and *Diplorhynchus condylocarpon* (Kalaba, Quinn and Dougill, 2013a). Continued browsing of the miombo's woody regrowth by livestock will negatively affect the vegetation, possibly causing suppression of regrowth (Frost, 1996). However, given the existence of better-quality forage in the proximity (cf. section 5.3.2 – Edaphic grassland), and given the practical extinction of large herbivore wildlife in the area, grazing is not expected to be a significant driving force in the Miombo woodlands around the Lukanga Swamps.

Miombo trees such as *Brachystegia boehmii* are also widely cut for the production of charcoal, with a significant proportion of households – especially in rural areas – relying on this as a source of energy or income (Chidumayo, 2019; Kalaba, Quinn and Dougill, 2013a) (Figure 37). Miombo is also one of the most important sources of firewood in its distribution, with species such as *Brachystegia boehmii*, *B. spiciformis* and *Julbernardia paniculata* being frequently harvested (Clarke, Cavendish and Coote, 1996).



Source: Nemus (2019).

Figure 37 – Charcoal production from local woodland species through the traditional earth kiln method

Forest lands are important sinks for atmospheric carbon, however, the characteristic disturbance regime of tropical open woodlands such as the miombo reduces its ability to effectively and lastingly store it (Williams *et al.*, 2007). Carbon is stored in biomass and in the soil, and uptake is naturally higher in younger stands, being sustained for 20 to 50 years (Frost, 1996). Conversion for agriculture and frequent burning will release the stored carbon and reduce the patch's ability to sequester more, so that effective management (e.g., through sustainable timber harvesting, reduced frequency of fire, etc.) and requalification can enhance both sequestration and storage (Williams *et al.*, 2007).

Faunal niches

Regarding the **miombo**, this is not a very valuable habitat for mammal and bird species in itself, but in contact with floodplain and swamp vegetations, can support important faunal communities (Frost, 1996). Islands of different habitat scattered in the miombo will increase habitat heterogeneity/complexity, increasing the landscape's support capacity of fauna. Termite mound vegetation, for instance, distinct from the miombo matrix where it is inserted, provides islands of more palatable plants for mammal and invertebrate species.

Hence, the miombo typically displays a low faunal density and biomass, the most important groups being birds, small mammals, dung beetles and lepidoptera (Frost, 1996).

Miombo trees are important caterpillar habitats for species such as *Gynanisa maja* and *Gonimbrasia zambesina*. These were found using *Isoberlinia angolensis* and *Julbernardia paniculata*, in the northern province (Mbata, Chidumayo and Lwatula, 2002), two species that dominate the miombo that surrounds the Lukanga Swamps.

None of the **miombo** endemic avifauna species referenced in Leonard (2001) and Frost (1996) are listed in the Lukanga IBA checklist (Willems and Leonard, 2019). This may just derive from the exclusion of miombo woodlands from the censuses, since they do not really occur within the Ramsar site, as opposed to other wooded vegetation such as the Chipya or Munga. Hence, the following miombo endemics should be mentioned as possibly occurring in the surrounding healthy woodlands: Miombo Grey Tit, *Melaniparus griseiventris*, Miombo Rock Thrush, *Monticola angolensis*, Shelley's Sunbird, *Cinnyris shelleyi*, and Stierling's Woodpecker, *Dendropicos stierlingi* (all classified as LC).

Other miombo specialists include the Pale-billed hornbill, *Tockus pallidirostris* (syn. *Lophoceros pallidirostris*), Miombo pied barbet, *Tricholaema frontata*, the Miombo rock-thrush, *Monticola angolensis*, the Miombo Scrub-robin, *Cercotrichas barbata* (syn. *Tychaedon barbata*), the Black-necked Eremomela, *Eremomela atricollis*, the Red-capped crombec, *Sylvietta ruficapilla*, Bohm's Flycatcher, *Muscicapa boehmi*, Anchieta's Sunbird, *Anthreptes anchietae*, Souza's shrike, *Lanius souzae*, and the Chestnut-backed sparrow-weaver, *Plocepasser rufoscapulatus* (all classified as LC) (IUCN; Leonard, 2001).

Bird species typically associated to **munga** wooded habitats and reported as occurring in the Lukanga IBA include the Ring-necked dove, *Streptopelia capicola*, the Stripped kingfisher, *Halcyon chelicuti*, the Little bee-eater, *Merops pusillus*, Black-collared barbet *Lybius torquatus*, the Cardinal woodpecker, *Dendropicos fuscescens*, the Long-billed crombec, *Sylvietta rufescens*, the Brubru, *Nilaus afer*, the Black-backed puffback, *Dryoscopus cubla* and the Burnt-necked eremomela, *Eremomela usticollis* (all classified as LC) (Leonard, 2001; Willems and Leonard, 2019).

In scrubby formations of munga vegetation, the following are typical and are listed for the Lukanga IBA (all classified as LC): White-browed scrub robin *Cercotrichas*

leucophrys, Rattling cisticola, *Cisticola chiniana*, Tawny-flanked prinia, *Prinia subflava*, and the Yellow bishop, *Euplectes capensis* (Leonard, 2001; Willems and Leonard, 2019).

Finally, the following scrub and woodland-associated species have unfavourable conservation statuses and are listed for the Lukanga IBA: the Pallid harrier, *Circus macrourus* (NT) and the Bateleur, *Terathopius ecaudatus* (NT) (Leonard, 2001; Willems and Leonard, 2019).

The low biomass of large herbivores is characteristic of this macro-habitat, with its poor nutritional quality and the relative inaccessibility of canopies. Large herbivores specific to the miombo include the sable antelope, *Hippotragus niger*, roan antelope, *H. equinus*, and Lichtenstein's hartebeest, *Alcephalus buselaphus* subsp. *lichtensteinii* (Frost, 1996). These are specialist grazers of the grass layer, and tend to move about looking for higher quality forage, which includes recently burnt patches (Frost, 1996).

However, because the more undisturbed woodland stands are fragmented and are still subjected to human presence (cf. Habitats Map, Appendix A), large mammal fauna is expected to be low or even locally extinct (personal communication, February 2020). In addition, the existence of GMAs, Forest Reserves and the Kafue NP in the proximity provide better conditions for fauna, which implies the possibility that animal populations have migrated towards these refugia. This has inclusively been suggested by local communities (key informant interviews, 2019).

Termite mound vegetation tends to be more palatable, inclusively for livestock (Fleming and Loveridge, 2003; personal communication, October 2019). Small mammals tend to be more diverse and abundant throughout the year on and around termite mounds in miombo woodland, and overall small vertebrate biomass is also greater in the mounds (Fleming and Loveridge, 2003). These provide shelter given their more evergreen cover, and often contain burrows (Fleming and Loveridge, 2003).

Hence, despite the absence of survey data for the plan area on this group, several species may be listed as potentially present, given their distribution range and the presence of favourable habitat (termite mounds on miombo), including insectivorous species such as the musk shrew complex *Crocidura hirta* spp., the woodland dormouse, *Graphiurus murinus*, and the pouched mouse, *Saccostomus campestris*, and granivorous and frugivorous species such as the red rock rat, *Aethomys chrysophilus* (all classified as LC) (Fleming and Loveridge, 2003).

5.3.7. Cultivated and managed land

Cultivated and managed land covers 156,658.19 ha, or 23.35%, of the plan area as a whole, and 16,912.63 ha, or 5.1%, of the Ramsar site (Figure 38).

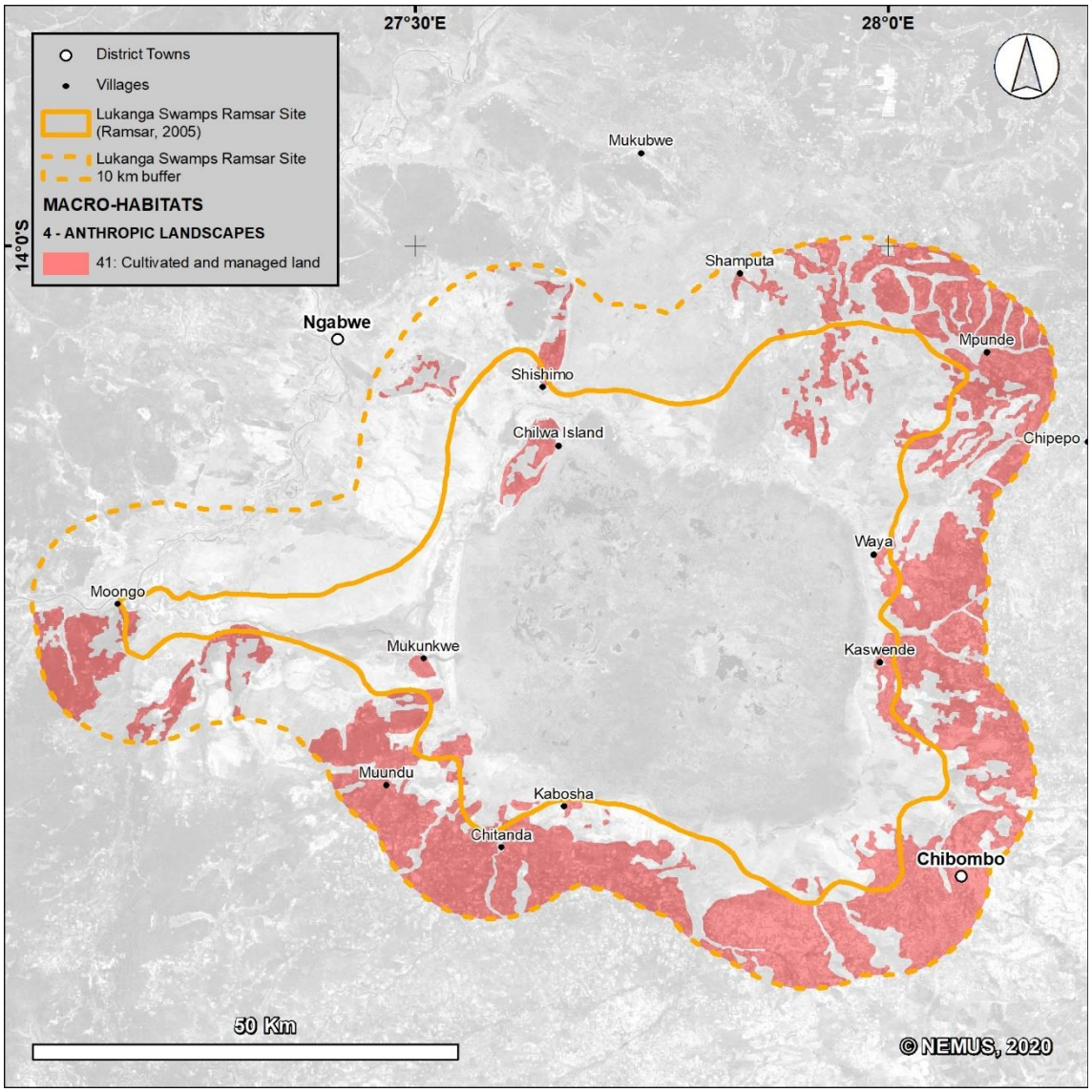


Figure 38 – Distribution of the cultivated and managed land cover

These areas include cultivated land, both annual and perennial crops, and fallow. Here, the vegetation is largely anthropogenic, as human intervention/management is needed for its maintenance.

Cultivated land is structurally and floristically simpler than the original woodland vegetation, typically presenting as a mosaic of cultivated plots with scattered tree cover, woodland regrowth and secondary grassland (Beilfuss *et al.*, 2001; Figure 39).



Source: Nemus (2019).

Figure 39 – Anthropic landscapes surrounding the Lukanga Swamp

Cropland consists of the anthropic replacement of the regional woodland and wooded grassland vegetation (miombo, munga, chipya and termitaria grassland) with less diverse vegetation composed of species of nutritional interest. The main crops grown in the area are maize, cassava, soya beans, cotton, groundnuts, and vegetables such as pumpkins, tomato and cabbage (key Informant Interviews, 2019; McCartney *et al.*, 2011; Kachali *et al*., 2008). Maize is grown during the wet season, while vegetables are grown in the dry season.

In the plan area, there are mainly low-input and low-yield small-holder farms, explored for household consumption, with surplus being commercialized locally or used as barter for fish (key Informant Interviews, 2019). The main farming systems employed are: shifting cultivation, semi-permanent hoe farming and semi-permanent hoe and ox plough (Saasa, 2003).

Crops are not irrigated, with the exception of garden crops on seasonally flooded areas, where shallow ponds are dug nearby for this purpose (key informant interviews, 2019). Medium-scale explorations for commercialization (mainly cotton, in the south) exist as well, with improved seed and fertilizer inputs (key informant interviews, 2019). Cotton is grown under an out-grower scheme, and is sold to a cotton ginning plant in Mumbwa (key informant interviews, 2019). Fertilizers such as top dressing / D compound and urea are added to the maize fields. Pesticides are mainly added to cotton crops.

Ecological conditions and functions

Rural African landscapes are largely characterized by the historical alteration of the original vegetation though traditional forms of shifting cultivation.

Traditional shifting cultivation combines slash-and-burn agriculture (e.g., chitemene) with long fallow periods for the renewal of soil structure, organic matter and nutrient content, allowing the exploitation of low-fertility soils. Land is usually cultivated for five years, after which it remains unexploited for a longer period, from 10 up to 25 years (Chidumayo, 1987, in Kapekele, 2006).

The chitemene system involves the pollarding, stocking and burning of woody material to raise the soil's pH and make phosphorus and nitrogen available to plants (Figure 40). Woody vegetation for burning is usually harvested from a larger outfield area, and brought in to the infield garden for burning prior to the first rains (Chidumayo, 1987).



Source: Nemus (2019).

Figure 40 – Traditional practice of ash-fertilizing the field by stocking woody material and burning it

Currently, the growth of human population density is reducing the area available for farming in rural communities, implicating a reduction of fallow periods and/or a shift towards semi-permanent to permanent cultivation systems instead (Chidumayo, 1987), with significant effects on the landscape and its ecology.

The reduction of the fallow period incurs in long-term reduction of fertility, hence rendering this practice unsustainable.

Slash-and-burn agriculture leads to a loss of biodiversity, and an increase in water runoff and erosion while it is practiced. Biodiversity values can recover over a long time, but species composition remains different from the original even after over 50 years (Kalaba, Quinn and Dougill, 2013b).

Initial vegetation clearing through fire incurs in the release of carbon stocks into the atmosphere, while the development of crops typically has a lower C-assimilation capacity, hence, the replacement of original vegetation with permanent crops significantly reduces carbon sequestration (in Hauser and Norgrove, 2013). Recovery of carbon uptake during the fallow period is also hindered, as the slash-and-burn, which includes the use of hand hoes, disturbs soil structure (Kalaba, Quinn and Dougill, 2013b). Carbon stocks from cleared Miombo vegetation are recovered after 20 years (Kalaba, Quinn and Dougill, 2013b).

Finally, land covered by this semi-natural macro-habitat no longer holds the original floristic values, and as a result, is devoid of the original (or pristine) faunal values to some extent. Their value is no longer ecological, but economic.

Faunal niches

As stated previously, animal assemblages of modified environments differ significantly to pristine ones, given the absence of the original natural supporting elements.

In addition to domesticated animals such as cattle and goats, cultivated and managed land is more likely to be used by generalists, capable of benefiting from a wide range of conditions, and anthropic species, particularly suited to take advantage of human presence.

Fallow is commonly used by the Common Buttonquail (LC), *Turnix sylvaticus*, and *Streptoptelia* and *Euplectes* species (Leonard, 2001; Willems and Leonard, 2019).

5.4. Flora

In this section, an overview of the area's phytoplankton and vascular flora is given, aiming at the identification of natural values with ecological or socio-economic value, as well as those in need of management or conservation action.

5.4.1. Phytoplankton

Phytoplankton organisms, i.e., microalgae that colonize the water column, constitute basal elements of aquatic ecosystems' trophic webs, and respond rapidly to environmental change, hence the group's utility in the assessment of ecosystem condition.

The distribution of phytoplankton species is predominately determined by temperature and light, depth, conductivity, nutrient concentration, flood pulse and habitat structure (channel, pond, grassland, river, etc.) (Marazzi, 2014). For this, microalgae community composition is often monitored as a bio-indicator for water quality assessments, a process which requires long-term, seasonal and spatially representative monitoring efforts for the establishment of reference values.

In flood pulse wetlands such as the Lukanga, phytoplankton distribution patterns, abundance and community composition fluctuate across the ecosystem's natural seasonal dynamics. In the dry season, the reduced flow and consequent lower turbidity favour the growth of phytoplankton, whereas during the wet season the higher turbidity levels impede photosynthetic activity, inhibiting its growth (Marazzi, 2014). Seasonal variations of algal assemblages in such wetlands have been described elsewhere, with abundance peaks of particular groups coinciding with different instances of the hydrological cycle. The succession of algal species composition has also been described along environmental gradients, such as nutrient or pollution concentrations.

Records of **phytoplankton species in the Lukanga Swamp**, however, are only available for the wet season of the year 2019, and the list presented in Appendix (Appendix B – Flora species list) was sourced from this study entirely (BWZ and DoF, 2019). Additional sources were consulted for taxonomic information, such as AlgaeBase (Guiry and Guiry, 2020).

A fisheries survey was conducted between 9 and 15 December 2019 by BirdWatch Zambia and the Department of Fisheries of the Ministry of Fisheries and livestock which

included a qualitative survey of plankton communities. As it is qualitative and derives from one sampling region and period only – four sites off Waya – it does not reflect the spatial or inter and intra-annual variability of phytoplankton population dynamics, and does not allow for in-depth conclusions to be drawn concerning the site's conditions.

The list includes eight (8) species and six (6) taxa only identified to the genus level (a total of 14 taxa), belonging to 11 families (Appendix B – Flora species list). Six (6) phylla are represented, including the three major freshwater wetland clades, Bacillariophyta (diatoms), Cyanobacteria (blue green algae) and Chlorophyta (green algae), as well as Charophyta (green algae), Euglenophyta and Ochrophyta.

The list includes potentially toxic and bloom-forming cyanobacteria genera, Microcystis and Anabaena (Pearl, Otten and Kudela, 2018), which tend to be favoured by nutrient enrichment.

5.4.2. Vascular flora

The Lukanga Swamp is located in the Great African Plateau, and reaches into the ecoregions of the Central Zambezian Miombo Woodland to the north, and both Kalahari Acacia Woodland and Southern Miombo Woodland ecoregions to the south (Burgess *et al.*, 2006).

It is set within the region classified by White (1983) as the Zambezian regional centre of endemism, the second largest phytochorion in Africa, showcasing a wide range of vegetation types, and with a tropical climate characterized by two dry seasons (cold and warm) and intense summer rainfall (from November to April).

Typical woodland habitats of the Zambezian region dominate the terrestrial landscape, which is interrupted by Zambezian seasonally flooded grasslands, permanent swamps and rivers, of the Kafue Freshwater Ecoregion (Abell *et al*., 2008).

As mentioned before, the woodland climate-related climax vegetation is interrupted by distinctive azonal vegetation units, shaped by the topographically originated environmental gradients in edaphic water content and water depth. In addition to these natural elements, traditional human-mediated disturbance regimes such as seasonal burning, harvesting and cultivation, further shape the existing flora.

The Zambezian regional center has one of the richest floras of the African continent, including 8,500 species, 54% of which endemic (White, 1983). It constitutes the center of variation of the *Brachystegia* genus, and includes the woody endemic genera *Colophospermum*, *Diplorhynchus*, and *Pseudolachnostylis* (cf., 5.5 – Natural and semi-natural macro-habitats) (White, 1983). Table 3 presents the approximate diversity of seed plants and endemics for the different Zambian ecosystems found around the Lukanga.

Table 3 – Diversity of seed plants in Zambia by ecosystem

Ecosystem	Approximate seed plant species (endemics)
Dry deciduous forest	400 (9)
Miombo woodland	650 (57)
Munga woodland	500 (49)
Termitary woodland	700 (33)
Grassland	1000 (no data)

Source: Forestry Department (2016).

The flora list compiled for the Lukanga swamp and its surroundings (Ramsar Site/Intervention Area + 10 km buffer) includes a total of **214** species and **20** genera belonging to **55** families (cf., Appendix B – Flora Species List). These were identified and classified according to their potential occurrence as follows:

- *Confirmed* (n=21): if the taxon had been observed in September or October 2019, during the field work;
- *Probable* (n=116): if the taxon was referenced in literature, official reports and documents as occurring in and around the Lukanga Swamp, namely, according to Chabwela (1998), Chabwela *et al*. (2010) and Chabwela, Chomba and Thole (2017);
- *Possible/potential* (n=97): if the taxon was included in VECEA's species list for the potential vegetation types of the area (Kindt *et al*., 2011a, b) **and** was labelled in Phiri (2005) as occurring in the Central Province.

Information on taxonomy, common names, use, conservation statuses and ecological preference/occurrence according to vegetation types was compiled from the following sources:

- Bingham *et al*., 2020 ("Flora of Zambia: Species information");
- Phiri, 2005 ("A Checklist of Zambian Vascular Plants. Southern African Botanical Diversity Network Report nº32");
- Kennedy and Murphy, 2012 ("A picture guide to aquatic plants of Zambian Rivers");
- van Oudtshoorn, 2012 ("Guide to Grasses of Southern Africa");
- IUCN, 2020 ("The IUCN Red List of Threatened Species, Version 2019-3");
- Bingham and Smith, 2002 ("Southern African Plant Red Data Lists: Zambia");
- POWO, 2019 ("Plants of the World Online");
- CABI, 2020 ("Invasive Species Compendium");
- BirdWatch Zambia [BWZ], 2020 ("Controlling an Invasive aquatic plant for improved livelihood biodiversity and livelihood on the Lukanga Swamp IBA");
- PROTA4U, 2020 ("Plant Resources of Tropical Africa");
- White, F. and ILDIS, 2018 ("LegumeWeb database, Version 10.01");
- Fern, 2019 ("Useful Tropical Plants Database");
- INRA, CIRAD, AFZ and FAO, 2012-2019 ("Feedipedia – Animal Feed Resources Information System").

Of the 55 families, *Fabaceae* and *Poacea* are the most represented ones, at 65 and 43 taxa respectively, followed by *Combretaceae* and *Malvaceae* both with nine (9), and *Cyperaceae* and *Phyllanthaceae* both with seven (7). 26 families are only represented by one (1) taxon, 14 by two (2), and the remaining 13 are represented by six (6), five (5), four (4) or three (3) taxa.

Regarding conservation statuses, of the 214 listed species, 114 are classified as **Least Concern** (LC) in IUCN's Red List of Threatened Species, two are classified as **Near Threatened** (NT) and the remaining 98 are not listed (IUCN, 2020). The NT species are the Mukusyi, or Zambezi Teak, *Baikiaea plurijuga* Harms (of probable occurrence in Baikieae vegetation) and the African Blackwood, *Dalbergia melanoxylon* Guill. and Perr. (of probable occurrence in Munga and Termitaria), both of which are additionally classified as "Vulnerable" in Zambia's Red List (Bingham and Smith, 2002).

One species is classified as “Lower Risk” in Zambia, *Dalbergiella nyassae* Baker f. (Bingham and Smith, 2002), and two are further classified as “locally threatened” due to over-harvesting for timber, the Mupaap, or Pod Mahogany, *Afzelia quanzensis* Welw. and the Mulonbe, or Mulonbwa, *Pterocarpus angolensis* DC. (Forestry Department, 2016).

Two species are classified as introduced on the Flora of Zambia (Bingham *et al*., 2020), *Mimosa pigra* L., and *Salvinia molesta* D. Mitch, both also classified elsewhere as invasive (CABI, 2020).

The giant sensitive plant, *Mimosa pigra* L., is referenced in Chabwela *et al*. (2010) as occurring in “Riverine wetland/floodplain” and in “Swamp and flood plain” (i.e., edaphic grassland). This species was not detected inside the area during the field work conducted in September and October 2019.

The giant sensitive plant is a small prickly shrub native to south and central America, and capable of forming large monospecific and impenetrable stands in floodplains, water ways and seasonally flooded areas (Psi-Delta, 2007). It is well established in the Kafue Flats, impeding movement of people and livestock, and obstructing access to water resources, which causes significant economic impacts (Psi-Delta, 2007). Given its ecological preferences, the Lukanga Swamp’s floodplains and grasslands provide ideal grounds for its propagation, which demands for the monitoring of its present distribution and extent of coverage.

The Kariba weed, *Salvinia molesta* D. Mitch, is a free-floating aquatic fern native to South America, and was detected during the field work (Figure 41), along waterways from the entry points of Kabosha, Waya, Kaswende and Chilwa, as well as in the outflow from the swamp, off Moongo. Its occurrence in open water areas such as lakes was found to be minimal, which is coherent with its known ecological preferences.



Source: Nemus (2019).

Figure 41 – Kariba weed, *Salvinia molesta*, invasion off Kabosha (on the left) and Waya (on the right)

Finally, food crops mentioned for the area around the Lukanga Swamp include the cultivated varieties of maize (*Zea mays* L.), common beans (*Phaseolus vulgaris* L.), cassava, Kalundwe in Bemba and Mwanja in Tonga (*Manihot esculenta* Crantz), sweet potato, Kalembula in Bemba and Chimbwali in Tonga (*Ipomea batatas* (L.) Lam.), soyabeans (*Glycine max* L. Merril.), tomato (*Solanum lycopersicum* L.), cabbage (*Brassica oleracea* L.), pumpkin, Fipuchi in Bemba and Lupushi in Tonga, groundnuts (*Arachis hypogaea* L.), and bush yam, or Mupama in Lenje (*Dioscorea praehensilis* Benth.) (Key Informant Interviews, 2019; McCartney *et al*., 2011; Mwila *et al*., 2008; Mingochi and Luchen, 1997). All of these have been introduced to the Zambian Territory for cultivation, except the yam, which is a native species (Bingham *et al*., 2020).

Species cultivated for commercial purposes include sunflowers (*Helianthus annuus* L.) and cotton (*Gossypium hirsutum* L.), both introduced.

5.5. Fauna

In this section, an overview of the area's animal assemblages is given, aiming at the identification of natural values with ecological or socio-economic value, as well as those in need of management or conservation action.

