Nile Basin Initiative

Nile Transboundary Environmental Action Project

The Wetlands of the Nile Basin: Baseline Inventory and Mapping

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Foreword

The Nile Basin Initiative (NBI) is a partnership between riparian countries of the Nile; namely Burundi, Democratic Republic of Congo, Egypt, Ethiopia, Kenya, Rwanda, Sudan, Tanzania, and Uganda. The NBI's shared vision is to "achieve sustainable socioeconomic development through the equitable utilization of, and benefit from the common Nile Basin water resources". To translate this shared vision into action, there are two complimentary programs: the Shared Vision Program (SVP) which creates a basin wide enabling environment for sustainable development; and the Subsidiary Action Programs (SAPs) engaged in concrete activities for long term sustainable development, economic growth and regional integration of the Nile Basin countries.

The Nile Transboundary Environmental Action Project (NTEAP), one of the eight Projects under the Nile Basin Initiative's (NBI) Shared Vision Program, was mandated to provide a strategic environmental framework for the management of the transboundary waters and environmental challenges in the Nile River Basin. One of the ways in which NTEAP met this objective was to conduct studies to improve the understanding of the relationship between water resources development and the environment enhancing basin wide cooperation and capacities for better environmental management of Nile Basin resources. This study was initiated by the Wetlands and Biodiversity Conservation component of NTEAP, to enhance the understanding of the status and functions of wetlands, biodiversity and water resources in the sustainable development of the Nile Basin.

The objective of this project was inventory and map the wetland resources in the Nile Basin as a basis for management and monitoring their trends using GIS and Remote Sensing, in order to support informed decision making in the sustainable management of wetlands.

HR Wallingford (the Consultant) has undertaken wetland mapping services of the Nile Basin to the NTEAP (the Client) based on a contract signed in September 2008. Main activities carried out by the consultant to achieve this objective include the following:

1. Carry out an initial data collection exercise regarding wetland mapping progress in the Nile Basin.
2. Determine GIS capabilities in the Nile Basin countries.
3. Conduct an inception workshop and submit an inception report describing the methodology to inventory and maps wetlands in the Nile Basin.
4. Carry out wetland mapping based on remote sensing data for the Nile Basin
5. Liaise with the NBI Decision Support System (DSS) project to ensure usability of the outputs of this project with the DSS.
6. Produce wetland maps, inventory manuals and assess trends
7. Conduct final workshop and provide final report (this report).

Although numerous challenges were faced during the conduct of the study, the project team has managed, through continuous communication and commitment, to work through these challenges and produce the required outputs for this project.

It is hoped that the NBI countries will find ways of cooperation in the utilization of the wetland inventory and use this report as a platform to:

- update information on wetlands and biodiversity initiatives
- show results and exchange information on lessons learned
- exchange ideas and engage in discussion forums
- provide information to users, stakeholders, and development partners

In addition to these national and regional level engagements and communication possibilities the inventory could act as a centralized and growing database in which multiple users can feed their information.

We wish to acknowledge the contribution of the Nile Basin Wetlands and Biodiversity Working Group members for their guidance and close follow up that has resulted in the successful conclusion of the study. NTEAP extends its gratitude to the NBI member countries through the Technical Advisory Committee (TAC) and the Project Steering Committee members, the Shared Vision Program projects, the Subsidiary Action Programs, the NBI Secretariat and the development partners (The World Bank, UNDP GEF) for the support provided in the conduct of this study.

We very much hope that this publication will facilitate cooperation among the NBI countries in the management of the wetlands of the Nile Basin through updating and sharing of the information generated through this study.

Gedion Asfaw
Regional Project Manager
Nile Transboundary Environmental Action Project

List of Acronyms

CBD	Convention on Biodiversity
CSA	Central Statistical Agency
DEM	Digital Elevation Model
EAC	East African Community
EIA	Environmental Impact Assessment
ENSAP	Eastern Nile Subsidiary Action Programme
ENTRO	Eastern Nile Technical regional Office
EPA	Environmental Protection Authority
FAO	Food and Agricultural Organization
GEF	Global Environmental Fund
GIS	Geographic Information System
IAS	Invasive Alien Species
IBAs	Important Bird Areas
IBC	Institute of Biodiversity Conservation and Research
IFAD	International Food and Agricultural Development
IMF	International Monetary Fund
IUCN	International Union for Conservation of Nature and Natural Resources (World Conservation Union)
IWMI	International Water Management Institute
JIT	Jonglei Investigation Teak
JMP	Joint Multipurpose Programme
km	Kilometre
km^2	Square kilometre
km^3	Cubic kilometre (1 billion m^3)
LVBC	Lake Victoria Basin Commission
m asl	Meters above sea level
MoARD	Ministry of Agriculture and Rural Development
MoWR	Ministry of water Resources
NBI	Nile Basin Initiative
NBSAP	National Biodiversity Strategy and Action Plan
NDVI	Normalized Difference Vegetation Index
NGO	Non-government Organization
NTEAP	Nile Transboundary Environmental Assessment
OCHA	Office for the Coordination of the Humanitarian Affairs
RCMRD	Regional Centre for Mapping of Resources for Development
SNNPR	Southern Nations, Nationalities, and Peoples' Region
SRTM	Shuttle Radar Topography Mission
UNDP	United Nations development Programme
USAID	United States Agency for International Development
WBISPP	Woody Biomass Inventory and Strategic Planning Project
EWUAP	Efficient Water Use in Agricultural Production

Glossary of Terms

Active sensor	Remote sensing instrument that emits its own energy and then measures that energy after it is reflected from features on the Earth's surface.
Africover	Africover was a UN project which collected and collated geographical information on Africa mostly using satellites. It gathered data on areas such as land usage, climate conditions and it also locates natural resources. One major usage of this system has been to provide flood warnings to governments and NGOs, who then pass the information onto farmers.
Alien species	A species occurring in an area outside of its historically known natural range as a result of intentional or accidental dispersal by human activities. Also known as introduced species.
Assemblage	See term, "Community."
Avifauna	All of the birds found in a given area.
Band	A single layer of an image created using a specific range of wavelengths. A colour digital image is composed of three bands that record red, green, and blue wavelengths of light.
Biodiversity	The totality of genes, species, and ecosystems in a region or the world. The variation of life forms within a given ecosystem.
Biological Resources	Those components of biodiversity of direct, indirect, or potential use to humanity (Used interchangeably with Biotic Resources).
Biome	A major portion of the living environment of a particular region (such as a fir forest or grassland), characterized by its distinctive vegetation and maintained by local climatic conditions.
Biota	All of the organisms, including animals, plants, fungi, and microorganisms, found in a given area.
Biotic	Pertaining to any aspect of life, especially to characteristics of entire populations or ecosystems.
Buffer zone	The region near the border of a protected area; a transition zone between areas managed for different objectives.
Carrying capacity	The maximum number of people, or individuals of a particular species, that a given part of the environment can maintain indefinitely.
Center of diversity	Geographic region with high levels of genetic or species diversity.
Center of endemism	Geographic region with numerous locally endemic species.
Channel	This is typically synonymous with "band" of a remote sensing sensor
Characteristic diversity	The pattern of distribution and abundance of populations, species, and habitats under conditions where humanity's influence on the ecosystem is no greater than that of any other biotic factor.
Class	In taxonomy, a category just beneath the phylum and above the order; a group of related, similar orders.

Classification	The process of identifying and labelling features in an image. Pixels are grouped into categories using manual or automated methods.
Co-management	The sharing of authority, responsibility, and benefits between government and local communities in the management of natural resources.
Common property resource management	The management of a specific resource (such as a forest or pasture) by a well-defined group of resource users with the authority to regulate its use by members and outsiders.
Community	An integrated group of species inhabiting a given area; the organisms within a community influence one another's distribution, abundance, and evolution (A Human Community is a social group of any size whose members reside in a specific locality).
Conservation	The management of human use of the biosphere so that it may yield the greatest sustainable benefit to current generations while maintaining its potential to meet the needs and aspirations of future generations: Thus conservation is positive, embracing preservation, maintenance, sustainable utilization, restoration, and enhancement of the natural environment.
Conservation of biodiversity	The management of human interactions with genes, species, and ecosystems so as to provide the maximum benefit to the present generation while maintaining their potential to meet the needs and aspirations of future generations; encompasses elements of saving, studying, and using biodiversity.
Cosmopolitan	Widely distributed over the globe.
Database	A database is an integrated collection of logically related records or files consolidated into a common pool that provides data for one or multiple uses. In one view, databases can be classified according to types of content: bibliographic, full-text, numeric, and image.
DEM	A digital elevation model (DEM) is a digital representation of ground surface topography or terrain. It is also widely known as a digital terrain model (DTM). A DEM can be represented as a raster (a grid of squares) or as a triangular irregular network. DEMs are commonly built using remote sensing techniques, but they may also be built from land surveying.
Demography	The rate of growth and the age structure of populations, and the processes that determine these properties.
Ecosystem	The organisms of a particular habitat, such as a pond or forest, together with the physical environment in which they live; a dynamic complex of plant, animal, fungal, and microorganism communities and their associated non-living environment interacting as an ecological unit. Ecosystems have no fixed boundaries; instead, their parameters are set according to the scientific, management, or policy question being examined. Depending upon the purpose of analysis, a single lake, a watershed, or an entire region could be an ecosystem. Within the Millennium Ecosystem Assessment (MA), ecosystems are described as the complex of living communities (including human communities) and non-living environment (Ecosystem Components) interacting (through Ecological Processes) as a functional unit which provides inter alia a variety of benefits to people (Ecosystem Services).

Ecotype	A genetically differentiated sub-population that is restricted to a specific habitat.
Electromagnetic Spectrum	The range of wavelengths of electromagnetic radiation. Remote sensing applications typically use wavelengths that include the visible wavelengths (blue through red), the infrared, and microwave regions of the electromagnetic spectrum. The shorter wavelength ultraviolet, x-ray, and gamma rays are not typically used. The long wavelength radio waves are also not typically used.
Endemic	Restricted to a specified region or locality.
Evolution	Any gradual change. Organic evolution is any genetic change in organisms from generation to generation.
Fauna	All of the animals found in a given area.
Flora	All of the plants found in a given area.
Gene	The functional unit of heredity; the part of the DNA molecule that encodes a single enzyme or structural protein unit.
Genetic diversity	Variation in the genetic composition of individuals within or among species; the heritable genetic variation within and among populations.
Genotype	The set of genes possessed by an individual organism.
GIS	A geographic information system (GIS) or geographical information system captures, stores, analyzes, manages, and presents data that is linked to location. Technically, GIS is geographic information systems which includes mapping software and its application with remote sensing, land surveying, aerial photography, mathematics, photogrammetry, geography, and tools that can be implemented with GIS software. Still, many refer to "geographic information system" as GIS even though it doesn't cover all tools connected to topology.
Globcover	Globcover was a two-year project that developed the sharpest map of Earth's global land cover so far. The project contributed information relevant to land use, ecosystems and climate change with data collected by Envisat.
Habitat	The environment in which an organism lives. Habitat can also refer to the organisms and physical environment in a particular place.
Hotspot	A biodiversity hotspot is a biogeographic region with a significant reservoir of biodiversity that is threatened with destruction.
Hybridization	Crossing of individuals from genetically different strains, populations, or species.
Hyperspectral	Many bands (often more than 100). Some hyperspectral sensors are capable of recording images with more than 200 bands and each band represents a specific (usually very narrow) portion of the electromagnetic spectrum.
Indicator species	A species whose status provides information on the overall condition of the ecosystem and of other species in that ecosystem.

Indigenous peoples	People whose ancestors inhabited a place or country when persons from another culture or ethnic background arrived on the scene and dominated them through conquest, settlement, or other means and who today live more in conformity with their own social, economic, and cultural customs and traditions than with those of the country of which they now form a part (also: native peoples or tribal peoples).
Infrared	The portion of the electromagnetic spectrum that lies between the visible and microwave wavelengths (0.7 nanometres – 100 micrometers).
Introduced species	A species occurring in an area outside of its historically known natural range as a result of intentional or accidental dispersal by human activities. Also known as alien species.
Life form	Characteristic structure of a plant or animal.
Mosaicing	The process of combining several neighbouring images together. This can be undertaken for display or analysis purposes although can introduce errors when classifying as each individual image has been acquired under slightly different environmental conditions.
Multispectral	Multiple bands, with each band recording a different portion of the electromagnetic spectrum.
Native species	Plants, animals, fungi, and microorganisms that occur naturally in a given area or region.
Open source software	Software that has the source code freely available and is licensed so that it can be freely distributed and modified as long as appropriate credit is provided to the developers. There are several licensing options for open source software but all of them follow these basic rules. More information about open source software is available at the Open Source Initiative web page (http://www.opensource.org/). More information about open source geospatial software can be found at the Open Source Geospatial (OSGeo) website: http://www.osgeo.org/.
Optical sensor	Sensor that is sensitive to visible and infrared wavelengths of light.
Panchromatic Band	A band available on some sensors that records information across a wide range of the electromagnetic spectrum. This band is often recorded at a higher spatial resolution and can be used to sharpen data across the other bands.
Passive sensor	Remote sensing instrument that measure energy that originated from the sun and was reflected by the Earth's surface or was emitted from features on the Earth's surface.
Pixel	An individual "picture element" from an image. When an image is magnified the individual pixels can be seen as a square or rectangular block in image.
Population	A group of individuals with common ancestry that are much more likely to mate with one another than with individuals from another such group.
Protected area	A legally established land or water area under either public or private ownership that is regulated and managed to achieve specific conservation objectives.

Radar	Radar is an acronym for Radio Detection and Ranging (RADAR – although the letters are usually not capitalized). It is a remote sensing instrument that emits a microwave signal and measures the time for the signal to return to the detector as well as the intensity of the returned signal. Interpreting the returned signal can provide digital elevation models (DEMs), changes in water level and information about land cover.
Radiance	Measure of radiation energy. Radiance is usually measured in watts per unit solid angle area.
Radiation	Energy transferred as particles or waves through space or other media. In remote sensing radiation often comes from the sun although it can also come from the sensor as is the case with LIDAR and RADAR sensors.
Ramsar	The Convention on Wetlands (Ramsar, Iran, 1971) is an intergovernmental treaty whose mission is "the conservation and wise use of all wetlands through local, regional and national actions and international cooperation, as a contribution towards achieving sustainable development throughout the world".
Reflectance	Ratio of the intensity of reflected radiation to that of incident radiation on a surface. Reflectance is expressed in percent and usually refers to a specific wavelength.
Rehabilitation	The recovery of specific ecosystem services in a degraded ecosystem or habitat.
Resolution	The smallest detail visible in an image. Usually resolution refers to spatial resolution. The spatial resolution of an image is an indication of the size of a single pixel in ground dimensions. It is usually presented as a single value that represents the length of one side of a square. For example, a spatial resolution of 30 metres means that one pixel represents an area 30 metre by 30 metre on the ground. If the pixel is rectangular, it will be recorded as a height and width dimension (i.e., 56m × 79m).
Restoration	The return of an ecosystem or habitat to its original community structure, natural complement of species, and natural functions.
Selection	Natural selection is the differential contribution of offspring to the next generation by various genetic types belonging to the same populations. Artificial selection is the intentional manipulation by man of the fitness of individuals in a population to produce a desired evolutionary response.
Sensor	A device that is capable of recording the intensity of electromagnetic radiation. In remote sensing these devices typically record this information in images, rather than from a single point.
Species	A group of organisms capable of interbreeding freely with each other but not with members of other species.
Species diversity	A function of the distribution and abundance of species. Approximately synonymous with species richness. In more technical literature, includes considerations of the evenness of species abundances. An ecosystem is said to be more diverse, according to the more technical definition, if species present have equal population sizes and less diverse if many species are rare and some are very common.

Species richness	The number of species within a region. A term commonly used as a measure of species diversity, but technically only one aspect of diversity.
Spectral reflectance curve	A curve describing the reflectance values for a particular feature over a range of wavelengths. The x-axis is for wavelength and the y-axis is for reflectance. Different features have unique spectral reflectance curves.
SRTM	The Shuttle Radar Topography Mission (SRTM) is an international research effort that obtained digital elevation models on a near-global scale from 56 °S to 60 °N, to generate the most complete high-resolution digital topographic database of Earth to date. SRTM consisted of a specially modified radar system that flew on board the Space Shuttle Endeavour during the 11-day STS-99 mission in February 2000.
Subspecies	A subdivision of a species; a population or series of populations occupying a discrete range of differing genetically from other subspecies of the same species.
Succession	The more or less predictable changes in the composition of communities following a natural or human disturbance. For example, after a gap is made in a forest by logging, clearing, fire, or treefall, the initial (or "pioneer") species are often fast-growing and shade-intolerant. These species are eventually replaced by shade-tolerant species that can grow beneath the pioneers. If a community is not further disturbed, the outcome of the successional sequence may be a so-called climax community whose composition is unchanging. In practice, many communities are frequently disturbed and may never reach a climax composition.
Sustainable development	Development that meets the needs and aspirations of the current generation without compromising the ability to meet those of future generations.
Systematics	The study of the historical evolutionary and genetic relationships among organisms and of their phenotypic similarities and differences.
Taxon (pl. taxa)	The named classification unit (e.g. Homo sapiens, Hominidae, or Mammalia) to which individuals, or sets of species, are assigned. Higher taxa are those above the species level.
Taxonomy	The naming and assignment of organisms to taxa.
Trophic level	Position in the food chain, determined by the number of energy-transfer steps to that level.
Vascular plants	Plants with a well-developed vascular system that transports water, minerals, sugars, and other nutrients throughout the plant body. Excludes the bryophytes: mosses, hornworts, and liverworts.
Visible spectrum	The portion of the electromagnetic spectrum between the ultraviolet and infrared wavelengths. This is the range of wavelengths (including the colours in the spectrum from blue through red) that can be detected by the human eye.
Wavelength	Distance between two crests of a wave. In remote sensing electromagnetic waves are typically measured in nanometres, millimetres, and centimetres.

Wetland	As defined by the Ramsar Convention, wetlands include a wide variety of habitats such as marshes, peatlands, floodplains, rivers and lakes, and coastal areas such as saltmarshes, mangroves, and seagrass beds, but also coral reefs and other marine areas no deeper than six metres at low tide, as well as human-made wetlands such as waste-water treatment ponds and reservoirs.

Executive Summary

The Wetlands of the Nile Basin: Baseline Inventory and Mapping

October 2009

The Nile has been and is still an active area for research. For decades, researchers have been studying its unique features. Wetlands in the Nile are one of the most complex features with a variety of aspects driving these ecosystems with their rich biodiversity. The project has mapped and described the overall wetland situation in the Nile basin using remote sensing technology and supplementing this information with data obtained through field campaigns, literature research and stakeholder consultation. Considering the vast dimensions of the Nile Basin the project has yielded a baseline inventory and maps for the overall basin and has focused on a selection of important larger scale wetlands for more detailed investigations. These wetlands include:

1. Sio Malaba Malakisi
2. Mara wetlands
3. Sudd Swamps
4. Nile Delta
5. Sobat–Machar/Gambela Marches
6. Bahr el Ghazal Ghazal swamps
7. Lake Kyoga swamps
8. Albert Nile Swamps
9. Winam Gulf (Kisumu Bay)
10. Kagera swamps
11. Lake Tana Wetlands Complex

As an example for in depth evaluation of available information, knowledge for Lake Tana has been exploited in-depth including compiled species lists.

Based on the contract rerquirements, the project collected satellite as well as ground control information in form of georeferenced photographs of wetland locations, conducted field visits to obtain information from local stakeholders regarding institutional capacities and wetland management efforts within the different countries and developed methodologies to compile the collected information.

Mapping of the wetlands was undertaken using Landsat TM5 and ETM7 Satellite images covering the whole of the Nile Basin with a resolution of 28 x 28 m. The sensor was chosen due to data accessibility reasons, free availability, coverage of the whole basin and proven methodologies for the desired mapping work. After initial data collection was concluded and a number of possible approaches were considered, an optimum solution for a basin wide mapping exercise was chosen. The methodology was presented and agreed in a project inception workshop held in Khartoum in November 2008.

With the agreed methodology the wetlands were mapped using the collected dry season Landsat images showing most distinct wetland boundaries not influenced by rain induced flooding. The Nile Basin as well as its sub basins were delineated based on a SRTM DEM. The satellite images were mosaiced and the images corrected performing e.g. haze reduction. Utilizing the Normalized Difference Vegetation Index (NDVI), wetlands were mapped and results calibrated with ground control data for the individual sub-basins with their destinct vegetation types and

seasonsonal particularities. The resulting information was then classed based on the Ramsar classification system using a reduced set of classes that could be distinguished with the remote sensing approach. In order to increase the accuracy of the derived wetlands, regional and local institutions and individuals were approached to confirm or correct the derived wetland bopundaries based on their detailed knowledge of their individual regions. The feedback received in this exercise was used to correct the wetland information where appropriate.

The derived wetland maps were stored in a GIS database developed within the ArcGIS 9.2 environment, integrating different data layers including Russian and English topographical maps of the 1950es, hotspot layers, ramsar site layers, NDVI results, derived wetland information in different formats, wetland maps as well as respective metadata and attribute information for selected wetlands. The stored data also includes biodiversity information that was derived from literature as well as through approaching local knowledge groups for their input.

The status and biodiversity of the selected major wetlands in the Nile Basin has been assessed and described using available literature sources as well as reports and narrative information as well as data provided by the project working group members and data collected through direct approaches from local knowledge groups. This information was included in the report as well as stored in the GIS database, linking them to the respective wetland maps.

As the main project result, the developed GIS database allows the user to carry out spatial and attribute queries to assist in management and decision making. It is anticipated that the database will act as baseline system that will be maintained and updated by NBI partners. As examples wetland maps were produced and attached to the report, giving both a basin wide as well as sub-basin focused overview of the major Nile wetlands. The reports contains management information for the different areas including challenges, constraints and threats/pressures that will be important for decision making that includes wetland related aspects.

For selected wetlands as listed above, the detailed information provided with the report as well as within the database provides valuable knowledge for wetland related questions. The information as well acts as an example for upgrading the wetland inventory with information that in the future can be derived from local or regional studies. Respective hints for maintenance and updating related issues are given. The NBI will attempt to find protocols and regulations for the necessary maintenance and upgrading procedures that will allow interaction and data transfer between individual initiatives and the weland database. These protocols will facilitate both providing the data to users as well as incorporating data that is available in national inventories or will be obtained through future studies.

Results of the study were further used to analyze wetland status and “trends” for selected sites by comparing change pairs between the topographic maps of the 1950es with the newer Landsat derived data of the current study representing the situation of the 1980es to 1990es. For this purpose, wetlands as indicated on the historic topographical maps were digitized and compared with the Landsat derived wetlands. Comparing the wetlands over this approximately 40 year gap the results show partly significant changes with increasing wetland sizes for the equatorial lakes, and large natural swamps like the Sudd and Bahr el Ghazal, and decreasing areas for the Mara Wetlands, Winam Gulf and the Nile Delta. The observed differences may be related to changes in hydrological regimes as well as anthropogenic pressures. Uncertainties based on the unknown conditions under which the historical topographic maps have been derived have to be considered when judging these results.

For detailed information about maintenance and updating of the database an inventory manual has been developed in line with the respective Ramsar guidelines. The manual includes strategic as well as technical information about issued important with regards to wetlands management efforts, maintenance and updating works and gives respective hints. While highlighting administratively relevant aspects, the manual can not replace protocols that need to be developed in-between the Nile Basin countries and especially need to detail the resources that have to be allocated to maintain the database and keep it updated.

The report finally gives conclusions and recommendations, highlighting maintenance and training needs for a sustainable inventory operation and recommends the exploration of different methodologies that may be favourable for local or regional assessments for which finer resolutions are adequate. Recommendations are as well given to include socioeconomic aspects, water quality and especially information about the hydrological regime into the inventory. This information would significantly enhance the data density of the inventory and provide decisionmakers with additional wetland relevant information. The urgent need for transboundary monitoring strategies oarticularly highlighted considering that due to their dependency on river hydrology, most wetlands are transboundary in nature despite their physical limits not crossing national borders.

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1. Introduction

1.1 THE NILE BASIN WETLANDS

The Nile Basin as shown in Figure 1 is an extensive river and watershed system with a length of approximately 6,800 km and a catchment area of 2,9 million km^2 (Dumont, 2009), stretching over central and north-eastern Africa (Hurst & Phillips, 1931). The Nile has five major tributaries. The Bahr el Jebel, the Bahr el Ghazal, the Sobat, the Blue Nile and the Atbara. The Blue Nile is the source of most of the Nile's water, the Bahr el Jebel reaching into the Equatorial Lakes region is the farthest source. The waters feeding the Bahr el Jebel originate from the Equatorial Lakes region of central Africa, with the most distant source in southern Rwanda The waters then flow north through Tanzania, Lake Victoria and Uganda, with the DRC contributing waters at Lake Albert, and continue through southern Sudan. The Blue Nile starts at Lake Tana in Ethiopia, flowing into Sudan from the southeast, merging with the Bahr el Ghazal and the Sobat. Then the White Nile meets the Blue Nile at the Sudanese capital Khartoum. While the upper stretches of the White Nile are flowing through tropical areas and the Blue Nile originates from the Ethiopian Highlands, the northern section of the Nile flows almost entirely through desert from Sudan into Egypt. The Nile ends in a large delta at the Mediterranean Sea. Eritrea which is within the Nile Basin, also contributes to the Nile flow.

The wetlands along the Nile are unevenly distributed in the basin. Near to the source of the Nile in East & Central Africa many wetlands are found. The equatorial lakes also host extensive wetlands, mainly along the lake shores, and wetlands continue to be a nearly permanent feature along the course of the Victoria Nile down to the Ugandan-Sudanese border at Nimule.

Further downstream between Nimule and Juba, the Nile, here called the Bahr el Jebel, crosses a mountainous region with no significant wetlands, then spreading into the massive Sudd wetland area, 60,000 km^2 in size but widely varying depending on inflow. In the northern Sudd region, the Bahr el Ghazal joins the system with negligible contribution as the waters from its large catchment area mostly evapotranspirated in the extensive Bahr el Ghazal swamps. The Sobat which joins the system slightly further downstream near Malakal drains the large Baro-Pibor area, 225,000 km^2 in size, contributing a significant flow to the downstream White Nile originating from the Baro-Akobo-Sobat wetlands, the two former being on the Ethiopian side, as well as from the Machar Marshes. The combined waters now named White Nile flow further downstream, fringed by smaller wetlands along the shores.

Ethiopia in the eastern part of the Nile Basin is the source of the Blue Nile, originating from Lake Tana. The lake hosts a variety of wetlands along its shore and boasts a significant biodiversity. In this study it was selected as a pilot site for an in-depth assessment of its biodiversity resources, acting as an example for respective future assessments for other sites. Downstream of Lake Tana, further wetlands are found along the course of the Blue Nile as well as along its tributaries. At Khartoum the Blue and White Nile join to form the River Nile.

Further downstream wetlands are relatively small and only fringing the river shores. This situation as found throughout the north of Sudan and in Egypt is only interrupted by some larger wetland areas in shallow parts of the Merowe and Aswan reservoirs. Rising from the high mountains west of Lake Tana, the Atbara River shows a similar picture with wetlands constricted to the river shores while flowing through the incised landscape. Reaching the Mediterranean and forming the Nile Delta, a last significant wetland area can be observed, most of which has been converted to agricultural land. The Lakes in Fayoum and northern Egypt are also examples of wetlands in Egypt.

Figure 1 The Nile Basin (World Bank, 2000)

1.2 WETLAND ECOSYSTEMS

Wetlands deliver a wide range of critical and important services (e.g. fish and fibre, water supply, water purification, coastal protection, recreational opportunities, and increasingly, tourism) vital for human well-being. Maintaining the natural functioning of wetlands will enable them to continue to deliver these services.

The described wetlands fulfil several of these functions and roles in the Nile ecology. They act as biodiversity strongholds, breeding areas, flood retention assets, climate drivers and productivity areas just to name some, providing strong economical asset due to their natural resources and production capacity. Their destruction would lead to unforeseeable changes in the ecology of the river with related impacts on human livelihoods. Their preservation and management on the other hand will ensure optimized benefits based on their functions.

The Nile Basin Initiative (NBI) acknowledges the important ecosystem functions of wetlands and therefore strives to understand the wetland resources of the Nile in order to optimize management and decision making in this regard. As for a coordinated management of wetlands knowledge about their resources as well as their behaviour is necessary, the NBI has launched this study to create a wetland inventory by mapping these and collating relevant resource information into a GIS database.

1.3 DEVELOPING A WETLAND INVENTORY

The services requested for developing the wetland inventory include the collection of satellite imagery, photographs and topographic maps for delineating wetland boundaries, and establishing wetland maps. In addition there is the collection of related information such as ground truthing data, management and institutional information, pressures and threats as well as biodiversity data. The services then required to develop wetland maps and store these including biodiversity and other attribute information in a GIS database, utilizing and collating information from a variety of sources. Based on the knowledge collected, management efforts as well as capabilities of GIS institutions in the Nile Basin countries were to be described and recommendations expected for future maintenance and updating efforts.

In addition to the wetland maps that were to be generated, the services included to judge on trends in the wetlands which was agreed to be carried out through a change comparison between historical maps drafted in the 1950s and the Landsat derived wetland maps, aiming to display changes in the Nile Basin over a longer period. In addition to the technical outputs, policy information was requested by developing policy recommendations regarding the maintenance and updating of the inventory.

Chapter 2 of this report provides a detail description of the methodology that was used to develop the Wetland Inventory and Chapter 3 details the results of realising the inventory and maps across the Nile Basin. Chapter 4 descibes how the maps and inventory can be updated post-project and finally Chapter 5 describes the status and trends of key identified Wetlands. This report lastly presents the conclusion of the study together with recommendations for next steps.

2. Methodology

2.1 BASELINE CONSIDERATIONS

Due to the size of the Nile Basin, mapping the Nile Wetlands is an ambitious task, with several 'trade-offs' to ensure best use of project resources. During the inception period of the project, all the aspects of the methodology described below were discussed with the NBI NTEAP, members of the Nile Basin wetlands regional working group and other stakeholders of the project. At the project inception workshop it was agreed to use:

1. The freely available Landsat images for mapping the wetlands (due to cost/availability/coverage reasons).
2. Dry season images for the mapping exercise rather than wet season images to map the permanent wetlands which remain wet throughout the year.
3. The Normalized Difference Vegetation Index (NDVI) to detect wetlands as, through testing during the project inception period, it has proved to give good results for identifying wetland areas.
4. A core or minimum dataset for ground truthing applied to a number of sites to verify and improve the NDVI maps.

Data for the Nile wetland mapping and inventory has been collected from or located at various sources and includes remote sensing data, photographic and narrative ground truthing information as well as attribute information taken from reports and tables. An overview is given in Table 1; more information is given in the references.

As a part of this work, GIS capabilities in the region were also determined to recommend suitable future methods of updating the wetlands inventory.

Table 1 Overview of available data

Satellite images
Full Landsat images of the Nile Basin
Individual Landsat images from different years
MrSID 2000 series
MrSID 1990 series
Topographical maps
Russian maps (~1950)
British maps (~1950)
Topographic maps (Ethiopia – EMA) only part coverage
Other spatial data
Land cover (Africover)
DEM (SRTM)
Globe Cover (Ethiopia)
RCMRD Africa dataset.
Transboundary Environmental Analysis (Maps)
TECCONILE maps
UN OCHA maps (Sudan)
Uni Bern maps (some areas of Sudan)
Woody Biomass dataset (Ethiopia)

Aerial/ground photographs for ground truthing
Sudd image data sets (2004-2006)
Africover ground truthing images for Lakes and White Nile
Aerial Photo Coverage 1:50,000 / 1:40,000 for Ethiopia – (various years). (Located but not acquired).
Photographs from HRW 2009 ground truthing campaign (Ethiopia)
Reports
Nile Basin Initiative & Nile Transboundary Environmental Action Project eds. (In Press) Status of Wetlands and Biodiversity in Ethiopia. Wetlands and Biodiversity Conservation component of the Nile Transboundary Environmental Action Project. Nile Basin Initiative Secretariat, Addis Ababa, Ethiopia.
Wetland management in Uganda, Wetlands Management Department
The South Sudan Road and Dike Rehabilitation Project (SSRDRP) EIA wetlands report
Regional Transboundary Diagnostic Analysis for the Lake Victoria Basin
EAC/LVBC Strategic Action / Investment plan for the Lake Victoria Basin
Remotes Sensing and GIS data requirements, research in Sudano-Sahelian landscapes (Hof 2006)
Nile Basin Initiative (In Press) The Wetlands, Biodiversity and Water Quality studies on Lake Tana. Nile Basin Initiative, Nile Transboundary Environmental Project, Addis Ababa, Ethiopia.
Sustainable Wetlands Management in Illubabor Zone (Woldu 2000) Woldu, Z. (2000) Sustainable Wetland Management in Illubabor Zone, South-West Ethiopia. Report 3 for Objective 2 on Plant Biodiversity in the Wetlands of Illubabor Zone. In: Ethiopian Wetlands Research Programme
Geheb, K., Yilma, D. A., IUCN Eastern Africa Programme & IUCN Wetlands and Water Resources Programme (Eds.) (2003) Wetlands of Ethiopia : proceedings of a seminar on the resources and status of Ethiopia's wetlands
Nile Basin Initiative Shared Vision Program Transboundary Environmental Analysis (2001)
Woody Biomass Inventory and Strategic Planning project – Phase 2, TECSULT, Addis, 2004
Indicative Land Use Status Rapid Assessment for Alatish National Park
Hydrological System Rapid Assessment of Alatish National Park
Study of The Flora In The Cohoha Sub-Basin
Sudan Biodiversity Strategy - 2003
Regional Workshops for Wetlands and Biodiversity Component proceedings
National Report on 43 Surveyed Wetlands, EPA, Addis, 2003
Environment Protection Authority (EPA) 2003. National Report on the 43 Surveyed Wetlands
Hillman, J. C. & Abebe, D. A. (1993) Wetlands of Ethiopia. In: Ethiopia : compendium of wildlife conservation information
Mengistou, S., Getahun, A. & Kelbessa, E. 2004. Wetlands and aquatic resources of Ethiopia : status, challenges, and prospects
MoARD 2004. Woody Biomass Inventory and Strategic Planning Project (WBISPP)
Asmelash, E. (Ed.) (2004) Proceedings of the “National Consultative workshop on the Ramsar Convention and Ethiopia"
Ethiopian Wildlife and Natural History Society (Ed.) (1996) Important bird areas (IBAs) Project
EPA 2003. State of the Environment Report for Ethiopia. Environment Protection Authority
Ministry of Agriculture (2001) The Development of irrigation agriculture in the Baro-Akobo, Awash, Abay, Omo-Ghibe River Basins
Ministry of Water Resources (1997) Baro-Akobo River Basin integrated development Master Plan studies
Ministry of Water Resources (1998) Tekeze River Basin integrated development Master Plan
Ministry of water Resources (1998) Abay (Nile) River Basin integrated development Master Plan studies
Ministry of Water Resources (1999) Ethiopian water resources management policy
Ministry of Water Resources (2002) Ethiopian water resources strategy
Egypt 4th National report on Biodiversity (2008) Ministry of Environment

Literature
Report of the Jonglei Investigation Team, 1954
The Nile Basin, Volume I, Hurst & Phillips, 1931
The Nile Basin, Volume VIII, Hurst, 1950
The Nile Basin, Volume V, Hurst & Phillips, 1938
Development studies in the Jonglei Canal Area, Mefit Babtie, 1983
The Nile, Howell & Allan, 1994
Hughes, R. H., and J. S. Hughes. 1992. A directory of African wetlands. IUCN-The World Conservation Union, Gland, Switzerland, and Cambridge, United Kingdom, United Nations Environment Programme, Nairobi, Kenya, and World Conservation Monitoring Centre, Cambridge, United Kingdom.
Shahin, M. M. A. (2002) Hydrology and Water Resources of Africa
Collins, R. O. (2002) The Nile, Yale University Press
Bullock, A., Gilman, K., McCartney, M., Waughray, D. & Blyth, K. (1998) Hydrological strategy to develop and manage African wetland resources for sustainable agricultural use. In: Wetland characterization and classification for sustainable agricultural development.
A Directory of Wetlands of International Importance, Frazier S (editor), 2002. Compact Disc.
Dugan, P. 1993. Managing the wetlands. People and rivers: Africa
Web sites with relevant broad scale data and information
The Convention on Biological Diversity (CBD) http://www.cbd.int/
The Ramsar Convention for Wetlands http://www.ramsar.org/
The International Union for Conservation of Nature http://www.iucn.org/
Bird Life International http://www.birdlife.org/
Invasive Species Database http://www.issg.org/database/welcome/
Biomap project http://www.biomap.org/
NTEAP Baseline reports
Wetlands and Biodiversity Baseline reports for Burundi, Sudan, Uganda, DR Congo, Egypt, Ethiopia and Kenya

2.2 STAKEHOLDER CONSULTATION

Stakeholder consultation and discussion was an important process in the development of the wetland inventory. In addition to the wetland data collection, discussions with stakeholders as well as remote sensing experts and the gathering of information regarding wetland status, resources- and data availability in different institutions with their various sources have played an important role in conducting the work. Finalizing the assessments, questionnaires and preliminary wetland maps were used to get feedback from a variety of stakeholders and scientists in the Nile Basin.

In addition to the in country consultation of stakeholders and institutions, different workshops were held with a range of participants including the wetland focal points of the different countries as well involved people from a variety of institutions and technical staff who will be working with the final product. Workshops were held as follows:

- Inception workshop, October 2008, Khartoum
- DSS coordination workshop, March 2009, Addis Ababa

- Final workshop, June 2009, Addis Ababa
- Handover workshop, September 2009, Addis Ababa

During these workshops, information was shared and discussed with the participants and decisions made regarding the way forward of the work and details of what to include into the reports. The work presented by the Consultant was scrutinized and steps agreed to improve the products. In addition to their comments, the participants supplied valuable country specific materials for inclusion into the report and database.

2.3 SATELLITE IMAGES COLLECTION

Landsat images of the period 1984-1990 covering the whole of the Nile Basin have been used for the mapping exercise (Courtesy of the Ministry of Water Resources and Irrigation in Egypt as well as US Geological Service). The number of images used is 200 images. Dates and locations of these are shown in Figure 2.

Dry season varies across the Nile Basin with each region having its own wet and dry periods. Based on the experience of the project team members the dry seasons were defined, upon which appropriate images were selected out of the available database or downloaded from the US Geological Survey website (http://landsat.usgs.gov/).

2.1 GROUND TRUTHING DATA IDENTIFICATION AND COLLECTION

Ground truthing information has been collected from a number of different sources, mainly from:

1. The Africover database for most of the Nile Basin countries despite Ethiopia and DRC, holding ground photographs as well as their respective location and description
2. Photos taken during 2004-2006 field visits in Uganda and Sudan (Petersen, 2008)
3. Data including photographical evidence collected during a field visit in Ethiopia as this was not covered by Africover data (see Section 2.1 for more details).

Table 2 shows the number of sites per country in the Nile Basin. The total number of photos collected is 3095.

Table 2 Photo sites by country (each photo site has between 1-4 photos)

Country	Number of Sites
Burundi	33
DRC	–
Egypt	69
Eritrea	25
Ethiopia	56
Kenya	85
Rwanda	41
Sudan	51
Tanzania	8
Uganda	197
Total	565

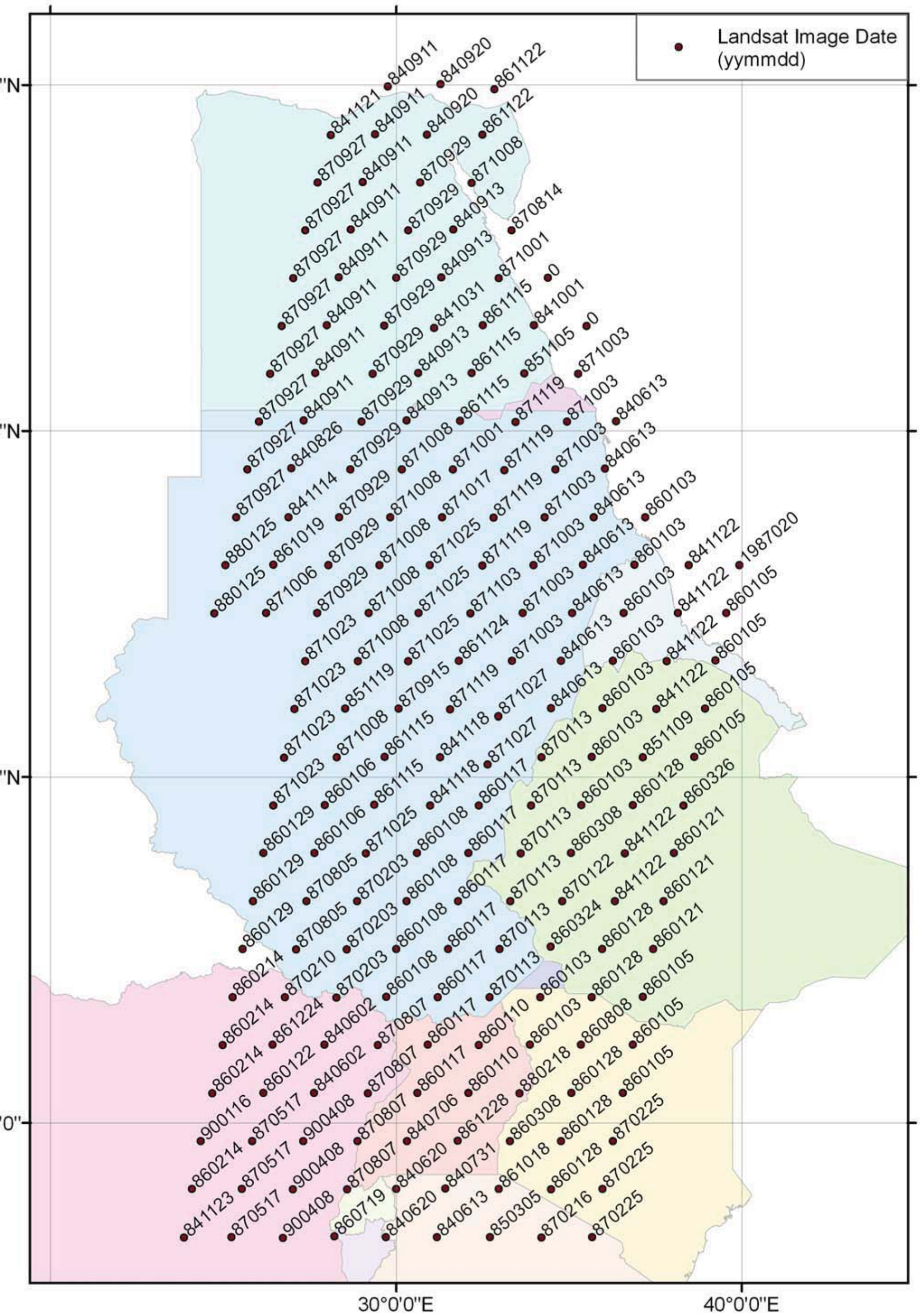

Figure 2 **Satellite images dates and locations for the Nile Basin**

2.1.1 Gorund Truth Data Collection

While large amounts of georeferenced ground truthing data have been collected for most of the Nile Basin as described by Africover (2008) and Petersen (2008), only limited information was available for the Blue Nile region. Field work that was carried out as part of the wetland project to establish the Nile wetland inventory included visits to institutions and agencies in different Nile Basin countries as well as field work, mainly in Ethiopia where the data situation concerning the ground truthing data was limited and not supported by existing data available from the earlier work. Institutional visits included meetings with agencies as listed in Section 3.5.1 with details described in the Inception Report.

The Ethiopian field data component was collected during surveys from the 5th to the 13th of April 2009. The survey team targeted wetlands that are found in the central regions west of Addis Ababa. The team travelled along the main road from Addis Ababa on the way to Asosa (Benishangul-Gumuz Region). A number of wetland sites were visited along a corridor following the road. The wetlands surveyed were located in the administrative zones of East and West Wellega.

The information collected consisted of geo-referenced ground survey points that were required to evaluate the mapping results and to validate the wetland classes generated by the project. The location of each ground survey point was recorded using GPS; at each location the vegetation characteristics were recorded and photographs were taken.

Efforts were made to collect detailed field data at each wetland site. Bio-physical data were collected including a general description of the site and the landscape, characterisation of the dominant wetland type, the hydro-geomorphology, land use and land cover types, disturbance level, the farming system in place and management schemes, and threats to the wetland (current and future).

At each site, a number of points were surveyed along transects perpendicular to the slope or along the dryer zones of the wetlands in cases where access to the site was limited by high water levels. Three to five transects were established per wetland site and distributed as evenly as possible around a segment of the wetland perimeter. Four 10×10 m quadrants were positioned around each point. In each quadrant, detailed plant species composition was recorded, including a list of the main species ranked by order of importance (dominance), percent cover for each species, and biomass ranking. A series of four photographs were taken at each point, one for each quadrant. The ground data was included into a relational database, which was subsequently used to create a *Shapefile* with associated wetland attributes for display in GIS software.

The list of sites visited included two of the most important wetland areas in Ethiopia, the Fincha'a-Chomen reservoir and associated marshes and wet meadows and the Dabus marshes. Additional minor sites were surveyed along the road and valley bottom wetlands seen from the road were also identified and photographed. (See Table 3).

Table 3 Summary of field data collected for selected wetland sites in Ethiopia

Wetland type	Name of site	Ram-sar[a]	Geographic coord. (Lat/Lon)[b]	Alt. (m)[c]	HRW class[d]	Woody Biomass[e]	Topo-graphic[f]
Sedge-grass marsh	Fincha'a-Chomen Marsh	Ts	9.40100°N 37.34560°E	2222	Wetland	Perennial Marsh	Swamp
Sedge-grass/grazed wet meadow	Fincha'a-Chomen Marsh	4	9.39288°N 37.37310°E	2218	–	–	Swamp
Sedge marsh-riparian/water	Fincha'a-Chomen Lake (dam site)	Tp	9.55555°N 37.36364°E	2212	Wetland	Open Water	Lake
Lake/permanent	Fincha'a-Chomen Lake	M/Tp	9.64625°N 37.31216°E	2212	Wetland	Open Water	Lake
Sedge-grass marsh	Amerti Reservoir	Tp	9.63468°N 37.24825°E	2318	Open Water	Perennial Marsh	Lake

Wetland type	Name of site	Ram-sar[a]	Geographic coord. (Lat/Lon)[b]	Alt. (m)[c]	HRW class[d]	Woody Biomass[e]	Topo-graphic[f]
Sedge-grass marsh along stream	Amerti River	Tp	9.62350°N 37.16061°E	2447	–	–	Swamp
Sedge-grass marsh	Fincha'a-Chomen Marsh	Tp	9.48621°N 37.14496°E	2213	Wetland	Open Water	Swamp
Sedge-grass marsh	Fincha'a-Chomen Marsh	Ts	9.48670°N 37.13213°E	2227	–	–	Swamp
Cropland	Fincha'a-Chomen Marsh	4	9.38063°N 37.12752°E	2227	Wetland	–	Swamp
Grazed wet meadow	Fincha'a-Chomen Marsh	4	9.38240°N 37.12493°E	2234	Wetland	Open Water	Swamp
Sedge marsh/riparian	Fincha'a-Chomen Marsh	Tp	9.33414°N 37.17383°E	2222	Wetland	Perennial Marsh	Swamp
Sedge marsh	Hora Sorga Reservoir Marsh	Tp	9.06511°N 36.51495°E	2016	–	–	Reservoir
Seasonally flooded agricultural land	No name	4	9.05076°N 35.93552°E	1725	–	–	–
Seasonally flooded agricultural land	No name	4	9.40787°N 35.59585°E	1876	–	–	Stream
Seasonally flooded agricultural land	No name	4	9.45588°N 35.55590°E	1847	–	–	Stream
Permanent stream	Fugiso River	M	9.49450°N 35.16255°E	1466	–	–	Stream
Permanent stream	Sedela River	M	9.55529°N 34.98875°E	1397	–	–	Stream
Permanent stream	Dabus River	M	9.55345°N 34.92664°E	1383	Open Water	–	Stream
Tree-dominated wetland	Dabus River/ Riparian area	Xf	9.55257°N 34.92682°E	1380	–	–	Stream
Sedge-grass marsh	Dabus River Floodplain/Marsh	Ts	9.55034°N 34.92584°E	1373	–	–	–
Sedge-grass marsh/ Tree-domin. wetland	Dabus River Floodplain/Marsh	Ts/Xf	9.54797°N 34.92409°E	1377	–	–	–
Sedge-grass marsh	Dabus Marsh	Tp	9.51089°N 34.91126°E	1377	–	–	–
Sedge-grass marsh	Dabus Marsh	Tp	9.55775°N 34.95279°E	1407	–	–	–
Tree-dominated wetland	Dabus Marsh/ Flood Forest	Xf	9.51046°N 35.03430°E	1408	–	–	–
Sedge-grass marsh	Dabus Marsh	Ts	9.51228°N 35.03808°E	1405	–	–	–
Sedge-grass marsh	Dabus Marsh	Tp	9.49742°N 35.00029°E	1381	–	–	–
Shrub marsh/swamp	Dabus Marsh	W	9.49786°N 35.00253°E	1388	–	–	–
Tree-Dominated wetland	Dabus Marsh/ Flood Forest	Xf	9.50702°N 35.00672°E	1396	–	–	–
Sedge-grass marsh	Dabus Marsh	Tp	9.49633°N 35.02357°E	1442	–	–	–
Permanent River	Didesa River	M	9.02694°N 36.15896°E	1137	Open Water	–	Stream

[a] Ramsar convention code.
[b] Geographic coordinates in Latitude and Longitude using WGS 84 datum.
[c] Altitude at location in meter asl was derived from GPS unit and compared with contour data from topographic map.
[d] HRW wetland classes and [e] Woody Biomass classes are indicated when overlapping with ground data are found.
[f] Land cover features shown on the topographic map and corresponding to wetland features are indicated.