The diversity of faunal species potentially utilizing the plan area derives from the site's heterogeneity in ecological conditions and associated habitat pattern and niche range. Wetland habitats with different characteristics interrupt the matrix of Zambezian woodlands, which in turn are modified by human activity. Different species with diverse life-histories and strategies occur, from truly aquatic to terrestrial, with the group more charismatically influenced by these habitats being birds (cf., 5.5.4 - Avifauna).

The region has been poorly surveyed in terms of animal species, meaning that complete faunal inventories or community composition data are not available. Current species lists were compiled from regional and/or national checklists, coupled with the assessment of each taxon's ecological preferences and correspondence to those available in the area, also making use of each species' published distribution range and any available accounts for the plan area in particular. The next sections provide brief descriptive accounts of the following faunal groups:

- Invertebrates;
- Ichthyofauna;
- Herpetofauna;
- Avifauna;
- Mamofauna.

5.5.1. Invertebrates

The description, inventory and distribution of invertebrates – the group encompassing all animals without a vertebral column and hence composed of numerous phyla - is significantly lagging behind that of vertebrates (and especially in Africa), so that complete checklists, guides or distribution atlases with finer resolutions are not available.

Existing accounts tend to be biased towards taxa with economic or public health implications. Freshwater molluscs, and gastropods in particular (snails), are the most widely studied group, given that some species can be vectors of animal or human diseases (Marshall, 2004).

According to Zambia's NBSAP-2 (Professor Keith Mbata, *in* MLNREP, 2014), national invertebrate diversity is estimated at 6,135 species, 69 of which endemic.

The major invertebrate phyla associated to **wetlands** include Mollusca (snails and clams), Arthropoda (insects, mites, crustaceans, etc.), Nematoda (roundworms), Annelida (segmented worms and leeches), Platyhelminthes (flat worms), Rotifera and Gastrotricha (Batzer and Boix, 2016).

Within insects, which make up the most diverse group of all wetland invertebrates, the major families are *Diptera* (flies), *Hemiptera* (water bugs), *Coleoptera* (water beetles), *Odonata* (damselflies and dragonflies), *Ephemeroptera* (mayflies) and *Trichoptera* (caddis flies).

Terrestrial invertebrate assemblages are predominantly composed of Arthropoda, typically including myriapods (e.g., millipedes and centipedes), arachnids (e.g., spiders and mites), and insects (e.g., termites and beetles).

Invertebrates are usually grouped into two **size-based** categories, macro and microinvertebrates, <1 mm long and > 1 mm long, respectively. In wetlands, **micro**invertebrates include nematodes (dominant), tardigrades, flatworms and gastrotrichs in the **benthos**, and rotifers and microcrustaceans in the **water column** (zooplankton). **Macro**invertebrates include insects, annelids, crustaceans, molluscs, acarine and turbellarians.

Hydrology and vegetation are the primary determinants of aquatic invertebrate assemblages in wetlands (Batzer and Boix, 2016). In permanently flooded systems, however, the hydrology loses importance, and biotic interactions acquire a stronger role (Zimmer, Hanson and Wrubleski, 2016). This is the case of wetlands that support fish communities, in which predation diminishes invertebrate taxon richness and biomass. The preservation of the channels and pools network and of diverse bird and fish populations within the swamp are key elements in the maintenance of invertebrate biodiversity.

In flood-pulse systems such as the floodplain, invertebrate assemblages (macro and micro alike) are characterized by seasonal population dynamics (Hoberg *et al*., 2002) which cannot be accurately represented with one-off surveying.

Given data limitations, the following groups were considered in the present assessment:

- **Zooplankton** – microinvertebrates colonizing the water column (pelagic), mainly planktivores and detritivores; the species occurrence list was compiled from the fisheries survey conducted between 9 and 15 December 2019 by BirdWatch Zambia and the Department of Fisheries of the Ministry of Fisheries and livestock, in four sites off Waya, and which included a qualitative survey of plankton communities (BWZ and DoF, 2019);
- **Phyllum Mollusca** – macroinvertebrates colonizing the bottom (benthic), mainly herbivores, detritivores and filter feeders; a taxon was considered as possibly occurring if listed in Marshall (2004) or Dudley (2000) as occurring in the Upper Zambezi basin, **and** in IUCN (2020) as occurring in Zambia, **and** its preferred habitat types were available in the plan area.

Additional information on taxonomy, conservation status and habitat preferences was sourced from IUCN (2020), the Rotifer World Catalog (Jersabek and Leitner, 2013) and the World Register of Marine Species (WoRMS Editorial Board, 2020).

Regarding **zooplankton**, a total of 14 taxa (12 species and two [2] genera) were found in the 2019 wet season survey, belonging to the two (2) typical phyla Rotifera and Arthropoda (subphylum Crustacea) (cf. Appendix C – Fauna species list). Rotifers dominate the list, with 10 species and one (1) genus, belonging to one class (Euratatoria), one (1) order (Ploima) and five (5) families (Lepadellidae, Brachionidae, Trichocercidae, Asplanchnidae and Lecanidae).

Copepod and cladoceran microcrustaceans make up the remaining three (3) species and one (1) genus. These represent two (2) classes (Branchiopoda and Hexanauplia), two (2) orders (Anomopoda and Cyclopoida) and three (3) families (Chydoridae, Cyclopidae and Daphniidae).

Regarding **molluscs**, a total of 19 species was compiled, consisting of 14 gastropods belonging to six (6) orders and six (6) families, and five (5) bivalves belonging to one (1) order and three (3) families (cf. Appendix C – Fauna species list).

Of the 19 species, two (2) are classified as **Data Deficient**, and one (1), *Lobogenes michaelis* Pilsbry and Bequart, 1927, is **Endangered** (IUCN, 2020). All others are considered of **Least Concern** (IUCN, 2020).

Finally, species of the gastropod genera *Biomphalaria* and *Bulinus* (possibly occurring in the area) can be intermediate hosts to *Schistosoma haematobium* or *S. mansoni*, parasitic platyhelminths that cause Schistosomiasis, or Billharzia, in humans (Kalinda, Chimbari & Mukaratirwa, 2018). In terms of disease prevalence, the area is currently classified as “Low Risk” (≥1% and <10%) (Kalinda, Chimbari & Mukaratirwa, 2018).

5.5.2. Ichthyofauna

Zambia holds a rich fish biodiversity with up to 201 species recorded for its water bodies with commercial or subsistence fisheries, excluding the 289 species endemic to Lake Tanganyika (MLNREP, 2014).

The Lukanga wetland complex is believed to play an important role as a breeding site for several species of the Kafue river system, since high water levels allow fish to migrate horizontally towards the swamp and floodplain to reproduce (DoF, 2014). Fish assemblages vary throughout the year in response to hydrological fluctuations. In drier years, only low-oxygen tolerant species are able to remain in the swamp, so that the community is generally dominated by *Clarias* sp. and tilapiines (*Oreochromis* and *Tilapia* sp.), which include several species of economic importance (MFL, 2020).

The current checklist was obtained from gillnet surveys undertaken in July 2015 (two sites) and December 2019 (four sites), with mesh sizes from 25 to 102 (BWZ and DoF, 2019). A species’ occurrence was classified as **confirmed** (C) if it was caught in the 2019 survey, and **probable** (Prb) if it was only caught in 2015.

Additional information on taxonomy, common names, habitat preferences, diet and movement patterns was compiled from IUCN (2020) and FishBase records (Froese and Pauly, 2019).

A total of **16 species** was listed, belonging to five (5) orders (Perciformes, Cypriniformes, Characiformes, Siluriformes and Osteoglossiformes) and six (6) families (*Cichlidae, Cyprinidae, Alestidae, Clariidae, Anabantidae* and *Mormyridae*) (cf. Appendix C – Fauna species list). The list is dominated by Perciformes (perch-like fishes), followed by Siluriformes (cat fishes). Within Perciformes, Cichlidae is the most represented family, as expected. The 2014 Frame Survey of the Lukanga Swmap (DoF, 2014) references three other families as recurrently occurring in the swamp, *Characidae* (Characiformes), *Mochokidae* (catfishes) and *Schilbeidae* (catfishes).

Regarding habitat use, more than half the listed species (13) are reported as utilizing swamp habitats, and all are reported as utilizing rivers and streams (IUCN, 2020; BWZ and DoF, 2019). Lakes are suitable for 13 species (IUCN, 2020; cf. Appendix C – Fauna species list).

Several different **trophic strategies** are represented in the list. Five (5) species are omnivorous, two (2) of which bottom feeders. One (1) species is an exclusive herbivore (feeding mainly on phytoplankton and benthic algae), and one (1) other feeds on detritus in addition to algae and macrophytes. Six (6) species hunt other fish, five (5) of which complement their diet with invertebrates, three (3) of these keeping only to insects and crustaceans. Three (3) species eat only invertebrates, mainly insect larvae from the bottom and off plant stems. The straightfin barb (*Enteromius paludinosus* [Peters, 1852]) is prey to catfishes, largemouth breams and birds (Skelton, P. H., 1993, *in* Froese and Pauly, 2019).

Of the 16 listed species, 13 are classified as **Least Concern** (LC), two (2) are classified as **Vulnerable** (VU), the greenhead Tilapia (*Oreochromis macrochir* [Boulenger, 1912]) and the many spined climbing perch (*Ctenopoma multispine* Peters, 1844). One (1) species is classified as **Critically Endangered** (CR), the yellow-belly bream (*Serranochromis robustus* [Gunther, 1864]).

The yellow-belly bream was caught only in the 2015 survey, and was therefore classified as "probably" occurring in the swamp. This is a non-migrant piscivore cichlid who prefers vegetated rivers over lakes, lagoons or swamps. It breeds in summer and is an oviparous mouthbrooder. The yellow-belly bream is classified as **CR** under criteria **A2c+3cde**, for (IUCN, 2020):

- **"A**. Reduction in population sized based on:
  - **2.** An observed, estimated, inferred or suspected population size reduction of ≥80% over the last 10 years or three generations, whichever is the longer, where the reduction or its causes may not have ceased OR may not be understood OR may not be reversible based on (**c**) a decline in area of occupancy, extent of occurrence and/or quality of habitat."
  - **3**. A population size reduction of ≥80%, projected or suspected to be met within the next 10 years or three generations, whichever is the longer (up to a maximum of 100 years), based on (**c**) a decline in area of occupancy, extent of occurrence and/or quality of habitat; (**d**) actual

or potential levels of exploitation; and € the effects of introduced taxa, hybridization, pathogens, pollutants, competitors or parasites."

One species, the Nile tilapia (*Oreochromis niloticus* [Linnaeus, 1758]), has been introduced in Zambian waters and can become invasive (CABI, 2020). This species was not caught in the 2019 survey.

Native to the Nile river basin and one of the most important species in freshwater fish farms, it has been introduced to African water systems inadvertently, escaping from fish farms. It has now become invasive in several ecosystems, including Zambian waters, since the 1980s (CABI, 2020; Deines *et al*., 2014).

The Nile tilapia threatens native species for habitat, resources and through hybridization:

- **Advantage over habitat**: Owing to its tolerance to a wide range of ecological conditions including disturbed ones, it is considered an opportunistic pioneer species, in that it is capable of migrating to, reproducing in, and therefore colonizing disturbed habitats.
- **Competition for resources**: The native greenhead tilapia (classified as **VU**) is appointed as one of the species more impacted by the Nile tilapia (CABI, 2020), through competition for resources. These occupy the same niche: both are herbivores, feeding on phytoplankton and benthic algae, and juveniles of both species tend to be omnivorous, including insect larvae and detritus in their diet as well (Froese and Pauly, 2019).
- **Genetic pool change**: the Nile tilapia also potentially poses a threat to the conservation of native *Oreochromis* populations' genetic diversity by hybridizing with these (Deines *et al*., 2014).

5.5.3. Herpetofauna

Zambian herpetofauna is also still poorly documented, with estimates of 74 amphibian species and 156 reptile species evenly distributed across the country (MLNREP, 2014).

There are only regional or national (and often outdated) lists (e.g. Broadley, 2000 for the Zambezi Basin; Broadley, 1971 for Zambia), and recent local-level lists cover mainly northern and western Zambia (Pieterson *et al*., 2017; Bittencourt-Silva, 2019). There are no surveys or census data for the area.

The current list for the Lukanga Swamp and surrounding area was primarily based on SASSCAL's (Southern African Science Service Centre for Climate Change and Adaptive Land Management) "Systematic list of amphibians recorded in Zambia" (Lumbwe, 2018), crossed with each taxon's distribution, taxonomy, and habitat preferences as published in the IUCN Red List of Threatened Species (IUCN, 2020), when available, complemented with peer-reviewed papers on the subject.

A species was included in the list as **possibly occurring** if:

- It was referenced in the sources mentioned above as occurring in Zambia (Lumbwe, 2018; Pieterson *et al*., 2017; Bittencourt-Silva, 2019),
  - **and** if its ecological preferences matched those available in the swamo and surrounding area,
  - **and** if its distribution covered the site (IUCN, 2020; Ihlow *et al*., 2019; Baker *et al*., 2015; Broadley and Boycott, 2008) **or** it was referenced as occurring in the area by Broadley, 1971 (in Chabwela *et al*., 2010).

References in the main texts of Chabwela *et al*. (2010) and Kamweneshe and Beilfuss (2002) were also considered.

A total of **42 amphibian species** belonging to one (1) order (Anura) and 12 families was listed as possibly occurring in the plan area (cf. Appendix C – Fauna species list). The most represented family is Ptychadenidae (11, or 27%), also known as grassland frogs, followed by Hyperoliidae (7, or 17%), sedge or bush frogs. These consist mainly of common species with broad geographical distributions and favorable conservation status (**Least Concern**, LC), which probably results from the lack of localized surveys and from the compilation method, which might have biased the list towards abundant and widespread species. Amphibians are carnivorous, predominantly consuming invertebrates such as insects and molluscs.

A total of **21 reptile** species belonging to three (3) orders (Squamata, Testudines and Crocodylia) and 14 families was listed, 13 of which possibly occurring and one (1) historically occurring, but known to not occur anymore (cf. Appendix C – Fauna species list). Of these, 11 are classified as **LC**, and the other nine (9) are **Not Evaluated** (NE). Colubridae (snakes) is the most represented family, with 4 species (20%).

The African Python is referenced by Kamweneshe and Beilfuss (2002) based on respondents (44% of which reported to sighting them regularly), as *Python sebae*. It is

not clear, however, whether this species remains in the area, nor is it clear, assuming it does, what species is actually present. There is some confusion surrounding the taxonomy and distribution of the southern African python *Python natalensis* Smith, 1840 and the northern African python *Python sebae* (Gmelin, 1788), but the former is more coherently referenced as occurring in Zambia (Fallschirmjager, 2011; Lumbwe, 2018; Uetz and Hallermann, 2020), and was the taxon included in the list in appendix.

The Nile crocodile *Crocodylus niloticus* Laurenti, 1768 (LC) was also included in the list, despite being known to not occur in the area anymore, given its historical distribution and importance for conservation. Kamweneshe and Beilfuss (2002) still reported seeing crocodiles (two individuals) in "the tall vegetation", and that "60% of the people they talked to during the survey reported sighting crocodiles "quite often". However, more recent reports suggest it is now absent: Chabwela *et al.* (2010) claims they were "driven out", and local fishermen stated that they occurred only in the banks of the Kafue River (informal conversation, September 2019). Similarly, the species' assessment in the Red List of Threatened Species (IUCN, 2000) locates it only in the KNP and in the Copperbelt (Isberg *et al*., 2019).

5.5.4. Avifauna

Th Lukanga wetland is a particularly relevant habitat for avifauna, as demonstrated by its Important Bird Area (IBA) designation back in 2015, following criteria A1 and A4iii (BirdLife International, 2020), namely:

- **A1. Globally threatened species** – "The site is known or thought to regularly hold significant numbers of a globally threatened species", here, the Wattled Crane *Bugeranus carunculatus* (Gmelin, 1789) and the Pallid Harrier *Circus macrourus* (Gmelin, 1770);
- **A4. Congregations** – "The site is known to hold congregations of 1% or more of the global population of one or more species on a regular of predictable basis", here, for the Species group "waterbirds".

The site's Ramsar designation also targets waterfowl (among other, under **criterion 2**, which refers to the hosting of several endangered species) and calls for the inclusion of its conservation in management decisions.

The plan area's species list can be consulted in Appendix C (Fauna Species List), and was compiled from the Zambian species checklist (Willems and Leonard, 2019), which follows the taxonomy and nomenclature of the Illustrated Checklist of the Birds of the World (HBW and BLI, 2020), and of the IOC World Bird List, versions 7.3 and 8.1 (Gill and Donsker, 2020), and is based on the previous Zambian list (Leonard, 2013), itself based on Dowsett *et al*., 2008.

Further information on taxonomy, common names, phenology, conservation statuses, ecological preference and occurrence according to available habitat types was compiled from the IUCN Red List of Threatened Species (IUCN, 2020), Leonard (2001) and Willems and Leonard (2019).

A total of **356 species** belonging to 24 orders and 79 families constitutes the avifauna inventory for the Lukanga swamp and its surroundings. These were identified and classified according to their occurrence as follows:

- *Confirmed* (n=12) if the species was observed utilizing a habitat within the area (feeding or resting);
- *Probable* (n=334): if the species was listed under the Lukanga Swamp in Willems and Leonard (2019)'s species checklist for Zambian IBAs;
- *Possible* (n=10): if the species was referenced in Leonard (2001) as endemic or typically found on a particular habitat occurring in the area, **and** its distribution according to IUCN's Red List of Threatened Species (IUCN, 2020) covers the plan area.

The most represented order in number of taxa is Passeriformes (perching or song birds), with 148 species, over 40% of the total, followed by Charadriiformes (waders and gulls, most closely associated to water) with 35 species (9.83%), Accipitriformes (hawks, eagles and kites) with 28 species (7.87%), and Pelecaniformes (shoebill, pelicans, ibises, herons, egrets and bitterns) with 25 species (7.02%). The most represented family is Accipitridae, with 28 species (7.86%).

Of the 356 species listed, **119 are water birds** (associated exclusively with wetland habitats: permanent swamp, edaphic grassland, lakes, rivers and streams), 12 of which are exclusive to the swamp.

Phenology wise, 47 species are Palearctic migrants (i.e., wintering in the area), 42 are afro-tropical migrants (i.e., breeding in the area), 89 are partial or possible migrants, and 178 are resident species (i.e., both wintering and breeding in the area).

Diet wise, 48.7% of species belong to predominantly **omnivorous** orders, 45.5% belong to predominantly **carnivorous** orders (mainly insectivores, piscivores and generalist invertebrate eaters), and 4.8% to predominantly **herbivore** orders (granivores and frugivores).

The majority of the animals observed in September and October 2019 were ibises, herons and egrets, ducks, openbills, and gulls – mostly carnivorous species feeding on invertebrates (insects, molluscs, crustaceans, worms, etc.), fish, amphibians, reptiles and others birds' eggs; and omnivorous species feeding on plant matter (fruits, seeds, roots, leaves, and stems of aquatic and terrestrial plants), invertebrates, fish, amphibians, reptiles and other birds' eggs.

Regarding conservation statuses, of the 356 species listed, 343 are classified as **Least Concern** (LC), five (5) as **Near Threatened** (NT), five (5) as **Vulnerable** (VU), one (1) as **Endangered** (EN) and two (2) as **Critically Endangered** (CR), in IUCN's Red List of Threatened Species (IUCN, 2020). One (1) species is introduced, the house sparrow (*Passer domesticus* [Linnaeus, 1758]), nine (9) are "of global conservation concern", and other nine (9) are of "regional conservation concern" according to Willems and Leonard (2019). Eight (8) species have distributions with restricted ranges. Table 4 lists all the species with unfavorable statuses and restricted ranges.

Table 4 – Summary of bird species with unfavorable conservation statuses and/or restricted distribution ranges

Species	Common name	IUCN status	Zm status	Phen.	Habitat	Occur.
Aquila nipalensis Hodgson, 1833	Steppe Eagle	EN	-	P	T	Probable
***Ardea goliath* Cretzschmar, 1829**	Goliath Heron	LC	cc	R	Rs; Sw; L	Probable
***Balaeniceps rex* Gould, 1850**	Shoebill	VU	CC	R; RR	Rs	Probable
***Botaurus stellaris* (Linnaeus, 1758)**	Eurasian Bittern	LC	cc	R; RR	Sw	Probable

Species	Common name	IUCN status	Zm status	Phen.	Habitat	Occur.
Bucorvus leadbeateri (Vigors, 1825)	Southern Ground-hornbill	VU	cc	R	Mmb; Bk; Ch; Mg; T; Cm	Probable
***Bugeranus carunculatus* (Gmelin, 1789)**	Wattled Crane	VU	CC	PP	Eg; L	Probable
Buphagus africanus Linnaeus, 1766	Yellow-billed Oxpecker	LC	cc	R	Ch; Mg; T	Probable
Buphagus erythroryhnchus (Stanley, 1814)	Red-billed Oxpecker	LC	cc	R	Ch; Mg; T	Probable
Calidris ferruginea (Pontoppidan, 1763)	Curlew Sandpiper	NT	-	P	L	Probable
Circus macrourus (Gmelin, 1770)	Pallid Harrier	NT	CC	P	Ch; Mg; Sw	Probable
***Circus ranivorous* (Daudin, 1800)**	African Marsh-harrier	LC	cc	R	Sw	Probable
Charadrius forbesi (Shelley, 1883)	Forbes's Plover	LC	-	PP; RR	Ch; Mg; T; Rs; L	Probable
Crex crex (Linnaeus, 1758)	Corncrake	LC	CC	P	Ch; Mg; Sw; Eg	Probable
***Egretta vinaceigula* (Sharpe, 1895)**	Slaty Egret	VU	CC	PP	L	Probable
***Ephippiothynchus senegalensis* (Shaw, 1800)**	Saddlebill	LC	cc	R	Eg; Rs; Sw	Probable
Eremomela atricollis Barboza du Bocage, 1894	Black-necked eremomela	LC	-	R-RR	Mmb; Bk; Ch; Mg; T	Possible
Falco naumanni Fleischer, 1818	Lesser Kestrel	LC	CC	P	Ch; Mg; T; Eg	Probable
Gallinago media (Latham, 1787)	Great Snipe	NT	CC	P	Ch; Mg; T; Eg; Sw	Probable

Species	Common name	IUCN status	Zm status	Phen.	Habitat	Occur.
Gyps africanus Salvadori, 1865	White-backed Vulture	CR	-	R	Mmb; Mg; T; Rs	Probable
Lybius chaplini Clarke, 1920	Zambian Bartbet	LC	CC	R; RR	Ch; Mg; T	Probable
***Muscicapa aquatica* Heuglin, 1864**	Swamp Flycatcher	LC	-	R; RR	Rs; Sw; L	Probable
Polemaetus bellicosus (Daudin, 1800)	Martial Eagle	VU	-	R	Ch; Mg; T; Rs	Probable
Pterocles gutturalis Smith, 1836	Yellow-throated Sandgrouse	LC	cc	A	Ch; Mg; T; Eg; Rs	Probable
***Rynchops flavirostris* Vieillot, 1816**	African Skimmer	NT	CC	PP	Rs; Sw; L	Probable
Terathopius ecaudatus (Daudin, 1800)	Bateleur	NT	cc	PP	Mmb; Ch; Mg; Bk; T	Probable
Trigonoceps occipitalis (Burchell, 1824)	White-headed vulture	CR	-	R	Ch; Mg; T	Probable
***Xenus cinereus* (Guldenstadt, 1775)**	Terek Sandpiper	LC	-	P; RR	Rs; Sw; L	Probable
***Zapornia pusilla* (Pallas, 1776)**	Baillon's Crake	LC	-	PP; RR	Eg; Rs; Sw; L	Probable

Legend:
IUCN status: LC-Least concern; VU-Vulnerable; NT-Near threatened; EN-Endangered; CR-Critically endangered (IUCN, 2020).
Zambian (Zm) status: cc- "of regional conservation concern"; CC- "of global conservation concern" (Willems and Leonard, 2019).
Phenology: P-palearctic migrant; A- Afro-tropical migrant; PP-partial or possible migrant; R-resident; RR-restricted range (Willems and Leonard, 2019).
Habitat (i.e., potential habitat use): Sw-permanent swamp; Eg-edaphic grassland; L-lakes; Rs-Rivers and streams; T-termitaria; Mmb-miombo; Ch-chipya; Mg-munga; Bk-Baikiaea.
In **bold** – wetland birds.

5.5.5. Mamofauna

While Zambian mamofauna is relatively well documented in terms of charismatic megafauna, particularly within protected areas, small mammals and faunal assemblages outside of designated areas are comparatively understudied (Namukonde, 2017).

This is the case of the plan area, whose large mammal populations have last been surveyed in 2001 (Kamweneshe and Beilfuss, 2002), and there are no surveys of small mammals. As a result, the current mammal inventory is composed solely of possibly occurring species, as opposed to probably occurring or confirmed ones. The list contains several species believed not to occur in the area anymore which need mentioning given their historical distribution, importance for conservation and the availability of suitable habitat.

The list was primarily based on SASSCAL's "Systematic list of mammals recorded in Zambia" (Lumbwe, 2018), crossed with each taxon's distribution, taxonomy, and habitat preferences as published in the IUCN Red List of Threatened Species (IUCN, 2020), when available, and complemented with other published articles on the subject, for instance, Namukonde (2017).

The list of possibly/potentially occurring mammal fauna consists of **122 species** belonging to 11 orders and 34 families (cf. Appendix C – Fauna species list). Local mammal assemblages are mainly composed of small insectivores, herbivores and omnivores well-adapted to the exploitation of herbaceous wetland vegetation and associated invertebrate diversity. Chiroptera (bats), Carnivora (felines, mustelids, etc.), Cetartiodactyla (ungulates) and Rodentia (rodents) are the most represented orders in number of taxa. *Vespertilionidae* (insectivorous bats) and *Bovidae* (ungulates such as antelopes and buffalos) are the most represented families in terms of number of taxa, as expected given their ecological preferences.

Of the 122 taxa, 113 are classified as **Least Concern** (LC), while two are **Vulnerable** (VU) and seven (7) are **Near Threatened** (NT) (IUCN, 2020), namely:

- **NT**: Red Lechwe, *Kobus leche* subsp. *leche*; African Straw-coloured Fruit Bat, *Eidolon helvum* (Kerr, 1792); Large-eared Free-tailed Bat, *Otomops martiensseni* (Matschie, 1897); African Clawless Otter, *Aonyx capensis* (Schinz, 1821); Spotted-necked Otter, *Hydrictis maculicollis* (Lichtenstein, 1835); Yellow-backed Duiker, *Cephalophus silvicultor* (Afzelius, 18145); Puku, *Kobus vardonii* (Livingstone, 1857);

- **VU**: Ground Pangolin, *Smutsia temminckii* (Smuts, 1832); Hippopotamus, *Hippopotamus amphibius* Linnaeus, 1758.