During these field trips photographic evidence of different vegetation covers was taken and position as well as specific features recorded.

The applicability and suitability of the ground truthing method was tested for the Sudd marshes and the Sobat river basin areas. Based upon the ground referenced images the mapping methods were refined and the mapping output tuned in a way to match the documented on-ground situation. More details are given in the Polygon Cleaning description in Section 2.6.

2.2 HABITAT CLASSIFICATION

Different options for classification of the wetlands in the Nile Basin have been discussed with NBI NTEAP, members of the Nile Basin wetlands regional working group and other stakeholders of the project. The agreed classification method was presented in an Inception Report. While a variety of different classification system for habitats are available, two well known systems had been closely considered for this project, the Ramsar as well as the FAO Africover Land Cover Classification System (LCCS). Both systems have their advantages and disadvantages but due to suitability reasons it was agreed to adopt the Ramsar system.

The definition of wetlands in the Ramsar system is deliberately broad, encompassing "areas of marshes, fen, peat land or water, whether natural or artificial, permanent or temporary, with water that is flowing or static, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six metres". It may also include riparian and coastal zones adjacent to the wetlands, and islands or bodies of marine water deeper than six meters at low tide lying within the wetlands. These characteristics form the basis for classifying different wetland types contained in the `Ramsar Classification of Wetland Types', which is further described below.

Wetlands can generally be organised into five basic systems, namely: Lacustrine, Riverine, Palustrine, Marine and Estuarine (Frazier, 1996). These comprise complex wetland and deepwater habitats that share the influence of similar hydrologic, geomorphologic, chemical, or biological factors.

The Ramsar Classification of Wetland Type currently in use, was adopted by the Conference of the Parties in 1990. It divides wetlands into three main categories, namely: marine and coastal wetlands, inland wetlands, and man-made wetlands. The categories have further subdivisions which give a total of 40 wetland types as had been listed in the inception report.

Out of the described Ramsar wetland types only a few could be established through processing of Landsat TM5 and ETM7 derived remote sensing data. The wetland maps derived in this study have been classified accordingly as:

1. Open water
2. Permanent wetland
3. Irrigated area.
4. No data (land)

For selected wetlands, these classes were further classified based upon a subset of the Ramsar classification system. The Ramsar classes representing the wetland types that can be found in the Nile Basin include:

F. Estuarine waters; permanent water of estuaries and estuarine systems of deltas. This type is found in the Nile Delta
J. Coastal brackish/saline lagoons; brackish to saline lagoons with at least one relatively narrow connection to the sea.
K. Coastal freshwater lagoons; includes freshwater delta lagoons.
L. Permanent inland deltas.
M. Permanent rivers/streams/creeks; includes waterfalls.
N. Seasonal/intermittent/irregular rivers/streams/creeks.
O. Permanent freshwater lakes (over 8 ha); includes large oxbow lakes.
P. Seasonal/intermittent freshwater lakes (over 8 ha); includes floodplain lakes.
Tp. Permanent freshwater marshes/pools; ponds (below 8 ha), marshes and swamps on inorganic soils; with emergent vegetation water-logged for at least most of the growing season.
Ts. Seasonal/intermittent freshwater marshes/pools on inorganic soil; includes sloughs, potholes, seasonally flooded meadows, sedge marshes.
U. Non-forested peat lands; includes shrub or open bogs, swamps, fens.
W. Shrub-dominated wetlands
Xf. Freshwater, tree-dominated wetlands; includes freshwater swamp forest, seasonally flooded forest, wooded swamps; on inorganic soils.
Y. Freshwater springs; oases.
1. Aquaculture (e.g. fish/shrimp) ponds.
2. Ponds; includes farm ponds, stock ponds, small tanks; (generally below 8 ha).
3. Irrigated land; includes irrigation channels and rice fields.
4. Seasonally flooded agricultural land.
6. Water storage areas; reservoirs/barrages/dams/impoundments; (generally over 8 ha).
7. Excavations; gravel/brick/clay pits; borrow pits, mining pools.
8. Wastewater treatment areas; sewage farms, settling ponds, oxidation basins, etc.
9. Canals and drainage channels, ditches.

These wetland types are included in the attribute description of selected wetlands in the GIS database.

2.3 WETLAND MAPS DEVELOPMENT

The following methodology was agreed during the Inception workshop for the production of the wetland maps from Landsat 5 & 7 imagery. Figure 3 shows the steps taken in producing the NDVI wetland maps, the steps are described in detail in the following sections.

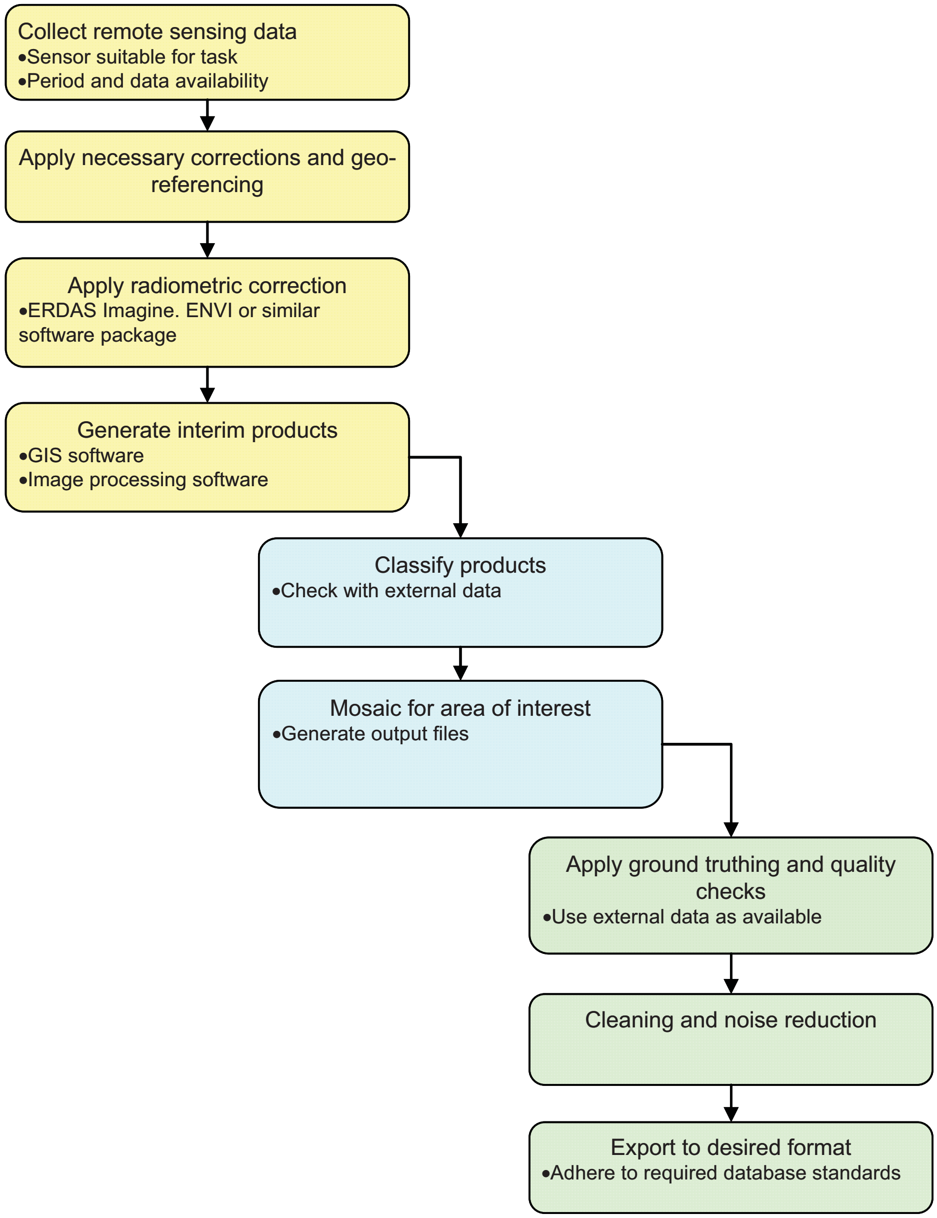

Figure 3 Method used to produce wetland maps

2.3.1 Image Preparation

The initial aim of the project was to collect images from the 1990s but most of the images used are from 1984-88. It was found that there were more 1980s images available from the same time of year, which was given a higher priority than images from the same year. Some of the Landsat images are available with proper geo-referencing and some are not. The collected images were checked for geo-referencing and proper projection type. Those without projection information were geo-referenced. Radiometric correction was also applied on each image separately to remove the atmospheric effects which is known as Haze Correction. This correction eliminates the haze from water vapour and aerosol particles that influences the recorded signal. In addition, in rugged terrain, varying illumination conditions (sunny and shady hills) modify the "true" spectral behaviour of surfaces. Haze reduction and atmospheric correction also eliminates solar illumination effects. This is a pre-processing for satellite images in order to analyse the real reflectance values of the earth surface. The built in haze correction function in ERDAS Imagine software was used to carry out this task for this project.

2.3.2 Normalized Difference Vegetation Index (NDVI)

A vegetative index is a value that is calculated (or derived) from sets of remotely-sensed data to quantify the vegetative cover on the Earth's surface. Though many vegetative indices exist, the most widely used index is the Normalized Difference Vegetative Index (NDVI). The NDVI, like most other vegetative indices, is calculated as a ratio between measured reflectivity in the red and near infrared portions of the electromagnetic spectrum. These two spectral bands are chosen because they are most affected by the absorption of chlorophyll in leafy green vegetation and by the density of green vegetation on the surface. Also, in red and near-infrared bands, the contrast between vegetation and soil is at a maximum.

This type of product is especially useful in multi-spectral remote sensing since transformations can be created that highlight relationships and differences in spectral intensity across multiple bands of the electromagnetic spectrum. The NDVI transformation is computed as the ratio of the measured intensities in the red (R) and near infrared (NIR) spectral bands using the following formula:

$$NDVI = (NIR - R) / (NIR + R)$$

The resulting index value is sensitive to the presence of vegetation on the Earth's land surface and can be used to address issues of water extent, vegetation type, amount, and condition (see Figure 4). This process was carried out using ERDAS imagine software.

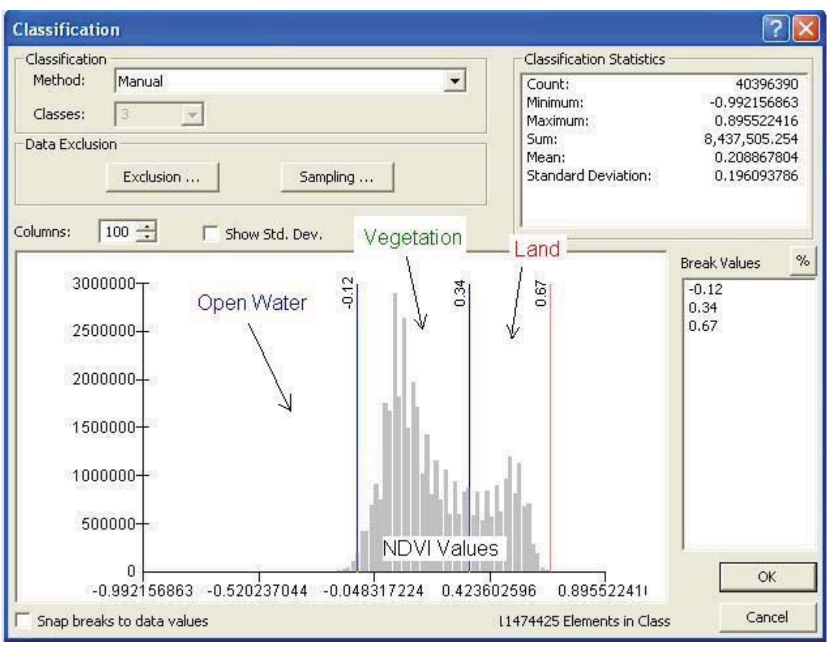

Figure 4 NVDI classification

The Thematic Mapper (TM) and Enhanced Thematic Mapper Plus (ETM+) bands 3 and 4 provide R and NIR measurements and therefore can be used to generate NDVI data sets with the following formula:

(ETM+) NDVI = (Band 4 - Band 3) / (Band 4 + Band 3)

An example of classification based on NDVI classes is given below in Figure5.

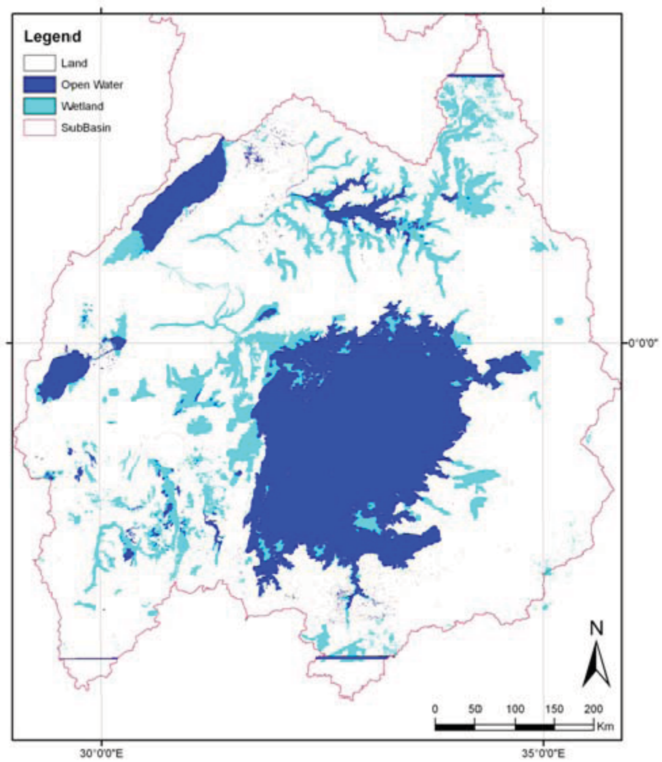

Figure 5 Classification for a part of the Equatorial Lakes region based on NDVI

2.3.3 Corrections and NDVI Classification

The generated NDVI product has spatial resolution about 28 meters according to the original satellite images. This high spatial resolution cannot be compared or evaluated directly with different products that have different resolutions. However, to check general trends, the SPOT Satellite NDVI images of the year 2000 were used to generally compare the generated files before and after the NDVI classification process. As no similar, older spatial RS based products were available, after testing for its suitability, it was decided that despite the time difference between the 2000 SPOT image and the 1980s to 1990s Landsat images, it still provided a useful benchmark. The NDVI images were then classified to 10 classes with equal intervals from -1 to +1 in an unsupervised approach.

Double check process has been conducted using the SPOT NDVI and visual interpretation of the original images in true colour composite. This was important to select the classes to be merged in order to separate the open water, wetlands, vegetation, and land. Due to the individually varying conditions in the different sub-basins in the overall Nile Basin, a supervised classification process was chosen to carry out this task.

2.3.4 Basin Delineation

The Nile Basin outline used in the project was derived based on the hydrologically correct 90m SRTM DEM dataset provided by NASA. Hydrological algorithms within the ArcGIS 9.2 environment were used to delineate the catchments and obtain the basin outline (Figure 6).

1. Equatorial Lakes (Lake Victoria and others)
2. Bahr El Jebel
3. Bahr El Ghazal
4. Baro Akobo Sobat
5. White Nile
6. Abay-Blue Nile
7. Tekeze Atbara
8. The Main Nile

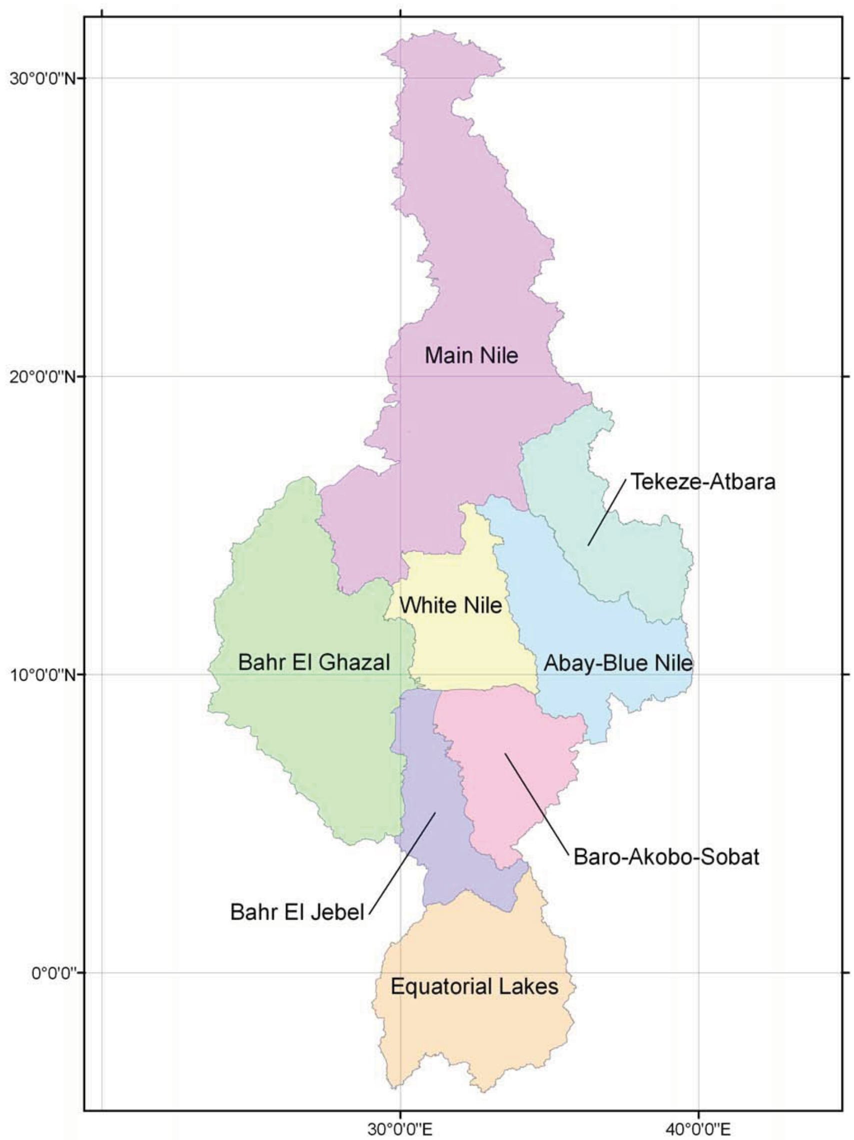

Figure 6 Nile sub-basins

2.3.5 Mosaic

Two methods for mosaicing the different Landsat image based tiles have been tested; mosaic of the original NDVI values and mosaic of the classified NDVI values. Both trials were conducted on sub-basin boundaries where due to the classification approach differences occur.

The result of comparing the two sets of mosaic images shows that using the original NDVI values for mosaic is much better than using the classified NDVI. Therefore a merged image of NDVI values was produced for each sub-basin based on which then a repeated classification was carried out.

2.4 DATA ANALYSIS

2.4.1 NDVI Analysis

The mosaiced NDVI images for each of the sub-basins were classified with different threshold values for each sub-basin. This process was conducted in several iterations and comparison to the original classified images in order to reach good results for setting threshold values for each class (water, wetland, and agriculture). The results were compared to ground truthing data and the threshold values were fine-tuned. The selected threshold values for the different basin are given in Table 4.

Table 4 NDVI threshold values for different sub-basins

Sub Basin	Range	water	wetland	land	irrigated areas
Equatorial Lakes	*from*	-1	-0.2	-0.1	N.A
	to	-0.2	-0.1	0.6	N.A
Bahr El Jebel	*from*	-0.54	-0.33	0	N.A
	to	-0.33	0	0.25	N.A
Bahr El Ghazal	*from*	-0.56	-0.35	0	N.A
	to	-0.35	0	0.5	N.A
Baro-Akobo-Sobat	*from*	-1	-0.35	-0.15	N.A
	to	0.35	-0.15	0.65	N.A
White Nile	*from*	-1	-0.3	-0.1	0.2
	to	-0.3	-0.1	0.2	0.63
Abay-Blue Nile	*from*	-1	-0.33	-0.14	0.22
	to	-0.33	-0.14	0.22	0.68
Tekeze-Atbara	*from*	-0.4	-0.19	-0.12	0.12
	to	-0.19	-0.12	0.12	0.54
Main Nile	*from*	-1	-0.25	-0.2	0
	to	-0.25	-0.2	0	0.5

2.4.2 Cleaning and Noise Reduction

Following the classification step, the results might still have errors and noise values. This can be identified when comparing the classes with the ground truth data and images. The sources of error will be explained in the methodology limitations in Section 2.7. Other sources of information used to verify the classes were the enhanced Landsat satellite images available in MrSID format, Africover maps, and other global maps for rivers and wetlands. Three different steps were applied to clean the error and noise from the NDVI classified images. The steps are illustrated below as follows:

Polygon Cleaning

Polygons have been used to clean noise in cases where the ground truthing data verified that the wetlands generated by the NDVI there is an error. The error can be under or over presentation of a wetland. Africover data was one of the sources where some streams were copied to enhance the NDVI classifications. Another type of error found and verified using satellite classified images where polygons of other classes were copied and used to clean the NDVI classifications. The third source of cleaning polygons was traced out manually wherever the ground truth and local experts provided adequate information.

Noise Filtering

For the separate pixels with noise, a noise filter by 3×3 pixels was applied to clean out the noise. This method is the standard filter used in situations where there is sparse ground truthing information, and after testing, was most appropriate for a basin-wide approach. Some noise values around lakes could not be removed because it is difficult to remove them without changing the natural morphology of the lake. This type of noise around lakes is acceptable and can be considered as water or wetland. The filter was applied only whenever a pixel of water exist in the middle of 9 pixels of land. The water class is presented in value of 1 however the land class is presented as 3. This process is shown in Figure 7.

3	3	3
3	***1***	3
3	3	3

Noise as defined in the filter

=====➢

3	3	3
3	***3***	3
3	3	3

Noise after cleaning

Figure 7 Filtering noise process

2.4.3 NDVI Evaluation and Wetland Map Development

Once suitable threshold values had been selected for each basin the cleaning tasks had been completed, the NDVI results were grouped into 3 classes – Open Water, Wetlands and Land. The Land areas were removed from the raster image and the remaining open water and vegetation classes were carried forward to the next stage. The 8 sub-basin results were converted to vector *Shapefiles* and then merged to one basin-wide polygon *Shapefile*. The result is stored in the geodatabase – The layer named 'Wetlands_NDVI_WNB_2009'. The result contained over 1000000 polygons. This file is useful for detailed searching and area calculations but the file size is very large. To be able to use the results practically for attribution, naming and mapping the results were generalised. The 1000000 polygons were grouped into approximately 250 wetland areas. These were grouped through supervised selections taking into account hydrological and national boundaries. Figure 8 shows an example of this step.

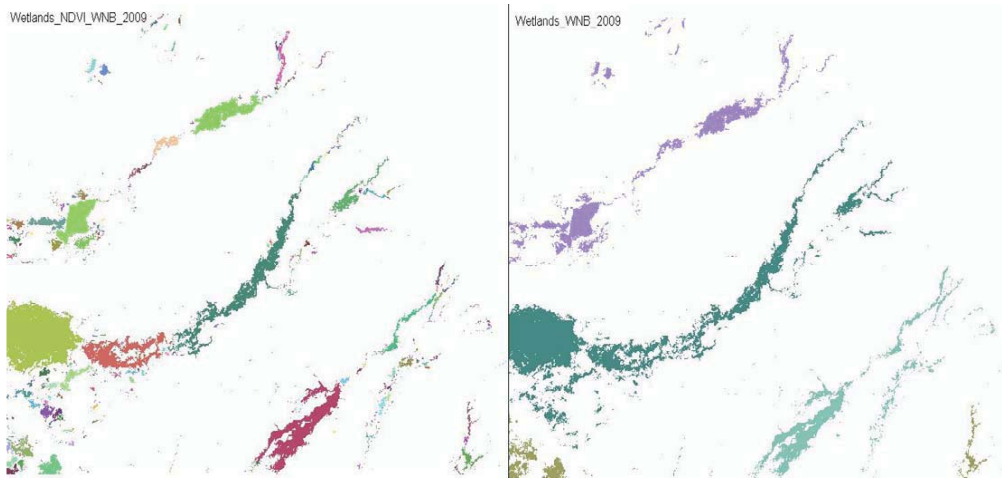

Figure 8 Wetland results - Grouping

2.4.4 *Extracting Agricultural Irrigation*

The vegetation cover can be easily defined using the NDVI values however separating the natural vegetation from Irrigated agriculture is a very difficult process. The final classification of the wetland map does not include vegetation as a separate class; however RAMSAR classifications consider that irrigated land is wetland. The large irrigation schemes were mapped out of the vegetation classes using Africover classifications and other sources of information provided by experts. This class has been enhanced separately and added to the wetland map.

2.5 SECOND STAGE UPDATING

Based on discussions during a meeting between the project team and the Nile DSS team in Addis Ababa, Ethiopia in March 2009, add-ons to the initial wetland inventory work were agreed in order to maximize study outputs and facilitate the DSS data requirements. Two work packages, "Second stage updating of wetland inventory on regional level by local institutions" and "Reporting on biodiversity trends based on historical available literature" were agreed.

In liaison with local institutions and stakeholders, the second stage updating exercise collected and utilized detailed input on top of the mapping products derived under the main inventory work. The task comprised the identification of players and local knowledge groups in the different Nile Basin regions, contacting these players and getting their feedback on gaps in the mapping products as well as valuable information on biodiversity aspects, pressures, threats, socioeconomy and other attributes of the respective wetlands. Questionnaires and map extracts from the project outputs were used for this undertaking.

Approached players and local knowledge groups included the following:

- Wetland Inventory working group members of all NBI countries
- Addis Ababa University, Ethiopia
- FAO Nile, Entebbe, Uganda
- Tanzania National Parks Authority
- Makerere University, Uganda

- Dar es Salaam University, Tanzania
- Nairobi University, Kenya
- University of Khartoum, Sudan
- Ministry for Water and Environment, Entebbe, Uganda
- RCMRD, Nairobi, Kenya
- UN OCHA, Rumbek, Sudan
- Individual scientists working in the different sub-basins
- CGIS-NUR, Kigali, Rwanda
- Egyptian Environmental Affairs Agency, Egypt

2.6 METHODOLOGY LIMITATIONS AND LESSONS LEARNED

Landsat satellite images, because of their high spatial resolution (28 m before any enhancement) were a good choice regarding their resolution but included some problems regarding noise that needed to be handled. The noise was experienced as having under and over presentation of wetlands in many areas and in having discontinuity of streams and channels. Another limitation regarding the spatial resolution was the presentation of canals and streams with the canals cross sections varying from wide section at the intake to narrow section at the tail. This phenomenon affected the presentation of irrigation canals in Egypt. Other sources of vector layers were used to enhance the product, including data from Africover, GLWD (Global Lakes and Wetlands Database) and the Woody Biomass Project (Ethiopia).

A problem that persists with the Landsat data is the Scan Line Corrector (SCL) failure that occurred in May 2003. Since that time the instrument can not compensate for the forward motion of the satellite anymore resulting in image duplications and striping. An estimated 22% of any scene is affected leading to their unsuitability for mapping purposes since the failure date. For the current study pre 2003 images were used.

One shot of Landsat satellite images were used as defined in the methodology. This limits the analysis as it misses the temporal and spatial change detection. The approved methodology selects one shot of Landsat satellite images to extract wetlands and verify it with other sources of data. The exact location, size and extent of wetlands vary with time from one month to another and from one year to another. Comparing one shot of images with other maps could not fully show the wetlands, only resulting in an indicative product. Detailed temporal analysis and computations can not be conducted.

Dry season analysis of satellite images for wetlands mapping was defined in the approved methodology. The assumption was to map the permanent wetlands which remain wet during the dry season. This can work only on the perennial rivers such as White Nile however it cannot be applied on seasonal rivers where the river system can be completely dry. Therefore the middle part of the Nile river were perfectly mapped out including Equatorial Lakes, Bahr El-Jebel, White Nile, and the main River Nile. However the seasonal rivers were not easy to map including Bahr El-Ghazal, Baro-Akobo-Sobat, Abay-Blue Nile, and Tekeze-Atbara. In a similar way, smaller irrigated areas may have been missed or were indistinguishable from the surrounding vegetation. Therefore only areas in Sudan and Egypt have been explicitly mapped as irrigation fields while those in countries with more lush vegetation had to be included in the wetland class.

The accuracy achieved with the applied methodology is suitable for the Nile Basin wide approach; anyhow some particularities need to be taken into consideration as the accuracy with this methodology depends on:

1. Images quality: The selected images had minimal cloud coverage and no lines error
2. Image preparation including geometric and radiometric correction,
3. NDVI calculation and classification
4. Ground truthing data: Considering the large area of the Nile Basin it was important to achieve a reasonable coverage of sampling points. Data from external sources, secondary remote sensing data such as SPOT derived information and MrSID imagery as well as personal experience was used to verify the classes. This approach requires engineering judgement and there is always room for improvement when it comes to the number of sampling points. With this approach the large and permanent wetland were mapped with sufficient accuracy for a basin wide approach; however the approach lacks behind what would be possible in detailed studies regarding small area wetlands and exact wetland boundaries.
5. The ground cover variability within the basin: The used methodology proved to yield very good results with high accuracy in the middle and lower part of the basin with its arid conditions. For the upper catchments the methodology proved to be very sensible to fine differences in the vegetation and accurate tuning was necessary to achieve acceptable results.

3. Results

This section reports on the results of the wetland inventory and mapping exercise, summarizing the outcome of the data collection trips and data evaluation. It describes the derived wetland maps and database as the main outcome of the project and details main wetland parameters related to the different Nile Basin countries. The map and database related sections are followed by an overview of wetlands within the Nile Basin, giving a short description of their physical environment and biodiversity, drivers and pressures as well as management efforts. The section is closed by giving information about wetland inventory policy related requirements and highlights steps and issues to be considered for developing respective policies.

3.1 SUMMARY OF INCEPTION STAGE

An inception report was presented to the NBI-NTEAP and discussed in detail during an inception workshop held in Khartoum in November 2008. The workshop objectives were to:

1. Present the data collected since the start of the project.
2. Present the methodology to inventory and map the wetlands in the Nile Basin.
3. Discuss the methodology with experts and interested parties in the Nile Basin.
4. Present project work plan and expected outputs.
5. Finalise the project inception report.

The main findings of the workshop included a revision of the identified involved institutions and their capacities especially related to the mapping exercise, data sources as well as current and previous similar studies on the topic. Workshop participants provided additional information regarding the discussed topics as follows

- Other important contact agencies
- Places where more data was to be located and collected
- Email contacts of contact persons who will be of assistance during the consultancy

Methods for the wetland mapping process were explained to the participants. The project outcomes were to show water bodies as well as different classes of wetlands based on a selection of Ramsar classes. It was explained that not all Ramsar classes can be found within the Nile Basin or could be presented based on the remote sensing approach, leading to the decision to group the classes. It was agreed that the maps that will be produced will contain an appropriate legend for an easy understanding of the displayed information.

The issue of classifying the wetlands was discussed intensively with the workshop participants. It was agreed that Ramsar classification will be used in the project and that the classes will be selected as described in the above paragraph.

The potential compatibility and possible link between the Wetland Mapping project and the Nile DSS project was discussed as a last point of the meeting. The Nile DSS setup was introduced and the potential for linking of the two systems discussed. It was agreed, where possible, to ensure compatibility to facilitate future input of the wetland database into the Nile DSS. Based upon the workshop discussions, the project inception report was finalised by the Consultant and approved by NTEAP in November 2008.

3.2 WETLAND MAPS

The full size maps generated by the project are shown in Annex 1 for the different sub-basins of the Nile. The maps were published as a layer in a GIS geo-database (See Section 3.3). This wetlands layer includes attributes to each identified wetland as shown in Table 5.

Table 5 Additional wetland attributes

Field Name	Description	Data Type
HydroID	Wetland ID number	Integer
Name	Wetland name	Text
Country	Wetland country	Text
Ccode	Wetland country code	Text
SubBasin1	Wetland first level sub-basin	Text
TBI	Wetland trans-boundary issues	Text
Threats	Wetland management threats	Text
AreaSqKm	Wetland area in square kilometres	Double
NDVIClass	NDVI Class	Text
Class	Ramsar Class	Text
Source	Wetland polygon data source	Text
BioAreaID	ID to link wetlands to biodiversity data table	Integer

This additional information provides the basis for spatial queries of the underlying data. Examples of this are shown in Table 6 and Table 7. Table 6 gives the size in each country of each wetland class. The limitations of the coarse scale approach need to be considered when looking at e.g. irrigated areas which were only captured individually where they were distinguishable from surrounding vegetation. Table 7 gives the size in each country of each major wetland.

Such spatial analyses also provide a useful check on the wetland extents derived from the remotely sensed data. Compared to wetland areas as published in different literature (with varying values), the figures shown in Table 6 and Table 7 generally show larger wetland areas by country. This can be explained by the fact that the remote sensing approach picks up all scattered wetlands and sums these areas. Sources based on land surveys on the other hand generally rely on the measurements of isolated larger wetlands. Differences are as well caused by seasonal and inter-annual variability depending on the precipitation conditions. Figure 9 shows the location of the assessed wetlands.

Table 6 Nile wetland classification in each country within their Nile Basin area

	County area	Open water area[1]		Wetlands area[1]		Irrigated area[1]		EWUAP[2]
	Km^2	Km^2	%	Km^2	%	Km^2	%	Km^2
Burundi	13249	103	0.8%	387	2.9%	N/A	N/A	146
DR Congo	21210	4146	19.5%	373	1.8%	N/A	N/A	-
Egypt	335742	4681	1.4%	N/A	N/A	24680	7.4%	29636
Eritrea	25846	3	0.x%	1	0.x%	N/A	N/A	-
Ethiopia	364969	3419	0.9%	4271	1.2%	N/A	N/A	908
Kenya	50998	3969	7.8%	1449	2.8%	N/A	N/A	342
Rwanda	20870	435	2.1%	2656	12.7%	N/A	N/A	176
Sudan	1913683	6457	0.3%	64711	3.4%	8040	0.4%	17493
Tanzania	120234	34908	29.0%	8912	7.4%	N/A	N/A	5
Uganda	237207	36627	15.4%	22963	9.7%	N/A	N/A	251

Table 7 Identified major wetlands in each country (in km^2) of the 11 major Nile Basin wetlands

	Sio-Malaba-Malakisi	Mara Wetlands	Sudd Swamps	Nile Delta	Baro-Akobo-Sobat Mashes	Bahr el Ghazal Swamps	Kyoga Swamps	Lake Albert Swamps	Winam Gulf Wetlands	Kagera Swamps	Lake Tana Wetlands
Burundi	-	-	-	-	-	-	-	-	-	-	-
DR Congo	-	-	-	-	-	-	-	-	-	71.8	-
Egypt	-	-	-	18408.1	-	-	-	-	-	-	-
Eritrea	-	-	-	-	-	-	-	-	-	-	-
Ethiopia	-	-	-	-	3640.5	-	-	-	-	-	3130.6
Kenya	389.3	17.9	-	-	-	-	-	-	621.2	-	-
Rwanda	-	-	-	-	-	-	-	-	-	3113.8	-
Sudan	-	-	25166.4	-	7022.2	28340.9	-	-	-	-	-
Tanzania	-	1680.5	-	-	-	-	-	-	-	2341.9	-
Uganda	41.7	-	-	-	-	-	14220.2	630.8	-	205.7	-
TOTAL	**431.0**	**1698.4**	**25166.4**	**18408.1**	**10662.7**	**28340.9**	**14220.2**	**630.8**	**621.2**	**6145.7**	**3130.6**

[1] All areas releate to areas within Nile Basin. Areas in this table reflect the distribution of open water, wetlands and irrigated areas at the time of satellite image acquisition and carry the restrictions of the methodology employed to evaluate the data. Area sizes found today may therefore differ from the displayed figures

[2] EWUAP (Efficient Water Use in Agricultural Production) external project data for comparison with the remote sensing derived data

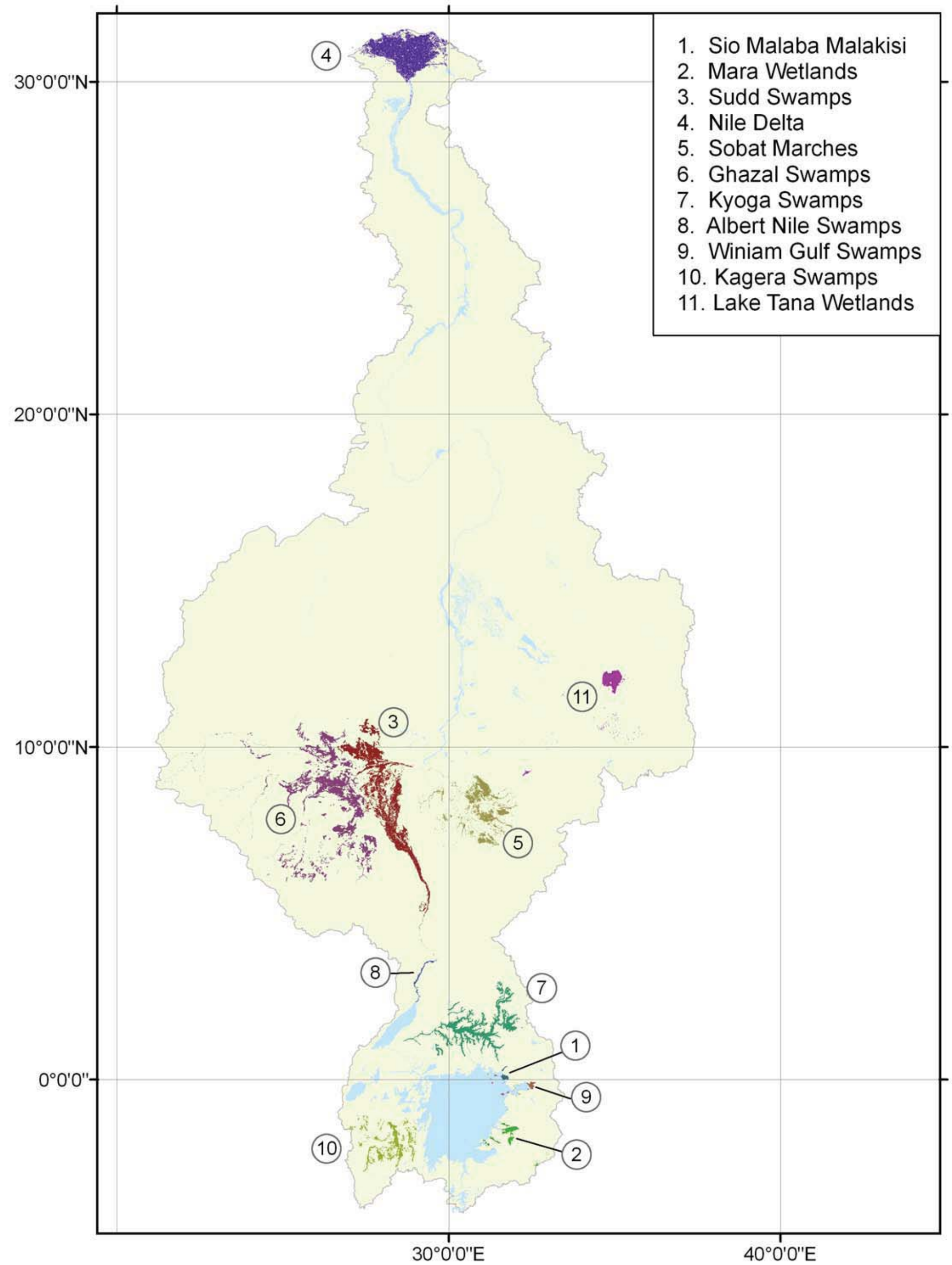

Figure 9 Selected wetlands locations within the Nile Basin

3.3 THE GIS DATABASE

A GIS system has been developed within the ArcGIS 9.2 package to integrate all the wetlands data. The system was demonstrated to NBI NTEAP, members of the Nile Basin wetlands regional working group and other stakeholders of the project at the Final Workshop.

Figure 10 shows the structure of the geodatabase, an ESRI File Geodatabase. The geodatabase is a store for a variety of geographical data formats. This includes *Shapefiles* representing vector points, polylines and polygons, raster files showing images, maps, remote sensing data and tabular data. The data has been grouped into layers which have a common theme, for example administration, landcover and wetlands. All of the data within the geodatabase is accessible through most GIS software. GIS software is required to be able to view, query and manipulate the data. By using S*hapefiles* as the leading file format, it is also possible to link to other sources of data such as websites, photographs and text documents. The structure of the geodatabase allows users to organise and store data in an effective way whilst retaining the ability to customise and add to the geodatabase in the future.

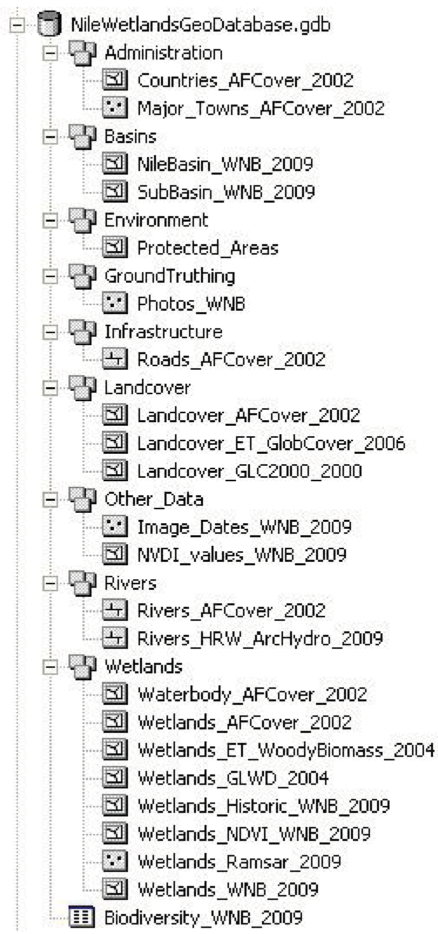

Figure 10 GIS system user interface

3.3.1 GIS Data

Table 8 lists the datasets in the geodatabase. Each of the datasets in Table 8 has a metadata file associated with it, which gives more information on the data type, creation, source attributes and had links to further information for third party datasets. This file is in the commonly used FDGC ESRI format. Figures 11-14 show some examples of using data held in the geodatabase.

Table 8 Geo-database layers

THEME	NAME	DESCRIPTION	SOURCE
Administration	Countries_AFCover_2002	Country extents	Africover
Administration	Major_Towns_AFCover_2002	Major towns	Africover
Infrastructure	Roads_AFCover_2002	Major Roads	Africover
Basins	NileBasin_WNB_2009	The Nile Basin extent	This Project
Basins	SubBasin_WNB_2009	Sub-basin extents	This Project
Wetlands	Waterbody_AFCover_2002	Waterbodies	Africover
Wetlands	Wetlands_AFCover_2002	Wetlands	Africover
Wetlands	Wetlands_ET_WoodyBiomass_2004	Wetlands	Woody Biomass
Wetlands	Wetlands_WNB_2009	Wetlands	This Project
Wetlands	Wetlands_NDVI_WNB_2009	Wetlands (NDVI Results)	This Project
Wetlands	Wetlands_Historic_WNB_2009	Wetlands (Historic Map Outlines)	This Project
Wetlands	Wetlands_Ramsar_2009	Wetlands	Ramsar
Wetlands	Wetlands_GLWD_2004	Wetlands	Global Lakes and Wetlands Database
Rivers	Rivers_HRW_ArcHydro_2009	River network	This Project
Rivers	Rivers_AFCover_2002	Major Rivers	Africover
Environment	Protected Areas	Protected Areas/National Parks	Multiple Sources
Ground Truthing	Photos_WNB	Ground Truthing photographs	This Project, Africover and other sources
Landcover	Landcover_AFCover_2002	Landcover classification	Africover
Landcover	Landcover_ET_GlobCover_2006	Landcover classification	Globcover
Landcover	Landcover_GLC2000_2000	Landcover classification	Global Land Cover Survey 2000
Other Data	Image_Dates_WNB_2009	Image dates used	This Project
Other Data	NDVI_Values_WNB_2009	NDVI Values used	This Project
Biodiversity	Biodiversity_WNB_2009	Wetland biodiversity information	This Project

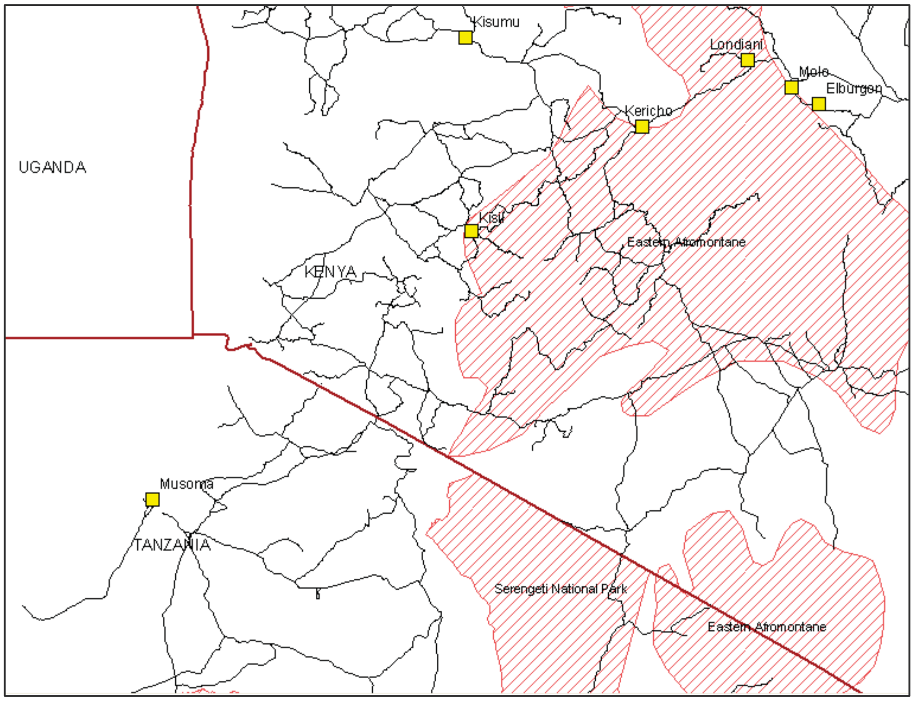

Figure 11 Example administration (countries, major towns), infrastructure (road network) and environment (protected areas) data

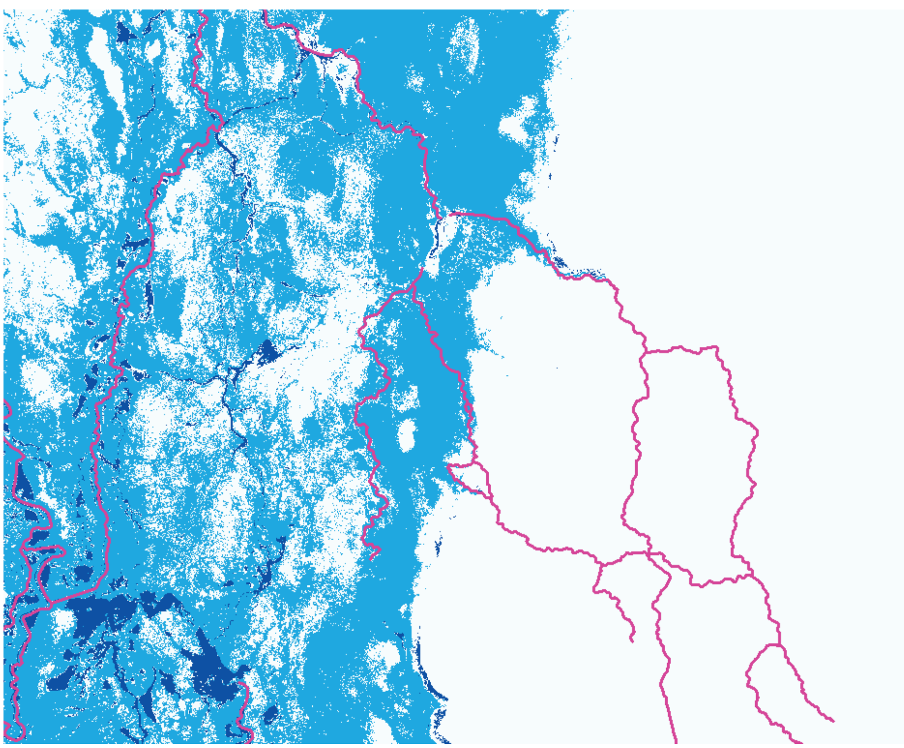

Figure 12 Example wetland and river layers

Figure 13 shows an example of a user comparing two different layers. The NDVI wetlands results (Blue) with the Africover river network dataset (Pink). Figure 1014 shows some ground truthing data in ArcMap – GIS software. The user can view a *Shapefile* of ground truthing points which link to ground truthing photographs (photo in the top right corner) and wetland attribute data. (Identify box in the bottom left corner).