The characteristic reduncine antelope of Central African floodplains, red Lechwe, *Kobus leche* subsp. *leche* Gray, 1850 is a semi-aquatic grazer particularly well-adapted to the exploitation of swamp habitats, classified as **NT**. According to the most recent assessment from the IUCN SSC Antelope Specialist Group, from 2017, it still occurs in the Lukanga, mainly towards the western half of it, in the Itundo Plain up to the Lunga-Luwishi GMA and in the confluence of the Kafue and Lukanga Rivers (Figure 1). According to Kamweneshe and Beilfuss (2002), the lechwe occurs in the flood-line and shallower reaches of the swamp, up to 1 m deep. This renders them particularly vulnerable to poaching during the high-water period in the wet season, when the animals come closer to human settlements. The population was first estimated at 800 individuals in the late 60s (Hanks, 1969, in Kamweneshe and Beilfuss, 2002), and was then estimated at less than 100 only three decades later (Kamweneshe and Beilfuss, 2002). There are no estimates of the current population.

The African straw-coloured fruit bat, *Eidolon helvum* (Kerr, 1792), is a widespread frugivore bat species associated to woodland and savanna habitats with fruit bearing plants. It is a migratory species that roosts in colonies under tree canopies, for instance of palm and mahogany trees, and its movement patterns seem to be associated to the life-history traits of *Uapaca* and *Syzygium* tree genera (ACR, 2019). This species is classified as **NT** and its numbers are decreasing locally owing to over-harvesting for food and medicinal use, while also being threatened by deforestation (ACR, 2019).

The large-eared free-tailed bat, *Otomops martiensseni* (Matschie, 1897), classified as **NT**, is an insectivorous species associated with woodland and savanna vegetation (ACR, 2019). This is a long-range forager who roosts in human-made structures such as houses, and is thus threatened by roost disturbance (ACR, 2019).

The African clawless otter, *Aonyx capensis* (Schinz, 1821), classified as **NT**, is a predominantly aquatic carnivore species preferring wetland habitats with abundant and thick vegetation cover, and threatened by the disturbance of these habitats. Reed beds are appointed as a commonly used habitat type, when the preferred rocky river with closed riparian vegetation is not available (Okes *et al*., 2016). Its diet is composed of crabs, amphibians, insects and fish. Given the absence of tall and thick vegetation along the area's rivers and streams, the African clawless otter is unlikely to occur in rivers, the

exception being the Lukanga River downstream of the swamp, which seems to offer more favorable conditions.

The spotted-necked otter, *Hydrictis maculicollis* (Lichtenstein, 1835), classified as **NT**, is also a predominantly carnivore aquatic species with riparian vegetation as preferred habitat (Ponsonby *et al.*, 2016). Because it is diet-wise more fish specialized compared to the clawless otter, these can co-occur. The spotted-necked otter is primarily threatened by overgrazing of riverside vegetation and infestation by invasive weeds.

The yellow-backed duiker, *Cephalophus silvicultor* (Afzelius, 18145) is an antelope primarily found in secondary forest and edge habitats, including woodland and savanna mosaics, specializing in fallen fruit. It is not clear whether is still occurs in the Lukanga.

The puku, *Kobus vardonii* (Livingstone, 1857) is a reduncine antelope primarily found around lake, river and swamp floodplains, as well as in dambos (Rduch, 2013). The Puku is indirectly threatened by habitat loss and fragmentation, and directly through poaching. Neither Kamweneshe and Beilfuss (2002) or Chabwela *et al*. (2010) mention the Puku, suggesting it no longer occurs around the Lukanga, possibly having migrated towards the Lunga-Luwishi GMA and Kafue National Park (Rduch, 2013).

The ground pangolin, *Smutsia temminckii* (Smuts, 1832) is a secretive and nocturnal insectivore typically occurring in woodlands (including the miombo), savannas and floodplains (Pieterson *et al*., 2020). Together with water availability, prey availability, i.e., ants and termites, is an important determinant of this species occurrence (Chao *et al*., 2020; Pieterson *et al*., 2020). Their role as predators of social insects makes them important ecosystem components. This species is classified as **VU** and is mainly threatened by over-harvesting for consumption and medicinal use, and indirectly by habitat fragmentation and loss through conversion to cropland (Chao *et al*., 2020; Pieterson *et al*., 2020).

The hippopotamus, *Hippopotamus amphibius* Linnaeus, 1758, commonly associated with swamp habitats, is also listed as possibly occurring. Local fishermen report they still exist deeper inside the swamp (Personal communication, October 2019). One fisherman actually claimed to have seen evidence of their presence, such as trampled vegetation, back in October 2019 along a water channel off Kabosha, close to land. It is classified as **VU** and its IUCN geographic range (Lewison and Pluháček, 2017) does not cover the swamp, its boundaries being restricted to the Kafue NP and Lunga-Lushwishi GMA up

to the west bank of the Kafue River. Kamweneshe and Beilfuss' 2001 aerial survey did not detect any hippopotamuses.

According to comments from local communities from September and October 2019, large mammals are likely to occur towards the Itundu Plain and Lunga-Luwishi GMA rather than the rest of the swamp and grassland areas.

In general, large ungulate populations have been driven into protected area networks (including buffer areas such as GMAs) through the encroachment by rural communities and land-use change, as is illustrated by the negative relation of ungulate biomass and diversity to human settlements within NPs, GMAs and game ranches found by Lindsey *et al*. (2014).

In 2001, Kamweneshe and Beilfuss (2002) did not detect buffalos (*Syncerus caffer* [Sparrman, 1779]), elands (*Tragelaphus oryx* [Pallas, 1766]), antelopes (*Hippotragus equinus* [É. Geoffroy Saint-Hilaire, 1803], and *Hippotragus niger* [Harris, 1838]) or waterbucks (*Kobus ellipsiprymnus* [Ogilbyi, 1833]). Only those species more closely related to the swamp than to savannah or grassland habitats (and, possibly, less exposed to encroachment) were observed, including red Lechwes (*Kobus leche* subsp. *leche* Gray, 1850), oribi (*Ourebia ourebia* [Zimmermann, 1783]), and sitatunga (*Tragelaphus spekii* Speke, 1863).

Informal communications with different local stakeholders (tourism operators from Kabwe, local residents and researchers) between September 2019 and March 2020 support the hypothesis that these ungulates, with distribution ranges covering the swamp and surrounding savanna and grassland habitats, are actually not present. If present, or visiting, these will be restricted to the Itundu Plain.

Similarly, carnivores such as hyaenas (*Crocuta crocuta* [Erxleben, 1777]), caracals (*Caracal caracal* [Schreber, 1776]) servals (*Leptailurus serval* [Schreber, 1776]), and jackals (*Canis adustus* Sundevall, 1847), were listed given their historical distribution and hypothetically suitable habitat, but are unlikely to still occur or visit.

Most of the listed large carnivore species occur in the KNP and are expected to occur in surrounding GMAs, down to the Kafue River boundary (Purchase, Mateke and Purchase, 2007

2007). Owing to the high trophic level occupied by large carnivores, their low occurrence densities, the dimension of rangeland they require, and their threat to human lives and livestock, these are particularly susceptible to human encroachment and edge effects, ultimately being prone to persecution to a greater extent than small carnivores or herbivores (in Watson *et al*., 2014).

Hence, the Lukanga Swamp's level of encroachment, coupled with the conservation requirements of this trophic group and the availability of PA networks in the vicinity, suggests it is no longer suitable for the occurrence of large carnivores. The area's viability as carnivore corridor is also jeopardized/limited by the current situation (Watson *et al*., 2014).

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Appendix A – Habitats map

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27°50'0"E
28°0'0"E
28°10'0"E
14°0'0"S
14°10'0"S
14°20'0"S
14°30'0"S
14°40'0"S

Ngabwe
Shampolo
Shuiamo
Mounde
Chiwa Island
Chipepo
Warila
Kaiwende
Mukuluwa
Woongo
Musondo
Kabosha
Chifanda
Chibombo

- District Towns
- Villages
- Lukanga Swamps Ramsar Site (Ramsar, 2005)

MACRO-HABITATS

1 - FOREST LAND
- 11: Miombo woodland
- 12: Baikiaea forest and deciduous thicket
- 13: Lake Basin Chipya
- 14: Munga or Miombo woodland

2 - WOODED GRASSLAND
- 21: Termitaria

3 - GRASSLAND
- 31: Edaphic grassland
- 32: Permanent swamp
- 33: Stream-associated wetland vegetation

4 - ANTHROPIC LANDSCAPES
- 41: Cultivated and managed land
- 42: Rural built-up land

5 - INLAND WATER
- 51: Lakes
- 52: Rivers

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Projected	Maria Espirito Santo
Verified	Maria Espirito Santo
Designed	Carolina Carvalho
Approved	Pedro Bettencourt

CONSERVATION PLAN FOR LUKANGA SWAMP AND UPPER KAFUE BASIN

Ecological assessment

Habitats

Scale	1:175 000
Number	1
Graphic scale	0 2 500 5 000 m
Date	February 2020
Page	1/1
Code	TI9024-2101_Eco_HABITATS_A1_v3

Appendix B – Flora species list

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Table 5 – Flora species list for the Lukanga swamp and surrounding terrestrial macro-habitats

Family	Species	Syn.	Common names	Statuses	Occ.	Macro-habitat	Potential uses
BACCILARIOPHYTA							
Fragilariales	*Synedra* sp. Ehrenberg	-	-	-	C	Sw	-
Naviculales	*Navicula* sp. Bory	-	-	-	C	Sw	-
CHAROPHYTA							
Closteriaceae	*Closterium* sp. Nitzsch ex Ralfs	-	-	-	C	Sw	-
Desmidiaceae	*Micrasterias radiosa* Ralfs	-	-	-	C	Sw	-
	Staurastrum pseudosebaldi Wille	-	-	-	C	Sw	-
CHLOROPHYTA							
Chlamydomonadaceae	*Carteria* sp. Diesing	-	-	-	C	Sw	-
Hydrodictyaceae	*Pediastrum duplex* Meyen	-	-	-	C	Sw	-
	Pediastrum simplex Meyen	-	-	-	C	Sw	-

Family	Species	Syn.	Common names	Statuses	Occ.	Macro-habitat	Potential uses
CYANOBACTERIA							
Micricystaceae	*Microcystis novacekii* (Komárek) Compère	-	-	-	C	Sw	-
Nostacaceae	*Anabaena* sp. Bory ex Bornet and Flahault	-	-	-	C	Sw	-
	Anabaena smithii (Komárek) M. Watanabe	-	-	-	C	Sw	-
EUGLENOPHYTA							
Euglenidae	*Euglena* sp. Ehrenberg	-	-	-	C	Sw	-
Phacidae	*Lepocinclis ovum* (Ehrenberg) Lemmermann	-	-	-	C	Sw	-
OCHROPHYTA							
Centritractaceae	*Centritactus brunneus* Fott	-	-	-	C	Sw	-

Family	Species	Syn.	Common names	Statuses	Occ.	Macro-habitat	Potential uses
PTERIDOPHYTA							
Dennstaedtiaceae	*Pteridium centrali-africanum* (Hieron. ex R. E. Fr.) Alston	-	-	LC	Ps	Ch	Medicine; raw material/ fibre
Salviniaceae	*Azolla* Lam. n.i.	-	-	-		Sw	-
	Salvinia molesta D. Mitch	-	Kariba weed; Javani weed	Int./Inv.		Sw	-
Thelypteridaceae	n.i.	Aspleniaceae	-	-	C	Sw	-
ANGIOSPERMAE: MONOCOTYLEDONAE							
Arecaceae	*Phoenix reclinate* Jacq.	-	Dwarf date palm (Eng.); Dattier du Senegal (French)	LC	Prb	T; Mg	-
	Borassus aethiopum Mart.	-	Kakunka (Lenje); Kahuma (Tonga); Cibangalala (Bemba); Rhun Palm (Eng.)	LC	Ps	Mg; Ch	Wild food; fuel; Medicine; raw material/ fibre
	Hyphaene petersiana Klotzsc ex Mart.	-	Llala palm (Eng.); Real fan palm (Eng.); Vegetable ivory palm (Eng.)	LC	Ps	Mg	Medicine; raw material/ fibre

Family	Species	Syn.	Common names	Statuses	Occ.	Macro-habitat	Potential uses
Cyperaceae	*Cyperus difformis* L.	-	Smallflower umbrella sedge (Eng.)	LC	C	Rs	-
	Cyperus digitatus Roxb. subps. *auricomus* (Sieber ex Spreng.) Kuk.	-	Minyanja (Lenje); Manyanja (Tonga)	-	C	Rs	-
	Cyperus n.i. Poir.	-	-	-	C	Rs	-
	Cyperus papyrus L.	-	Papyrus sedge (Eng.); Luko (Bemba)	LC	Prb	Sw	Raw material/ fibre
	Cyperus rotundus L.	-	Nutgrass (Eng.); Nutsedge (Eng.); Purple nutsedge (Eng.)	LC	Prb	Rs; Eg	-
	Eleocharis dulcis (Burm. F.) Trin. Ex Hensch.	-	Chinese water chestnut (Eng.); Kasemembe (Bemba); Masyinge (Bemba)	-	C	Sw	-
	Scirpus sp. Tourn. Ex L.	-	-	-	Prb	Sw	-
Hydrocharitaceae	*Elodea* Michx. sp.	-	-	-	Prb	Sw	-
	Najas L. n.i.	-	-	-	C	Sw	-

Family	Species	Syn.	Common names	Statuses	Occ.	Macro-habitat	Potential uses
Poaceae	*Acroceras macrum* Stapf	-	Nile grass (Eng.)	-	Prb	Eg; T; Rs	Forage
	Andropogon gayanus Kunth	-	Blue grass (Eng.); Rhodesian blue grass (Eng.)	-	Prb	T	Forage
	Andropogon schirensis A. Rich.	-	Stab grass (Eng.)	-	Ps	Eg	Raw material/ fibre; forage
	Bothriochloa bladhii (Retz.) S. T. Blake	-	Purple plume grass (Eng.)	-	Ps	Eg	Forage
	Brachiaria brizantha (A. Rich.) Stapf	*Urochloa brizantha* (A. Rich.) R. D. Webster	Bread grass (Eng.)	-	Prb	T	Forage
	Cenchrus purpureus (Schumach.) Morrone	*Pennisetum purpureum* Schumach.	Napier grass (Eng.); Elephant grass (Eng.)	-	Prb	Eg	-
	Chloris gayana Kunth	-	Rhodes grass (Eng.)	-	Prb	T	Forage; medicine; raw material/ fibre
	Chloris Sw. sp.	-	-	-	Prb	T	-
	Chrysopogon nigritanus (Benth.) Veldkamp	*Vetiveria nigritana* (Benth.) Stapf	Vetiver grass (Eng.)	-	Prb	T	-

Family	Species	Syn.	Common names	Statuses	Occ.	Macro-habitat	Potential uses
	Cymbopogon nardus (L.) Rendle	*C. validus* (Stapf) Stapf ex Burtt Davy	Ceylon citronella (Eng.); Giant turpentine grass (Eng.); Citronella grass	-	Prb	T	Medicine
	Cynodon dactylon (L.) Pers.	-	Couch grass (Eng.)	-	Ps	Eg	Forage; medicine
	Dichanthium annulatum (Forssk.) Stapf	-	Vlei finger grass (Eng.)	-	Ps	Eg	Forage; medicine
	Digitaria milanjiana (Rendle) Stapf	-	Milanje finger grass (Eng.)	-	Prb	T	Forage
	Echinochloa haploclada (Stapf) Stapf	-	Cockspur (Eng.)	-	Ps	Eg	Forage; medicine; raw material/ fiber
	Echinochloa pyramidalis (Lam.) Hitchc. and Chase	-	Antelope grass (Eng.)	LC	Ps	Eg	Forage; medicine; raw material/ fiber
	Echinochloa stagnina (Retz.) P. Beauv.	-	Hippo grass (Eng.); Long-awned water grass (Eng.); Water grass (Eng.)	-	Prb	Rs; Eg	Raw material/ fiber; wild food; forage

Family	Species	Syn.	Common names	Statuses	Occ.	Macro-habitat	Potential uses
	Eragrostis atrovirens (Desf.) Trin. ex Steud	-	Thalia love grass (Eng.)	-	Ps	Eg	Forage; medicine
	Eragrostis Wolf sp.	-	-	-	Prb	Eg	-
	Hyparrhenia bracteate (Humb. and Bonpl. Ex Willd.) Stapf	-	-	-	Ps	Eg	Forage
	Hyparrhenia diplandra (Hack.) Stapf	-	-	-	Ps	Eg	Forage; medicine
	Hyparrhenia filipendula (Hochst.) Stapf	-	Fine thatching grass (Eng.); Hairy blue-grass (Eng.)	-	Ps	Eg	Forage; medicine; raw material/ fiber
	Hyparrhenia newtonii (Hack.) Stapf	-	-	-	Ps	Eg	Forage; raw material/ fiber
	Hyparrhenia nyassae (Rendle) Stapf	-	-	-	Ps	Eg	Forage; raw material/ fiber
	Hyparrhenia rufa (Nees) Stapf	-	Giant thatching grass (Eng.)	-	Prb	T	Raw material/ fiber; forage
	Imperata cylindrica (L.) P. Beauv.	-	Alang-alang (Eng.); Cottonwool grass (Eng.); Cogongrass	-	Prb	Eg; Sw	Medicine; forage; raw material/ fiber
	Leersia hexandra Sw.	-	Rice grass (Eng.); Cutgrass; Swamp cut grass (Eng.)	LC	Prb	Eg; Sw	Forage

Family	Species	Syn.	Common names	Statuses	Occ.	Macro-habitat	Potential uses
	Loudetia simplex (Nees) C. E. Hubb.	-	Common Russet Grass (Eng.)	-	Prb	Eg	-
	Monocymbium ceresiiforme (Nees) Stapf	-	Boat grass (Eng.)	-	Ps	Eg	Forage; raw material/ fibre
	Oryza longistaminata A. Chev. and Roehr.	-	Wild rice (Eng.); Red rice	LC	Ps	Eg	Forage; wild food; raw material/ fiber; medicine
	Panicum maximum Jacq.	*Urochloa maxima* (Jacq.) R. D. Webster	-	-	Prb	T	-
	Panicum repens L.	-	Couch panicum (Eng.); Creeping panic (Eng.); Torpedo grass (Eng.)	-	Prb	T	Forage
	Pennisetum macrourum Trin.	*Cenchrus caudatus* (Schrad.) Kuntze; *Cenchrus macrourus* (Trin.) Morrone	Riverbank pennisetum (Eng.); Riverbed grass (Eng.); African Feather grass (Eng.); Waterside reed (Eng.)	LC	Ps	Eg	Forage
	Phragmites australis (Cav.) Trin. Ex	-	Common reed (Eng.)	LC	C	Eg ; Sw	Medicine

Family	Species	Syn.	Common names	Statuses	Occ.	Macro-habitat	Potential uses
	Phragmites mauritianus Kunth	-	-	LC	C	Rs; Eg	-
	Rottboellia cochinchinensis (Lour.) Clayton	*Rottboellia exaltata* L. f.	-	-	Prb	T	-
	Sacciolepis africana C. E. Hubb. and Snowden	-	-	LC	Ps	Eg	Wild food; forage
	Sacciolepis typhura (Stapf) Stapf	-	-	-	Ps	Eg	Forage
	Setaria incrassata (Hochst.) Hack.	*S. phragmitoides* Stapf	Vlei bristle grass (Eng.)	-	Prb	T; Eg	Forage; raw material/ fibre
	Setaria sphacelate (Schumach.) Stapf and C. E. Hubb. Ex Moss	*S. anceps* Stapf	Buffalo grass (Eng.); Common Bristle grass (Eng.); Golden setaria (Eng.)	-	Prb	T; Eg	Forage; medicine; raw material/ fibre; wild food
	Sorghum arundinaceum (Desv.) Stapf	*S. verticilliflorum* (Steud.) Stapf	Sudan grass	-	Prb	T; Eg	-
	Sporobolus pyramidalis P. Beauv.	-	Cat's tail dropseed (Eng.); Cat's tail grass (Eng.)	-	Ps	Eg	Forage; medicine; raw material/ fibre

Family	Species	Syn.	Common names	Statuses	Occ.	Macro-habitat	Potential uses
	Tristachya superba (De Not.) Schweinf. and Asch.	-	-	-	Prb	Eg	-
	Vossia cuspidata (Roxb.) Griff.	-	Hippo grass (Eng.)	LC	Prb	Eg; Sw; Rs; T	Forage; raw material/fibre
Potamogetonaceae	*Potamogeton* Walter n.i.	-	Pondweeds	-	C	Sw	-
Smilacaceae	*Smilax anceps* Willd.	-	West African sarsaparilla (Eng.)	-	Ps	Mmb; Ch; Bk	Wild food; medicine; raw material/ fibre
Typhaceae	*Typha capensis* (Rohrb.) N. E. Br.	-	-	LC	C	Sw	-
Zingiberaceae	*Aframomum alboviolaceum* (Ridl.) K. Schum	-	Grape-seeded amomum (Eng.)	LC	Ps	Ch	Wild food; medicine

Family	Species	Syn.	Common names	Statuses	Occ.	Macro-habitat	Potential uses
ANGIOSPERMAE: DICOTYLEDONAE							
Acanthaceae	*Blepharis maderaspatensis* (L.) B. Heyne ex Roth	-	-	-	Ps	Bk	-
	Hypoestes forskaolii (Vahl) R. Br.	-	White-ribbon bush (Eng.)	-	Ps	Bk	Medicine
Amaranthaceae	*Achyranthes aspera* L.	-	Devil's horsewhip (Eng.); Burweed (Eng.)	-	Ps	Bk	Medicine
	Puppalia lappacea (L.) Juss	-	Forest burr (Eng.)	-	Ps	Bk	-
Anacardiaceae	*Lannea schweinfurthii* var. *stulhmannii* (Engl.) Kokwaro	*L. stuhlmannii* (Engl.) Engl.	-	-	Prb	Mg; T; Ch	Medicine; Wild food
	Lannea discolour (Sond.) Engl.	-	-	LC	Prb	Mmb; T; Mg; Ch	Wild food
	Sclerocarya birrea (A. Rich.) Hochst. subsp. *caffra* (Sond.) Kokwaro	*Sclerocarya caffra* Sond.	-	-	Prb	Rs ; Eg ; Ch ; Mg	Medicine; wild food; fuel; raw material/ fibre
	Ozoroa insignis Delile	-	Tropical resin tree (Eng.)	LC	Ps	Mg	Wild food; fuel; medicine

Family	Species	Syn.	Common names	Statuses	Occ.	Macro-habitat	Potential uses
Anisophylleaceae	*Anisophyllea boehmii* Engl.	-	Mufungu (Bemba)	-	Ps	Mmb; Ch	Wild food; raw material/ fibre; medicine
Annonaceae	*Friesodielsia obovate* (Benth.) Verdc	*Popowia obovata* (Benth.) Engl. and Diels; *Monanthotaxis obovata* (Benth.) P. H. Hoekstra	Bastard dwaba-berry (Eng.); Northern dwaba-berry (Eng.)	LC	Prb	Bk	Medicine; wild food; fuel
	Hexalobus monopetalus (A. Rich.) Engl. and Diels	-	-	LC	Ps	Mmb	Fuel; Medicine; raw material/ fibre
	Annona senegalensis Pers.	-	Wild custard apple (Eng.)	LC	Ps	Ch	Wild food; forage; medicine; raw material/ fibre
	Xylopia odoratissima Welw. ex Oliv.	-	-	LC	Ps	Ch	-
Apiaceae	*Steganotaenia araliacea* Hochst.	-	-	LC	Prb	Mg	-

Family	Species	Syn.	Common names	Statuses	Occ.	Macro-habitat	Potential uses
Apocynaceae	*Diplorhynchus condylocarpon* (Mull.-Arg.) Pichon	-	Munto (Bemba); Mutowa (Tonga); Mwenge (Bemba)	LC; End.	Prb	Mg; Mmb; Ch	Wild food
	Landolphia kirkii Dyer	-	Kirk's Landolphia (Eng.)	-	Ps	T; Mmb	Medicine
Asteraceae	*Vernonia amygdalina* Delile	*Gymnanthemum amygdalinum* (Delile) Sch. Bip.	Bitter leaf (Eng.); River vernonia (Eng.); Tree vernonia (Eng.)	-	Ps	Mg	Forage; fuel; medicine; raw material/ fibre
Bignoniaceae	*Markhamia obtusifolia* (Bak.) Sprague	-	-	LC	Prb	Ch; T; Mmb; Mg; Bk	Medicine
	Kigelia africana (Lam.) benth	*Kigelia pinnata* (Jacq.) DC.	Sausage Tree (Eng.)	LC	Prb	Rs; Eg; Mg; T; Ch	-
	Markhamia zanzibarica (Bojer ex DC.) K. Schum	-	Bell-bean Tree (Eng.); Bean Tree (Eng.)	LC	Ps	T; Bk	Medicine; raw material/ fibre
	Stereospermum kunthianum Cham.	-	Pink jacaranda (Eng.); Kayubule (Bemba); Mukulukayubule (Bemba)	LC	Ps	Ch	Medicine; raw material/ fibre

Family	Species	Syn.	Common names	Statuses	Occ.	Macro-habitat	Potential uses
	Tecomaria capensis (Thunb.) subsps. *nyassae* (Oliv.) Brummitt	*Tecoma nyassae* Oliv.	-	-	Ps	Ch	-
Boraginaceae	*Heliotropium* Tourn ex L. sp.	-	-	-	Prb	T	-
Burseraceae	*Commiphora mollis* (Oliv.) Engl.	-	-	LC	Prb	Mg; Ch	-
	Commiphora madagascariensis Jacq.	-	-	-	Prb	Mg	-
Capparaceae	*Boscia salicifolia* Oliv.	-	-	LC	Prb	Ch; T; Mg	Medicine
	Capparis tomentosa Lam.	-	Woolly caper bush (Eng.)	-	Prb	T; Mg; Bk	Wild food; medicine; fuel
Ceratophyllaceae	*Ceratophyllum demersum* var. *demersum* L.	-	Rigid Hornwort (Eng.); Hornwort (Eng.)	LC	C	Sw	-
Chrysobalanaceae	*Parinari curatellifolia* Planch. ex Benth.	-	Mobola	LC	Prb	Mg; T; Mmb; Ch	Wild food; raw material/ fibre