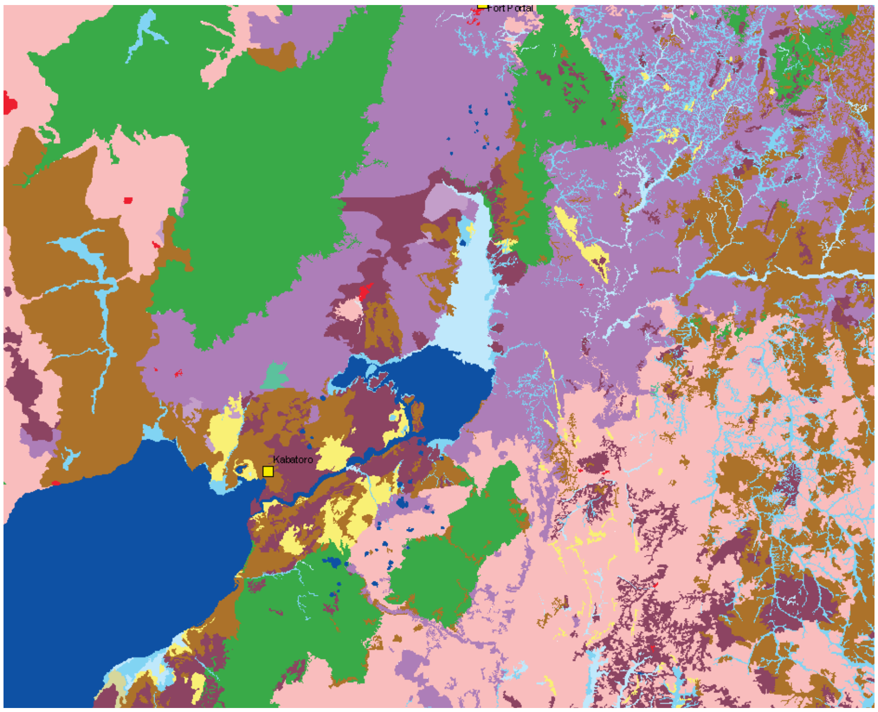

Figure 13 Example landcover data (Africover landcover map)

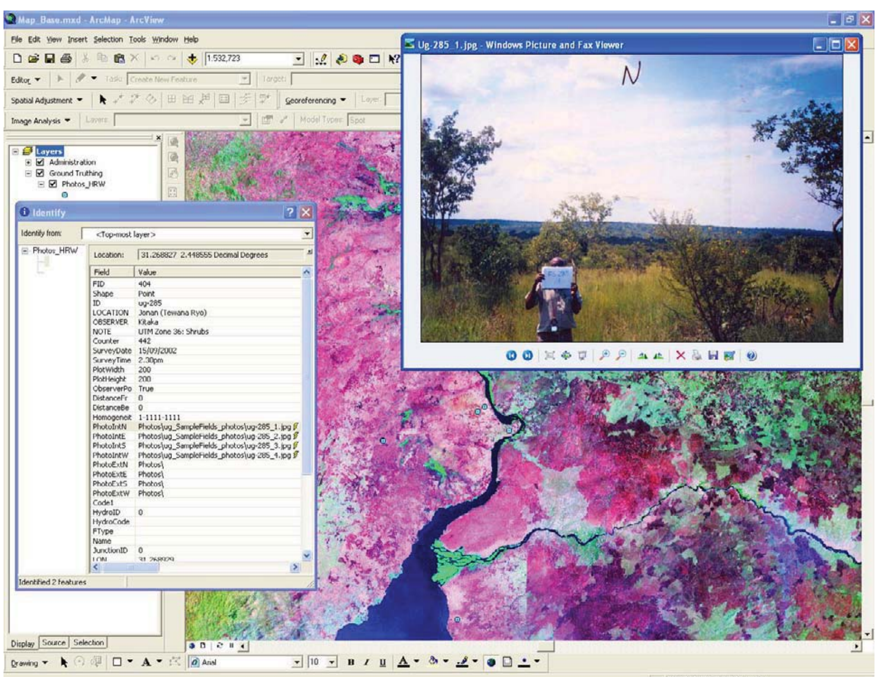

Figure 14 A screenshot of example ground truthing data

3.3.2 GIS Data Uses - Queries

The geodatabase system enables the user to carry out spatial and attribute queries on the data. The ability to perform these detailed queries provides the user with a powerful tool to assist in management activities and decision making, as outlined in Section 3.3.

Figure 15 shows an example of an attribute query. Each wetland has a field 'AreaSqKm'. This field can be used to perform a selection on the data. In this example the user wants to find out the total area of wetlands in Rwanda which are greater than 1km^2. Using the selection tools in the GIS software and the search criteria "Country = 'Rwanda' " and "AreaSqKm >1" a selection can be requested. The results can be exported to a separate table and the areas totalled.

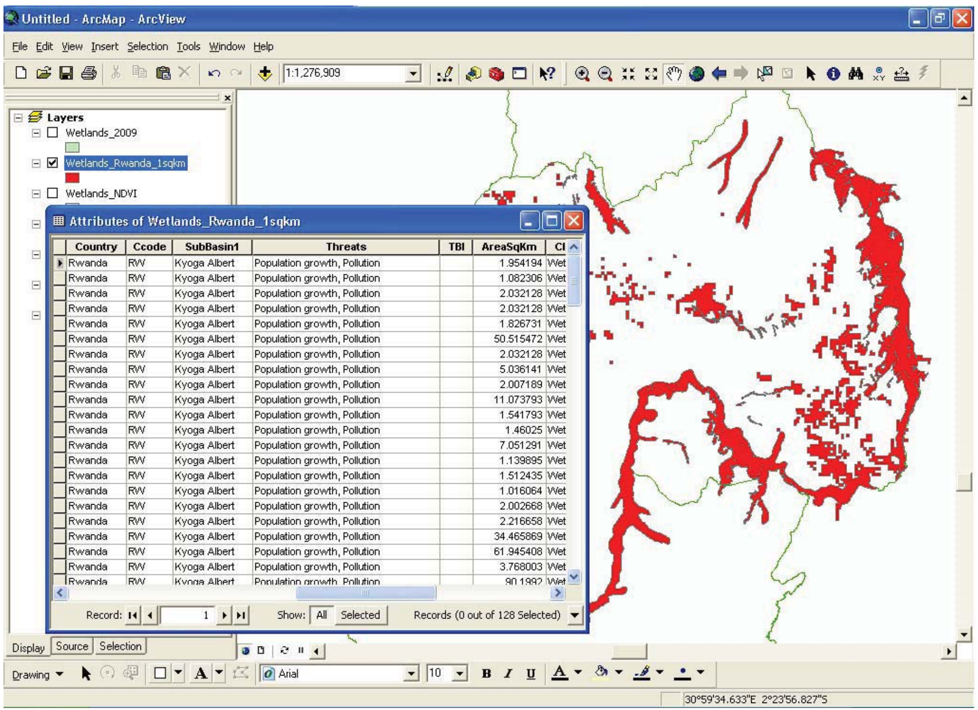

Figure 15 A screenshot of an example attribute query

Figure 16 shows an example of a spatial query. In this case the user would like to produce a map showing wetlands that cross or are within 10km of the DR Congo and Uganda borders. Using the selection tools in the GIS software and the administration layer 'Countries_Africover_2002' a selection can be made to spatially search the wetlands layer for all wetlands that are within 10km of the border. The results can be exported as a separate *Shapefile* and added to a custom map.

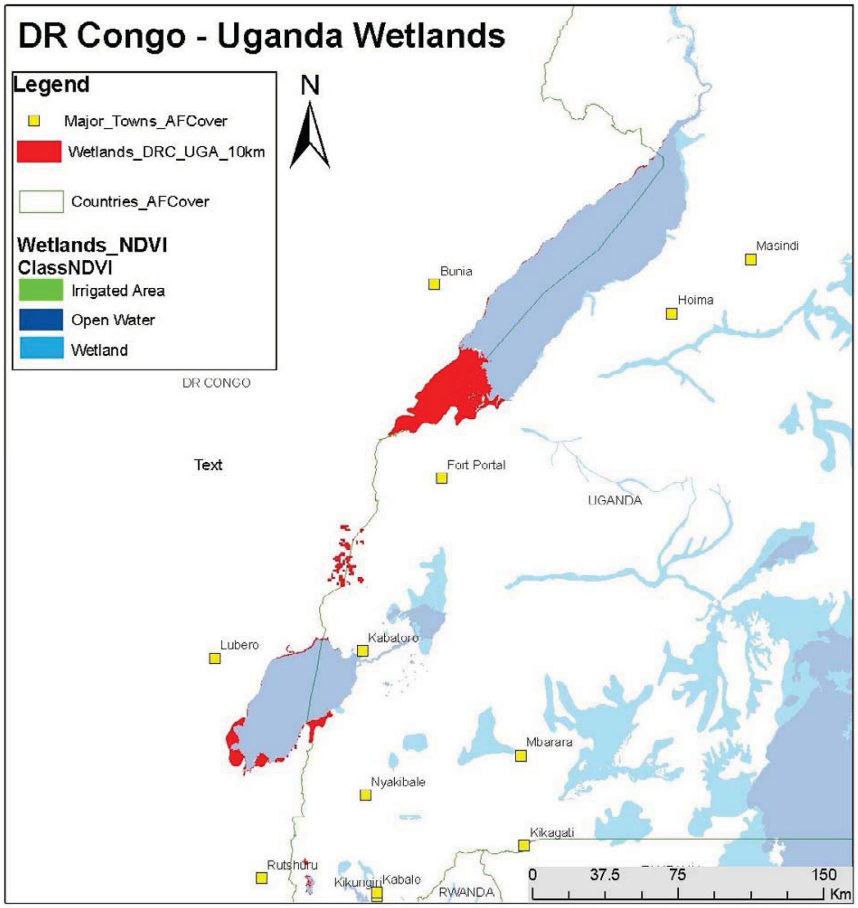

Figure 16 Example spatial query

3.4 OVERVIEW OF WETLANDS AND THEIR MANAGEMENT IN THE NILE BASIN

3.4.1 Wetland Inventory within the Overall Wetland Management Context

Wetland management, after years of neglect, has been accepted and promoted to be an important issue by the Nile riparian countries. All Nile Basin countries therefore have wetland management systems in place to some extent, (Mesfin 2003, NBI 2001) while detailed regional and especially transboundary management efforts are still to be developed in most cases. For these transboundary management efforts it needs to be considered that wetlands receive inflowing water which is a driving factor in the system from remote upstream sources.

A transboundary situation is therefore not only existing if the wetland itself is shared by two countries but also in cases where upstream hydrological and hydrodynamic changes may have a strong influence on a downstream wetland. The strong dependence of the Sudd wetland in southern Sudan and its dependence on Lake Victoria water releases in Uganda is a good example for such a case. In order to describe the current management efforts along the Nile, the descriptions have been split for different main example regions in the following paragraphs. Within these the regional particular conditions including threats and management efforts are described. For wetlands of all type and locations, potential pressures and threats could include:

- Anthropogenic or natural changes to the hydrological regime
- Accruing population pressure with increased utilization of the wetlands
  - Increased pressure due to pasture grazing
  - Encroachment of settlements
  - Draining and dike construction
  - Conversion to agricultural area
  - Poaching
  - Pollution
  - Affluent discharge
- Climate change impacts
- Changes in water quality
- Introduction of invasive species

3.4.2 Equatorial Lakes

The Equatorial Lakes region is home of a variety of hydrological units and interlinked ecosystems of which the most important ones are described in the following paragraphs.

Starting from the farthest source of the Nile, the Kagera watershed is an important area for Rwanda and the basin has been studied with different approaches. The Geographic Information System and Remote Sensing Centre CGIS-NUR of Rwanda is working on a number of wetland management and mapping related projects. Feeding Lake Victoria and being situated between Tanzania and Rwanda, the Kagera Basin is transboundary in nature. Next to country specific issues, downstream transboundary factors need to be considered looking at potential impacts in Lake Victoria. Being highly agriculturally utilized, the wetlands in the basin have come under considerable pressure from agricultural activities and population growth. Degradation of the wetlands is seen as an issue and research and management projects, though on a local scale, look into possibilities for their sustainable management. Prior to the conflicts in Rwanda and Burundi, the area of the Kagera was only lightly populated and was probably not over-exploited (BirdLife International, 2009).

Wetlands management efforts in the Lake Victoria basin are plentiful and conducted at different scales. The LVEMP (Lake Victoria Environmental Management Project) is a project within the Lake Victoria Basin Commission which is an institution of the EAC to oversee the programs regarding Lake Victoria. It follows a basin wide approach, while multiple other initiatives look into more detailed aspects like e.g. wetland rehabilitation work, water quality issues, wastewater treatment capacity of wetlands, fish breeding habitats and similar. These smaller initiatives are managed by sectoral or regional bodies like for example the Tanzania National Park Authority with partly great success with their efforts. These smaller scale management efforts, while having local impacts, are not connected at a larger scale management structures. A centralized database and exchange of lessons learned and good practice examples is missing.

Management efforts have been further challenged by the water levels in the lake that declined with an alarming rate over the last years, not allowing the wetland vegetation to migrate to appropriate water depth and adjust to the rapidly changing conditions. With the decrease of water levels stopped, a more balanced situation is reached allowing for a slow adaptation to the new conditions.

The situation in Lake Victoria can be seen as truly transboundary in nature. The lake is shared by Uganda, Tanzania and Kenya and tributaries are in addition influenced by

Rwanda and Burundi. Management efforts therefore need to be carefully coordinated between the riparian countries in order to achieve the desired benefits. NELSAP is providing substantial support to the management of the Lake Victoria Basin.

Management issues in the lower Equatorial Lakes region are mainly concerned with hydropower development. Main issues include population pressure, agriculture, deforestation and anthropogenic changes. While not directly focusing on wetlands, the studies and projects undertaken in this direction naturally have to include the assessment of potential wetland related impacts.

An important factor for changes in Lake Victoria's biodiversity in the recent past was the introduction of new species. In the 1950s, the Nile perch (*Lates niloticus*) was first introduced into the lake's ecosystem in an attempt to improve fishery yields of the lake. Introduction efforts intensified during the very early-1960s. However, the species was present in small numbers until the early to mid-1980s, when it underwent a massive population expansion and came to dominate the fish community and ecology of the world's largest tropical lake. Also introduced was the Nile tilapia (*Oreochromis niloticus*), now an important food fish for local consumption. The abrupt change in fisheries is rather startling. The Nile perch is a predator and has devastated *Haplochromine cichlids* populations to a point where many species are becoming extinct in the wild or extinct totally. Some species are being maintained in zoos and aquaria, e.g. as part of the Association of Zoos and Aquarium's Species Survival Plan for these species. Some species which were extirpated from Lake Victoria itself, are known to survive in nearby smaller so-called satellite lakes, such as Lake Koyoga, Lake Edward and Lake Albert. The damage is not limited to *Haplochromine cichlids*. For example, the *Singidia tilapia* (also called "ngege" - *Oreochromis esculentus*) is also assessed as critically endangered and is found only in a few satellite lakes.

The Nile perch has become the most important commercial species and is exported for consumption worldwide. The impact of perch fishing upon the local economy is the subject of the documentary "Darwin's Nightmare". However, Nile perch catches have diminished dramatically in recent years due to overfishing and poor enforcement of fisheries regulations. The overfishing of the Nile perch maybe having the side effect of allowing the populations of a few endemic cichlid species to increase again, particularly one to three species of zooplankton-eating, herring-like cichlids ("Yssichromis") that school with the abundant native *Rastrineobola argentea*.

In 1996, the World Bank funded the LVEMP to restore and sustain the ecology of Lake Victoria and its fisheries. Meanwhile, the European Union invested another large sum in fisheries infrastructure and monitoring. One product of these foreign aid programmes has been the training of a new generation of East African aquatic ecologists, conservation professionals, and fisheries scientists. There has also been an increase in the fishery research institutes of the lake.

Another exotic species introduced to Lake Victoria has also caused major environmental problems, the water hyacinth (*Eichhornia crassipes*), a plant native to the tropics of South America. It appears to have been introduced to the region by Belgian colonists to Rwanda in the nineteenth century to beautify their holdings and then advanced by natural means to Lake Victoria where it was first sighted in 1988. In ten years, it had spread along the shorelines in thick mats that covered an estimated 200 km^2 impacting fishers, transportation and hydroelectric power production. Aggressive efforts to halt its spread included the introduction of the mottled water hyacinth weevil (*Neochetina eichhorniae*) which ate the plant. After initial success, when the plants coverage was dramatically reduced, it has returned as shown on satellite images. As an example, these images show the Winam Gulf, in the northeast corner of Lake Victoria in Kenya. The gulf was the most severely affected region during the first hyacinth outbreak in 1998, with as much as 17,231 hectares of the plant growing on its surface. By 2000, the area covered by water hyacinth was down to about 500 hectares, and in December 2005 the lake appeared to be clear. In November and December 2006, however, unusually heavy rains flooded the rivers that feed into the Winam Gulf. The rain and floods raised water levels on the lake and swept agricultural run-off and nutrient-rich sediment into the water. As a result, the Winam Gulf was brown from the influx of fertilizer and sediments. The event anyhow did not only turn the water brown, but it also fed a fresh outbreak of water hyacinth, covering much of the Winam Gulf after a short time.

As a special situation for Lake Kyoga, significant wetlands management and research efforts have been spent related to the obstructions to outflow from the lake due to water hyacinth blockage of the lake outlet. Excessive growth and accumulation of water hyacinth before the lake outlet had lead to significantly rising water levels causing flooding along the lake shores. Weed control is therefore one of the most pressing issues for Lake Kyoga.

Similar to the upper Lake Victoria Basin, the situation in the lower Equatorial Lakes region is also truly transboundary in nature. In addition to the above mentioned riparian countries, changes to the flow regime in the Equatorial Region will have a strong influence on the Sudd wetlands in southern Sudan.

Sio-Malaba-Malakisi

The Sio-Malaba-Malakisi catchments which feed the Equatorial Lakes, both Lake Victoria and Lake Kyoga are transboundary in nature and some sections of both rivers form the boundary of the two countries. The Sio River discharges into Lake Victoria while the Malaba River flows westwards into Lake Kyoga after it is joined by the Malakisi River. The catchment areas of these rivers are part of the Nile Basin. On the Kenyan portion, the catchments comprise the Sio-Malaba-Malakisi Management Unit which is part of the Lake Victoria North Catchment Area. The Lake Victoria North Catchment area is managed by the Kenyan Water Resources Management Authority (WRMA). The Sio-Malaba-Malakisi River Basin is shared by the Bududa, Bugiri, Busia, Butaleja, Manafwa, Namutumba, Pallisa, and Tororo districts in Uganda, and Bungoma (North, South, East, and West), Busia, Mt. Elgon, and Teso districts in Kenya.

Lake Victoria has numerous shallow bays and swamps, including extensive papyrus swamps. There are a number of small "satellite" lakes that connect to Lake Victoria, including lakes Kanyaboli, Sare, and Namboyo in Kenya; lakes Nabugabo, Gigati and Agu in Uganda; and, lakes Ikimba and Burigi in Tanzania.

Yala Swamp

Yala Swamp wetlands are located on the north-eastern shoreline of Lake Victoria. It is one of the most important riparian and floodplain wetlands around the lake. The swamp forms the mouth of both Rivers Nzoia and Yala and is a freshwater deltaic wetland arising from backflow of water from Lake Victoria as well as the rivers' floodwaters. The wetlands cover approximately 175 km² and contain three satellite lakes to Lake Victoria which are freshwater lakes, near, but isolated from Lake Victoria itself under normal conditions. The lakes are Kanyaboli with 15 km², Sare with 5 km² and Namboyo with 1 km². The lakes are separated from Lake Victoria by massive papyrus swamps that presently inhibit faunal exchanges between the two lakes. No Nile Perch has ever been observed in Lake Kanyaboli, corroborating that it has been isolated from Lake Victoria at least since the 1950's. Very few nuisance/ invasive species occur in the swamp. However, *Pistia stratiotes* and *Lemna* sp. are found around Lakes Namboyo and Kanyaboli (Mavuti 1992).

Drainage of the Yala swamp began as early as 1956, and there are still plans to extend the 'reclaimed' area over much of the present swamp. This is despite the fact that the 'reclaimed' land has not proved productive (and a substantial part has reverted to swamp thanks to breaches in the barrier dyke along the Yala). This is an intensely controversial issue, pitting the obvious needs of a swelling population for agricultural land against the less conspicuous values of wetlands for instance, water filtration, flood control, and protection of fish stocks. In the case of Yala, biodiversity conservation must be added high on the list of values. This is a very important site for protecting the increasingly threatened suite of papyrus birds, as well as one of the last remnants of Lake Victoria's extraordinary cichlid radiation. The area around the swamps is densely populated, and most people make a living from agriculture and fishing. Apart from drainage, major threats include water offtake for irrigation upriver, intensification of fertilizer and biocide inputs, and unsustainable exploitation of papyrus. Large-scale cutting, mainly for the mat-making industry, and extensive burning to open up land for cultivation are taking their toll on the swamp, despite the remarkable regenerative abilities of papyrus. Study of the papyrus-endemic birds shows that several species, including Chloropeta gracilirostris, are negatively affected by disturbance and fragmentation of the habitat. Many questions remain, however, regarding population sizes, movements, and habitat requirements, and further study is needed. Rehabilitation of the feeder canal to Lake Kanyaboli should be a high priority, as the lack of regular inflows from the river are changing its water chemistry and may interfere with its functions as a fish refuge and nursery. A weir to divert water into Kanyaboli was under construction in 1999, but has not been completed. This also formed the first phase of a controversial project to expand the reclaimed area by extending the existing dyke along the Yala River. Lake Kanyaboli shows considerable potential for ecotourism, which could potentially be developed through a local site-support group as at other sites. The biodiversity value of Yala swamp should be recognized by affording the site some formal protection, such as listing as a wetland of international importance under the Ramsar Convention. Yala would comfortably qualify for this, as it is both an outstanding example of a specific type of wetland and supports an appreciable assemblage of threatened and endemic species (Birdlife International, 2009g).

Dunga Swamp

The swamp is located on the South Eastern shores of Lake Victoria 10km south of Kisumu town on the shores of Winam Gulf, Lake Victoria. It covers an area of 100 ha at an altitude of 1130-1130m.At the western limit is a beach, used as a major fish landing point. Papyrus (*Cyprus papyrus)* stands stretch south-eastwards along the shore from here for c.1.5 km, in a strip that varies in width from about 50 to 800 m. A number of streams drain into the lake through the swamp, the main one being Tako river.

Dunga is close to a major town, and this puts particular strain on the wetland. Papyrus harvesting is often excessive and unsustainable. The incoming streams bring pollution in the form of sewage and solid wastes from nearby residential estates. Lake Victoria's papyrus swamps are under increasing pressure in general. Water-hyacinth *Eichhornia crassipes* has infested much of the Winam Gulf. By preventing fishermen from fishing, it forces them to seek other forms of livelihood. Often, the only alternative available is to harvest papyrus, or to clear it in order to cultivate crops. Dunga urgently requires formal protection, as it has no conservation status at present. The site is already a popular area for recreation. Its proximity to Kisumu gives it potential for environmental education and bird tourism focused on the papyrus endemics (BirdLife International, 2009).

The major threats to Dunga swamp and associated biodiversity include:

- Pressure caused by high population densities on its edges
- Over-harvesting of Papyrus for thatching and making products such as mats and baskets
- Clearing of Papyrus beds for agriculture by the local people rendering them less suitable for bird
- Grazing ground for cattle at times of drought
- Dunga swamp is close to Kisumu town. As a result, it is prone to pollution in form of sewage and solid wastes from nearby residential estates channelled through incoming streams and the major Tako River.
- Infestation of Winam Gulf by the water hyacinth (*Eichhornia crassipes*)

The communities heavily depend on the wetland for their livelihood. They are in involved agriculture-fisheries /aquaculture and papyrus-harvesting.

Winam Gulf

NBI (2009) states that the bottom waters of Winam Gulf form a dead zone, devoid of oxygen and fish life. The amount of algae present in the water is 5-10 times more than it was in the 1960's. This is an indication of massive eutrophication (oxygen-depleted condition caused by high nutrient levels), which encourages massive growth of algae, whose death and decay depletes water of its oxygen. Water quality has declined during the last two decades owing to increased flow of nutrients into the wetlands and bays. Nutrient input load has increased by 3-4 times since the 1960's. The concentration of phosphorus has increased in the deeper Lake waters and that of nitrogen around the edges. Enhanced eutrophication has shifted the composition of phytoplankton towards the domination by the potentially toxic blue-green algae. The transparency index of surface water has declined from five meters in the 1960's to one meter in the 1990's. The water in the small bays and adjacent wetlands is highly turbid due to high silt load transported to the Lake by affluent rivers. Water hyacinth, which was absent in 1989 has rapidly spread and choked important waterways and landing beaches on all the shores of Winam Gulf.

Over-fishing and oxygen depletion in the bottom waters of the Winam Gulf threaten the artisanal fisheries and biodiversity. Current evidence on the impact of these activities on the fish fauna indicates that over 200 species of indigenous cichlids are threatened with extinction. Silt and nutrient inputs from the surrounding catchments also contribute to the changes in the biodiversity of Lake Victoria and its fringing wetlands (LVEMP1, 2001). Some areas along the affluent rivers and the shores of the Lake are heavily polluted with municipal and industrial waste discharges. These pollutants as well as ecotone disturbance have serious negative effects on invertebrate fauna, especially molluscs and aquatic insects, such as dragonflies, which breed there. The driving forces of change in Lake Victoria ecosystem are human population pressure, especially its increasing size, rapid growth rate and increasing urbanisation and migration from inland to the shores. They are also linked to the use of inappropriate technology in harvesting of natural resources and economic factors, such as prices of imported and locally produced commodities, unfavourable distribution of family income, poverty and trends in market prices of local products, especially fish, cotton and sugar.

Socio-cultural factors, such as the traditions, lifestyles and informal resource-use rules of the local community have also influenced wetlands perception, use and management. Lack of adequate and appropriate knowledge about the functions and values of wetlands has hindered active management, including rehabilitation of degraded areas by the local community. Inappropriate policy and, weak legal and institutional frameworks have also contributed towards unfavourable environment for wetland conservation and sustainable use.

3.4.3 The Sudd

The Sudd wetlands in Southern Sudan are a massive swamp system fed by the Bahr el Jebel. The conditions in the swamp are controlled by the water released from the Equatorial Lakes region as well as influenced through the torrential runoffs in the Nimule-Juba area during the rainy season.

The Sudd stretches from Mongalla to near the Sobat confluence with the White Nile just upstream of Malakal as well as westwards along the Bahr el Ghazal. Its size is highly variable, averaging over 30,000 km². During the wet season it may extend to over 130,000 km², depending on the inflowing waters, with the discharge from Lake Victoria being the main control factor of flood levels and area inundation. A main hydrological factor is that in the Sudd with its various meandering channels, lagoons, reed- and papyrus fields, half of the inflowing water is lost through evapotranspiration in the permanent and seasonal floodplains.

From 1961 to 1963 a great increase in the inundated area occurred when the level of Lake Victoria rose and the outflow increased. The total area is related to the amount of water reaching Bor from Albert Nile and from torrents or seasonal watercourses that can add substantial amounts to the flow in the upstream end of the Sudd. During the 1960th increase in Lake Victoria discharge, where flows at Mongalla have roughly doubled, the flows at Malakal at the northern end of the swamps had increased by 1.5 times the previous average flow. As a consequence of these high flows, the areas of permanent swamp and seasonal floodplains have, together, increased to 2.5 times their former size. The swamps have increased the most but even so the seasonal floodplain is 1.5 times its previous size.

From the southern inflow of the Bahr al Jebel at Mongalla, the defined riverbed successively widens into a floodplain, where the waters flow in meandering river stretches and various channels and lagoons throughout the dry season. It expands over the semi flooded grasslands during the flood season with rising water levels. Downstream of Bor, the Bahr el Zeraf River branches off the Bahr el Jebel to the east, diverting part of the flow, to join the Bahr el Jebel again just before reaching Malakal. During the course of its flow, the Bahr el Jebel passes Lake No, where the Bahr el Ghazal connects to the system, contributing an inflow with seasonal variation.

Hydrologically the Sudd plays an important role in storing floodwaters and trapping sediments from the Bahr el Jebel. Roughly 55 percent of water entering the area is lost to evapotranspiration. Water levels fluctuate up to 1.5 meters, depending on the intensity of seasonal flooding. The region receives less rainfall (typically between 55 and 65 centimetres per year) than other areas at the same latitude.

Vegetation cover of the area can generally be divided in five categories which occur depending on the elevation of the area above river flood level: Swamp, river flooded grasslands (Toic), rain flooded grasslands, wooded grasslands, woodlands, cultivated area. The density of the grasslands here is changing depending on the season, being tall grass in the rainy season and short and dry in the dry season, where also frequent burnings occur. The fluvial area is generally overgrown with vegetation, with some main and side channels as well as lagoons of open water. The main species are:

- *Phragmites communis* (shallow flooded, buried roots)
- *Echinochloa pyramidalis* (shallow flooded, buried roots)
- *Oryza barthii* (shallow flooded, buried roots)
- *Echinochloa stagnina* (deep flooded, superficial/floating roots)
- *Vossia cuspidate* (deep flooded, superficial/floating roots)
- *Cyperus papyrus* (deep flooded, superficial/floating roots)
- *Typha domingensis*

The first three species are anchored so their distribution is limited to depth of flooding, for the last species their root system needs to be in water or saturated soil permanently which gives a good indicator on flood patterns. *P. communis, E. pyramidalis* and *O. barthii* for example dominate only in areas where the depth of flooding does not exceed 130 cm over a period of ten years or 118 cm for a month in the year. Floating vegetation of C. papyrus had caused blockages in the Sudd swamps in a number of occasions between 1879 and 1900 when, the plants were torn out by increased floods. From this it can be concluded that *C. papyrus* needs saturated conditions, can tolerate deep flooding but is limited to a certain range of flooding which appears to be 150 cm.

Pastoralists use the Sudd and the surrounding areas extensively. Livestock and rain-fed agriculture are the dominant means of support for the largely rural population for which the seasonal flooded grasslands along the Sudd provides valuable grazing lands.

Sometimes the matted vegetation breaks free of its moorings, building up into floating islands of vegetation. Such islands, in varying stages of decomposition, eventually break up. The sluggish waters are host to a large population of mosquitoes and parasites that cause waterborne diseases. The shallow water is frequented by crocodiles and hippopotami. In more upland areas the Sudd has been known as a historic habitat for the endangered Painted Hunting Dog, *Lycaon pictus*; however, this canid may be extirpated in the region.

The Sudd was designated as a Ramsar Wetland of International Importance in 2006. The management efforts in the Sudd are controlled by the Ministry of Housing, Physical Planning and Environment in the Government of Southern Sudan. While situated within one country only, the dependence on upstream flow conditions causes a transboundary cause-consequence relation that needs to be considered by management efforts in the region. Both for scenarios within the Sudd (due to its dependency) and in the upstream regions (due to the possible effects) need to be considered. Being an area that has been inaccessible during the long lasting civil war, efforts have now started to assess and plan in the Sudd region. For a sustainable development multiple stakeholder aspects need to be considered in the Sudd. Ideas for conducting an all-embracing strategic plan are currently under way but would need funding. The strategic plan would harness the multiple stakeholder efforts that include power generation plans, fisheries, oil industry demands, local population needs, infrastructure projects including the controversial Jonglei Canal and others.

The Jonglei canal scheme was first studied by the government of Egypt in 1946 and plans were developed in 1954-59. Construction work on the canal began in 1978 but the outbreak of political instability in Sudan has held up work for many years. By 1984 when the Southern Sudanese SPLA brought the works to a halt, 240 km of the canal of a total of 360 km had been excavated. As peace returned after 2000, speculation grew about a restart to the project. In 2008, the Sudanese Government declared the revival of the project not a priority. It is estimated that the Jonglei Canal project would have caused complex environmental and social issues which may have limited the scope and benefits of the project in practical terms.

The Sudd includes Shambe National Park (62,000 ha) and its proposed extension, Fanyikang Game Reserve (48,000 ha) and Zeraf Game Reserve (970,000 ha). The Sudd is inhabited principally by the Nuer, Dinka and Shilluk peoples. In the central and southern parts there are small and widely scattered fishing communities, some on small areas of dry land within the permanent swamp, but most of the population is concentrated on the comparatively small areas of relatively high ground. Up to 1 million livestock (cattle, sheep and goats) are kept within the area. During the dry season, cattle-camps are set up on the banks of the main channels. Populations of larger mammals also congregate here, which leads to some competition for water and grazing. They are hunted and are an important food source. Sorghum, maize, cowpeas, ground-nuts, sesame, pumpkins, okra and tobacco are all cultivated. The heavy, impermeable, low-nutrient soils mean that crop yields are low.

3.4.4 Bahr el Ghazal

The Bahr el Ghazal, located to the west of the Sudd swamps, is a tributary to the White Nile that has negligible influence and impact on the downstream system as 96 % of the waters collected in the basin are lost through evapotranspiration and potentially percolation into the ground. Being a sensitive wetland, management plans for the basin are important while not transboundary in nature. The Congolese border is only touched by the upper catchment. The area is challenged by difficult access and lack of data so that assessments of the region start on a basic level. Main issues in the area include potential hazards through oil exploitation and its related infrastructure. Much of the biodiversity and management efforts in the Bahr el Ghazal swamps can be compared with those of the Sudd.

3.4.5 Machar Marshes/Gambela Marshes – Baro-Akobo-Sobat Sub-Basin

The Baro-Akobo-Sobat system is a vast and complex area containing numerous wetlands stretching over a wide expanse of plains. The Baro-Akobo-Sobat basin includes an extensive network of wetlands criss-crossed by watercourses generally draining into the White Nile through the lower Sobat system. The Sobat River is the final tributary of the White Nile and contributes about half its flow (Sutcliff 2009). The Sobat has two major tributaries: East, the Baro River, which drains an area of the Ethiopian mountains, east of Gambela, and to the south, the Pibor, which receives the flow of the Gila and the Akobo south of the Baro Basin. This southern system also drains a wide area of the plains east of the Bahr el Jebel.

The Baro, Gilo, Alwero and Akobo are the main rivers within the Baro-Akobo basin. The rivers rise from the south-western Ethiopian highlands (about 1,500 to 3,100 m asl) and flow in westerly direction, first along deep incised valleys over steep gradients then open across the Gambela Lowland plains at about 500 m asl where they meanders through a vast plain stretching all the way to the border with Sudan.

The Sobat River rises in the far southeast as the Pibor River (in Uganda on Mount Moruogole, 2,750 m asl). Water from these headstreams only reaches the Pibor in years of very high rainfall. The Pibor joins the Akobo at the westernmost point of the Sudan-Ethiopian border. Along its last stretch the Pibor forms the outfall for a number of ephemeral streams which drain a large area of the plain between the Bahr el Jebel and the mountain (Sutcliff 2009). The Pibor-Akobo-Gilo catchment is important and represents almost a quarter of the total sub-basin area compared with only 9% for the Baro. However, the Baro supplies 75% of the Sobat flow (ENTRO 2007b).

The entire area of wetlands may reach up to 1 million ha during wetter years. The wetland complex system is very difficult to map. It extends at least 200 km from north to south and 180 km from east to west. The major wetlands are associated with two distinct catchments, the Baro-Akobo, located in Gambela regional State, hence sometime referred as the Gambela marshes, and the Sobat and its well known Machar Marshes, located between the upper Sobat and the White Nile. The area of wetlands in Sudan is about 500,000 ha and 400,000 ha in Ethiopia. In Ethiopia it covers much of the lower valley of the Gambela Region (Hughes and Hughes 1992).

The Machar Marshes is located mainly north of the Sobat River. The wetlands are fed by several spill channels from the Baro River as well as other small tributaries, the eastern torrents (the Tombak, Yabus, Daga and other small stream) draining the Ethiopian Highlands, which joins the Khor Daga and the Khor Adar, next (ENTRO 2007b). Outflow from these marshes sometimes reaches the White Nile via the Khor Adar (Sutcliff 2009).

Along the lower Baro, spill of the higher flows are feeding the Machar marshes. Also, the Baro splits into the Adura and Baro about 100 km above the junction with the Pibor. The two rivers eventually rejoin below the junction with the Khor Machar. Spills and excess water during the rainy season overtops its banks and inundate wide areas and form wide areas of marshes and swamps in Gambela. Wetlands are also found across most of the Gambela plains stretching along all the main rivers including the Alwero, the Gilo and the Akobo. Mapping of land cover conducted as part of the WBISPP (2005) identified permanent and seasonal marshes and swamps, and temporary streams, covering an area of approximately 240,000 ha.

Further to the south-west, a lesser known area covered with extensive wetlands is found between the Akobo and the Pibor. Studies report of a spillway between the Akobo and the Pibor, which lies to the east of Pibor Post. There is an area of approximately 230,000 ha of permanent inundated swamp and 250,000 ha of seasonally inundated swamp associated with the spillway (ENTRO 2007b).

Machar Marshes

The Machar Marshes are an extensive wetland system and they are the least known of the southern Sudan wetlands. There is neither direct ground evidence for the distribution of permanent and seasonal swamp nor direct evidence of the swamp and grassland vegetation types. The area appears to be experiencing high variability in the timing and intensity of flooding. This may have an impact on the establishment of typical permanent swamps where papyrus sedge, phragmites and typha dominate (ENTRO 2007b).

Estimates from various studies area as follow:

- Swamp and grassland annually flooded: 600,000 to 2,000,000 ha (JIT 1954);
- Permanent swamp (60 % grass and forest): 870,000 ha (El-Hemry and Eagleson 1980, based on Landsat imagery);

- Permanent and Seasonally flooded swamp: 96,700 ha and 194,700 ha, respectively Adding grassland area: 539,200 ha, which may have been partly seasonally flooded (FAO Africover;
- Inundated area: 150,000 to 600,000 ha (Sutcliff and Parks 1999, using water balance mode) – 300,000 ha (based on 1986 thermal infrared image)

Gambela Marshes and Swamps

The Gambela Marshes and swamps are found in a region equally sparsely populated. Its remote nature and limited infrastructure development would partly explain why such a large wetland area has received relatively limited attention to date. Information on its biodiversity is also limited. Its marshes and swamps are typically dominated by papyrus sedge, common cattail and common perennial reed (*Phragmites karka*). *Cyperus papyrus* forming tall stands fringing watercourses and deeper waterbodies. Away from the deeper area, *Typha domingensis* dominates, and emergent *Vossia cuspidata* (hippo grass) as the dominant fixed-floating species.

The seasonally flooded grasslands are dominated by *Oryza longistaminata* and by *Echinochloa pyramidalis*. Riparian forests species include: *Celtis kraussiana, Ficus sycomorus, Mimusops kummel, Tamarindus indica, Maytenus senegalensis, Kigelia aethiopum, Syzygium guineense* and *Acacia* spp. (ENTRO 2007b)

There are two national parks established in the Sub-basin: the Gambela National Park in Ethiopia and the Boma National Park in Sudan (see Section 5.2.5 for detailed description about the rich biodiversity found in the parks). The Gambela Regional Park covers an area of 506,100 ha stretching between the Akobo and Gilo Rivers and includes numerous wetland habitats. The Boma National Park area is 2.28 million ha and encompasses the clay plains, mosaic of wetlands including seasonally flooded grassland, open wooded savannah in the north-western section.

The floodplain areas are commonly used for cattle grazing during the dry season. The cattle population is most likely going to increase as a result of influx of population migrating in areas that had been deserted due to the civil wars. Large livestock population are causing environmental stress. Overgrazing will challenge the natural vegetation and may contribute to land degradation, increase erosion and associated sedimentation of waterbodies.

There is a substantial untapped potential for hydropower development, and opportunities for developing irrigation as well as improving rainfed agriculture. Portions of the basin which are subject to extensive flooding and high evaporation and seepage rates could potentially yield important conservation gains. Studies identified the role of regional wetlands in high rainfall area for hydro-power development (TAMS-ULG 1996, as cited by Wood 2000). The Eastern Nile Subsidiary Action Program (ENSAP)'s project for Integrated Watershed Management targets the Baro-Akobo-Sobat watershed. Efforts are focusing on erosion control to reduce environmental degradation and to protect critical aquatic habitats. The Baro-Akobo-Sobat Multipurpose project is the next step in the current development drive in the region.

There are other issues that have potential impacts on wetlands. More recently, the rate of deforestation in the region is increasing and the lost of high forest and woodland in the Baro-Akobo basin is significant (ENTRO 2007b). Forest lost impacts on the watershed as a whole. Forest services such as watershed protection, biodiversity conservation and carbon storage will be severely reduced or lost as a consequence.

Altered hydrology, water flow and water quality are likely to affect the vast extent of wetlands found in the region.

An important aspect of the potential lost from environmental degradation is the likely negative impact on the local fisheries. The combined yield from the Baro, Alwero and Gilo Rivers make up the largest fisheries in Ethiopia (Abrha and MoWR 2005).

3.4.6 White Nile (North of Malakal)

The White Nile between Malakal and Khartoum flows in a relatively confined bed that is fringed by papyrus and reed areas also including islands, floodplains, Khors and the shores of the Jebel Aulia dam. Wetland management efforts are handled by the Sudan Government as well as on a local scale where inhabitants utilize the wetlands as a source of income through multiple competing uses such as pasture grazing or their function of fish breeding grounds.

3.4.7 Lake Tana Wetlands Complex

Lake Tana and its associated wetlands play an important role in the densely populated north western region of Ethiopia. It is one of the 'flagship' wetland sites targeted by the Nile Basin Initiative in their efforts to demonstrate the understanding of the functions of wetlands, biodiversity and water resources in sustainable development (NBI in press). Lake Tana is the largest lake in Ethiopia located on a basaltic plateau part of the Ethiopia highlands. The lake is shallow with an average depth of 9.53 m (max. Depth 14 m) and contains half the country's freshwater resources (ENTRO 2007a). It is the third largest lake in the Nile Basin (Vijverberg et al. 2009). Lake Tana is bordered by wetlands all around most of its shore and floodplains, with the exception of the northeast region. They consist of permanent and seasonal marshes and swamps as well as areas regularly inundated which forms an extensive network connected to the lake at the height of the rainy season. Wetland habitats connected to the lake act as nursery grounds for fish inhabiting the lake. They also serve as breeding ground for avian and terrestrial fauna and as such are responsible for maintaining a rich biodiversity. A number of important wetland sites are examined separately next. The entire Lake Tana wetland complex area including the largest part of the lake, which has a surface area of 304,000 ha, along with its marginal floodplains adding another 45,000 ha (Asmelash 2004), forms an imposing area of wetlands. It is usually cited as the largest in Ethiopia (NBI in press, Shewaye in press, p.28, Vijverberg et al. 2009). However, the delineation of wetland area is often open to interpretation. This position may be disputed by other wetlands sites such as the Gambela marshes whose areas of marshes are larger.

Along the north shore the rocky Gorgora separates two marshy stretches: east lies the Dembia plains drained by the Megech, Dirma and other streams. Along the eastern shore, the Fogera floodplain is a large plain forming an extensive bay drained by the Gumara and Rib Rivers into Lake Tana. The Rib River is the largest of the two and seasonally, at the height of the rainy season, will overflows its bank and floods surrounding area as it reaches the level of Lake Tana. Similarly the perennial Gumera River overflows its bank as it approaches the lake; however the flooding is less than the Rib (EWNHS 1996). Originating from the south western mountains the Little Abay River (Gilgel Abay) flows through an open valley and enter the lake at its south western end along a stretched deltaic arm.

A brief overview of aquatic and wetland biodiversity found in and around Lake Tana area is presented here. Additional information on the lake's biodiversity is further detailed in Section 5.2.10. The riparian area along the eastern and southern region of the lake is dominated by papyrus reed beds 4 m tall (*Cyperus papyrus*), common cattail (*Typha domingensis*) and common reed (*Phragmites karka*). *Persicaria senegalensis*, hippo grass (*Vossia* spp.), bulrush (*Scirpus* spp.), and *Nymphaea lotus* are common throughout (Muluneh 2005). Further inland sedges, reed grasses and bulrushes area found, along with swamp grasses such as *Echinochloa* spp. and *cynodon aethiopicus* that is grazed during the dry season (EWNHS 1996). Common submersed macrophytes are *Ceratophyllum demersum* and *Vallisneria spiralis*. Invasive species of concern in Ethiopia include the Water Hyacinth (*Eichhornia Crassipes*).

The management of the Lake Tana wetland complexes presents an overwhelming challenge. Recent assessments of the current situation are raising concerns about the state of environment (NBI in press). Wetlands degradation is widespread and for some areas it is beyond repair. Large swaths of land are converted for human use. Pressures and threats confronting the wetlands are varied and almost all types of threats are represented in this vast region. Lack of awareness is probably the overarching threats for any wetland areas, here and beyond, compounding both the socio-economic as well as the institutional and policy environment. Environmental degradation resulting from expanding agriculture activities is a confronting reality resulting from an ever increasing population pressure, and this especially acute for agricultural-based economies. This in combination with unabated deforestation along the steep slopes characterising the surrounding watersheds present an imminent risk to the ecosystems with a steady deterioration of soil conditions. An increase in the sediment load directly impacts on the wetlands by an acceleration of the sedimentation process[3]. Over harvesting of wetland plants as well as unregulated fishing practises are direct causes to the loss of biodiversity. In areas where wetlands have been transformed to agricultural lands, the biodiversity has been completely transformed from wetland species to cropland species. Problems linked to the presence of invasive species are also creeping up. Urban encroachment, pollution, and alteration of the hydrology of the lake and its tributaries are also compounding factors.

At a macro-scale, impacts from climate changes will increase the frequency of extreme events such as floods and droughts. Climate change scenarios conducted on the Abay River derived from various General Circulation Models (GCMs)[4] (assuming that concentration of atmospheric CO_2 would double by 2075, the equilibrium response) indicated that the basin is highly sensitive to climate change especially in the distribution of runoff throughout the year. Two out of the three models predicted significant decrease in runoff, 12.6% and 18.2%, using CCCM and GFD3 GCMs respectively, whereas changes in annual runoff from UK89 GCM projections indicated wetter conditions with an increase of 2.5%. However, all the models agree that there will be a reduction of river flow from 15% to 80% of the monthly mean in some months of the year all over the basin (Deksyos and Tadege 2007). The first two GCMs predict a reduction of monthly runoff by as much as 32% and 28% in the main rainy month of July. The decrease in river flow might cause small streams to dry up completely and in the medium to large rivers the magnitude of flow will decrease significantly. Such alteration in water availability combined with an increase in air temperature and evaporation will most likely translate in the loss of wetland. This will have a serious

[3] Increased accumulation and sedimentation will ultimately accelerate the ontogeny of waterbodies such as wetlands, i.e., the rate of conversion of the aquatic ecosystem to a terrestrial one (Wetzel 2001)

[4] Canadian Climate Change Model (CCCM), Geophysical Fluid Dynamics Laboratory – Model Wave No. 30 (GFDL R-30), United Kingdom Meteorological Office model-1989 (UK89 GCM)

impact on agricultural production and further exacerbate the difficulties that the local population will be facing in the future.