Family	Species	Syn.	Common names	Statuses	Occ.	Macro-habitat	Potential uses
Clusiaceae	*Garcinia livingstonei* T. Anderson	-	Mungingu (Tonga); African mangosteen (Emg.) Lowveld mangosteen (Eng.); Wild plum (Eng.)	-	Ps	T	Forage; wild food; raw material/ fibre; medicine; fuel
Combretaceae	*Combretum adenogonium* Steud. ex A. Rich	*C. ghasalense* Engl. Et Diels	-	LC	Prb	Mg; Mmb; Ch	Medicine; fuel
	Combretum celastroides Welw. ex. M. A. Laws.	-	-	-	Prb	Ch; Bk	-
	Combretum collinum Fresen.	*C. mechowianum* O. Hoffim	-	LC	Prb	Mg; Bk; Mmb; Ch	Medicine; raw material/ fibre
	Combretum elaeagnoides Klotzsch	-	Large-fruited jessebush combrteum (Eng.); Caprivi combretum (Eng.); Grey jesse-bush combretum (Eng.)	LC	Ps	Bk	Medicine; raw material/ fibre

Family	Species	Syn.	Common names	Statuses	Occ.	Macro-habitat	Potential uses
	Combretum imberbe Wawra	-	Bastard yellow wood (Eng.); Elephant trunk (Eng.); Ivory Tree (Eng.); Large fruited combrteum (Eng.)	LC	Prb	Rs; Eg; Mg; T; Bk	Medicine; raw material/ fibre; fuel
	Combretum zeyheri Sond.	-	Large-fruited combretum (Eng.); Bush-willow (Eng.)	LC	Ps	Mmb; Mg; Bk	Forage; medicine; raw material/ fibre
	Terminalia prunioides M. A. Lawson	-	Purple-pod cluster-leaf (Eng.)	LC	Ps	Mg	Raw material/ fibre; medicine
	Terminalia sericea Burch. Ex DC.	-	-	LC	Prb	Mmb; Ch; Mg; Bk	Medicine
	Terminalia stenostachya Engl. and Diels	-	-	-	Prb	Mg	-
Convolvulaceae	*Ipomea aquatica* Forssk.	-	Swamp morning glory (Eng.)	LC	Prb	Eg; Sw	Medicine
	Pteridium centrali-africanum (Hieron. ex R. E. Fr.) Alston	-	-	-	Ps	Ch	Medicine; raw material/ fibre

Family	Species	Syn.	Common names	Statuses	Occ.	Macro-habitat	Potential uses
Dipterocarpaceae	*Marquesia macroura* Gilg	-	Musesye (Bemba)	-	Ps	Mmb; Ch	Fuel; raw material/ fibre; wild food
	Marquesia Gilg sp.	-	-	-	Prb	Mmb	-
Ebenaceae	*Diospyros kirkii* Hiern	-	-	-	Prb	Mg;Mmb	Wild food; raw material/ fibre; fuel
	Diospyros mespiliformis Hochst. Ex A. DC.	-	West african ebony (Eng.); African ebony (Eng.); Ebony (Eng.)	-	Prb	Rs; Eg; T	Wild food; medicine; fuel; raw material/ fibre
	Diospyros quiloensis (Hiern) F. White	-	Crocodile-bark diospyros (Eng.)	-	Ps	Bk	Wild food; raw material/ fibre
	Diospyros senensis Klotzsch	-	-	-	Prb	Ch	-
	Euclea divinorum Hiern	-	Diamond leaf (Eng.); Magic gwarri (Eng.); Toothbruch tree (Eng.)	-	Ps	T	Forage; raw material/ fibre; fuel; medicine
	Euclea racemose L. subsp. *schimperi* (A. DC.) F. White	-	-	-	Ps	T	Forage; raw material/ fibre; fuel; medicine

Family	Species	Syn.	Common names	Statuses	Occ.	Macro-habitat	Potential uses
Euphorbiaceae	*Antidesma venosum* E. Mey. Ex Tul.	-	-	LC	Prb	Mg; T; Ch	Medicine; fuel
	Croton megalobotrys Mull.Arg.	-	Fever-berry croton (Eng.)	LC	Ps	Mg	Medicine
	Erythrococca menyharthii (Pax) Prain	-	-	-	Ps	Bk	-
	Excoecaria bussei (Pax) Pax	-	-	-	Ps	Bk	-
	Schinziophyton rautanenii (Schinz) Radcl.-Sm.	*Ricinodendron rautanenii* Schinz	Featherweight tree (Eng.); Mongongo	LC	Prb	Mg; T; Ch	-
Fabaceae	*Acacia albida* Delile	*Faidherbia albida* (Delile) A. Chev.	White acacia (Eng.)	LC	Prb	Eg; Mg; Ch	Fuel; medicine
	Acacia ataxacantha DC.	*Senegalia ataxacantha* (DC.) Kyal. and Boatwr.	Flame acacia (Eng.)	LC	Ps	Bk	Raw material/ fibre
	Acacia fleckii Schinz	*Senegalia fleckii* (Schinz) Boatwr.	Blade thorn (Eng.); Sandvel acacia (Eng:)	LC	Ps	Bk	Fuel; raw material/ fibre
	Acacia gerrardii Benth.	*Vachellia gerrardii* (Benth.) P. J. Hurter	Grey-haired acacia (Eng.)	-	Ps	T; Mg	Forage; raw material/ fibre; fuel; medicine

Family	Species	Syn.	Common names	Statuses	Occ.	Macro-habitat	Potential uses
	Acacia nigrescens Oliv.	*Senegalia nigrescens* (Oliv.) P.J.H.Hurter	-	-	Ps	T; Mg; Bk	Fuel; medicine; wild food
	Acacia nilotica (L.) Wild. Ex Del.	*Vachellia nilotica* (L.) P. J. H. Hurter and Mabb.	Gum arabic Tree (Eng.); Acacia	LC	Prb	Mg; T	Medicine; wild food
	Acacia polyacantha Willd.	*Senegalia polyacantha* (Willd.) Seigler and Ebinger	White thorn tree (Eng.)	-	Prb	Mg; Ch	Medicine; wild food
	Acacia robusta Burch.	*Vachellia robusta* (Burch.) Kyal. and Boatwr.	-	-	Ps	Mg	Fuel; medicine; raw material/ fibre
	Acacia seyal Delile var. *fistula* (Schweinf) Oliv.	*Vachellia seyal* (Delile) P. J. H. Hurter	-	-	Prb	Mmb	Medicine
	Acacia sieberiana DC.	*Vachellia sieberiana* (DC.) Kyal. and Boatwr.	Paperbark acacia (Eng.)	-	Prb	Mg	Medicine; forage; raw material/ fibre
	Acacia tortilis (Forssk.) Hayne	*Vachellia tortilis* (Forssk.) Galasso and Banfi	-	-	Ps	Mg	Forage; fuel; medicine; raw material/ fibre
	Acacia xanthophloea Benth.	*Vachellia xanthophloea* (Benth.) Banfi and Galasso	Fever tree (Eng.)	LC	Prb	Mg	Medicine; wild food

Family	Species	Syn.	Common names	Statuses	Occ.	Macro-habitat	Potential uses
	Aeschynomene fluitans Peter	-	-	-	Prb	T; Eg; Sw	-
	Afzelia quanzensis Welw.	-	Pod Mahogany (Eng.); Mupaap (Bemba)	LC	Prb	Ch; Mg	Medicine
	Albizia adianthifolia (Schumach.) W. Wight	-	Mubanse (Bemba); Mutanga (Bemba); Flat-crown albizia (Eng.)	LC	Prb	Mg; Mmb; Ch	Medicine
	Albizia amara (Roxb.) Boivin	-	Bitter albizia (Eng.)	LC	Prb	Mg; T; Ch	Medicine, raw material/ fibre
	Albizia anthelmintica (A. Rich.) Brongn.	-	Mwihangwe (Tonga); Worm-bark albizia (Eng.); Worm-bark false-thorn; Worm-cure albizia	-	Prb	Mg	Medicine
	Albizia antunesiana Harms	-	Musase (Lenje; Bemba); Kawisi (Tonga)	LC	Prb	Mmb; Ch	Wild food; medicine; raw material/ fibre
	Albizia harveyi E. Fourn.	-	Common false-thorn (Eng.); Sickle-leaved albizia (Eng.)	LC	Prb	Mg; T	Medicine; raw material/ fibre; fuel

Family	Species	Syn.	Common names	Statuses	Occ.	Macro-habitat	Potential uses
	Albizia versicolor Welw. ex Oliv.	-	Posion-pod albizia (Eng.)	LC	Ps	Mg	Medicine; fuel
	Amblygonocarpus andongensis (Welw. ex Oliv.) Exell and Torre	-	-	LC	Ps	Mg; Ch	Fuel; medicine
	Baikiaea plurijuga Harms	-	Mukusyi (Tonga; Bemba); Zambezi teak (Eng.); Rhodesian teak (Eng.)	NT; Vulnerable	Prb	Bk	Medicine
	Baphia massaiensis Taub.	-	-	LC	Prb	Bk; Ch	-
	Bauhinia macranta Oliv.	*Bauhinia petersiana* Bolle subsp. *macranta* (Oliv.) Brummitt and J. H. Ross	-	-	Prb	Ch; Bk	Medicine; wild food
	Bauhinia petersiana Bolle	-	Zambesi Coffee (Eng.)	LC	Prb	Mg; T; Ch; Bk	Medicine; wild food
	Bobgunia Schreb. sp.	-	-	-	Prb	Mmb	-

Family	Species	Syn.	Common names	Statuses	Occ.	Macro-habitat	Potential uses
	Bobgunnia madagascariensis (Desv.) J. H. Kirkbr. and Wiersema	*Swartzia madagascariensis* Desv.	Ndale (Lenje, Bembe); Snake bean (Eng.)	LC	Ps	Mmb; Ch	Forage; fuel; medicine; raw material/ fibre
	Brachystegia allenii Hutch. and Burtt Davy	-	Cifuku (Bemba)	LC	Ps	Mmb	-
	Brachystegia boehmii Taub.	-	Musamba (Bemba; Lenje); Muwombo (Bemba; Tonga)	LC	Prb	Mmb	Medicine; fuel; raw material/ fibre
	Brachystegia bussei Harms	-	Mukongolo (Bemba)	LC	Ps	Mmb	Raw material/ fibre; medicine
	Brachystegia floribunda Benth.	-	Kasabwa (Bemba)	-	Ps	Mmb	Raw material/ fibre; medicine; fuel
	Brachystegia longifolia Benth.	-	Musamba (Lenje; Bemba); Mubombo (tonga); Muwombo (Tonga)	LC	Ps	Mmb; Ch; Bk	Fuel; medicine; raw material/ fibre; wild food
	Brachystegia manga De Wild.	-	Musyiwe (Tonga); Mukongolo (Bemba)	LC	Ps	Mmb	-

Family	Species	Syn.	Common names	Statuses	Occ.	Macro-habitat	Potential uses
	Brachystegia spiciformis Benth.	-	Msasa; Muputi (Bemba); Musewe (Tonga); Muputu (Bemba)	LC	Prb	Mg; Ch	Medicine; raw material/ fibre; fuel
	Brachystegia stipulata De Wild.	-	Musamba (Lenje; Bemba)	-	Ps	Mmb	Fuel
	Brachystegia taxifolia Harms	-	Lukwe (Lenje); Ngalati (Bemba; Lenje)	-	Prb	Mmb	-
	Brachystegia utilis Hutch. and Burtt Davy	-	Musamba (Lenje); Musaka (Bemba)	LC	Ps	Mmb	Wild food; fuel; raw material/ fibre
	Burkea africana Hook	-	-	LC	Prb	Mmb; Ch; Mg	Medicine
	Cryptosepalum exfoliatum De Wild.	-	-	-	Prb	Ch	-
	Dalbergia boehmii Taub.	-	-	LC	Ps	Mg	Medicine
	Dalbergia martinii F. White	-	-	-	Ps	Bk	-
	Dalbergia melanoxylon Guill. and Perr.	-	African blackwood (Eng.)	NT; Vulnerable	Prb	Mg; T	Medicine; fuel
	Dalbergia nitidula Welw. ex Baker	-	Glossy flat-bean (Eng.)	LC	Ps	Mmb	Medicine

Family	Species	Syn.	Common names	Statuses	Occ.	Macro-habitat	Potential uses
	Dalbergiella nyasse Baker f.	-	Mwabma (Lenje); Kakwete (Bemba)	Lower risk	Prb	Ch	Medicine
	Erythrina abyssinica Lam.	-	Red-hot-poker tree (Eng.)	LC	Ps	T; Mg; Ch	Wild food; raw material/ fibre; fuel; medicine
	Erythrophleum africanum (Benth.) Harms	-	Mukoso (Bemba)	LC	Prb	Mmb; Bk; Mg; Ch	Medicine
	Guibourtia coleosperma (Benth.) J. Léonard	-	Rhodesian copalwood (Eng.); African rosewood (Eng.); Large false mopane; Rhodesian teak; Rhodesian Mahogany	-	Prb	Ch	Wild food; medicine; raw material/ fibre
	Julbernardia globiflora (Benth.) Troupin	-	Mutobo (Bemba)	LC	Prb	Mmb; Ch	-
	Julbernardia paniculata (Benth.) Tropin	-	Kabunga (Lenje; Bemba); Kamponi (Bemba; Tonga); Mpasa (Bemba); Mnondo	LC	C	Mmb; Ch	Medicine; raw material/ fibre
	Isoberlinia angolensis (Welw. Ex Benth.) Hoyle and Brenan	*Isoberlinia paniculata* (Benth.) Greenway	Mutondo (Bemba; Lenje)	LC	Prb	Mg; Mmb; Ch	Medicine; fuel

Family	Species	Syn.	Common names	Statuses	Occ.	Macro-habitat	Potential uses
	Lonchocarpus capassa Rolfe	*Philenoptera violacea* (Klotzsch) Shrire	-	LC	Prb	Mg; T; Ch	Medicine; toxins; raw material/ fibre
	Mimosa pigra L.	-	Giant sensitive plant (Eng.)	Int./ Inv.	Prb	Rs; Eg	Medicine
	Peltophorum africanum Sond.	-	Mwikalankanga (Bemba); African wattle (Eng.); Weeping wattle (Eng.)	LC	Ps	T; Mg	Forage; raw material/ fibre; fuel; medicine
	Pericopsis angolensis (Baker) Meeuwen	-	-	LC	Prb	Mg; Ch	Medicine; raw material/ fibre
	Philenoptera violacea (Kloyzsch) Schrire	*Loncocarpus capassa* Rolfe	Apple-leaf Tree (Eng.); Rain Tree (Eng.)	LC	Prb	Mg; T	Medicine; raw material/ fibre
	Piliostigma thonningii (Schumach.) Milne-Redh.	*Bauhinia thonningii* Schumach.	Camel's foot (Eng.)	-	C	Mg; Ch; T	Medicine; forage
	Pterocarpus angolensis DC.	-	Mulonbe (Lenje); Muwamulowa (lenje); Mulombwa (Bemba); Mukula (Tonga); Ambila	LC	Prb	Mmb; T; Mg; Ch	Raw material/ fibre; medicine

Family	Species	Syn.	Common names	Statuses	Occ.	Macro-habitat	Potential uses
	Pterocarpus lucens Lepr. Ex Guill. and Perr. subsp. *antunesii* (Taub.) Rojo	*Pterocarpus antunesii* (Taub.) Harms	-	LC	Prb	Bk; Mg	Medicine; fuel; raw material/ fibre
	Pterocarpus rotundifolius (Sond.) Druce	-	Round-leaved bloodwood (Eng.); Round-leaved teak (Eng.)	LC	Ps	Mg	Medicine
	Senna singueana (Delile) Lock	-	-	LC	Ps	T	Forage; raw material/ fibre; fuel; medicine
	Sesbania rostrate Bremek. and Oberm.	-	Spiny sesbania (Eng.)	-	Prb	T; Eg; Sw	Medicine
	Tamarindus indica L.	-	Musika (Tonga); Musiika (Tonga)	LC	Ps	T; Mg	Forage; raw material/ fibre; fuel; medicine; wild food
	Thespesia garckeana F. Hoffm.	*Azanza Garckeana* (Schmach.) W. F. Wight	-	LC	Prb	Ch; T; Mg	Wild food; medicine
	Vachellia erioloba (E. Mey.) P. J. H. Hurter	*Acacia giraffae* Willd.; *Acacia erioloba* E. Mey.	Camel thorn (Eng.); Giraffe thorn (Eng.); Mimosa (Eng.)	-	Prb	Bk; Mmb	Raw material/ fibre; medicine

Family	Species	Syn.	Common names	Statuses	Occ.	Macro-habitat	Potential uses
	Xeroderris stuhlmannii (Taub.) Mendonça and E. P. Sousa	*Aganope stuhlmannii* (Taub.) Adema	-	LC	Prb	Mg	Medicine; fuel; raw material/ fibre
Francoaceae	*Bersama abyssinica* Fresen.	-	Winged Bersama (Eng.); Bitter bark (Eng.)	-	Ps	Ch	Fuel; medicine
Lamiaceae	*Vitex doniana* Sweet	-	Black plum (Eng.)	LC	Ps	T; Ch	Forage; wild food; fuel; medicine
Lentibulariaceae	*Utricularia* L. sp.	-	-	-	C	Sw	-
Loganiaceae	*Strychnos cocculoides* Baker	-	Wild orange (Eng.); Bush orange (Eng.); Kasongole (Bemba)	LC	Ps	Mmb; Mg; Ch	Wild food; medicine
	Strychnos innocua L.	-	Dull-leaved strychnos (Eng.); Mulungi (Bemba)	LC	Ps	Mmb	Wild food; fuel; medicine; raw material/ fibre
	Strychnos lucens Baker	-	-	-	Ps	T	Medicine
	Strychnos potatorum L. f.	-	Grape strychnos (Eng.)	-	Ps	T ; Mg ; Ch ; Bk	Raw material/ fibre; medicine
	Strychnos pungens Soler.	-	-	LC	Prb	Ch	Wild food; medicine

Family	Species	Syn.	Common names	Statuses	Occ.	Macro-habitat	Potential uses
	Strychnos spynosa Lam.	-	-	-	Prb	Mg ; Ch ; Bk	-
Malvaceae	*Hibiscus* L. sp.	-	-	-	Prb	T	-
	Sterculia africana (Lour.) Fiori	-	False baobab (Eng.); Mukosa (Tonga)	LC	Ps	T	Forage; raw material/ fibre; medicine
	Abutilon angulatum (Guill. and Perr.) Mast.	-	Elephant's ear (Eng.); Fluted abutilon (Eng.)	-	Ps	T	Forage; fuel; medicine; raw material/ fibre
	Dombeya kirkii Mast.	-	-	-	Ps	T	Wild food; medicine; raw material/ fibre
	Dombeya rotundifolia (Hochst.) Planch.	-	Wild pear (Eng.)	LC	Ps	T; Mmb; Ch	Forage; wild food; medicine
	Grewia bicolor Juss.	-	Bastard brandy bush (Eng.); False brandy bush (Eng.); White-leaved grewia (Eng.)	-	Ps	T; Bk	Forage; fuel; medicine
	Sterculia quinqueloba (Garcke) K. Schum.	-	Mweemwe (Lenje; Bemba); Mukose (Tonga); Mulende (Tonga)	-	Ps	T	Medicine; raw material/ fibre

Family	Species	Syn.	Common names	Statuses	Occ.	Macro-habitat	Potential uses
	Adansonia digitate L.	-	Baobab (Eng.); Muuyu (Lenje); Ibbuyu (Bemba)	-	C	Mg; Bk; Mmb; Ch	Wild food; fuel; medicine; raw material/ fibre
	Triumfetta annua L.	-	Burweed (Eng.)	-	Ps	Bk	-
Meliaceae	*Ekebergia benguelensis* Welw. ex C. DC	-	Natal Mahogany (Eng.)	LC	Prb	Rs; Eg	Wild food; medicine; fuel
	Trichilia emetica Vahl	-	Mwela (Bemba); Cape ash (Eng.); Dog plum (Eng.)	-	Ps	Ch	-
Moraceae	*Ficus sycomorus* L.	-	Cikunyu (Bemba); Mukuyu (Tonga); Mupanda (Tonga); Sycamore fig (Eng.); Mulberry fig	LC	Prb	Mg; T; Ch	Medicine; wild food; raw material/ fiber; fuel
Myrtaceae	*Syzygium cordatum* Hochst. ex C. Krauss	-	Umdoni (Eng.); Water pear (Eng.); Waterberry (Eng.)	LC	Ps	T	Forage; wild food; raw material/ fiber; medicine
	Syzygium guineense (Willd.) DC.	-	-	LC	Prb	Ch; Eg; Mmb; Mg	-

Family	Species	Syn.	Common names	Statuses	Occ.	Macro-habitat	Potential uses
Nymphaeaceae	*Nymphaea lotus* L.	-	Egyptian lotus (Eng.)	LC	C	Rs	-
	Nymphaea nouchali Burm. f. var. *caerulea* (Savigny) Verdc.	*N. capensis* Thunb.	Blue lotus (Eng.)	LC	C	Sw	Medicine
Olacaceae	*Olax obtusifolia* De Wild.	-	-	-	Prb	Mmb	-
	Ximenia Americana L.	-	-	LC	Prb	Mg; T; Ch; Bk	-
Oleaceae	*Schrebera trichoclada* Welw.	-	-	LC	Prb	Mg; Ch	Fuel; raw material/ fibre; medicine
Onagraceae	*Ludwigia leptocarpa* (Nutt.) H. Hara	-	-	LC	C	Sw	Medicine

Family	Species	Syn.	Common names	Statuses	Occ.	Macro-habitat	Potential uses
Phyllanthaceae	*Pseudolachnostylis maprouneifolia* Pax	-	Mukunku (Tonga); Musangati (Bemba); Musolo (Tonga; Bemba)	-	Prb	Mg; Mmb; Ch	Wild food; medicine
	Securinega virosa (Roxb. Ex. Willd) Baill.	*Flueggia virosa* subsp. *virosa* (Roxb. Ex. Willd) Voigt	White-berry bush (Eng.)	-	Prb	Mg; Rs; T	Medicine; forage
	Uapaca nitida Mull. Arg.	-	-	-	Prb	Mmb; T	Wild food; fuel
	Uapaca kirkiana Mull. Arg.	-	-	LC	Prb	Mmb; T	-
	Bridelia micrantha (Hochst.) Baill.	-	-	LC	Prb	Mmb	-
	Phyllanthus reticulatus Poir var. *glaber* (Baill.) Mull-Arg.	-	-	-	Prb	T; Eg	Wild food; medicine; fuel
	Uapaca sansibarica Pax	-	Musokolwe (Lenje; Bemba)	LC	Ps	T	Wild food; raw material/ fibre; fuel; medicine
Polygalaceae	*Securidaca longepedunculata* Fresen.	-	Mupapala (Lenje); Bwazi (Tonga); Mupapi (Bemba); Violet tree (Eng.)	-	Ps	Mmb; Mg; Ch	Wild food; fuel; medicine; raw material/ fibre

Family	Species	Syn.	Common names	Statuses	Occ.	Macro-habitat	Potential uses
Polygonaceae	*Persicaria senegalensis* (Meisn.) Soják	*Polygonum senegalense* Meisn.	-	LC	C	Sw; T	-
	Polygonum sp.	-	-	-	Prb	Rs; Eg	-
Proteaceae	*Faurea saligna* Harvey	-	-	-	Prb	Mmb	-
Rhamnaceae	*Ziziphus mucronate* Willd.	-	Buffalo thorn (Eng.)	LC	Prb	Mg; Ch; T	Wild food; medicine
	Berchemia discolour (Klotzsc) Hemsl.	-	Bird plum (Eng.); Brown ivory (Eng.)	LC	Ps	T; Bk	Forage; wild food; raw material/ fibre; fuel
	Ziziphus mauritiana Lam.	-	-	LC	Ps	Mg	Forage; wild food; fuel; medicine
	Ziziphus abyssinica Hochst. ex A. Rich.	-	Abyssinian jujube; Catch thorn (Eng.); Kalanangwa, Kangwa, Kankono (Bemba)	LC	Ps	Mg; Ch	Wild food; fuel; medicine; raw material/ fibre

Family	Species	Syn.	Common names	Statuses	Occ.	Macro-habitat	Potential uses
Rubiaceae	*Canthium glaucum* Hiern subsp. *frangula* (S. Moore) Bridson	-	-	LC	Ps	Bk	-
	Catunaregam Wolf sp.	*Xeromphis* Raf. sp.	-	-	Prb	Mmb	-
Salicaceae	*Flacourtia indica* (Burm. f.) Merr.	-	-	LC	Prb	Mg; T	-
	Oncoba spinosa Forssk.	-	Snuff-box tree (Eng.)	LC	Ps	T	Wild food; raw material/ fibre; medicine
	Salix L. sp.	-	-	-	Prb	Rs; Eg	-
Steganotaenia	*Steganotaenia araliacea* Hochst.	-	Carrot tree (Eng.)	LC	Ps	T	Forage; fuel; medicine
Thymelaeaceae	*Craterosiphon quarrei* Staner	-	Mufundansofu (Bemba); Mujansefu (Tonga); Mukole (bemba)	LC	Prb	Mmb	-
Vitaceae	*Rhoicissus tridentate* (L. f.) Wild and R. B. Drumm.	-	-	-	Ps	T	Forage; medicine; wild food

Family	Species	Syn.	Common names	Statuses	Occ.	Macro-habitat	Potential uses
Zygophyllaceae	*Balanites aegyptiaca* (L.) Delile	-	Desert date (Eng.)	LC	Ps	T; Bk	Forage; wild food; raw material/ fibre; fuel; medicine

Sources:
Bingham *et al*., 2020; Bingham and Smith, 2002; BirdWatch Zambia, 2017; BWZ and DoF, 2019; CAB International, 2020; Chabwela, 1998, in Chabwela *et al*., 2010; Chabwela *et al*., 2010; Chabwela, Chomba and Thole, 2017;
Fern, 2019; Golding, 2002; Guiry and Guiry (2020); INRA, CIRAD, AFZ and FAO, 2012-2019; IUCN, 2020; Kennedy and Murphy, 2012; Kindt *et al*., 2011a and b; van Oudtshoorn, 2012; Phiri, 2005; POWO, 2019; PROTA4U, 2020; White, F. and ILDIS, 2018.