The management of Lake Tana and its catchment is shared among national and regional institutions. However, mechanisms to coordinate the various stakeholders are not clear articulated. At the federal level, the Ministry of Water Resources (MoWR) is responsible of overall planning. The Ministry of Agriculture and Rural Development (MoARD) is in charge of water management (irrigation extension). The Environmental Protection Authority (EPA) is responsible for the preparation of environmental protection policy, laws and directives. At the regional level institutions involved in the water sector include various Bureaus such as the Bureaus of Water, Mines and Energy (BoWME) and the Irrigation Development Authorities (IDA) (NBI in press). The Environmental Protection and Land Use Authority of Amhara Regional State (EPLAUA) is also attempting to assume a significant role in the management and the protection of Lake Tana's natural resources. The purpose of the management efforts is halting wetland degradation through introducing wise use approaches by implementing community owned integrated wetland-watershed natural resource management activities. Other projects focus on rehabilitating the upper watersheds to reduce soil erosion.

Fogera Plains (Gumara and Rib River Sub-Catchments of Lake Tana)

The Fogera plains found along the eastern region of Lake Tana is a vast fertile alluvial plain that used to be forming permanent and seasonal marshes and swamps, part of which formerly belonged to the lake (NBI in press). Currently, the area seasonally inundated is about 28,000 ha. For the longest time the Fogera plains have been used for agriculture which has intensified as a response to population pressure. The plain is also used as a demonstration site for rice cultivation. Other parts of the plain are significantly overgrazed. Meanwhile, land conversion to agriculture activities is keeping pace with population growth. The Fogera plains are a highly impacted site exhibiting a significant loss in biodiversity, including hydrophytic plants, fishes and birds. The papyrus stands have been entirely removed and the hippopotamus population is threatened (NBI in press).

Despite holding such a rather sombre environmental 'report card', the Fogera plains are among a number of sites that are being considered to be designated as Ramsar sites for the Lake Tana sub-basin. The importance for waterfowls and terrestrial birds is significant and two sites to established IBAs are being identified. Efforts are made to counter the adverse effects resulting from unrestricted agricultural practices by conducting awareness raising campaigns with local communities. Restoration of papyrus stands and reforestation of buffer zone on the eastern catchment are being suggested a first step towards mitigating the impact from human activities (NBI in press).

Gilgel Abay Floodplain

The Gilgel Abay or little Nile River is recognised as the source of Lake Tana, which, in return is the well-known source of the Blue Nile (Great Abay). This is probably the most impacted area of the Late Tana watershed. This is the longest of all feeder streams which drain the largest of Lake Tana's sub-catchments and contribute a high sediments loads into L. Tana (EPLAUA various dates, cited in NBI in press).

Dembia / Gorgora Floodplain

Dembia and Gorgora floodplain is part of the Megech River sub-catchment located north of Lake Tana. Environmental pressures resulting from human activities are similar to those found in the wider area of Lake Tana. This area is highly degraded. Intensive agriculture uses with further development are being considered (eucalyptus plantation and rice crop). Long-term watershed rehabilitation programmes are a priority. The Gorgora peninsula has been suggested as the best site for conservation area for endangered wildlife (NBI in press).

Delgi–Takusa Wetlands

North-western region. Takusa wetlands have remained relatively intact. Important bird species are still visiting this site, species that are also found in the Alatish wetlands further west near the Sudanese border. This site is regarded as potential Ramsar site candidate.

Kunzila Floodplain (Bahir Dar Zuria) Wetlands

South-west region. This site is potentially threatened by the development of the Tana-Beles hydropower scheme, which involves the excavation of a tunnel for diverting water from L. Tana to the Beles River (a tributary of the Abay River located downstream) and significant ecological changes are anticipated.

Gelda River Floodplain

South-west region. The river runs over a relatively short distance in parallel with the Gumera River to the north.

Zegie Wetlands

At Gerima near the Zeghe peninsula.

3.4.8 Western River Floodplains – Abay-Blue Nile Sub-Basin

Some of the most important wetlands known in Ethiopia are described below. This selection of wetlands concerns those that are associated with river floodplains of the Abay-Blue Nile sub-basin. Rivers of the Baro-Akobo-Sobat sub-basin are described separately. The Fincha'a-Chomen marshes and the Dabus River marshes are among the largest area of wetlands in Ethiopia. Fincha'a, also identified as Chomen marshes on official topographic maps, is found about 250 km west of Addis Ababa. Because of the relative ease of access to this wetland this site is relatively well known (EPA 20003). Dabus marsh, on the other hand, is further afield and for that reason has only recently begun to attract the attention of the scientific community and natural resource managers. The presence of a newly built road located north of the Dabus marsh will significantly change the fate of this remote wetland that has remained in pristine condition hitherto.

Fincha'a-Chomen Marsh

One of the largest wetland complexes in Ethiopia, the Fincha'a-Chomen marsh is found surrounding a man-made reservoir that was constructed in 1972 for hydroelectric power production. The reservoir is under the supervision of the Ethiopian Electric and Power Corporation (EEPCO). Fincha town is located near the dam outlet. The estimated area of wetlands totalled about 50,000 ha (WBISPP and MoARD 2005). This includes area of open water, which dominates the landscape with approximately 15,700 ha and a mean depth of 6 m (BCEOM 1998). The reservoir is fringed with large expanses of marshes forming a buffer zone particularly wider along the south-western section of the reservoir. At the edges, large floating mats of vegetation can be seen drifting off. These floating mats, which are dominated by stoloniferous grass (*Panicum hygrocharis*) (BCEOM et al. 1998), can be seen from space (Landsat) travelling extensively across the whole basin, and appear at times to be closing off the narrow isthmus located across the lower third.

Only a few km north of Fincha, there is a smaller and narrow water body stretching north, the Amerti Reservoir (1,500 ha). The Amerti was created to increase water supply to the main reservoir. An underground tunnel carries excess water over the 2.5 km distance that separate the two reservoirs. Permanent and seasonal marshes stretching along the narrow valley can be seen from the ridge separating the two reservoirs.

Wetland flora identified during the field visit carried out as part of this project showed some differences in the plant composition between the two sites surveyed. Along the south-eastern area, the flora was dominated by sedges in association with a few species grasses, including: *Cyperus digitatus, C. aff. denudatus, C. dichroostachys, C. elegantulus, Juncus dregeanus, Ascolepis capensis, Floscopa glomerata,* and *Syngonanthus wahlbergii.* The site located along the western edge of the reservoir presented a wider mix of grass and sedges, including *Cyperus latifiolius, Persicaria decipiens* and other *Persicaria* spp., *Ludwigia abyssinica, Chenopodium aff. album, Ranunculus multifidus, Sphaeranthus sp., Plectranthus punctatus, Leersia hexandra,* and *Artemisia abyssinica*. Additional wetland plant species that can be included for Fincha'a marshes are: *Panicum hygrocharis, Nymphaea lotus,* and *Phoenix reclinata* (EWNHS 1996). The wetlands are of particular conservation importance as a location for the globally threatened Wattled Crane.

There is no known environmental management measure in place. The wetlands are under constant pressure from agricultural expansion, overgrazing, and various types of land use changes such as the introduction of new crops, Eucalyptus plantation among others (EPA 2003).

Dabus River Marshes

The Dabus River is an important tributary draining the relatively wet southeast region of the Abay Basin. The Dabus enters the Abay River as it is nearing the Sudanese border. Together with the Didessa River, the two rivers contribute a third of the total flow in the Abay-Blue Nile Basin (Sutcliff 2009). The Dabus marshes are mainly found in the headwaters of the Dabus River. Information on the area of wetlands is limited. Land cover mapping based on Landsat images were carried out during the early 2000 and identified area of seasonally inundated sedge/grass marshes along the upper Dabus covering about 12,600 ha (WBSIPP and MoARD 2005). This estimate could be regarded as a very conservative one. Recent survey conducted as part of this project provided evidence that the area of wetlands may be significantly larger. Extensive stands of papyrus sedge were noted near the lower sections of the Dabus marshlands where it reaches the end of an extensive flatter area. Assessment of the area of wetlands using visual interpretation of Landsat images combined with the most recent ASTER derived 30 m digital elevation model suggests that the Dabus wetlands area could reach up to 70,000 ha. This is in keeping with estimates cited in earlier studies (USBR 1964b cited in Conway 1997) with area of approximately 90,000 ha. Due to its physiographic nature, there are large losses of water from the wetlands to evaporation and transpiration.

The area is relatively remote and no research appears to have been conducted on the Dabus wetlands. Little is known about the management of this wetland and its use by local communities. It can be safely assumed that the wetland is used along its edges for dry season grazing. Areas of burnt grass were noted along drier sections of the wetland. Burnt scars were also noted from the Landsat historical images. Representatives from The Cyperaceae family dominated the wetland flora and included *Cyperus latifiolius, C. macranthus, C. papyrus L., C. nitidus, C. pectinatus,* and *Eleocharis acutangula*. Also found in the collection of wetland plants surveyed were *Ottelia ulvifolia, Burnatia enneandra, Nymphaea nouchalii, Potamogeton thunbergii* indicating the permanence of the inundated conditions, and *Echinochloa stagnina* a common grass found along edges of wetlands. The extensive areas covered by Papyrus sedge would suggest that there are potential uses of wetland raw materials by local people. Fishing activity was observed during the field visit.

The current mapping exercise is a step forward in raising attention on the importance of this wetland before it faces threats from large-scale development projects.

Beles River Floodplain

Mainly represented by wetland fringes along the stream riparian zone. Area of wetlands unknown.

Cheffie Meti

Located near the town of Gimbi. Area unknown. This site is an area of wetland dominated by shrub, and located along the Meti River (EPA 2003).

Sorga Reservoir

A small reservoir (30 ha) used for supplying water to the town of Nekempt located just a few km along the road west to Gimbi. A small area of marsh (about 10 ha) dominated by sedges and grasses is found immediately downstream of the reservoir and is partially maintained by water seeping underneath the earthen dyke.

Wonchi Lake

A small crater lake, about 422 ha, lying next to the watershed divide with the Awash River basin but allegedly within the Nile Basin (BCEOM et al. 1998). The Lake is located approximately 100 km west of Addis Ababa.

Chemoga – Yeda Floodplains

Located around Debre Markos (central highlands); listed in most literature on wetlands in Ethiopia, however there is little available information for this site (Abrha in press).

3.4.9 Illubabor Wetlands – South-western Highlands in Ethiopia (Upper Baro-Akobo Rivers)

This wetter part of the Nile Basin is known for its abundance of mainly small wetlands, marsh and swamps, widely found along narrow valley bottoms. Wetland areas may reach 5% of the region (McKee 2007). This is a value much above the average for the Nile Basin in Ethiopia. Various estimates are found in the literature. EPA (2003b) estimated the total area of wetlands to be about 1.5% of the total land area.

An overview of the wetland situation and trends in wetland use was carried out during the late 1990 and early 2000. This was part of the project entitled “Sustainable wetland management in Illubabor Zone" investigating the nature and extent of the wetland drainage practices in this administrative zone and trends (Hailu et al. 2000).

Within the highland plateau area wetlands, *Cyperus latifiolius, Leersia hexandra, and Panicum hymeniochilum* are common among the wetland flora. *Guizotia scarba*, *Phyllanthus boehmii* and *Snowdenia petitiana* are more commonly found in pristine wetlands and cultivated wetlands at the end of the rainy season and *Anagallis serpens*, *Cyperus brevifolius*, *Fuirena stricta* and *Hygrophila auriculata* were more common in degraded wetlands and cultivated wetlands during the dry season (Woldu, 2000).

Wetlands in Illubabor are under constant pressure. The smaller headwater ones in particular, have been subjected to drainage for dry season maize cultivation. Wetland cultivation represents a major threat to wetland survival, often resulting in complete loss of the wetland ecosystem and associated ecological services. Other sources of pressures include destructive crops, Teff cultivation, overgrazing, and deforestation.

3.4.10 Wetlands of the Lower Abay-Blue Nile Sub-Basin

The wetlands that belong to this section are found at lower altitudes in Ethiopia, along the Alatish River, and extend across Sudan along the Dinder and Rahad River. The Alatish–Dinder forms a trans-boundary wetland lying across the Ethiopian-Sudanese border and the largest area of wetlands is found in Sudan. In Sudan the Dinder floodplain covers an area estimated at 500,000 ha (Hughes and Hughes 1992). Alatish Park, in Ethiopia, is drained by three major streams, Alatish, Gelegu and Ayma Rivers. There the wetlands are sparsely found throughout the park.

The Dinder and the Rahad join the Blue Nile downstream of the Sennar Dam. By Roseires[5] the slope has nearly levelled out and the river begins to meander through the Sudan plains, an Acacia-grass savannah, and finally merges with the White Nile at Khartoum (Vijverberg et al. 2009).

Among the lesser known wetlands found in the Abay-Blue Sub-basin are the '*Stunt Forests*'. They are distinct wetlands dominated by pure stands of *Acacia nilotica*, found along the Blue Nile and other silt-laden streams of Ethiopia and elsewhere (El-Moghraby in press). An example of Stunt Forest can be seen in Khartoum City at the confluence of White Nile and Blue Nile.

Alatish-Dinder Floodplain (An International Transboundary Wetland Complex)

The Dinder and Rahad Rivers, which originate in the Ethiopian high plateau, rise to the west of Lake Tana and flow westward across the border joining the Blue Nile below Sennar (ENTRO 2007a). With basin areas of 16,000 and 8,200 km^2, respectively, the Dinder and Rahad Rivers together contribute about 10% of the total Blue Nile flow with 20 % of the total Abay-Blue Nile Sub-basin area. These two rivers are highly seasonal, with significant flows between June and September due to the seasonal rains over the Ethiopian highlands, but reduced to sandy riverbed and intermittent pools during the rest of the year (Collins 2002).

[5] The two main dams in the Blue Nile Basin are Roseires completed in 1966 with a storage capacity of 2.4 km^3 and the Sennar completed in 1925 with a capacity of 0.7 km^3. The hydro-electric facilities at each of the dams have installed capacities of 250 MW and 15 MW at Roseires and Sennar respectively. Both dams are affected by siltation (Sources: ENTRO 2007a)

The Dinder and the Rahad Rivers and their tributaries drain a large area which boundaries are forming the Dinder National Park (DNP). The park was proclaimed in 1935. The park covers an area of 8,960 km². It is also a designated Biosphere Reserve and has been designated under the Ramsar Convention as a Wetland of international importance. The Ramsar site covers an area of 1,084,600 ha (Ramsar Information Sheet 2003).

The Dinder and Rahad rise in the Ethiopian Highlands. Due to the abrupt change in gradient the rivers form an extensive network of meanders across the plains. A large number of cut-off meanders have been formed locally called Maya'as. Maya’as are depressions along and between the rivers. The area away from the river is covered with numerous fossil streams and rivers. These depressions are abandoned meanders which have formed forming "ox-bow" lakes. They are generally flat and cover an area some 0.16 to 4.5 km² (ENTRO 2007a). Rain and flood water fill them during the rainy season. The Maya'as provide a valuable source of water and forage for domestic livestock and wildlife which are enduring a long dry season, as well as unique habits rich in biodiversity (El-Moghraby in press).

The areas of wetlands formed by the Maya’as lakes are difficult to estimate. These lakes are ephemeral. Under natural conditions there is a constant evolutionary sequence of the formation of young Maya'as that are deeper with clear water. Gradually they pass through stages of becoming gradually silted up. Over long periods of time with the meandering new Maya'as are being formed. The spectrum runs from young productive Maya'as to old non-productive dry ones. With the accelerated erosion in the Ethiopian Highlands this gradual and long term evolutionary process has been altered due to increased flood peaks and high sediment loads. The area is now subject to annual flooding and many of the Maya'as are becoming more rapidly silted up with a consequent loss of habitat biodiversity and forage productivity (ENTRO 2007a).

It should be noted that the vast majority of these wetlands are found outside the Dinder National Park and most are within large to medium semi-mechanized farms agricultural expansion such as large-scale rainfed agriculture. This situation represents a significant threat to these wetlands.

Immediately across the border within Ethiopia the Amhara regional State has designated an area as the Alatish National Park. There is considerable scope to develop an international trans-boundary park by combining the Dinder and the proposed Alatish National Parks.

Dinder National Park (DNP) lies on a transition ecotone between two floristic regions: the Ethiopian High Plateau and the arid Saharan-Sudanese biomes. It also lies along the boundary of two major faunal Realms of the world: the Palaearctic and the Ethiopian. It is also located along a major north-south flyway of migratory birds and also gives refuge to a large number of migratory birds in the wetland ecosystem. It has a high level of biodiversity with over 250 species of birds, 27 species of large mammals, some of which are listed by the IUCN as endangered, vulnerable or threatened species, and unknown number of small mammals (Ramsar Information Sheet 2003). The park comprises the last extensive tract of woodland in eastern Sudan. Its importance to conservation is significant. The proximity of the Park to the desert and semi-desert makes it an important buffer zone for the vegetation cover of central Africa in addition to its significance in providing genetic material for the rehabilitation in the semi-arid and arid areas. The Park, together with the south-western corner of the Ethiopian Plateau make a complete Ecosystem for wild animals, for which the Park is the dry season habitat for migratory species. The park also supports a high diversity of fauna and flora, including such animals of international conservation importance as the African elephant, African buffalo and the lion (ArabMAB 2006, as cited in ENTRO 2007a; Ramsar Information Sheet 2003).

Dinder National Park is fully protected and there is an extensive buffer zone (270,000 ha) immediately to the west. However, poaching and illegal herding are a threat to the ecosystem. Large areas of the park are burnt each year and illegal farming is encroaching over the buffer zone (Hughes and Hughes 1992).

Alatish Regional Park in Ethiopias Amhara region where the Regional Government has proposed to develop the Alatish Regional Park in Quara Wereda of North Gondar Zone, almost opposite the Dinder national Park in the Sudan. The area represents the Sudan-Guinea Biome. The park has now been gazetted as a Regional Park and its demarcation has been established. However, the Park lacks national legislation and international recognition (Enawgaw et al. 2006).

The Park covers an area of 2,666 km² lying north of the Dinder River, which forms its southern boundary, and to the south of the Gelegu River that forms its northern boundary. The Alatish and other ephemeral streams drain the central area. Its altitude ranges from 500 to 900 m asl. The main vegetation is woodland, shrubland and lowland bamboo thicket.

Seasonally inundated swamps, including swamp forest, and marshes are present in the park and wetlands associated with floodplains stretching along small streams appear to be predominant (Enawgaw et al. 2008). Tree species most commonly found along riverine habitats include *Diospyros mespliformis, Tamarindus indica, Ficus glumosa, F. sycomorus,* and *Acacia sieberana* (Mengesha 2005).

Fishing, mainly using gillnet, is an important socio-economic activity for the local communities and is carried out on numerous small streams, however no fishing activity was observed on the Alatish. Destructive fishing activities have been reported.

In the Ethiopia Lowlands there has been a substantial increase in clearing woodland and shrubland for both small and large scale agriculture. This has occurred on the clay plains that extend into Ethiopia from Sudan. The area from Humera southwards to the Dinder watershed has seen voluntary resettlement of people from the Highlands as well as expansion of commercial agriculture. In the absence of monitoring of land use changes in this area it is not possible to quantify the amount of clearing that has taken place (ENTRO 2007c).

3.4.11 Tekeze–Atbara Sub-Basin

Wetlands associated with the Tekeze-Atbara sub-basin are primarily represented by man-made aquatic habitats established for irrigation purpose. These are mainly found along the lowlands stretching from the eastern most section of the basin in Ethiopia to the confluence with the Main Nile. Areas of wetlands are limited to the fringes along the main streams cutting through the mountainous relief characterising the upper sections of the sub-basin. The combination of extremely rugged terrains and lowlands exposed to highly seasonal flow conditions that are prevailing in the Tekeze-Atbara are creating an interesting environment shaping its wetland habitats.

The Tekeze-Atbara sub-basin extends from the north-western highlands in Ethiopia, draining parts of Eritrea, and extends to the lowlands in Sudan, joining the Main Nile approximately 300 km downstream of Khartoum (Sutcliff 2009). The Tekeze rises on the Ethiopian plateau from Meket mountain range near Lalibela, east of Lake Tana. Its source is located near Lake Ashenge. The Atbara River and its principal tributaries rise on the western slopes of the mountains enclosing Lake Tana. The headwaters of the Atbara arise close to those of the Blue Nile and flows swiftly north-westwards parallel to the Blue Nile to an impoundment at Kashm el Girba. The Tekeze travels over more than 750 km through extremely rugged topography across the regional States of Amhara and Tigray to the border with Sudan. About 70 % of the Tekeze basin lies in the highland part of Ethiopia. The Tekeze River joins the Atbara about 100 km after entering Sudan, then the river extends another 575 km in a north-westerly direction (ENTRO 2007c).

The Tekeze flows through mountainous landscape, incised gorges and deep valleys in the Ethiopian highlands and Eritrea, whereas the relief is flatter close to the Ethiopia-Sudan border. In the Ethiopia and Sudan the topography of the lowlands is almost flat or slightly undulating. Considering the extent of the lowlands, compare to the mountainous area, most of the sub-basin is characterized by slopes lower than 2.5 % (ENTRO 2007c). The discharge of the Atbara River is highly seasonal, and may run dry for several months each year, reduced to a trickle, and sometimes to a series of shrinking pools, towards the end of the dry season (Shahin 2002). The Tekeze, meanwhile, experiences extreme fluctuation in stream discharge; low flows are in the order of 5 $m^3 \cdot s^{-1}$, whereas average daily high flows can reach as high as 2,000 $m^3 \cdot s^{-1}$ (NEDECO 1998).

Area of wetland, swamps and marshes in the Tekeze-Atbara sub-basin are negligible with merely 87 ha (FAO Africover Sudan 2002, WBISPP 2005). Irrigated land, however, are more significant. Wetlands presented in this section are divided into highlands and lowland.

Wetlands in the Upper Tekeze and Atbara Rivers

Areas of wetlands along the Tekeze and Atbara floodplains are not known. Marshes with patches of tall sedges and bulrushes are formed in the shallow valleys where drainage is impeded (EWNHS 1996). Riverine woodland below 1,500 m asl stretches along the lowlands. *Salix subserrata* and *Tamarix nilotica* are early to colonize newly formed river bank, which are eventually established with xerophytic species such as *Ziziphis spina-christi*. Species found along the upper parts of the basin include *Apodytes dimidiata, Carrisa spinarum, Euclea racemosa, Ficus vasta, Syzygium guineense, Mimusops kummel, Phoenix reclinata,* and *Tamarindus indica* (ENTRO 2007c). Flatter areas on the lowlands towards the Eritrea and Sudan borders are extensively cultivated, primarily for cotton, sorghum and sesame.

Wetlands in the Lowlands

Irrigated land covers nearly 243,000 ha mainly from the New Halfa and Gash irrigation schemes, while large-scale semi-mechanized rainfed cultivated land are more prevalent with 513,240 ha (ENTRO 2007c). Important areas of semi-mechanized rainfed cultivated land are also found in the Atbara River sub-basin. The Kashm el Girba Dam6 on the upper Atbara valley was completed in 1965 (El-Moghraby in press). The New

[6] This scheme was designed to provide alternative livelihood to some 70,000 people displaced by the rise of water level behind the High Aswan Dam.

Halfa scheme (190,000 ha) is located below the Kashm el Girba dam. The dam has formed an artificial lake which covers an area of 12 500 ha.