Legend:
Statuses: LC - Low Concern; NT - Near Threatened (IUCN, 2020); End - endemic genus of the Zambezian Centre of Endemism (White, 1983); Int. – non-native species to Zambia; Inv. – species with invasive status (CAB International, 2020).
Occurrence: C – confirmed; Prb – probable; Ps – possible/ potential.
Macro-habitat: Sw – swamp; Eg – edaphic grassland; T – termitaria; Mmb – miombo; Mg – munga; Ch – chipya; Bk – Baikiaea.

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Appendix C – Fauna species list

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Table 6 – Fauna species list for the Lukanga swamp and surrounding terrestrial macro-habitats

Species name	Common name	Phenology / migration patterns	IUCN	Other statuses	Occ.	Habitat use	Uses
Phyllum ROTIFERA							
Class EUROTATORIA							
PLOIMA							
Asplanchnidae							
Asplanchna herricki Guerne, 1888	-	-	-	-	C	Sw (canal)	-
Brachionidae							
Brachionus angularis Gosse, 1851	-	-	-	-	C	Sw (canal)	-
Brachionus budapestinensis Daday, 1885	-	-	-	-	C	Sw (canal)	-
Brachionus quadridentatus Hermann, 1783	-	-	-	-	C	Sw (canal)	-
Keratella valga Ehrenberg, 1834	-	-	-	-	C	Sw (canal)	-
Lecanidae							
Lecane bulla (Gosse, 1851)	-	-	-	-	C	Sw (canal)	-
Monostyla sp. Ehrenberg, 1930	-	-	-	-	C	Sw (canal)	-

Species name	Common name	Phenology / migration patterns	IUCN	Other statuses	Occ.	Habitat use	Uses
Lepadellidae							
Colurella obtuse Gosse, 1886	-	-	-	-	C	Sw (canal)	-
Lepadella oblonga Ehrenberg, 1834	-	-	-	-	C	Sw (canal)	-
Trichocercidae							
Diurella stylata Eyferth, 1878	-	-	-	-	C	Sw (canal)	-
Trichocerca pusilla Jennings, 1903	-	-	-	-	C	Sw (canal)	-
Phyllum MOLLUSCA							
Class GASTROPODA							
ARCHITAENIOGLOSSA							
Ampullaridae							
Lanistes ovum Peters, 1845	-	-	LC	-	Pos	Rs; Sw	-
Pila occidentalis (Mousson, 1887)	-	-	LC	-	Pos	Rs; Sw; L	Food
Viviparidae							
Bellamyia capillata (Frauenfeld, 1865)	-	-	LC	-	Pos	Rs; L	-

Species name	Common name	Phenology / migration patterns	IUCN	Other statuses	Occ.	Habitat use	Uses
HYGROPHILA							
Lymnaeidae							
Cleopatra nsendweensis Dupuis and Putzeys, 1902	-	-	LC	-	Pos	Rs	-
Radix natalensis (Krauss, 1848)	-	-	LC	-	Pos	Rs; L; Sw	-
Planorbidae							
Biomphalaria pfeifferi (Krauss, 1848)	-	-	LC	-	Pos	Rs; L	-
Biomphalaria rhodesiensis Mandahl-Barth, 1957	-	-	DD	-	Pos	Rs; Rw	-
Bulinus forskalii (Ehrenberg, 1831)	-	-	LC	-	Pos	Rs; Sw; L	-
Bulinus globosus (Morelet, 1866)	-	-	LC	-	Pos	Rs; Sw; L	-
Bulinus scalaris (Dunker, 1845)	-	-	LC	-	Pos	Rs; Eg	-
Bulinus truncates (Audouin, 1827)	-	-	LC	-	Pos	Rs; Sw	-
Pettancylus victoriensis (Walker, 1912)	-	-	DD	-	Pos	Rs; Sw; L	-
LITTORINIMORPHA							
Bithyniidae							
Gabbiella kisalensis (Pilsbry and Beqaert, 1927)	-	-	LC	-	Pos	Rs	-
Hydrobiidae							
Lobogenes michaelis Pilsbry and Bequaert, 1927	-	-	EN	-	Pos	Rs; L; Sw	-

Species name	Common name	Phenology / migration patterns	IUCN	Other statuses	Occ.	Habitat use	Uses
SORBEOCONCHA							
Paludomidae							
Martelia dautzenbergi Dupuis, 1924	-	-	LC	-	Pos	L	-
Martelia tanganyicensis Dautzenberg, 1908	-	-	LC	-	Pos	L	-
Class BIVALVIA							
UNIONOIDA							
Iridinidae							
Aspatharia pfeifferiana (Bernardi, 1860)	**-**	**-**	LC	-	Pos	Rs	**-**
Mutela zambesiensis Mandahl-Barth, 1988	**-**	**-**	LC	-	Pos	Rs; L	**-**
Chambardia wahlbergi (Krauss, 1848)	**-**	**-**	LC	-	Pos	Rs; L	Food
Unionidae							
Cafferia caffer Krauss, 1848	-	-	LC	-	Pos	Rs; L; Sw	-
Coelatura kunenensis (Mousson, 1887)	-	-	LC	-	Pos	Rs	-

Species name	Common name	Phenology / migration patterns	IUCN	Other statuses	Occ.	Habitat use	Uses
Phyllum ARTHROPODA							
Subphyllum CRUSTACEA							
Class BRANCHIOPODA							
ANOMOPODA							
Chydoridae							
Chydorus sphaericus Muller, 1776	-	-	-	-	C	Sw (canal)	-
Daphniidae							
Simocephalus vetuloides Sars, 1899	-	-	-	-	C	Sw (canal)	-
CYCLOPOIDA							
Cyclopidae							
Cyclops sp. Muller, 1785	-	-	-	-	C	Sw (canal)	-

Species name	Common name	Phenology / migration patterns	IUCN	Other statuses	Occ.	Habitat use	Uses
Phyllum CHORDATA							
Class ACTINOPTERYGII (ichthyofauna)							
CHARACIFORMES							
Alestidae							
Brycinus imberi (Peters, 1852)	Spot-tail Robber	Full migrant	LC	-	Prb	Rs; Sw; L	Food
Brycinus lateralis (Boulenger, 1900)	Stripped Robber; Stripe-tailed Robber	-	LC	-	C	Rs	Food
CYPRINIFORMES							
Cyprinidae							
Enteromius paludinosus (Peters, 1852)	Straightfin Barb	Full migrant	LC	-	C	Rs; Sw; L	Food

Species name	Common name	Phenology / migration patterns	IUCN	Other statuses	Occ.	Habitat use	Uses
OSTEOGLOSSIFORMES							
Mormyridae							
Marcusenius macrolepidotus (Peters, 1852)	Bulldog; Lububu (Bemba); Mintesa (Bemba); Nchesu (Bemba)	Full migrant	LC	-	C	Rs; Sw	Food
Petrocephalus catostoma David and Poll, 1937	-	Full migrant	LC	-	C	Rs; Sw; L	Food
PERCIFORMES							
Anabantidae							
Ctenopoma multispine Peters, 1844	Many Spined Climbing Perch	-	VU	-	C	Rs; Sw	Food
Cichlidae							
Oreochromis macrochir (Boulenger, 1912)	Greenhead Tilapia	-	VU	-	C	Rs; L	Food
Oreochromis niloticus (Linnaeus, 1758) (syn. Tilapia niloticus [Linnaeus, 1758])	Nile Tilapia	-	LC	Int./Inv.	Prb	Rs; Sw; L	Food

Species name	Common name	Phenology / migration patterns	IUCN	Other statuses	Occ.	Habitat use	Uses
Pseudocrenilabrus philander (Weber, 1897)	-	Nomadic	LC	-	C	Rs; L	Food
Serranochromis angusticeps (Boulenger, 1907)	Thinface Cichlid; Speckleface Bream; Thinface Bream	-	LC	-	C	Rs; Sw; L	Food
Serranochromis robustus (Gunther, 1864)	Yellow-belly bream	Not a migrant	CR	-	Prb	Rs; L	Food
Tilapia sparrmanii Smith, 1840	Banded Tilapia; Banded Bream; Sparrman's Bream	Full migrant	LC	-	C	Rs; Sw; L	Food

Species name	Common name	Phenology / migration patterns	IUCN	Other statuses	Occ.	Habitat use	Uses
SILURIFORMES							
Clariidae							
Clarias gariepinus (Burchell, 1822)	African catfish; African Sharptoothed Catfish; barbell; Common catfish; Mudfish	Not a migrant	LC	-	C	Rs; Sw; L	Food
Clarias ngamensis Castelnau, 1861	Blunt-toothed African catfish	Full migrant	LC	-	C	Rs; Sw; L	Food
Clarias stappersii Boulenger, 1915	Blotched Catfish	Not a migrant	LC	-	C	Rs; Sw; L	Food
Clarias theodorae Weber, 1897	Snake Catfish	-	LC	-	C	Rs; Sw; L	Food

Species name	Common name	Phenology / migration patterns	IUCN	Other statuses	Occ.	Habitat use	Uses
Class AMPHIBIA (herpetofauna)							
ANURA							
Arthroleptidae							
Arthroleptis stenodactylus Pfeffer, 1893	Common Squeaker; Dune Squeaker	-	LC	-	Pos	Ch; Mg; T; Cm	-
Leptopelis bocagii (Gunther, 1865)	Bocage's Tree Frog	-	LC	-	Pos	Ch; Mg; T; Eg	-
Brevicipitidae							
Breviceps poweri Parker, 1934	Power's Rain frog	-	LC	-	Pos	Ch; Mg; T	-
Bufonidae							
Sclerophrys gutturalis (Power, 1927)	African Common Toad; Gutteral Toad	-	LC	-	Pos	Mmb; Ch; Mg; Bk; T; Eg; L; Cm	-
Sclerophrys lemairii (Boulenger, 1901)	Lemaire's Toad	-	LC	-	Pos	Eg; Sw	-
Sclerophrys pusilla (Mertens, 1937)	Merten's Striped Toad	-	LC	-	Pos	Ch; Mg; T; Rs	-

Species name	Common name	Phenology / migration patterns	IUCN	Other statuses	Occ.	Habitat use	Uses
Schismaderma carens (Smith, 1848)	African Red Toad; African Split-skin Toad	-	LC	-	Pos	Ch; Mg; T; Cm	-
Hemisotidae							
Hemisus guineensis Cope, 1865	Guinea Snout-burrower	-	LC	-	Pos	Ch; Mg; T	-
Hemisus marmoratus (Peters, 1854)	Marbled Shovel-snout Frog	-	LC	-	Pos	Mmb; Ch; Mg; Bk; T; Eg; Cm	-
Hyperoliidae							
Afrixalus wittei (Laurent, 1941)	De Witte's Spiny Reed Frog	-	LC	-	Pos	Eg; Sw	-
Hyperolius marginatus Peters, 1854	Margined Reed Frog	-	LC	-	Pos	Ch; Mg; T; Eg; Rs; Sw; L; Cm	-

Species name	Common name	Phenology / migration patterns	IUCN	Other statuses	Occ.	Habitat use	Uses
Hyperolius benguellensis (Bocage, 1893)	Benguella Long reed frog	-	LC	-	Pos	Ch; Mg; T; Eg; Rs; Sw; L	-
Hyperolius kivuensis Ahl, 1931	Kivu Reed frog	-	LC	-	Pos	Mmb; Ch; Mg; Bk; Eg; Cm	-
Hyperolius quinquevittatus Bocage, 1866	Five-striped Reed frog	-	LC	-	Pos	Sw	-
Kassina senegalensis (Duméril and Bibron, 1841)	Senegal Kassina; Bubbling Kassina	-	LC	-	Pos	Ch; Mg; T; Sw	-
Hyperolius nasicus Laurent, 1943	Pointed Long Reed Frog	-	LC	-	Pos	Ch; Mg, T; Eg; Rs; Sw	-

Species name	Common name	Phenology / migration patterns	IUCN	Other statuses	Occ.	Habitat use	Uses
Microhylidae							
Phrynomantis affinis Boulenger, 1901	Spotted Rubber Frog	-	LC	-	Pos	Ch; Mg; T	
Phrynomantis bifasciatus (Smith, 1847)	Banded Rubber Frog	-	LC	-	Pos	Ch; Mg; T; Eg; Cm	-
Phrynobatrachidae							
Phrynobatrachus mababiensis FitzSimons, 1932	Mababe Puddle Frog; Dwarf Puddle Frog	-	LC	-	Pos	Ch; Mg; T; Eg; Rs; Sw; L; Cm	-
Phrynobatrachus natalensis (Smith, 1848)	Natal Dwarf Puddle Frog; Snoring Puddle Frog	-	LC	-	Pos	Mmb; Ch; Mg; Bk; T; Eg; Rs; Sw; L; Cm	-
Phrynobatrachus parvulus (Boulenger, 1905)	Dwarf Puddle Frog	-	LC	-	Pos	Eg; Sw; Cm	-
Phrynobatrachus perpalmatus Boulenger, 1898	Webbed Puddle Frog	-	LC	-	Pos	Mg; Ch; T; Eg; Sw; Cm	-

Species name	Common name	Phenology / migration patterns	IUCN	Other statuses	Occ.	Habitat use	Uses
Pipidae							
Xenopus laevis (Daudin, 1802)	African Clawed Frog	-	LC	-	Pos	Ch; Mg; T; Eg; Rs; L; Sw	-
Xenopus muelleri (Peters, 1844)	Muller's Clawed Toad/Frog	-	LC	-	Pos	Ch; Mg; T; Eg; Rs; L; Sw; Cm	-
Xenopus petersii Bocage, 1895	Peter's Platanna	-	LC	-	Pos	Ch; Mg; T; Eg; Rs; L; Sw; Cm	-
Ptychadenidae							
Ptychadena anchietae (Bocage, 1868)	Plain Grass Frog; Anchieta'a Ridged Frog	-	LC	-	Pos	Ch; Mg; T; Rs; L; Cm	-
Ptychadena ansorgii (Boulenger, 1905)	Ansorge's Ridged Frog	-	LC	-	Pos	Mmb; Ch; Mg; Bk; T; Eg; Rs	-

Species name	Common name	Phenology / migration patterns	IUCN	Other statuses	Occ.	Habitat use	Uses
Ptychadena guibei Laurent, 1954	Gube's Ridged Frog	-	LC	-	Pos	Eg; Sw	-
Ptychadena mascareniensis (Duméril and Bibron, 1841)	Mascarene Grass Frog	-	LC	-	Pos	Mmb; Ch; Mg; Bk; T; Rs; Eg; L; Cm; Sw	-
Ptychadena mossambica (Peters, 1854)	Mozambique Ridged Frog	-	LC	-	Pos	Mmb; Ch; Mg; Bk; T; Eg; Sw; Cm	-
Ptychadena obscura (Schmidt and Inger, 1959)	Dark Ridged Frog	-	LC	-	Pos	Eg; Sw; L	-
Ptychadena oxyrhynchus (Smith, 1849)	Sharp-nosed Frog; Sharp-nosed Ridged Frog	-	LC	-	Pos	Mmb; Ch; Mg; Bk; T; Eg; Cm	-
Ptychadena subpunctata (Bocage, 1866)	Spotted Ridged Frog	-	LC	-	Pos	Ch; Mg; T; Rs; Sw	-

Species name	Common name	Phenology / migration patterns	IUCN	Other statuses	Occ.	Habitat use	Uses
Ptychadena taenioscelis Laurent, 1954	Dwarf Grass Frog; Lukula Grassland Frog; Small Ridged Frog; Spotted Throated Risged Frog	-	LC	-	Pos	Ch; Mg; T; Eg; Sw	-
Ptychadena upembae (Schmidt and Inger, 1959)	Upemba Ridged Frog	-	LC	-	Pos	Eg	-
Ptychadena uzungwensis (Loveridge, 1932)	Udzungwa Ridged Frog	-	LC	-	Pos	Eg; Sw	-
Pyxicephalidae							
Pyxicephalus adspersus Tschudi, 1838	African Bullfrog	-	LC	-	Pos	Ch; Mg; T; Cm	-
Pryxicephalus edulis Peters, 1854	Edible Bullfrog; lesser Bullfrog	-	LC	-	Pos	Mmb; Ch; Mg; Bk; T; Eg; Cm	-
Tomopterna tuberculosa (Boulenger, 1882)	Rough Sand Frog	-	LC	-	Pos	Ch; Mg; T	-

Species name	Common name	Phenology / migration patterns	IUCN	Other statuses	Occ.	Habitat use	Uses
Ranidae							
Amnirana darling (Boulenger, 1902)	Darling's White-liped Frog	-	LC	-	Pos	Mmb; Ch; Mg; Bk; T; Rs; Eg; L; Cm	-
Rhacophoridae							
Chiromantis xerampelina Peters, 1854	Grey Foam-nest Tree frog	-	LC	-	Pos	Mmb; Ch; Mg; Bk; T; Sw; L; Cm	-
Class REPTILIA (Herpetofauna)							
CROCODYLIA							
Crocodylidae							
Crocodylus niloticus Laurenti, 1768	Nile crocodile	-	LC	-	Ext	Rs	-
SQUAMATA							
Chamaelonidae							
Chamaeleo dilepis Leach, 1819	Common Flap-necked CHameleon	-	LC	-	Pos	Mmb; Bk; Ch; Mg; T	-

Species name	Common name	Phenology / migration patterns	IUCN	Other statuses	Occ.	Habitat use	Uses
Colubridae							
Dasypeltis scabra (Linnaeus, 1758)	Common Egg Eater; Rhombic Egg Eater	-	LC	-	Pos	Mmb; Bk; Ch; Mg; T;Cm	-
Meizodon semiornatus (Peters, 1854)	Semiornate Smooth Snake	-	-	-	Pos	-	-
Philothamnus hoplogaster (Gunther, 1863)	Green Water Snake	-	-	-	Pos	-	-
Thelotornis capensis A. Smith, 1849	Southern Twig Snake; Bird Snake	-	LC	-	Pos	Mmb; Bk; Ch; Mg; T	-
Elapidae							
Elapsoidea guentheri Bocage, 1866	Gunther's Garter Snake	-	-	-	Pos	Mmb; Ch; Mg; T	-
Elapsoidea semiannulata Bocage, 1882	Angola Garter Snake	-	-	-	Pos	Mmb; Ch; Mg; T	-

Species name	Common name	Phenology / migration patterns	IUCN	Other statuses	Occ.	Habitat use	Uses
Lamprophiidae							
Gracililima nyassae (Gunther, 1888)	Black File Snake	-	LC	-	Pos	Mmb; Ch; Mg; Bk	-
Psammophis lineatus (Duméril, Bibron and Duméril, 1854)	Lined Olympic Snake	-	-	-	Pos	-	-
Natricidae							
Natriciteres olivacea (Peters, 1854)	Olive Marsh Snake	-	LC	-	Pos	Mmb; Bk; Ch; Mg; T; Eg; Sw	-
Limnophis bicolor Gunther, 1865	Bicoloured Swamp Snake	-	-	-	Pos	-	-
Prosymnidae							
Prosymna ambigua Bocage, 1873	East African Shovel-snout	-	LC	-	Pos	Mmb; Ch; Mg; Bk; T	-

Species name	Common name	Phenology / migration patterns	IUCN	Other statuses	Occ.	Habitat use	Uses
Psammophiidae							
Psammophylax tritaeniatus (Gunther, 1868)	Three-lined Grass snake; Striped Grass Snake	-	LC	-	Pos	Ch; Mg; T; Eg	-
Pythonidae							
Python natalensis Smith, 1840	Southern African Python	-	-	-	Pos	Ch; Mg; Mmb; T; Sw	-
Scincidae							
Mochlus sundevallii (A. Smith., 1849)	Sundevall's Writhing Skink	-	LC	-	Pos	Mmb; Bk; Ch; Mg; T	-
Varanidae							
Varanus niloticus (Linnaeus, 1766)	Nile monitor	-	-	-	Pos	Mmb; Ch; Mg; T; Sw; Rs; L	
Viviperidae							
Causus bilineatus Boulenger, 1905	Two-lined Night Adder	-	-	-	Pos	-	-

Species name	Common name	Phenology / migration patterns	IUCN	Other statuses	Occ.	Habitat use	Uses
Pelomedusidae							
Pelusios rhodesianus Hewitt, 1927	Mashona Hinged Terrapin	-	LC	-	Pos	Sw; Eg	-
Testudinidae							
Stigmochelys pardalis (Bell, 1828)	Leopard tortoise	-	LC	-	Pos	T	-
Kinixys spekii Gray, 1863	Speke's Hinged-back Tortoise	-	-	-	Pos	Mmb; Ch; Mg; T	-
Class AVES (avifauna)							
ACCIPITRIFORMES							
Accipitridae							
Accipiter badius (Gmelin, JF, 1788)	Shikra	R	LC	-	Prb	Ch; Mg; T; Cm	-
Accipiter melanoleucus Smith, A, 1830	Black Sparrowhawk	R	LC	-	Prb	T; Rs; Cm	-
Accipiter ovampensis Gurney, 1875	Ovambo Sparrowhawk	R	LC	-	Prb	Ch; Mg; T; Cm	-
Accipiter tachiro (Daudin, 1800)	African Goshawk	R	LC	-	Prb	Rs; Cm	-

Species name	Common name	Phenology / migration patterns	IUCN	Other statuses	Occ.	Habitat use	Uses
Aquila nipalensis Hodgson, 1833	Steppe Eagle	P	EN	-	Prb	T	-
Aquila spilogaster (Bonaparte, 1850)	African Hawk-eagle	R	LC	-	Prb	Ch; Mg; T	-
Buteo buteo (Linnaeus, 1758)	Eurasian Buzzard	P	LC	-	Prb	Sw; L; Eg; Cm	-
Circaetus cinerascens von Müller, JW, 1851	Western Banded Snake-eagle	R	LC	-	Prb	Mg; Ch; Rs	-
Circaetus cinereus Vieillot, 1818	Brown Snake-eagle	PP	LC	-	Prb	Mmb; Mg; Bk; Ch; T	-
Circaetus pectoralis Smith, A, 1829	Black-chested Snake-eagle	PP	LC	-	Prb	Ch; Mg; T	-
Circus macrourus (Gmelin, SG, 1770)	Pallid Harrier	P	NT	CC	Prb	Ch; Mg; Sw	-
Circus ranivorus (Daudin, 1800)	African Marsh-harrier	R	LC	cc	Prb	Sw	-
Clanga pomarina (Brehm, CL, 1831)	Lesser Spotted Eagle	P	LC	-	Prb	Ch; Mg; T; Eg	-

Species name	Common name	Phenology / migration patterns	IUCN	Other statuses	Occ.	Habitat use	Uses
Elanus caeruleus (Desfontaines, 1789)	Black-winged Kite	PP	LC	-	Prb	Mg; Ch	-
Gyps africanus Salvadori, 1865	White-backed Vulture	R	CR	-	Prb	Mmb; Mg; Bk; Ch; T; Eg	-
Haliaeetus vocifer (Daudin, 1800)	African Fish-eagle	R	LC	-	Prb	Rs; Sw; L	-
Hieraaetus ayresii (Gurney, 1862)	Ayres's Hawk-eagle	PP	LC	-	Prb	Mmb; Mg; Ch; Bk	-
Hieraaetus wahlbergi (Sundevall, 1850)	Wahlberg's Eagle	A	LC	-	Prb	Ch; Mg; T	-
Kaupifalco monogrammicus (Temminck, 1824)	Lizard Buzzard	**R**	**LC**	**-**	**Prb**	Ch; Mg; T	-
Lophaetus occipitalis (Daudin, 1800)	Long-crested Eagle	R	LC	-	Prb	T; Eg; Sw	-
Macheiramphus alcinus Bonaparte, 1850	Bat Hawk	R	LC	-	Prb	Mmb; Ch; Mg; Bk; T; L	-

Species name	Common name	Phenology / migration patterns	IUCN	Other statuses	Occ.	Habitat use	Uses
Melierax metabates Heuglin, 1861	Dark Chanting-goshawk	R	LC	-	Prb	Mmb; Ch; Mg; Bk; T	-
Micronisus gabar (Daudin, 1800)	Gabar Goshawk	R	LC	-	Prb	Mmb; Ch; Mg; Bk; T; Rs	-
Milvus migrans (Boddaert, 1783)	Black Kite	P-migrans A-parasitus	LC	-	Prb	Mmb; Mg; Ch; Bk; T;Sw; Eg; Cm	-
Polemaetus bellicosus (Daudin, 1800)	Martial Eagle	R	VU	-	Prb	Ch; Mg; T; Rs	-
Polyboroides typus Smith, A, 1829	African Harrier-hawk	R	LC	-	Prb	Ch; Mg; Rs	-
Terathopius ecaudatus (Daudin, 1800)	Bateleur	PP	NT	cc	Prb	Mmb; Ch; Mg; Bk; T	-
Trigonoceps occipitalis (Burchell, 1824)	White-headed Vulture	R	CR	-	Prb	Ch; Mg; T; Eg	-

Species name	Common name	Phenology / migration patterns	IUCN	Other statuses	Occ.	Habitat use	Uses
ANSERIFORMES							
Anatidae							
Alopochen aegyptiaca (Linnaeus, 1766)	Egyptian Goose	PP	LC	-	Prb	Eg; Sw; L	-
Anas erythrorhyncha Gmelin, JF, 1789	Red-billed Teal	PP	LC	-	Prb	Eg; Rs; L; Sw	-
Anas sparsa Eyton, 1838	African Black Duck	R	LC	-	Prb	T; Rs;L	-
Anas undulata Dubois, CF, 1838	Yellow-billed Duck	PP	LC	-	C	Eg; Rs; Sw; L	-
Dendrocygna bicolor (Vieillot, 1816)	Fulvous Whistling-duck	PP	LC	-	Prb	Sw	-
Dendrocygna viduata (Linnaeus, 1766)	White-faced Whistling-duck	PP	LC	-	Prb	Sw	-
Netta erythrophthalma (zu Wied-Neuwied, 1833)	Southern Pochard	PP	LC	-	Prb	L; Sw	-
Nettapus auritus (Boddaert, 1783)	African Pygmy-goose	**PP**	**LC**	**-**	**Prb**	Rs; L; Sw	**-**

Species name	Common name	Phenology / migration patterns	IUCN	Other statuses	Occ.	Habitat use	Uses
Plectropterus gambensis (Linnaeus, 1766)	Spur-winged Goose	PP	LC	-	Prb	T; Eg; Sw; Rs	-
Sarkidiornis melanotos (Pennant, 1769)	African Comb Duck	PP	LC	-	Prb	Eg; Rs; Sw; L	-
Spatula hottentota (Eyton, 1838)	Hottentot Teal	PP	LC	-	Prb	Eg; Sw	-
Thalassornis leuconotus Eyton, 1838	White-backed Duck	PP	LC	-	Prb	Sw	-
APODIFORMES							
Apodidae							
Apus apus (Linnaeus, 1758)	Common Swift	P	LC	-	Prb	Ch; Mg; T, Eg; L	-
Apus caffer (Lichtenstein, MHK, 1823)	White-rumped Swift	A	LC	-	Prb	Ch; Mg; T	-
Cypsiurus parvus (Lichtenstein, MHK, 1823)	African Palm-swift	R	LC	-	Prb	Mmb; Ch; Mg; Bk; T	-

Species name	Common name	Phenology / migration patterns	IUCN	Other statuses	Occ.	Habitat use	Uses
BECEROTIFORMES							
Bucerotidae							
Bycanistes bucinator (Temminck, 1824)	Trumpeter Hornbill	R	LC	-	Prb	Mmb; Bk; Ch; Mg; T	-
Lophoceros alboterminatus Büttikofer, 1889	Crowned Hornbill	R	LC	-	Prb	Mmb; Bk; Ch; Mg; T	-
Lophoceros nasutus (Linnaeus, 1766)	African Grey Hornbill	R	LC	-	Prb	Mmb; Bk; Ch; Mg; T	-
Lophoceros pallidirostris (Hartlaub and Finsch, 1870)	Pale-billed Hornbill	R	LC	-	Prb	Mmb; Bk; Ch; Mg; T	-
Phoeniculidae							
Bucorvus leadbeateri (Vigors, 1825)	Southern Ground-hornbill	R	VU	cc	Prb	Mmb; Bk; Ch; Mg; T; Cm	-
Rhinopomastus cyanomelas (Vieillot, 1819)	Common Scimitarbill	R	LC	-	Prb	Mmb; Bk; Ch; Mg; T	-

Species name	Common name	Phenology / migration patterns	IUCN	Other statuses	Occ.	Habitat use	Uses
Upupidae							
Upupa epops Bechstein, 1811	Common Hoopoe	A	LC	-	Prb	Ch; Mg; T; Cm	-
CAPRIMULGIFORMES							
Caprimulgidae							
Caprimulgus fossii Hartlaub, 1857	Mozambique Nightjar	PP	LC	-	Prb	Ch; Mg; T	-
Caprimulgus pectoralis Cuvier, 1816	Fiery-necked Nightjar	PP	LC	-	Prb	Ch; Mg; T	-
Caprimulgus vexillarius (Gould, 1838)	Pennant-winged Nightjar	A	LC	-	Prb	Ch; Mg; T	-
CHARADRIIFORMES							
Burhinidae							
Burhinus vermiculatus (Cabanis, 1868)	Water Thick-knee	R	LC	-	Prb	Ch; Mg; T; Rs; L	-
Charadriidae							
Charadrius asiaticus Pallas, 1773	Caspian Plover	P	LC	-	Prb	Eg; Rs; L	-
Charadrius forbesi (Shelley, 1883)	Forbes's Plover	PP-RR	LC	-	Prb	Ch; Mg; T; Rs; L	-

Species name	Common name	Phenology / migration patterns	IUCN	Other statuses	Occ.	Habitat use	Uses
Charadrius hiaticula Linnaeus, 1758	Common Ringed Plover	P	LC	-	Prb	Eg; Rs; L	-
Charadrius marginatus Vieillot, 1818	White-fronted Plover	PP	LC	-	Prb	Rs; L	-
Charadrius pecuarius Temminck, 1823	Kittlitz's Plover	PP	LC	-	Prb	Eg; Rs; L	-
Charadrius tricollaris Vieillot, 1818	African Three-banded Plover	PP	LC	-	Prb	Rs; L	-
Vanellus armatus (Burchell, 1822)	Blacksmith Lapwing	PP	LC	-	Prb	Eg; Rs; L; T	-
Vanellus coronatus (Boddaert, 1783)	Crowned Lapwing	A	LC	-	Prb	Ch; Mg; T	-
Vanellus crassirostris (Hartlaub, 1855)	Long-toed Lapwing	R	LC	-	C	Eg; Rs; Sw; L	-
Vanellus senegallus (Linnaeus, 1766)	Wattled Lapwing	PP	LC	-	Prb	Ch; Mg; T; Rs; L	-

Species name	Common name	Phenology / migration patterns	IUCN	Other statuses	Occ.	Habitat use	Uses
Glareolidae							
Cursorius temminckii Swainson, 1822	Temminck's Courser	A	LC	-	Prb	Ch; Mg; T	-
Glareola pratincola (Linnaeus, 1766)	Collared Pratincole	PP	LC	-	Prb	Eg; Rs; L	-
Rhinoptilus chalcopterus (Temminck, 1824)	Bronze-winged Courser	A	LC	-	Prb	Ch; Mg; T	-
Jacanidae							
Actophilornis africanus (Gmelin, JF, 1789)	African Jacana	PP	LC	-	C	Eg; Rs; L; Sw	-
Microparra capensis (Smith, A, 1839)	Lesser Jacana	PP	LC	-	Prb	Rs; L	-
Laridae							
Chlidonias hybrid (Pallas, 1811)	Whiskered Tern	PP	LC	-	Prb	Sw	-
Chlidonias leucopterus (Temminck, 1815)	White-winged Tern	P	LC	-	Prb	Eg; Rs; Sw; L	-
Larus cirrocephalus Vieillot, 1818	Grey-headed Gull	PP	LC	-	C	Rs; Sw; L	-

Species name	Common name	Phenology / migration patterns	IUCN	Other statuses	Occ.	Habitat use	Uses
Rynchops flavirostris Vieillot, 1816	African Skimmer	PP	NT	CC	Prb	Rs; Sw; L	-
Rostratulidae							
Rostratula benghalensis (Linnaeus, 1758)	Greater Painted-snipe	PP	LC	-	Prb	Rs; Sw; L	-
Scolopacidae							
Actitis hypoleucos (Linnaeus, 1758)	Common Sandpiper	P	LC	-	Prb	Rs; L	-
Arenaria interpres (Linnaeus, 1758)	Ruddy Turnstone	P	LC	-	Prb	Sw; L; Rs	-
Calidris ferruginea (Pontoppidan, 1763)	Curlew Sandpiper	P	NT	-	Prb	L	-
Calidris minuta (Leisler, 1812)	Little Stint	P	LC	-	Prb	Rs; Sw	-
Calidris pugnax (Linnaeus, 1758)	Ruff	P	LC	-	Prb	Eg; L	-
Gallinago media (Latham, 1787)	Great Snipe	P	NT	CC	Prb	Ch; Mg; T; Eg; Sw	-
Gallinago nigripennis Bonaparte, 1839	African Snipe	PP	LC	-	Prb	Eg; Sw	-
Tringa glareola Linnaeus, 1758	Wood Sandpiper	P	LC	-	Prb	Eg; Rs; Sw; L	-

Species name	Common name	Phenology / migration patterns	IUCN	Other statuses	Occ.	Habitat use	Uses
Tringa nebularia (Gunnerus, 1767)	Common Greenshank	P	LC	-	Prb	Eg; Rs; Sw; L	-
Tringa ochropus Linnaeus, 1758	Green Sandpiper	P	LC	-	Prb	Eg; Rs; Sw; L	-
Tringa stagnatilis (Bechstein, 1803)	Marsh Sandpiper	P	LC	-	Prb	Rs	-
Xenus cinereus (Güldenstädt, 1775)	Terek Sandpiper	P-RR	LC	-	Prb	Rs; Sw; L	-
Turnicidae							
Turnix nanus (Sundevall, 1850)	Black-rumped Buttonquail	A	LC	-	Prb	Ch; Mg; T; Eg	-
Turnix sylvaticus (Desfontaines, 1789)	Common Buttonquail	R	LC	-	Prb	T	-
CICONIIFORMES							
Ciconiidae							
Anastomus lamelligerus Temminck, 1823	African Openbill	PP	LC	-	C	Eg; Rs; Sw; L	-
Ciconia abdimii Lichtenstein, MHK, 1823	Abdim's Stork	A	LC	-	Prb	Ch; Mg; Sw	-
Ciconia ciconia (Linnaeus, 1758)	White Stork	P	LC	-	Prb	Eg	-

Species name	Common name	Phenology / migration patterns	IUCN	Other statuses	Occ.	Habitat use	Uses
Ciconia microscelis Gray, GR, 1848	African Woollyneck	PP	LC	-	Prb	Eg; Rs; Sw	-
Ephippiorhynchus senegalensis (Shaw, 1800)	Saddlebill	R	LC	cc	Prb	Eg; Rs; Sw	-
Leptoptilos crumenifer (Lesson, R, 1831)	Marabou	PP	LC	-	Prb	Ch; Mg; L	-
Mycteria ibis (Linnaeus, 1766)	Yellow-billed Stork	PP	LC	-	Prb	Sw; L	-
COLIIFORMES							
Coliidae							
Urocolius indicus (Latham, 1790)	Red-faced Mousebird	R	LC	-	Prb	Ch; Mg; T	-
COLUMBIFORMES							
Columbidae							
Oena capensis (Linnaeus, 1766)	Namaqua Dove	A	LC	-	Prb	Ch; Mg; T	-
Spilopelia senegalensis (Linnaeus, 1766)	Laughing Dove	A	LC	-	Prb	Ch; Mg; T	-
Streptopelia capicola (Sundevall, 1857)	Ring-necked Dove	R	LC	-	Prb	Ch; Mg; T; Rs	-

Species name	Common name	Phenology / migration patterns	IUCN	Other statuses	Occ.	Habitat use	Uses
Streptopelia semitorquata (Rüppell, 1837)	Red-eyed Dove	R	LC	-	Prb	Ch; Mg; T; Rs	-
Treron calvus (Temminck, 1811)	African Green-pigeon	R	LC	-	Prb	Ch; Mg; T	-
Turtur afer (Linnaeus, 1766)	Blue-spotted Wood-dove	R	LC	-	Prb	Ch; Mg; T	-
Turtur chalcospilos (Wagler, 1827)	Emerald-spotted Wood-dove	R	LC	-	Prb	Ch; Mg; T	-
CORACIIFORMES							
Alcedinidae							
Ceryle rudis (Linnaeus, 1758)	Pied Kingfisher	R	LC	-	Prb	Eg; Rs; Sw; L	-
Corythornis cristatus (Pallas, 1764)	Malachite Kingfisher	R	LC	-	Prb	Mmb; Mg; Ch; Bk; T; Rs; Sw	-
Halcyon chelicuti (Stanley, 1814)	Striped Kingfisher	R	LC	-	Prb	Mmb; Mg; Ch; Bk; T	-

Species name	Common name	Phenology / migration patterns	IUCN	Other statuses	Occ.	Habitat use	Uses
Halcyon leucocephala (Statius Müller, PL, 1776)	Grey-headed Kingfisher	A	LC	-	Prb	Mmb; Mg; Ch; Bk; T; Rs	-
Halcyon senegalensis (Linnaeus, 1766)	Woodland Kingfisher	A	LC	-	Prb	Mmb; Mg; Ch; Bk; T; Rs	-
Ispidina picta (Boddaert, 1783)	African Pygmy-kingfisher	A	LC	-	Prb	Mmb; Mg; Ch; Bk; T; Rs; Eg	-
Megaceryle maxima (Pallas, 1769)	Giant Kingfisher	R	LC	-	Prb	Ch; Mg; T; Rs	-
Coraciidae							
Coracias caudatus Linnaeus, 1766	Lilac-breasted Roller	PP	LC	-	Prb	Mmb; Ch; Mg; Bk; T	-
Coracias garrulous Linnaeus, 1758	European Roller	P	LC	-	Prb	Ch; Mg; T	-
Coracias naevius Daudin, 1800	Purple Roller	PP	LC	-	Prb	Ch; Mg; T	-

Species name	Common name	Phenology / migration patterns	IUCN	Other statuses	Occ.	Habitat use	Uses
Eurystomus glaucurus (Statius Müller, PL, 1776)	Broad-billed Roller	A	LC	-	Prb	Mmb; Mg; Ch; Bk; T; Eg; Rs	-
Meropidae							
Merops apiaster Linnaeus, 1758	European Bee-eater	P(+A)	LC	-	Prb	Ch; Mg; T; Rs; L; Cm	-
Merops bullockoides Smith, A, 1834	White-fronted Bee-eater	R	LC	-	Prb	Mmb; Mg; Ch; Bk; Rs	-
Merops hirundineus Lichtenstein, AAH, 1793	Swallow-tailed Bee-eater	PP	LC	-	Prb	Mmb; Ch; Mg; Bk; T; Eg	-
Merops nubicoides Des Murs and Pucheran, 1846	Southern Carmine Bee-eater	A	LC	-	Prb	Ch; mg, T; Eg; Sw; L; Cm	-

Species name	Common name	Phenology / migration patterns	IUCN	Other statuses	Occ.	Habitat use	Uses
Merops persicus Pallas, 1773	Blue-cheeked Bee-eater	P	LC	-	Prb	Mmb; Mg; Ch; Bk; T; Rs; Sw; L	-
Merops pusillus Statius Müller, PL, 1776	Little Bee-eater	PP	LC	-	Prb	Ch; Mg; T; Eg; Rs; L	-
Merops variegatus Vieillot, 1817	Blue-breasted Bee-eater	R	LC	-	Prb	Mmb; Mg; Ch; Bk; T; Sw; L; Cm	-
CUCULIFORMES							
Cuculidae							
Centropus cupreicaudus Reichenow, 1896	Coppery-tailed Coucal	R	LC	-	Prb	Eg; Sw; L	-
Centropus grillii Hartlaub, 1861	Black Coucal	A	LC	-	Prb	Eg	-

Species name	Common name	Phenology / migration patterns	IUCN	Other statuses	Occ.	Habitat use	Uses
Centropus senegalensis (Linnaeus, 1766)	Senegal Coucal	R	LC	-	Prb	Ch; Mg; T; Eg; Sw	-
Centropus superciliosus Hemprich and Ehrenberg, 1829	White-browed Coucal	R	LC	-	Prb	Ch; Mg; T; Sw; L	-
Chrysococcyx caprius (Boddaert, 1783)	Diederik Cuckoo	A	LC	-	Prb	Ch; Mg; T	-
Chrysococcyx klaas (Stephens, 1815)	Klaas's Cuckoo	A	LC	-	Prb	Ch; Mg; T	-
Clamator levaillantii (Swainson, 1829)	Levaillant's Cuckoo	A	LC	-	Prb	Ch; Mg; T; Rs	-
Cuculus canorus Linnaeus, 1758	Common Cuckoo	P	LC	-	Prb	Ch; Mg; T	-
Cuculus clamosus Latham, 1801	Black Cuckoo	A	LC	-	Prb	Ch; Mg; T	-
Cuculus solitaries Stephens, 1815	Red-chested Cuckoo	A	LC	-	Prb	Ch; Mg; T	-

Species name	Common name	Phenology / migration patterns	IUCN	Other statuses	Occ.	Habitat use	Uses
FALCONIFORMES							
Falconidae							
Falco amurensis Radde, 1863	Amur Falcon	P	LC	-	Prb	Ch; Mg; T; Sw	-
Falco biarmicus Temminck, 1825	Lanner Falcon	PP	LC	-	Prb	Ch; Mg; T; Cm	-
Falco cuvierii Smith, A, 1830	African Hobby	A	LC	-	Prb	Mmb; Ch; Mg; Bk; T	-
Falco dickinsoni Sclater, PL, 1864	Dickinson's Kestrel	PP	LC	-	Prb	Mmb; Bk; Mg; Ch; T; Eg; Sw; Cm	-
Falco naumanni Fleischer, JG, 1818	Lesser Kestrel	P	LC	CC	Prb	Ch; Mg; T; Eg; Cm	-
Falco ruficollis Swainson, 1837	Red-necked Falcon	R	LC	-	Prb	Mmb; Ch; Mg; T; Eg	-
Falco Subbuteo Linnaeus, 1758	Eurasian Hobby	P	LC	-	Prb	Ch; Mg; T; Sw	-

Species name	Common name	Phenology / migration patterns	IUCN	Other statuses	Occ.	Habitat use	Uses
GALLIFORMES							
Numididae							
Numida meleagris (Linnaeus, 1758)	Helmeted Guineafowl	R	LC	-	Prb	Mmb; Mg; Bk, Ch; T	-
Phasianidae							
Coturnix delegorguei Delegorgue, 1847	Harlequin Quail	A	LC	-	Prb	Mg; Ch	-
Peliperdix coqui (Smith, A, 1836)	Coqui Francolin	R	LC	-	Prb	Mmb; Mg; Bk, Ch; T	-
Pternistis afer (Statius Müller, PL, 1776)	Red-necked Francolin	R	LC	-	Prb	Mg; Ch	-
Pternistis swainsonii (Smith, A, 1836)	Swainson's Francolin	R	LC	-	Prb	Mg; Ch; Eg; Rs	-
Synoicus adansonii (Verreaux, J and Verreaux, E, 1851)	African Blue Quail	A	LC	-	Prb	Sw	-

Species name	Common name	Phenology / migration patterns	IUCN	Other statuses	Occ.	Habitat use	Uses
GRUIFORMES							
Gruidae							
Bugeranus carunculatus (Gmelin, JF, 1789)	Wattled Crane	PP	VU	CC	Prb	Eg; L	-
Heliornithidae							
Podica senegalensis (Vieillot, 1817)	African Finfoot	R	LC	-	Prb	Eg; Rs; L	-
Rallidae							
Crex crex (Linnaeus, 1758)	Corncrake	P	LC	CC	Prb	Ch; Mg; Sw; Eg	-
Crex egregia (Peters, W, 1854)	African Crake	A	LC	-	Prb	Eg;Rs; Sw	-
Fulica cristata Gmelin, JF, 1789	Red-knobbed Coot	PP	LC	-	Prb	Rs; L	-
Paragallinula angulate (Sundevall, 1851)	Lesser Moorhen	A	LC	-	Prb	Eg; Rs; Sw; L	-
Gallinula chloropus (Linnaeus, 1758)	Common Moorhen	R	LC	-	Prb	Rs; Sw; L	-
Porphyrio alleni Thomson, 1842	Allen's Gallinule	A	LC	-	Prb	Eg; Rs; Sw; L	-

Species name	Common name	Phenology / migration patterns	IUCN	Other statuses	Occ.	Habitat use	Uses
Porphyrio porphyrio (Linnaeus, 1758)	Purple Swamphen	R	LC	-	C	Sw; L	-
Zapornia flavirostra (Swainson, 1837)	Black Crake	R	LC	-	Prb	Eg; Rs; Sw; L	-
Zapornia pusilla (Pallas, 1776)	Baillon's Crake	PP-RR	LC	-	Prb	Eg; Rs; Sw; L	-
Sarothruridae							
Sarothrura rufa (Vieillot, 1819)	Red-chested Flufftail	R	LC	-	Prb	Eg; Rs; Sw	-
MUSOPHAGIFORMES							
Musophagidae							
Corythaixoides concolor (Smith, A, 1833)	Grey Go-away-bird	R	LC	-	Prb	Mmb; Bk; Ch; Mg; T	-
OTIDIFORMES							
Otididae							
Lissotis melanogaster (Rüppell, 1835)	Black-bellied Bustard	R	LC	-	Prb	Eg	-

Species name	Common name	Phenology / migration patterns	IUCN	Other statuses	Occ.	Habitat use	Uses
PASSERIFORMES							
Acrocephalidae							
Acrocephalus arundinaceus (Linnaeus, 1758)	Great Reed-warbler	P	LC	-	Prb	Ch; Mg; T; Eg; Rs; Sw; L	-
Acrocephalus gracilirostris (Hartlaub, 1864)	Lesser Swamp-warbler	R	LC	-	Prb	Eg; Rs; Sw; L	-
Acrocephalus palustris (Bechstein, 1798)	Marsh Warbler	P	LC	-	Prb	T; Eg; Rs; Sw	-
Acrocephalus rufescens (Sharpe and Bouvier, 1877)	Greater Swamp-warbler	R	LC	-	Prb	Sw	-
Acrocephalus schoenobaenus (Linnaeus, 1758)	Sedge Warbler	P	LC	-	Prb	Ch; Mg; T; rs; Sw; L	-
Acrocephalus scirpaceus (Hermann, 1804)	Common Reed-warbler	P-scirpaceus/fuscus PP-baeticatus group	LC	-	Prb	Ch; Mg; T; Eg; Rs; Sw; L	-

Species name	Common name	Phenology / migration patterns	IUCN	Other statuses	Occ.	Habitat use	Uses
Hippolais icterina (Vieillot, 1817)	Icterine Warbler	P	LC	-	Prb	Cm	-
Alaudidae							
Mirafra Africana Smith, A, 1836	Rufous-naped Lark	R	LC	-	Prb	Mg; Ch; T	-
Mirafra rufocinnamomea (Salvadori, 1865)	Flappet Lark	R	LC	-	Prb	Mg; Ch; T	-
Pinarocorys nigricans (Sundevall, 1850)	Dusky Lark	A	LC	-	Prb	Mg; Ch; T	-
Buphagidae							
Buphagus africanus Linnaeus, 1766	Yellow-billed Oxpecker	R	LC	cc	Prb	Ch; Mg; T	-
Buphagus erythrorynchus (Stanley, 1814)	Red-billed Oxpecker	R	LC	cc	Prb	Ch; Mg; T	-
Campephagidae							
Campephaga flava Vieillot, 1817	Black Cuckooshrike	PP	LC	-	Prb	Ch; Mg; T; Cm	-
Cisticolidae							
Apalis flavida (Strickland, 1853)	Yellow-breasted Apalis	R	LC	-	Prb	Mmb; Bk; Ch; Mg; T	-

Species name	Common name	Phenology / migration patterns	IUCN	Other statuses	Occ.	Habitat use	Uses
Calamonastes stierlingi Reichenow, 1901	Stierling's Wren-warbler	R	LC	-	Prb	Ch; Mg; T	-
Camaroptera brachyuran (Vieillot, 1821)	Bleating Camaroptera	R	LC	-	Prb	Ch; Mg; T; Rs; Cm	-
Cisticola aridulus Witherby, 1900	Desert Cisticola	R	LC	-	Prb	Ch; Mg; T	-
Cisticola aridulus (Sharpe, 1870)	Short-winged Cisticola	R	LC	-	Prb	Mmb; Mg; Ch; T; Sw	-
Cisticola chiniana (Smith, A, 1843)	Rattling Cisticola	R	LC	-	Prb	Ch; Mg; T; Cm	-
Cisticola erythrops (Hartlaub, 1857)	Red-faced Cisticola	R	LC	-	Prb	T; Eg; Rs; Sw	-
Cisticola fulvicapilla (Vieillot, 1817)	Neddicky	R	LC	-	Prb	Ch; Mg; T; Cm	-
Cisticola juncidis (Rafinesque, 1810)	Zitting Cisticola	R	LC	-	Prb	T; Eg	-
Cisticola luapula Lynes, 1933	Luapula Cisticola	R	LC	-	Prb	Eg; Sw	-

Species name	Common name	Phenology / migration patterns	IUCN	Other statuses	Occ.	Habitat use	Uses
Cisticola natalensis (Smith, A, 1843)	Croaking Cisticola	R	LC	-	Prb	Ch; Mg; T; Eg; Sw	-
Cisticola rufilatus (Hartlaub, 1870)	Tinkling Cisticola	R	LC	-	Prb	Mmb; Ch; Mg; T	-
Eremomela atricollis Barboza du Bocage, 1894	Black-necked Eremomela	R-RR	LC	-	Prb	Mmb; Bk; Ch, Mg; T	-
Eremomela icteropygialis (Lafresnaye, 1839)	Yellow-bellied Eremomela	R	LC	-	Prb	Ch; Mg; T	-
Eremomela usticollis Sundevall, 1850	Burnt-necked Eremomela	R	LC	-	Prb	Mmb; Ch; Bk; Mg; T; Rs	-
Prinia subflava (Gmelin, JF, 1789)	Tawny-flanked Prinia	R	LC	-	Prb	Mmb; Bk; Mg; Ch; T; Rs; Sw	-

Species name	Common name	Phenology / migration patterns	IUCN	Other statuses	Occ.	Habitat use	Uses
Dicruridae							
Dicrurus adsimilis (Bechstein, 1794)	Fork-tailed Drongo	R	LC	-	Prb	Mmb; Bk; Mg; Ch; T; Cm	-
Emberizidae							
Emberiza flaviventris Stephens, 1815	Golden-breasted Bunting	PP	LC	-	Prb	Mmb; Ch; Mg; Bk; T	-
Estrildae							
Amandava subflava (Vieillot, 1819)	Zebra Waxbill	R	LC	-	Prb	Ch; Mg; T; Sw; Eg	-
Estrilda astrild (Linnaeus, 1758)	Common Waxbill	R	LC	-	Prb	Ch; Mg; T; Sw; Cm	-
Lagonosticta nitidula Hartlaub, 1886	Brown Firefinch	R	LC	-	Prb	Sw	-
Lagonosticta senegala (Linnaeus, 1766)	Red-billed Firefinch	R	LC	-	Prb	Ch; Mg; T	-
Ortygospiza atricollis (Vieillot, 1817)	African Quailfinch	R	LC	-	Prb	Eg; Sw	-

Species name	Common name	Phenology / migration patterns	IUCN	Other statuses	Occ.	Habitat use	Uses
Pytilia afra (Gmelin, JF, 1789)	Orange-winged Pytilia	PP	LC	-	Prb	Ch; Mg; T	-
Pytilia melba (Linnaeus, 1758)	Green-winged Pytilia	R	LC	-	Prb	Ch; Mg; T	-
Spermestes cucullata Swainson, 1837	Bronze Mannikin	R	LC	-	Prb	Mmb; Mg; Bk, Ch; T; Sw	-
Uraeginthus angolensis (Linnaeus, 1758)	Blue-breasted Cordon-bleu	R	LC	-	Prb	Ch; Mg; T	-
Fringillidae							
Crithagra atrogularis (Smith, A, 1836)	Black-throated Canary	R	LC	-	Prb	Mmb; Ch; Mg; Bk; T	-
Crithagra mozambica (Statius Müller, PL, 1776)	Yellow-fronted Canary	R	LC	-	Prb	Ch; Mg; T	-
Crithagra sulphurata (Linnaeus, 1766)	Brimstone Canary	R	LC	-	Prb	T	-

Species name	Common name	Phenology / migration patterns	IUCN	Other statuses	Occ.	Habitat use	Uses
Hirundinidae							
Cecropis abyssinica (Guérin-Méneville, 1843)	Lesser Striped Swallow	PP	LC	-	Prb	Ch; Mg; T; Rs	-
Cecropis senegalensis (Linnaeus, 1766)	Mosque Swallow	PP	LC	-	Prb	Ch; Mg; T; Rs	-
Delichon urbicum (Linnaeus, 1758)	Northern House Martin	P	LC	-	Prb	Ch; Mg; T	-
Hirundo albigularis Strickland, 1849	White-throated Swallow	A	LC	-	Prb	Ch; Mg, T; Eg; L	-
Hirundo dimidiate Sundevall, 1850	Pearl-breasted Swallow	PP	LC	-	Prb	Ch; Mg, T; Rs; Sw	-
Hirundo rustica Linnaeus, 1758	Barn Swallow	P	LC	-	Prb	Ch; Mg; T; Rs; L; Sw	-
Neophedina cincta (Boddaert, 1783)	Banded Martin	PP	LC	-	Prb	Ch; Mg; T	-
Pseudhirundo griseopyga (Sundevall, 1850)	Grey-rumped Swallow	PP	LC	-	Prb	Ch; Mg; T; Eg; Rs	-

Species name	Common name	Phenology / migration patterns	IUCN	Other statuses	Occ.	Habitat use	Uses
Riparia paludicola (Vieillot, 1817)	African Plain Martin	PP	LC	-	Prb	T; Rs; Sw; L	-
Riparia riparia (Linnaeus, 1758)	Collared Sand Martin	P	LC	-	Prb	Eg; Rs; Sw; L	-
Laniidae							
Lanius collaris Stanley, 1814	Common Fiscal	R	LC	-	Prb	Ch; Mg; T; Rs; Cm	-
Lanius collurio Linnaeus, 1758	Red-backed Shrike	P	LC	-	Prb	Ch; Mg; T; Sw; Cm	-
Lanius minor Gmelin, JF, 1788	Lesser Grey Shrike	P	LC	-	Prb	Ch; Mg; T	-
Lanius souzae Barboza du Bocage, 1878	Souza's Shrike	R	LC	-	Prb	Mmb; Ch; Mg; T	-
Leiothrichidae							
Turdoides hartlaubii (Barboza du Bocage, 1868)	Hartlaub's Babbler	R	LC	-	Prb	Ch; Mg; T; Sw	-

Species name	Common name	Phenology / migration patterns	IUCN	Other statuses	Occ.	Habitat use	Uses
Locustellidae							
Bradypterus baboecala (Vieillot, 1817)	Little Rush-warbler	R	LC	-	Prb	Sw	-
Schoenicola brevirostris (Sundevall, 1850)	Fan-tailed Grassbird	PP	LC	-	Prb	Eg; Rs; Sw; L	-
Macrospenidae							
Melocichla mentalis (Fraser, 1843)	Moustached Grass-warbler	R	LC	-	Prb	Ch; Mg; T; Rs	-
Sylvietta rufescens (Vieillot, 1817)	Long-billed Crombec	R	LC	-	Prb	Ch; Mg; T	-
Sylvietta ruficapilla Barboza du Bocage, 1877	Red-capped Crombec	R	LC	-	Pos	Mmb; Bk; Ch, Mg; T	-
Malaconotidae							
Chlorophoneus sulfureopectus (Lesson, R, 1831)	Orange-breasted Bush-shrike	R	LC	-	Prb	Mmb; Ch; Mg; Bk; T	-
Dryoscopus cubla (Latham, 1801)	Black-backed Puffback	R	LC	-	Prb	Mmb; Ch; Mg; Bk; T; Cm	-

Species name	Common name	Phenology / migration patterns	IUCN	Other statuses	Occ.	Habitat use	Uses
Laniarius aethiopicus (Hartlaub, 1848)	Tropical Boubou	R	LC	-	Prb	Mmb; Ch; Mg; Bk; T	-
Malaconotus blanchoti Stephens, 1826	Grey-headed Bush-shrike	R	LC	-	Prb	Mmb; Ch; Mg; Bk; T; Cm	-
Nilaus afer (Latham, 1801)	Brubru	R	LC	-	Prb	Mmb; Ch; Mg; Bk; T	-
Tchagra australis (Smith, A, 1836)	Brown-crowned Tchagra	R	LC	-	Prb	Mmb; Ch; Mg; Bk; T	-
Tchagra senegalus (Linnaeus, 1766)	Black-crowned Tchagra	R	LC	-	Prb	Mmb; Ch; Mg; Bk; T; Cm	-
Monarchidae							
Terpsiphone viridis (Statius Müller, PL, 1776)	African Paradise-flycatcher	A	LC	-	Prb	Mmb; Bk; Mg; Ch; T; Cm	-

Species name	Common name	Phenology / migration patterns	IUCN	Other statuses	Occ.	Habitat use	Uses
Motacillidae							
Anthus cinnamomeus Rüppell, 1840	African Pipit	PP	LC	-	Prb	Eg	-
Anthus leucophrys Vieillot, 1818	Plain-backed Pipit	R	LC	-	Prb	Ch; Mg; T; Eg	-
Anthus nyassae Neumann, 1906	Woodland Pipit	R	LC	-	Prb	Ch; Mg; T	-
Anthus trivialis (Linnaeus, 1758)	Tree Pipit	P	LC	-	Prb	Mmb; Ch; Mg; Bk; T; Cm	-
Anthus vaalensis Shelley, 1900	Buffy Pipit	A	LC	-	Prb	Eg	-
Macronyx ameliae de Tarragon, 1845	Rosy-throated Longclaw	R	LC	-	Prb	Eg	-
Macronyx fuelleborni Reichenow, 1900	Fülleborn's Longclaw	R	LC	-	Prb	Ch; Mg; T; Eg	-
Motacilla aguimp Temminck, 1820	African Pied Wagtail	R	LC	-	Prb	Rs	-
Motacilla capensis Linnaeus, 1766	Cape Wagtail	R	LC	-	Prb	Eg; Rs; Sw; L	-

Species name	Common name	Phenology / migration patterns	IUCN	Other statuses	Occ.	Habitat use	Uses
Motacilla flava (Cabanis, 1868)	Western Yellow Wagtail	P	LC	-	Prb	Rs; Sw; L	-
Muscicapidae							
Agricola pallidus (von Müller, 1851)	Pale Flycatcher	R	LC	-	Prb	Ch; Mg; T	-
Bradornis boehmi (Reichenow, 1884)	Bohm's Flycatcher	R	LC	-	Pos	Mmb; Ch; Mg; T	-
Cercotrichas leucophrys (Vieillot, 1817)	White-browed Scrub Robin	R	LC	-	Prb	Mmb; Mg; Bk; Ch; T	-
Cichladusa arquata Peters, W, 1863	Collared Palm-thrush	R	LC	-	Prb	Mmb; Ch; Mg; Bk; T; Cm	-
Cossypha heuglini Hartlaub, 1866	White-browed Robin-chat	R	LC	-	Prb	Mmb; Ch; Mg; Bk; T	-
Cossypha natalensis Smith, A, 1840	Red-capped Robin-chat	A	LC	-	Prb	Mmb; Ch; Mg; Bk; T	-

Species name	Common name	Phenology / migration patterns	IUCN	Other statuses	Occ.	Habitat use	Uses
Fraseria caerulescens (Hartlaub, 1865)	Ashy Flycatcher	R	LC	-	Prb	Ch; Mg; T; Cm	-
Melaenornis pammelaina (Stanley, 1814)	Southern Black-flycatcher	R	LC	-	Prb	Ch; Mg; T; Cm	-
Monticola angolensis Sousa, 1888	Miombo Rock-thrush	R	LC	-	Pos	Mmb; Bk; Ch, Mg; T; Cm	-
Muscicapa aquatic Heuglin, 1864	Swamp Flycatcher	R-RR	LC	-	Prb	Rs; Sw; L	-
Muscicapa striata (Pallas, 1764)	Spotted Flycatcher	P	LC	-	Prb	Mmb; Ch; Mg; T	-
Myrmecocichla nigra (Vieillot, 1818)	Sooty Chat	R	LC	-	Prb	T; Eg	-
Oenanthe pileata (Gmelin, JF, 1789)	Capped Wheatear	A	LC	-	Prb	T; Ch; Mg	-
Saxicola torquatus (Linnaeus, 1766)	Common Stonechat	R	LC	-	Prb	T; Sw; Cm	-
Tychaedon barbata (Hartlaub and Finsch, 1870)	Miombo Scrub-robin	R	LC	-	Prb	Ch; Mg; T; Cm	-

Species name	Common name	Phenology / migration patterns	IUCN	Other statuses	Occ.	Habitat use	Uses
Nectariniidae							
Anthreptes anchietae (Barboza du Bocage, 1878)	Anchieta's Sunbird	R	LC	-	Pos	Mmb; Ch; Mg; T	-
Chalcomitra amethystine (Shaw, 1812)	Amethyst Sunbird	PP	LC	-	Prb	T; Ch; Mg	-
Chalcomitra senegalensis (Linnaeus, 1766)	Scarlet-chested Sunbird	PP	LC	-	Prb	T; Ch; Mg	-
Cinnyris cupreus (Shaw, 1812)	Copper Sunbird	PP	LC	-	Prb	Mmb; Ch; Mg; Bk; T; Rs; Sw	-
Cinnyris shelleyi Alexander, 1899	Shelley's Sunbird	PP	LC	-	Pos	Ch; Mg; T; Mmb	-
Cinnyris talatala Smith, A, 1836	White-bellied Sunbird	PP	LC	-	Prb	T; Ch; Mg	-
Cinnyris venustus (Shaw, 1799)	Variable Sunbird	R	LC	-	Prb	Mmb; Ch; Mg; Bk; T; Rs; Cm	-

Species name	Common name	Phenology / migration patterns	IUCN	Other statuses	Occ.	Habitat use	Uses
Oriolidae							
Oriolus auratus Vieillot, 1817	African Golden Oriole	A	LC	-	Prb	Mmb; Bk; Mg; Ch; T	-
Oriolus larvatus Lichtenstein, MHK, 1823	Eastern Black-headed Oriole	R	LC	-	Prb	Mmb; Bk; Mg; Ch; T; Rs; Cm	-
Oriolus oriolus (Linnaeus, 1758)	Eurasian Golden Oriole	P	LC	-	Prb	Mmb; Bk; Mg; Ch; T	-
Paridae							
Melaniparus griseiventris (Reichenow, 1882)	Miombo Tit	R	LC	-	Pos	Mmb; Bk; Ch; Mg; T	-
Melaniparus leucomelas (Rüppell, 1840)	Dark-eyed Black Tit	R	LC	-	Prb	Mmb; Bk; Mg; Ch; T	-
Melaniparus niger (Vieillot, 1818)	Southern Black Tit	R	LC	-	Prb	Mmb; Bk; Mg; Ch; T	-

Species name	Common name	Phenology / migration patterns	IUCN	Other statuses	Occ.	Habitat use	Uses
Passeridae							
Gymnoris superciliaris Blyth, 1845	Yellow-throated Bush-sparrow	R	LC	-	Prb	Mmb; Ch; Mg; Bk; T	-
Passer domesticus (Linnaeus, 1758)	House Sparrow	R	LC	Int.	Prb	Mmb; Ch; Mg; Bk; T; Rs; Sw; Cm	-
Phylloscopidae							
Phylloscopus trochilus (Linnaeus, 1758)	Willow Warbler	P	LC	-	Prb	Ch; Mg; T; Sw; L	-
Platysteiridae							
Batis molitor (Küster, 1836)	Chinspot Batis	R	LC	-	Prb	Ch; Mg; T	-
Ploceidae							
Amblyospiza albifrons (Vigors, 1831)	Thick-billed Weaver	PP	LC	-	Prb	Eg; Sw	-
Euplectes albonotatus (Cassin, 1848)	White-winged Widowbird	R	LC	-	Prb	Sw; L	-

Species name	Common name	Phenology / migration patterns	IUCN	Other statuses	Occ.	Habitat use	Uses
Euplectes ardens (Boddaert, 1783)	Red-collared Widowbird	R	LC	-	Prb	Sw; T; Eg	-
Euplectes axillaris (Smith, A, 1838)	Fan-tailed Widowbird	R	LC	-	Prb	Eg; Sw	-
Euplectes capensis (Linnaeus, 1766)	Yellow Bishop	R	LC	-	Prb	T; Eg	-
Euplectes hordeaceus (Linnaeus, 1758)	Black-winged Bishop	R	LC	-	Prb	Eg	-
Euplectes macroura (Gmelin, JF, 1789)	Yellow-mantled Widowbird	R	LC	-	Prb	Eg; Sw	-
Euplectes orix (Linnaeus, 1758)	Southern Red Bishop	R	LC	-	Prb	Eg	-
Plocepasser rufoscapulatus Buttikofer, 1888	Chestnut-backed Sparrow-weaver	R	LC	-	Pos	Mmb; Bk; Ch; Mg; T	-
Ploceus cucullatus (Statius Müller, PL, 1776)	Village Weaver	R	LC	-	Prb	Mmb; Ch; Mg; Bk; T; Rs; Cm	-

Species name	Common name	Phenology / migration patterns	IUCN	Other statuses	Occ.	Habitat use	Uses
Ploceus intermedius Rüppell, 1845	Lesser Masked Weaver	R	LC	-	Prb	Mmb; Ch; Mg; Bk; T; Rs	-
Ploceus ocularis Smith, A, 1828	Spectacled Weaver	R	LC	-	Prb	Ch; Mg; Rs	-
Ploceus velatus Vieillot, 1819	Southern Masked Weaver	R	LC	-	Prb	Mmb; Ch; Mg; Bk; T; Rs; Cm	-
Ploceus xanthops (Hartlaub, 1862)	Holub's Golden Weaver	R	LC	-	Prb	Mmb; Ch; Mg; Bk; T; Rs	-
Quelea erythrops (Hartlaub, 1848)	Red-headed Quelea	A	LC	-	Prb	Rs	-
Quelea quelea (Linnaeus, 1758)	Red-billed Quelea	PP	LC	-	Prb	Rs	-
Prionopidae							
Prionops plumatus (Shaw, 1809)	White-crested Helmetshrike	R	LC	-	Prb	Mmb; Ch; Mg; Bk; T	-

Species name	Common name	Phenology / migration patterns	IUCN	Other statuses	Occ.	Habitat use	Uses
Pycnonotidae							
Calandrella cinerea (Gmelin, JF, 1789)	Red-capped Lark	A	LC	-	Prb	-	-
Chlorocichla flaviventris (Smith, A, 1834)	Yellow-bellied Greenbul	R	LC	-	Prb	Mmb; Bk; Mg; Ch; T	-
Phyllastrephus terrestris Swainson, 1837	Terrestrial Brownbul	R	LC	-	Prb	T; Rs	-
Pycnonotus barbatus (Hartlaub, 1862)	Common Bulbul	R	LC	-	Prb	Mg; Ch; t; Rs; Sw; Cm	-
Remizidae							
Anthoscopus caroli (Sharpe, 1871)	Grey Penduline-tit	R	LC	-	Prb	Mmb; Bk; Mg; Ch; T	-
Sturnidae							
Cinnyricinclus leucogaster (Boddaert, 1783)	Violet-backed Starling	A	LC	-	Prb	Mmb; Bk; Ch, Mg; T	-
Creatophora cinerea (Meuschen, 1787)	Wattled Starling	A	LC	-	Prb	Ch; Mg; T	-

Species name	Common name	Phenology / migration patterns	IUCN	Other statuses	Occ.	Habitat use	Uses
Lamprotornis chalybaeus Hemprich and Ehrenberg, 1828	Greater Blue-eared Starling	PP	LC	-	Prb	Ch; Mg; T	-
Lamprotornis chloropterus Swainson, 1838	Lesser Blue-eared Starling	PP	LC	-	Prb	Ch; Mg; T	-
Sylviidae							
Sylvia borin (Boddaert, 1783)	Garden Warbler	P	LC	-	Prb	Mmb; Mg; Ch; Bk; T; Cm	-
Sylvia communis Latham, 1787	Common Whitethroat	P	LC	-	Prb	Ch; Mg; T; Cm	-
Turdidae							
Psophocichla litsitsirupa (Smith, 1836)	Groundscraper Thrush	PP	LC	-	Prb	Mmb; Bk; Ch; Mg; T; Cm	-
Turdus libonyana (Smith, A, 1836)	Kurrichane Thrush	R	LC	-	Prb	Ch; Mg; T; Cm	-

Species name	Common name	Phenology / migration patterns	IUCN	Other statuses	Occ.	Habitat use	Uses
Viduidae							
Anomalospiza imberbis (Cabanis, 1868)	Cuckoo-finch	PP	LC	-	Prb	Eg	-
Vidua macroura (Pallas, 1764)	Pin-tailed Whydah	R	LC	-	Prb	Rs	-
Vidua obtuse (Chapin, 1922)	Broad-tailed Paradise-whydah	PP	LC	-	Prb	Ch; Mg; T	-
Vidua paradisaea (Linnaeus, 1758)	Long-tailed Paradise-whydah	R	LC	-	Prb	Ch; Mg; T	-
Zosteropidae							
Zosterops senegalensis Bonaparte, 1850	African Yellow White-eye	R	LC	-	Prb	Mmb; Mg; Bk; Ch; T; Cm	-
PELECANIFORMES							
Ardeidae							
Ardea alba Linnaeus, 1758	Great White Egret	PP	LC	-	Prb	Eg; Sw; L	-
Ardea brachyrhyncha (Brehm, AE, 1854)	Yellow-billed Egret	PP	LC	-	Prb	Eg; Rs; Sw; L	-

Species name	Common name	Phenology / migration patterns	IUCN	Other statuses	Occ.	Habitat use	Uses
Ardea cinerea (Linnaeus, 1758)	Grey Heron	PP	LC	-	Prb	Eg; Rs; L; Sw	-
Ardea goliath Cretzschmar, 1829	Goliath Heron	R	LC	cc	Prb	Rs; Sw; L	-
Ardea melanocephala Children and Vigors, 1826	Black-headed Heron	PP	LC	-	C	Mg; Ch; Rs; L; Sw	-
Ardea purpurea Linnaeus, 1766	Purple Heron	R	LC	-	Prb	Sw	-
Ardeola ralloides (Scopoli, 1769)	Squacco Heron	PP	LC	-	C	Rs; Sw	-
Ardeola rufiventris (Sundevall, 1850)	Rufous-bellied Heron	PP	LC	-	Prb	Eg; Rs; Sw; L	-
Botaurus stellaris (Linnaeus, 1758)	Eurasian Bittern	R-RR	LC	cc	Prb	Sw	-
Bubulcus ibis (Linnaeus, 1758)	Cattle Egret	A	LC	-	C	Eg; Rs; L	-
Butorides striata (Linnaeus, 1758)	Green-backed Heron	R	LC	-	Prb	Rs; Sw	-
Egretta ardesiaca (Wagler, 1827)	Black Heron	PP	LC	-	Prb	Eg; Rs; Sw; L	-

Species name	Common name	Phenology / migration patterns	IUCN	Other statuses	Occ.	Habitat use	Uses
Egretta garzetta (Linnaeus, 1766)	Little Egret	PP	LC	-	C	Eg; Rs; L	-
Egretta vinaceigula (Sharpe, 1895)	Slaty Egret	PP	VU	CC	Prb	L	-
Ixobrychus minutus (Linnaeus, 1766)	Common Little Bittern	P-minutus PP-paysii	LC	-	Prb	Eg; Sw; L	-
Ixobrychus sturmii (Wagler, 1827)	Dwarf Bittern	A	LC	-	Prb	Eg; Rs; Sw; L	-
Nycticorax nycticorax (Linnaeus, 1758)	Black-crowned Night-heron	PP	LC	-	Prb	Rs; Sw; L	-
Balaenicipitidae							
Balaeniceps rex Gould, 1850	Shoebill	R-RR	VU	CC	Prb	Rs	-
Pelecanidae							
Pelecanus onocrotalus Linnaeus, 1758	Great White Pelican	PP	LC	-	Prb	Sw	-
Pelecanus rufescens Gmelin, JF, 1789	Pink-backed Pelican	PP	LC	-	Prb	Eg; Rs; Sw; L	-
Scopidae							
Scopus umbretta Gmelin, JF, 1789	Hamerkop	R	LC	-	Prb	Eg; Rs; L	-

Species name	Common name	Phenology / migration patterns	IUCN	Other statuses	Occ.	Habitat use	Uses
Threskiornithidae							
Bostrychia hagedash (Latham, 1790)	Hadada Ibis	R	LC	-	Prb	Ch; Mg; Eg; Rs; L	-
Platalea alba Scopoli, 1786	African Spoonbill	PP	LC	-	Prb	Rs; L	-
Plegadis falcinellus (Linnaeus, 1766)	Glossy Ibis	PP	LC	-	C	Rs; Sw	-
Threskiornis aethiopicus (Latham, 1790)	African Sacred Ibis	PP	LC	-	C	Eg; Rs; L	-
PICIFORMES							
Indicatoridae							
Indicator indicator (Sparrman, 1777)	Greater Honeyguide	R	LC	-	Prb	Mmb; Ch; Mg; Bk; T; Cm	-
Indicator minor Stephens, 1815	Lesser Honeyguide	R	LC	-	Prb	Mmb; Mg; Ch; T; Cm	-
Lybiidae							
Lybius chaplini Clarke, S, 1920	Zambian Barbet	R-RR	LC	CC	Prb	Ch; Mg; T	-

Species name	Common name	Phenology / migration patterns	IUCN	Other statuses	Occ.	Habitat use	Uses
Lybius torquatus (Dumont, 1805)	Black-collared Barbet	R	LC	-	Prb	Ch; Mg; T; Rs	-
Pogoniulus chrysoconus (Temminck, 1832)	Yellow-fronted Tinkerbird	R	LC	-	Prb	Ch; Mg; T; Rs	-
Pogonornis macclounii (Shelley, 1899)	White-faced Barbet	R	LC	-	Prb	Ch; Mg; T; Ch	-
Stactolaema anchietae (Barboza du Bocage, 1869)	Anchieta's Barbet	R	LC	-	Prb	Ch; Mg; T	-
Tricholaema frontata (Cabanis, 1880)	Miombo Pied Barbet	PP	LC	-	Pos	Ch; Mg; T; Mmb	-
Picidae							
Campethera abingoni (Smith, A, 1836)	Golden-tailed Woodpecker	R	LC	-	Prb	Mmb; Ch; Mg; Bk; T	-
Campethera cailliautii (Malherbe, 1849)	Little Spotted Woodpecker	R	LC	-	Prb	Mmb; Ch; Mg; Bk; T	-

Species name	Common name	Phenology / migration patterns	IUCN	Other statuses	Occ.	Habitat use	Uses
Dendropicos fuscescens (Vieillot, 1818)	Cardinal Woodpecker	R	LC	-	Prb	Mmb; Ch; Mg; Bk; T; Rs; Cm	-
Dendropicos namaquus (Lichtenstein, AAH, 1793)	Bearded Woodpecker	R	LC	-	Prb	Mmb; Ch; Mg; Bk; T	-
PODIDIPEDIFORMES							
Podicioedidae							
Tachybaptus ruficollis (Pallas, 1764)	Little Grebe	PP	LC	-	Prb	Rs; L	-
PSITTACIFORMES							
Psittacidae							
Poicephalus meyeri (Cretzschmar, 1827)	Brown Parrot	R	LC	-	Prb	Ch; Mg; T	-
Poicephalus robustus (Gmelin, 1788)	Brown-necked Parrot	PP	VU	-	Prb	-	-

Species name	Common name	Phenology / migration patterns	IUCN	Other statuses	Occ.	Habitat use	Uses
PTEROCLIFORMES							
Pteroclidae							
Pterocles gutturalis Smith, A, 1836	Yellow-throated Sandgrouse	A	LC	cc	Prb	Ch; Mg; T; Eg; Rs	-
STRIGIFORMES							
Strigidae							
Asio capensis (Smith, A, 1834)	Marsh Owl	R	LC	-	Prb	Ch; Mg; T; Eg; Sw	-
Bubo africanus (Temminck, 1821)	Spotted Eagle-owl	R	LC	-	Prb	Ch; Mg; T	-
Bubo lacteus (Temminck, 1820)	Verreaux's Eagle-owl	R	LC	-	Prb	Ch; Mg; T	-
Otus senegalensis (Swainson, 1837)	African Scops-owl	R	LC	-	Prb	Ch; Mg; T	-
Ptilopsis granti (Kollibay, 1910)	Southern White-faced Owl	R	LC	-	Prb	Ch; Mg; T	-
Scotopelia peli Bonaparte, 1850	Pel's Fishing-owl	R	LC	-	Prb	Rs; Sw	-

Species name	Common name	Phenology / migration patterns	IUCN	Other statuses	Occ.	Habitat use	Uses
SULIFORMES							
Anhingidae							
Anhinga rufa (Daudin, 1802)	African Darter	PP	LC	-	Prb	Rs; Sw; L	-
Phalacrocoracidae							
Microcarbo africanus (Gmelin, JF, 1789)	Long-tailed Cormorant	PP	LC	-	Prb	Rs; Sw	-
Phalacrocorax carbo (Linnaeus, 1758)	Great Cormorant	PP	LC	-	Prb	Sw; L	-
Class MAMMALIA (mamofauna)							
CARNIVORA							
Canidae							
Canis adustus Sundevall, 1847	Side-striped Jackal	-	LC	-	Pos	Mmb; Bk; Ch; Mg; T; Sw	-
Felidae							
Caracal caracal (Schreber, 1776)	Caracal	-	LC	-	Pos	Mmb; Bk; Ch; Mg; T	-

Species name	Common name	Phenology / migration patterns	IUCN	Other statuses	Occ.	Habitat use	Uses
Felis silvestris Schreber, 177	Wild Cat	-	LC	-	Pos	Ch; Mg; T	-
Leptailurus serval (Schreber, 1776)	Serval	-	LC	-	Pos	Mmb; Bk; Ch; Mg; T; Eg; Rs	-
Herpestidae							
Atilax paludinosus (G. Cuvier, 1829)	Marsh Mongoose	-	LC	-	Pos	Eg; Rs; Sw	-
Helogale parvula (Sundevall, 1847)	Dwarf Mongoose	-	LC	-	Pos	Ch; Mg; T	-
Herpestes ichneumon (Linnaeus, 1758)	Large Grey Mongoose	-	LC	-	Pos	Ch; Mg; T; Rs; Sw	-
Herpestes sanguineus (Ruppell, 1835)	Slender Mongoose	-	LC	-	Pos	Mmb; Bk; Ch; Mg; T	-
Ichneumia albicauda (G. Cuvier, 1829)	White-tailed Mongoose	-	LC	-	Pos	Mmb; Bk; Ch; Mg; T; Rs; Cm	-

Species name	Common name	Phenology / migration patterns	IUCN	Other statuses	Occ.	Habitat use	Uses
Mungos mungo (Gmelin, 1788)	Banded Mongoose	-	LC	-	Pos	Mmb; Bk; Ch; Mg; T	-
Paracynictis selousi (de Winton, 1896)	Selou's Mongoose	-	LC	-	Pos	Ch; Mg; T	-
Rhynchogale melleri (Gray, 1865)	Meller's Mongoose	-	LC	-	Pos	Mmb; Bk; Ch; Mg; T	-
Hyaenida							
Crocuta crocuta (Erxleben, 1777)	Spotted Hyaena	-	LC	-	Pos	Ch; Mg; T	-
Viverridae							
Civettictis civetta (Schreber, 1776)	African Civet	-	LC	-	Pos	Mmb; Bk; Ch; Mg; T; Rs; Cm	-
Genetta angolensis Bocage, 1882	Miombo Genet	-	LC	-	Pos	Mmb; Ch; Mg; T	-

Species name	Common name	Phenology / migration patterns	IUCN	Other statuses	Occ.	Habitat use	Uses
Genetta maculate (Gray, 1830)	Central African Large Spotted Genet	-	LC	-	Pos	Ch;Mg; T; Cm	-
CETARTIODACTYLA							
Bovidae							
Aepyceros melampus (Lichtenstein, 1812)	Impala	-	LC	-	Pos	Ch; Mg; T	Food; Sport hunting
Alcephalus buselaphus subsp. *lichtensteinii* (Peers, 1849)	Lichtenstein's Hartebeest	-	LC	-	Pos	Ch; Mg; T	Food; Sport hunting
Cephalophus silvicultor (Afzelius, 1815)	Yellow-backed Duiker	-	NT	-	Pos	Ch; Mg; T; Cm	Food
Hippotragus equinus (É. Geoffroy Saint-Hilaire, 1803)	Roan Antelope	-	LC	-	Pos	Mmb; Bk; Ch; Mg; T	Food
Hippotragus niger (Harris, 1838)	Sable Antelope	-	LC	-	Pos	Mmb; Bk; Ch; Mg; T	Food; Sport hunting

Species name	Common name	Phenology / migration patterns	IUCN	Other statuses	Occ.	Habitat use	Uses
Kobus ellipsiprymnus (Ogilbyi, 1833)	Waterbuck	-	LC	-	Pos	Eg	Food; Sport hunting
Kobus leche subsp. *leche* Gray, 1850	Red Lechwe	-	NT	-	Pos	Eg; Sw	Food; Sport hunting
Kobus vardonii (Livingstone, 1857)	Puku; Nsebula (Bemba)	-	NT	-	Pos	Ch; Mg; T; Eg; Sw	Food
Ourebia ourebia (Zimmermann, 1783)	Oribi	-	LC	-	Pos	Ch; Mg; T; Eg; Sw	Food; Sport hunting
Raphicerus sharpei Thomas, 1897	Sharpe's Grysbok	-	LC	-	Pos	Ch; Mg; T	Food
Sylvicapra grimmia (Linnaeus, 1758)	Common Duiker	-	LC	-	Pos	Mmb; Bk; Ch; Mg; T; Cm	Food
Syncerus caffer (Sparrman, 1779)	African Buffalo	-	LC	-	Pos	Mmb; Bk; Ch; Mg; T; Eg; Sw	-

Species name	Common name	Phenology / migration patterns	IUCN	Other statuses	Occ.	Habitat use	Uses
Tragelaphus oryx (Pallas, 1766)	Common Eland	-	LC	-	Pos	Mmb; Bk; Ch; Mg; T; Cm	Food; Sport hunting
Tragelaphus scriptus (Pallas, 1766)	Bushbuck	-	LC	-	Pos	Mmb; Bk; Ch; Mg; T; Eg; Cm	Food; Sport hunting
Tragelaphus spekii Speke, 1863	Sitatunga	-	LC	-	Pos	Ch; Mg; T; Eg; Sw	Food; Sport hunting
Tragelaphus strepsiceros (Pallas, 1766)	Greater Kudu	-	LC	-	Pos	Mmb; Bk; Ch; Mg; T; Cm	Food; Sport hunting
Hippopotamidae							
Hippopotamus amphibious Linnaeus, 1758	Hippopotamus	-	VU	-	Pos	Eg; Rs; L	Food

Species name	Common name	Phenology / migration patterns	IUCN	Other statuses	Occ.	Habitat use	Uses
Suidae							
Phacochoerus africanus (Gmelin, 1788)	Warthog	-	LC	-	Pos	Mmb; Bk; Ch; Mg; T; Cm	Food
CHIROPTERA							
Emballonuridae							
Taphozous mauritianus É. Geoffroy, 1818	Mauritian Tomb Bat; Taphozous Bat of Mauritius; Tomb Bat	-	LC	-	Pos	Ch; Mg; T	-
Hipposideridae							
Hipposideros caffer (Sundevall, 1846)	Sundevall's Roundleaf Bat; Cape Leaf-nosed bat	-	LC	-	Pos	Mmb; Bk; Ch; Mg; T; Rs; Sw	-
Hipposederos vittatus (Peters, 1852)	Striped Leaf-nosed Bat	-	LC	-	Pos	Ch; Mg; T	-

Species name	Common name	Phenology / migration patterns	IUCN	Other statuses	Occ.	Habitat use	Uses
Miniopteridae							
Miniopterus natalensis (A. Smith, 1834)	Natal Long-fingered Bat; Natal Clinging Bat	-	LC	-	Pos	Ch; Mg; T	-
Miniopterus fraterculus Thomas and Schwann, 1906	Black Clinging Bat; Lesser Long-fingered Bat; Lesser bent-winged bat	-	LC	-	Pos	Mmb; Bk; Ch; Mg; T; Cm	-
Molossidae							
Chaerephon bivittatus (Heuglin, 1861)	Spotted Free-tailed Bat	-	LC	-	Pos	Ch; Mg; T	-
Chaerephon chapini J. A. Allen, 1917	Chapin's Free-tailed Bat	-	LC	-	Pos	Ch; Mg; T	-
Chaerephon nigeriae Thomas, 1913	Nigerian Free-tailed bat; Nigerian Wrinkle-lipped Bat	-	LC	-	Pos	Ch; Mg; T	-

Species name	Common name	Phenology / migration patterns	IUCN	Other statuses	Occ.	Habitat use	Uses
Chaerephon pumilus (Cretzschmar, 1830-1831)	Little Free-tailed Bat	-	LC	-	Pos	Mmb; Bk; Ch; Mg; T	-
Mops condylurus (A. Smith, 1833)	Angolan Free-tailed Bat; Angolan Mops Bat; Knob-tailed Mops Bat	-	LC	-	Pos	Ch; Mg; T	-
Mops niveiventer Cabrera and Ruxton, 1926	White-bellied Mops Bat; White-bellied Free-tailed Bat	-	LC	-	Pos	Ch; Mg; T	-
Otomops martiensseni (Matschie, 1897)	Large-eared Free-tailed Bat	-	NT	-	Pos	Mmb; Bk; Ch; Mg; T; Cm	-
Nycteridae							
Nycteris hispida (Schreber, 1775)	Hairy Long-eared Bat; hairy Slit-faced bat	-	LC	-	Pos	Mmb; Bk; Ch; Mg; T	-

Species name	Common name	Phenology / migration patterns	IUCN	Other statuses	Occ.	Habitat use	Uses
Nycteris macrotis Dobson, 1876	Large-eared Slit-faced Bat	-	LC	-	Pos	Mmb; Bk; Ch; Mg; T	-
Nycteris thebaica É. Geoffroy, 1818	Cape Long-eared Bat; Common Slit-faced Bat; Egyptian Slit-faced Bat	-	LC	-	Pos	Mmb; Bk; Ch; Mg; T	-
Pteropodidae							
Eidolon helvum (Kerr, 1792)	African Straw-coloured Fruit-bat; Pale Xantharpy; Straw-cooure Flying Fox; Straw-coloured Fruit Bat	-	NT	-	Pos	Mmb; Bk; Ch; Mg; T; Cm	-

Species name	Common name	Phenology / migration patterns	IUCN	Other statuses	Occ.	Habitat use	Uses
Epomophorus crypturus Peters, 1852	Peter's Epauletted Fruit Bat; Smaller Epauletted Fruit Bat	-	LC	-	Pos	Ch; Mg; T	-
Epomophorus wahlbergi (Sundevall, 1846)	Wahlberg's Epauletted Fruit Bat	-	LC	-	Pos	Mmb; Ch; Mg; T	-
Epomops dobsonii (Bocage, 1899)	Dobson's Fruit Bat	-	LC	-	Pos	Mmb; Bk; Ch; Mg; T	-
Lissonycteris angolensis Bocage, 1898	Angolan Fruit Bat; Angolan Riusette	-	LC	-	Pos	Ch; Mg; T	-
Rhinolophidae							
Rhinolophus fumigatus Ruppell, 1842	Ruppell's Horseshow Bat	-	LC	-	Pos	Mmb; Bk; Ch; Mg; T	-
Rhinolophus hildebrandtii Peters, 1878	Hildebrandt's Horseshoe Bat	-	LC	-	Pos	Mmb; Bk; Ch; Mg; T	-

Species name	Common name	Phenology / migration patterns	IUCN	Other statuses	Occ.	Habitat use	Uses
Rhinolophus landeri Martin, 1838	Lander's Horseshoe Bat	-	LC	-	Pos	Ch; Mg; T	-
Rhinolophus swinnyi Gough, 1908	Swinny's Horseshoe Bat	-	LC	-	Pos	Ch; Mg; T	-
Vespertilionidae							
Eptesicus hottentotus (A. Smith, 1833)	Hottentot Serotine Bat; Hottentot bat; long-tailed Greater Serotine Ba	-	LC	-	Pos	Ch; Mg; T; Rs; Sw	-
Glauconycteris variegate (Thomes, 1861)	Butterfly Bat; Leaf-winged Bat; Varigated Butterfly Bat	-	LC	-	Pos	Ch; Mg; T	-
Kerivoula lanosa (A. Smith, 1847)	Lesser Woolly Bat	-	LC	-	Pos	Ch; Mg; T	-

Species name	Common name	Phenology / migration patterns	IUCN	Other statuses	Occ.	Habitat use	Uses
Mimetillus moloneyi (Thomas, 1891)	Moloney's Flat-headed Bat	-	LC	-	Pos	Mmb; Bk; Ch; Mg; T	-
Myotis tricolor (Temminck, 1832)	Cape Hairy Bat; Cape Myotis; Temminck's Mouse-eared Bat	-	LC	-	Pos	Ch; Mg; T	-
Myotis welwitschii (Gray, 1866)	Welwitch's Bat; Welwitsch's Hairy bat; Welwitsch's Mouse-eared Bat	-	LC	-	Pos	Mmb; Bk; Ch; Mg; T	-
Neoromicia nana (Peters, 1852)	Banana Pipistrelle Bat; Banana Bat	-	LC	-	Pos	Mmb; Bk; Ch; Mg; T; Cm	-

Species name	Common name	Phenology / migration patterns	IUCN	Other statuses	Occ.	Habitat use	Uses
Neoromicia rendalli (Thomas, 1889)	Rendall's Serotine; Rendall's Pipistrelle	-	LC	-	Pos	Ch; Mg; T	-
Neromicia zuluensis (Roberts, 1924)	Zulu Pipistrelle Bat; Aloe Bat; Aloe Serotine	-	LC	-	Pos	Mmb; Bk; Ch; Mg; T	-
Nycticeinops schlieffeni (Peters, 1859)	Schlieffen's Bat; Schlieffen's Twilight Bat	-	LC	-	Pos	Ch; Mg; T	-
Pipistrellus rueppellii (Fischer, 1829)	Ruppell's Pipistrelle	-	LC	-	Pos	Ch; Mg; T	-
Pipistrellus rusticus (Tomes, 1861)	Rusty Bat; Rusty Pipistrelle Bat	-	LC	-	Pos	Mmb; Bk; Ch; Mg; T	-
Scotoecus hirundo de Winton, 1899	Dark-winged Lesser House Bat	-	LC	-	Pos	Mmb; Bk; Ch; Mg; T	-

Species name	Common name	Phenology / migration patterns	IUCN	Other statuses	Occ.	Habitat use	Uses
Scotophilus dinganii (A. Smith, 1833)	African Yellow Bat; Dingan's Bat	-	LC	-	Pos	Ch; Mg; T	-
Scotophilus viridis (Peters, 1852)	Green House Bat; Greenish Yellow bat; lesser Yellow House Bat	-	LC	-	Pos	Ch; Mg; T	-
EULIPOTYPHLA							
Soricidae							
Crocidura cyanea (Duvernoy, 1838)	Reddish-gray Musk Shrew	-	LC	-	Pos	Eg; Mmb; Ch; Mg; Bk	-
Crocidura fuscomurina (Heuglin, 1865)	Bicolored Musk Shrew; Tiny Musk Shrew	-	LC	-	Pos	Ch; Mg; T; Eg	-
Crocidura hirta Peters, 1852	Lesser Red Musk Shrew	-	LC	-	Pos	Ch; Mg; T; Eg; Cm	-

Species name	Common name	Phenology / migration patterns	IUCN	Other statuses	Occ.	Habitat use	Uses
Crocidura mariquensis (A. Smith, 1844)	Swamp Musk Shrew	-	LC	-	Pos	Sw	-
Crocidura olivieri (Lesson, 1827)	Olivier's Shrew; African Giant Shrew	-	LC	-	Pos	Mmb; Bk; Ch; Mg; T; Cm	-
Crocidura parvipes Osgood, 1910	Small-footed Shrew	-	LC	-	Pos	Ch; Mg; T	-
Crocidura turba Dollman, 1910	Tumultuous Shrew	-	LC	-	Pos	Eg; Mmb; Bk; Mg; Ch	-
Suncus lixus (Thomas, 1898)	Greater Dwarf Shrew	-	LC	-	Pos	Mmb; Bk; Ch; Mg; T; Eg	-
HYRACOIDEA							
Procaviidae							
Dendrohyrax arboreus (A. Smith, 1827)	Southern Tree Hyrax	-	LC	-	Pos	Mmb; Bk; Ch; Mg; T	Food

Species name	Common name	Phenology / migration patterns	IUCN	Other statuses	Occ.	Habitat use	Uses
Heterohyrax brucei (Gray, 1868)	Yellow-spotted Rock Hyrax	-	LC	-	Pos	Ch; Mg; T	Food
LAGOMORPHA							
Leporidae							
Lepus victoriae Thomas, 1893	African Savanna Hare	-	LC	-	Pos	Ch; Mg; T	-
MACROSCELIDEA							
Macroscelidae							
Elephantulus brachyrhynchus (A. Smith, 1836)	Dusky Elephant Shrew	-	LC	-	Pos	Ch; Mg; T	-
Petrodomus tetradactylus Peters, 1846	Four-toed Sengi; Four-toed Elephant-shrew	-	LC	-	Pos	Mmb; Bk; Ch; Mg; T	Food

Species name	Common name	Phenology / migration patterns	IUCN	Other statuses	Occ.	Habitat use	Uses
PHOLIDOTA							
Manidae							
Smutsia temminckii (Smuts, 1832)	Ground Pangolin; Teminck's Pangolin	-	VU	-	Pos	Mmb; Bk; Ch; Mg; T; Eg	Food; Medicine; Clothes
PRIMATES							
Cercopithecidae							
Cercopithecus mitis Wolf, 1822	Nlue Monkey; Diademed Monkey; Gentle Monkey	-	LC	-	Pos	Mmb; Bk; Ch; Mg; T; Cm	-
Galagidae							
Galago moholi A. Smith, 1836	Southern Lesser Galago	-	LC	-	Pos	Ch; Mg; T	-
Otolemur crassicaudatus (É. Geoffroy Saint-Hilaire, 1812)	Thick-tailed Bishbaby; Thick-tailed Greater Galago	-	LC	-	Pos	Mmb; Bk; Ch; Mg; T; Cm	-

Species name	Common name	Phenology / migration patterns	IUCN	Other statuses	Occ.	Habitat use	Uses
RODENTIA							
Anomaluridae							
Anomalurus derbianus Gray, 1842	Lord Derby's Flying Squirrel	-	LC	-	Pos	Mmb; Bk; Ch; Mg	Food; Medicine
Bathyergidae							
Fukomys mechowi Peters, 1881	Mechow's Mole Rat	-	LC	-	Pos	T	Food
Gliridae							
Graphiurus microtis (Noack, 1887)	Small-eared Dormouse	-	LC	-	Pos	Mmb; Bk; Ch; Mg; T; Cm	-
Hystricidae							
Hystrix africaeaustralis Peters, 1852	Cape Porcupine	-	LC	-	Pos	Eg; T; Cm	-
Muridae							
Aethomys chrysophilus (de Winton, 1897)	Red Rock Rat	-	LC	-	Pos	Mmb; Bk; Ch; Mg; Eg; T; Cm	-

Species name	Common name	Phenology / migration patterns	IUCN	Other statuses	Occ.	Habitat use	Uses
Dasymys incomtus (Sundevall, 1847)	African Marsh Rat	-	LC	-	Pos	Mmb; Bk; Ch; Mg; T; Eg; Sw	-
Gerbiliscus boehmi (Noack, 1887)	Behm's Gerbil	-	LC	-	Pos	Ch; Mg; T	-
Gerbiliscus leucogaster (Peters, 1852)	Bushveld Gerbil	-	LC	-	Pos	Ch; Mg; T; Eg	-
Gerbiliscus validus (Bocage, 1890)	Savanna Gerbil	-	LC	-	Pos	Ch; Mg; T; Eg	-
Grammomys dolichurus (Smuts, 1832)	Woodland Thicket Rat	-	LC	-	Pos	Mmb; Bk; Ch; Mg; T	-
Lemniscomys rosalia (Thomas, 1904)	Single-striped Grass Mouse	-	LC	-	Pos	Eg; T; Cm	-
Mastomys natalensis (Smith, 1834)	Natal Multimammate Mouse	-	LC	-	Pos	Ch; Mg; T; Cm	-
Mus minutoides Smith, 183	Pygmy Mouse	-	LC	-	Pos	Mmb; Bk; Ch; Mg; T; Cm	-

Species name	Common name	Phenology / migration patterns	IUCN	Other statuses	Occ.	Habitat use	Uses
Mus triton (Thomas, 1909)	Gray-bellied Pygmy Mouse	-	LC	-	Pos	Eg	-
Pelomys fallax (Peters, 1852)	Creek Groove-toothed Swamp Rat	-	LC	-	Pos	Ch; Mg; Eg; T	-
Thallomys paedulcus (Sundevall, 1846)	Acacia rat	-	LC	-	Pos	T	-
Nesomyidae		-					
Dendromus melanotis (Smith, 1834)	Gray African Climbing Mouse	-	LC	-	Pos	Ch; Mg; T; Eg	-
Dendromus mystacalis (Heuglin, 1863)	Chestnut Climbing Mouse	-	LC	-	Pos	Ch; Mg; T; Eg	-
Dendromus nyikae Wroughton, 1909	Nyika Climbing Mouse	-	LC	-	Pos	Mmb; Bk; Ch; Mg; T; Eg	-
Saccostomus campestris Peters, 1846	Pouched Mouse	-	LC	-	Pos	Ch; Mg; T	Food

Species name	Common name	Phenology / migration patterns	IUCN	Other statuses	Occ.	Habitat use	Uses
Steatomys parvus Rhoads, 1896	Tiny Fat Mouse	-	LC	-	Pos	Ch; Mg; T	-
Steatomys pratensis Peters, 1846	Fat Mouse	-	LC	-	Pos	Ch; Mg; T; Eg	Food
Pedetidae							
Pedetes capensis (Forster, 1778)	Spring Hare	-	LC	-	Pos	Ch; Mg; T; Eg	Food
Sciuridae							
Paraxerus capapi (A. Smith, 1836)	Smith's Bush Squirrel	-	LC	-	Pos	Ch; Mg; T	-
Thryonomyidae							
Thryonomys gregorianus (Thomas , 1894)	Lesser Cane Rat	-	LC	-	Pos	T	Food
Thryonomys swinderianus (Temminck, 1827)	Greater Cane Rat	-	LC	-	Pos	Eg; Rs; Cm	Food

Species name	Common name	Phenology / migration patterns	IUCN	Other statuses	Occ.	Habitat use	Uses
TUBULIDANTATA							
Orycteropodidae							
Orycteropus afer (Pallas, 1766)	Aardvark	-	LC	-	Pos	Mmb; Bk; Ch; Mg; T	Food

Sources:
Baker *et al.*, 2015; Batzer and Boix, 2016; BWZ and DoF, 2019; Bittencourt-Silva, 2019; Broadley, 1971 (in Chabwela *et al.*, 2010); Broadley and Boycott, 2008; Dudley, 2000; Ihlow *et al.*, 2019; Jersabek and Leitner, 2013; Leonar, 2001; Lumbwe, 2018; Marshall, 2004; Namukonde, 2017; Pieterson *et al.*, 2017; Willems and Leonard, 2019; WoRMS Editorial Board, 2020

Legend:
Statuses: LC - Low Concern; NT - Near Threatened; VU – Vulnerable; CR – Critically Endangered (IUCN, 2020); passer domesticus – non-native species to Zambia; Inv. – species with invasive status (CAB International, 2020).
Occurrence: C – confirmed; Prb – probable; Pos – possible/ potential; Ext – locally extinct.
Macro-habitat: Sw – swamp; Eg – edaphic grassland; T – termitaria; Mmb – miombo; Mg – munga; Ch – chipya; Bk – Baikiaea

…	
PHYLLUM	
CLASS	
ORDER	
Family	
Genus species Authority, year of description	…

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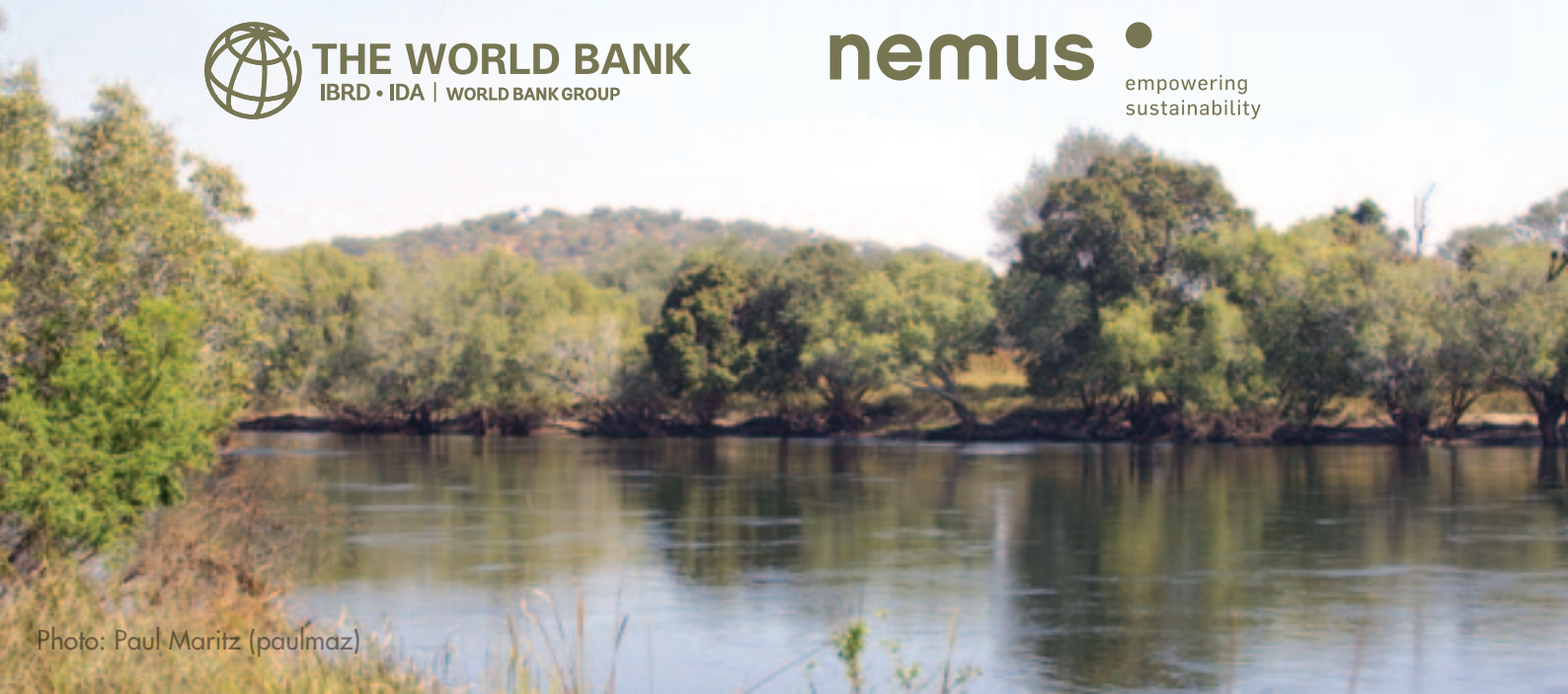


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