The Gash rises as the Mereb River and in its upper reaches forms the border between Ethiopia and Eritrea. Much of the upper Mereb-Gash River Catchment lies within Eritrea. As it enters the plains near Kassala the river forms an inland delta where the water is used for flood irrigation, tree irrigation, also known as the ‘Gash Flood Irrigation Scheme. The remaining surface flow is totally lost through evaporation and deep percolation, never to reach the Nile (ENTRO 2007c). The flood averages 88 days. Water is diverted into canals to large areas known “misgas”. Currently only 16,800 ha (40,000 feddans) can be irrigated due to breaks in the canals and sedimentation. Nearly 90 % of the total area that could be irrigated in the 1930’s has been lost.

In addition to the main rivers there are a large number of ephemeral khors. Khors, also classified as wetlands under ‘seasonal streams’ category, are fast flowing and laden with silt. Their roles in transport of nutrients to larger water bodies are significant for some areas. They are widely distributed all over the country[7]. It should be noted that the khor probably harbours the largest population of the lung fish *Protopterus* spp. (Moghraby in press). Although khors are sometimes contributing little or nothing to the main rivers, they are of considerable importance to the local population. The lower section of the Tekeze-Atbara includes the eastern, north-western and western khors catchments (third order) area representing about 14% of the total sub-basin area (Source: USGS, cited in ENTRO 2007c). The plains east and west of the Gash Delta are cut by some 30 large khors and many small khors draining to the Gash River. Numerous intermittent khor channels are also found in the south-west regions along the Blue Nile watershed where the highest density of waterways is found compared with the rest of the lowlands of the Tekeze-Atbara watershed (ENTRO 2007c).

Haffirs (Man-Made Wetlands)

For thousands of years, Haffirs have been used in Sudan for water harvesting. Much of the water is collected by water harvesting into haffirs for domestic and livestock watering and in *teras*[8] for crop cultivation (ENTRO 2007c). Haffirs use water harvesting techniques through excavation of natural depression sites of low permeability for storage of rain water. Haffirs are usually constructed in areas with no permanent sources of surface or ground water. They vary in size and holding capacities and they are usually not lined (Moghraby in press).

3.4.12 Main Nile between Khartoum and Lake Nasser

The main Nile in Sudan shows a situation similar to what can be found along the White Nile. Wetlands occur fringing the river and are utilized on a local scale. The Nile banks, along stretches covered by riparian forests, are used for agriculture and palm tree plantations. The importance of the wetlands resources are seen as pasture grounds by the local population and important functions like fish breeding habitats, allowing for the existing Nile biodiversity, are neglected. With the construction of the High Aswan Dam and impoundment of Lake Nasser transboundary effects have become controlled with the impounded lake creating a buffer to the downstream situation.

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[7] The largest khor in Sudan is Khor Abu Habil draining the Nuba Mountains contributing to the the economy of northern Kordofan (Source: El-Moghraby in press).

[8] *Teras* area traditional water harvesting method involving runoff manipulation by U-shaped earth bunds.

3.4.13 Main Nile in Egypt

The Nile Valley below Aswan varies between 20-30 km in width and is confined by steep sides, particularly on the east. The river forms an elongate wetland that meanders through the densely populated agricultural landscape of the Nile valley. Since the closure of the High Dam at Aswan in 1964, the valley is no longer flooded each year. This has allowed dense swamp vegetation, mainly *Phragmites* and *Typha*, to become established in many places along the riverbanks, which were previously largely devoid of vegetation. Bare sandy or muddy banks come into existence seasonally, depending on the water-level, which is lowest in winter. A number of islands are found along the river, many of which hold good reed-swamp vegetation that is attractive to waterfowl.

The Nile Valley is irrigated and traversed by a number of streams and canals on the western side. The longest of these, flowing in parallel with the Nile is the Bahr Yousef. This receives water from the Nile at various points and terminates in vicinity of El Fayoum, from where, ultimately, its waters drain to Lake Qaroun. A succession of deep wadis run down from the eastern hills to the right bank of the river, and comparatively little agriculture occurs on this side of the valley. The valley is becoming progressively more saline as a consequence of the use of artificial fertilisers. These are now used to compensate for the silt which is no longer deposited by the annual floods.

Along the shores of the river, dense swamp vegetation grows unchecked without the seasonal fluctuations of the Nile, held back by the Aswan Dam. *Phragmites* and *Typha* grow along riverbanks that were previously bare.

About 40% of the arable land in this section of the Nile valley is cultivated with sugar-cane. Other crops are date-palms, maize, wheat and alfalfa. Fishing probably provides important income to many families inhabiting the region. In 1990, 589 boats and 1,178 fishermen were active on the Nile in Aswan Governorate.

3.4.14 The Nile Delta in Egypt

From north to south the delta is approximately 160 km in length. From west to east it covers some 240 kilometres of coastline. The delta is sometimes divided into West and East sections, with the Nile dividing into two main distributaries, the Damietta and the Rosetta, flowing into the Mediterranean at port cities with the same name. In the past, the delta had several distributaries, but these have been lost due to flood control, silting and changing relief. One such defunct distributary is Wadi Tumilat. To the north-west are three other coastal lakes or lagoons: Lake Burullus, Lake Idku and Lake Maryut.

The Nile is considered to be an "arcuate" delta (arc-shaped), as it resembles a triangle or lotus flower when seen from above. The outer edges of the delta are eroding, and some coastal lagoons have seen increasing salinity levels as their connection to the Mediterranean Sea increases. Since the delta no longer receives an annual supply of nutrients and sediments from upstream due to the construction of the Aswan High Dam, the soils of the floodplains have become poorer, and large amounts of fertilizers are now used. Topsoil in the delta can be as much as 20 m in depth.

About half of Egypt's 80 million people live in the Nile Delta region. Outside of major cities, population density in the delta averages 1,000 persons/km² or more. Alexandria is the largest city in the delta with an estimated population of more than 4 million. Other large cities in the delta include Shubra al Khaymah, Port Said, El-Mahalla El-Kubra, El Mansura, Tanta, and Zagazig.

Several hundred thousand water birds winter in the delta, including the world's largest concentrations of little gulls and whiskered terns. Other birds making their homes in the delta include grey herons, Kentish Plovers, shovelers and cormorants. Also found are egrets and ibises. Other animals found in the delta include frogs, turtles, tortoises, mongooses, and the Nile monitor. Nile crocodiles and Hippopotamus, two animals which were widespread in the delta during antiquity are no longer found there. Fish found in the delta include the Striped Mullet and soles.

The Nile Delta was once known for large papyrus (*Cyperus papyrus*) swamps, but papyrus is now largely absent from the delta. Vegetation consists of *Phragmites australis, Typha capensis*, and *Juncus maritimus*, with some small sedge. Invasive species of concern on the Main Nile and in the Nile Delta include the Water Hyacinth (*Eichhornia Crassipes*).

The Nile Delta is part of one of the world's most important migration routes for birds. Every year, millions of birds pass between Europe and Africa along the 'eastern African flyway', and the wetland areas of Egypt are especially key as stopover sites. Large numbers and a wide diversity of waterbirds, passerines and other bird groups also pass through the country during the spring and autumn.

Several hundred thousand waterbirds winter here in the Delta, including the world's largest concentrations of little gull (*Larus minutus*) and whiskered tern (*Chlidonias hybrida*) in Lake Manzala (Baha El Din, 1999). This ecoregion contains the largest breeding population of slender-billed gull (*Larus genei*) in the Mediterranean Sea.

Most of the delta wetlands have been reclaimed for agriculture, but since the construction of the High Dam at Aswan the upper delta has tended to become progressively more saline. This is due in part to the intrusion of seawater, but also to the use of artificial fertilisers in the lower Nile Valley to compensate for the loss of silt which used to be deposited by the flood each year. By contrast the delta lakes have become less saline due to increased drainage from irrigation schemes.

Considering agricultural expansion and population pressure, practically no areas of delta habitat remain undisturbed. The completion of the first Aswan Dam (between 1912 and 1934) dampened the annual flood pulse in the Nile Delta. The completion of the second Aswan (High) Dam totally stopped flooding and most of the former seasonally or permanently flooded habitats have subsequently been converted to settled agriculture. Before the dams were built, floodplain farming had occurred for over 5,000 years, although flooded areas were only farmed after the flood receded. However, since the closure of Aswan Dam, floodplains are farmed year-round, causing the loss of much of the wetland habitats of the delta and lower Nile River floodplain. Only fragments of the former wetlands remain. The best remaining habitat is found in the Lakes El Mannah, El Qatta, Faraontya, Sinnéra, Sanel Hagar and the coastal lagoons of Manzala and Miheishar.

The ecoregion is largely unprotected. Ashtoun el Gamil-Tanee Island Natural Area and the Lake Burullus Ramsar site are the only two protected areas in the delta and cover a total area of less than 500 km^2. Lake Burullus is threatened by fishing and pollution although it remains the most unspoiled of the delta wetlands. Ashtoun El Gamil Protected Area was created largely to protect gravid fish and fry as they journey in and out of nearby Manzala Lake, and is not large enough to contain any suitable waterfowl habitat. There are plans to enlarge this protected area, which may give it a greater significance in the conservation of Egypt's resident and transient avifauna (Baha El Din, 1999).

Virtually all of the 63 million people of Egypt live in the Nile Delta Flooded Savannah ecoregion. Population densities average 1,000 persons/km^2; much higher densities occur in major towns. Population pressure on natural resources is consequently immense, and humans have altered all of the natural vegetation outside of small reserves. People arrived in the area around 250,000 years ago and have been farming intensively here for more than 5,000 years.

The Delta ecosystem no longer receives a yearly input of sediments and nutrients from upstream. Consequently, the soils of the floodplains are poor and large amounts of fertilizers are applied to the land each year. Run-off of fertilizers and dumping of wastewater and sewage sludge is leading to the accumulation of trace elements in the sediments of the delta (Elsokkary 1996). At least one species, the catfish *Clarias lazera,* has been shown to be accumulating metals, including mercury, iron and copper in its muscle and liver (Adham et al 1999). Fertilizers, along with salt-water intrusion, have also caused the upper delta to become more saline. Pesticides such as DDT and Lindane have been detected in at least one of the lakes (Hughes and Hughes 1992).

Another threat is increasing quantities of agricultural drainage-water with heavy fertilizer and pesticide loads being released into the lakes in the delta, contributing significantly to their eutrophication and pollution. Local fishermen complain that the combination of occasional siltation and increased drainage-water leads to the reduction of the salinity of the lake and the expansion of reed-swamps and reduces fishing opportunities. The large number of fishermen on the lake cause continuous disturbance to waterbirds, forcing them to utilize less optimal habitats or sites.

There are three major threats to the remaining habitats and species. Salinity may continue to increase in the delta from infiltration by seawaters as the delta face erodes and as erosion opens the existing lagoons to the sea. Wetlands and other migrating birds will increasingly be hunted and trapped to provide a food source for local populations, and for sale to other countries (e.g. quail trapping which occurs along the coast). Finally, inappropriate siting of windmills for electricity generation could cause considerable mortality in migrating birds.

Other concerns include rising sea levels due to changing global climatic conditions. For example, El-Raey et al. (1997) estimate that with only a half-meter rise in sea level, 26 percent of the city of Rosetta and the estuary of the River Nile would be inundated. Ongoing efforts to halt erosion along the Nile banks by lining them with rocks will likely make these areas less attractive to waterfowl (Baha El Din, 1999). In addition, political conflicts between upstream and downstream countries could intensify. Egypt is totally dependent on the Nile River and uses its considerable regional power to prevent upstream countries from developing water use schemes that threaten its water supply.

3.5 WETLAND INVENTORY POLICY WITH REFERENCE TO RAMSAR REQUIREMENTS

3.5.1 Overview of Wetland Mapping Initiatives

Most of the information required for this section has been presented in the Inception Workshop and described in the Inception Report. A selection of previous and current wetland management projects are listed below:

- Lake Victoria Environmental Management Project
- The East African Cross-Border Biodiversity Project, “Reducing Biodiversity Loss at Cross-border sites in East Africa”
- Wetlands buffering capacity study
- Western Kenya Integrated Ecosystem Management Project
- FAO support to Food Security Information Systems in Ethiopia
- Environmental map of Sudan
- Evaluation of water resources in Sudan
- Woody Biomass Project in Ethiopia
- Biodiversity Monitoring & Assessment Project (BioMAP) in Egypt
- MedWet Coast Project in Egypt
- Wadi ElRayan Protected Area Development Project in Egypt
- Wetlands study in Rwanda / Burundi (Lake Chohoha)
- Mara Project, Kenya and Tanzania
- Sio Malaba Malakisi Project, Kenya and Uganda
- Lake Victoria Environmental Management Project 2
- Bor Dikes EIA, Wetlands study, Southern Sudan
- Dinder/Aletash National Parks studies, Sudan and Ethiopia
- Inventory of Wetlands in Kenya, Kenyan Wildlife Service Wetlands Program
- National Wetlands Conservation Project in Uganda
- Wetlands Sector Strategic Plan and Support Project in Uganda

3.5.2 Harmonization Issues between Mapping Initiatives

The Nile Basin wetland inventory, delivered as an outcome of the wetland mapping project is a baseline database, summarizes the currently available wetland information in the whole of the Nile Basin. The inventory, build on a geodatabase architecture, was designed in a way to allow updating and refining of its contents trough future initiatives as well as through continuous data collection activities both through planned periodic maintenance as well as trough activities of smaller stakeholders. Considering the size of the Nile Basin, the variety of initiatives in several countries and the speed of data generation from different sources, keeping the wetlands inventory up to date and on a high quality standard will be a task that needs careful planning and implementation. The task will be challenged from several sides, including administrative, legislative, managerial, cooperative, and technical and standardization issues. These issues as well as proposed ways to handle them are described in further detail in the following paragraphs.

3.5.3 Technical Standardisation

From a technical point of view, the updating of the wetlands database needs to be conducted by experienced GIS/database personnel. Using GIS software it is possible to view, open, and query the existing data as well as add new data. It is possible to upload data such as *Shapefiles*, feature classes, tables and raster data.

A standard for handing in data to the wetland inventory database will be necessary to maintain low running costs, easy maintenance and especially quality standards. Detailed guidelines for the maintenance and updating of the wetland inventory are given in Volume 2 of this report: The Wetlands of the Nile Basin: Inventory Manual.

Next to technical standards it is advisable to carry out the updating based on Ramsar guidelines as followed by the Inventory Manual or as available in detail on the Ramsar website. Other specific guidelines that are available on the Ramsar website include:

- Guidelines for the rapid assessment of inland, coastal and marine wetland biodiversity http://www.ramsar.org/lib/lib_rtr01.pdf
- Low-cost GIS software and data for wetland inventory, assessment and monitoring http://www.ramsar.org/lib/lib_rtr02.pdf

3.5.4 Administrative

Next to the technical challenges, organization of the updating will be a major task. Two options are available. Periodic maintenance exercised through defined projects or "on the go" updating through data collected from smaller scale independent initiatives that provide their information to the wetland database. In order for the latter option to function, widespread information campaigns need to be conducted in order to make people aware of the existence of the database and pursue them to provide their data to the centralized database. The information about the database can be disseminated through conferences as well as the NBI website, describing the database, the cooperation options and the benefits a user has from contributing his information. It may be beneficial to anchor regional hubs with the regional NBI offices to provide easier access and closer relations with the targeted local contributors.

3.5.5 Legislative

Issues on the legal side may need to be considered when sharing data. Contributors to the database will need to be aware that their data can be used by a wide circle of stakeholders but conversely they would also benefit from information provided by other initiatives. Considering the current situation in the Nile Basin, some of the legal data sharing mechanisms would need to be coordinated.

3.5.6 Managerial

The database being developed to the current state at the end of the inventory project includes a baseline or as-is situation of the wetlands in the Nile Basin. Updating and expanding the database will be possible based on the guidelines provided in Volume 2 to this report, the Inventory Manual. Updating will need to be carefully managed in order to fulfil both quality as well as technical standards as described above and to allow users to provide and query information from the database. Important issues include:

- Acceptance of ownership of the Database through Nile Basin Countries
- Agreement to maintain a master database where all updates from different sources will be collected and integrated into the system
- Understanding of methodologies and limitations of methodologies used for generating the baseline dataset
- Availability of database data to potential users
- Provision of newly generated wetland specific or country specific data to the master database
- Conduct of periodic basin wide surveys for general updates and trend analysis using a uniform methodology to allow trend analysis

3.5.7 Cooperation

Sufficient cooperation and taking on ownership will be the key to a successful maintenance and updating of the wetlands database. Administrative and managerial hurdles will be encountered while establishing a good cooperation network in which the major stakeholders and potential contributors and users should be linked together. For smaller scale stakeholders the wetland database provides a platform to incorporate their raw data and query GIS formatted data and maps in return. Depending on the NBI in-house maintenance efforts that will be available, such a setup may significantly contribute to the willingness of especially small scale initiatives to provide their data.

In line with the data exchange paths it will be important to maintain links between the master database administrator and the satellite users in the different countries. As it can be expected that multiple users will work with and also supply database data, it may be recommendable to introduce a country specific focal point for data collection and distribution.

3.5.8 Wetland Management Efforts by Country

Different wetland management efforts are carried out in the Nile Basin by its different countries. While all countries have their wetland focal point, the administrative structures and efforts to manage the countries wetlands resources vary considerably. Table 9 shows an overview of the situation in the Nile Basin countries.

Table 9 Wetland management efforts in the Nile Basin countries

Country	Wetland management effort
Burundi	Though one must realize that Burundian knowledge in wetland management is still limited, the government, through research institutes, has started to devote attention to wetlands in Burundi and is on the track to reach a better understanding of their physical and biological importance as well as their social, economic and cultural functions. The National Geographical Institution is involved with efforts related to wetland management in Burundi.
Rwanda	The wetlands in Rwanda have come under considerable pressure from agricultural activities and population growth. In 2001, the Ministry for Agriculture developed a master plan of marshlands development, soil conservation and watersheds protection in which degradation of the wetlands is seen as an issue and research and management projects have been proposed, looking into possibilities for sustainable wetland management. Later, the Wetland Convention Implementation Office has formulated a National Wetland Conservation Program for 2002-2030 jointly working with the National Commission for Development and Reform, the Ministries of finance, Education Scientific Research and Technology, Environment, lands, water and natural resources and Agriculture. The Geographic Information System and Remote Sensing Centre CGIS-NUR of Rwanda is working on a number of wetland management and mapping related projects.
Uganda	Uganda is most advanced in its wetland management efforts. Wetlands have been identified as important assets for biodiversity strongholds as well as in their sewage treatment capacity and are treated with priority. Wetland mapping and inventorying efforts in Uganda are advanced.
Kenya	Kenya has recognized the benefits of wetlands managements and respective efforts have started. Kenya has passed several policies and legislations including the Environmental Management and Coordination Act, the Water Act and the Wildlife (Conservation and Management) Act to ensure sustainable management of wetlands and its component resources. As an important area, the Lake Victoria North Catchment area is managed by the Kenyan Water Resources Management Authority (WRMA) and also the Kenyan Wildlife Service has a stake in wetlands management.

Country	Wetland management effort
Tanzania	The Tanzania Wetlands Unit is a Government run wetlands focal point, secretariat to the National Wetlands working Group and National Wetlands Steering Committee. It was established in 2002, soon after the signing of the Ramsar Convention in 2000. The Unit has been supporting projects in Ramsar and wetland sites since 2003, mostly with support from Danida. The Wetlands Unit functions to coordinate the implementation of the national wetlands strategy of the 2007 Wildlife Policy, act as the Ramsar Secretariat, support Ramsar Site Managers in 4 Ramsar Sites, provide technical assistance, training, CEPA and information to district level and community based management. Further initiatives are managed by sectoral or regional bodies like the Tanzania National Park Authority with partly great success with their efforts.
Sudan	Wetland management efforts in Sudan are handled by the Sudan Government - the Higher Council for Environment and Natural Resources (HCENR) of the Ministry of Environment and Physical Development of the Government of National Unity (GONU) and the Ministry of Environment, Wildlife Conservation and Tourism (MEWCT) of the Government of Southern Sudan (GOSS). A draft for a National Plan for Environmental Management (NPEM) in post-conflict Sudan has been established based on which environmental management efforts shall be derived. The management efforts in the Sudd and Bahr el Ghazal have been taken up with priority and are controlled by the Ministry of Housing, Physical Planning and Environment in the Government of Southern Sudan. Ideas for conducting an all-embracing strategic plan are currently under way but would need funding. The strategic plan would harness the multiple stakeholder efforts that include power generation plans, fisheries, oil industry demands, local population needs, infrastructure projects including the controversial Jonglei Canal and others.
Egypt	Various institutions and initiatives work in the field of wetland management in Egypt. The Ministry of State for Environmental Affairs / Egyptian Environmental Affairs Agency (www.eeaa.gov.eg) is the leading involved body. The agency formulates environmental policies, prepares necessary plans and promotes environmental affairs. Further initiatives are linked on http://www.egyptchm.org/. Egypt has adopted a National Biodiversity Strategy that sets the path from 1997 to 2017. The strategy was developed under involvement of a large amount of scientists and decision makers and is incorporated in national plans for sustainable development.
Ethiopia	The management of Lake Tana and its catchment is shared among national and regional institutions. However, mechanisms to coordinate the various stakeholders are not clear articulated. At the federal level, the Ministry of Water Resources (MoWR) is responsible of overall planning. The Ministry of Agriculture and Rural Development (MoARD) is in charge of water management (irrigation extension). The Environmental Protection Authority (EPA) is responsible for the preparation of environmental protection policy, laws and directives. At the regional level institutions involved in the water sector include various Bureaus such as the Bureaus of Water, Mines and Energy (BoWME) and the Irrigation Development Authorities (IDA) (NBI in press). The Environmental Protection and Land Use Authority of Amhara Regional State (EPLAUA) is also attempting to assume a significant role in the management and the protection of Lake Tana's natural resources.
DRC	In the DRC, the Directorate of Forestry Inventory in the Ministry of Environment, Nature Conservation and Tourism as well as the National Geographic Institute are involved with wetland management related activities.

All countries have identified areas of concern and importance in-between their wetland resources and research, management and conservation efforts focus on these sites. Criteria for the selection of the sites can be plentiful and include conservation driven aspects like already visible degradation and pressure driven aspects like agricultural conversion or plans for e.g. hydropower projects that would have an effect on the wetlands. The importance of a wetland can thereby not generally be judged. Wetlands may be important on a local scale supporting villagers' livelihoods while being neglected in the bigger picture. Careful assessments should anyhow be undertaken in such cases in order to establish and consider multiplicator effects of the summarized effects of many smaller sites.

3.5.9 Challenges in Wetland Management

Wetland management is a process concerning multiple aspects and including the interests of multiple stakeholders. Challenges are therefore encountered on different levels.

- Conflicting interest
  - Local
  - National
  - Regional
  - Basin wide
- Data availability for decision making
- Legislation and current regulations that are in place
- Research needs for better understanding
- Lack of knowledge of wetland services and benefits expressed in monetary value

To overcome these challenges, information about the wetland value through tackling the above challenges and studying the wetlands is important. To judge the benefits of a wetland against an asset that is to replace or influence it, a cost-benefit analysis is best suited. To assign a monetary value to the services a wetland offers (e.g. fish breeding, flood retention, construction materials and others), a detailed case-by-case understanding is anyhow necessary to derive a thorough understanding of the individual situation. Hints regarding the improvement of understanding wetland functions are given in Volume 2 to this report: The Wetlands of the Nile: Inventory Manual.

4. Updates of Wetland Inventory

Issues and constraints regarding the updating of the wetland inventory have been briefly described regarding their overall approach in the previous chapters. The wetland maps that have been generated with the Wetland Inventory and Mapping Project provide an overall information dataset about the current locations and state of the Nile Basin wetlands from both a physical and biodiversity point of view. The approach has generated a regional scale overview and has evaluated top level information for the wetlands, resulting in an extensive database.

Two issues have to be considered when working with this database, both on a short term as well as on a long term basis. Being a basin wide product and based on a remote sensing approach the generated data is firstly comparably rough when looking at it in detail. Secondly, it shows the wetland situation based on satellite images between the years 1994 and 1990 and collected attribute information that can be assigned to different years depending on the different sources. The information normalized based on feedback from different information sources leading to a baseline product that provides a good general overview but for which details should be carefully investigated. These two issues, as described in the following sections, will need to be tackled in order to update the database both concerning its accuracy and update status including the ability to monitor changes over time.

4.1 IMPROVEMENT OF DATABASE

Considering the nature of the assignment under which the wetland database was developed, there is an improvement potential for wetland details of the individual wetlands with regards to their individual spatial extent as well as regarding specific attribute information. Wetlands as well may show gradients over distance or just general features that in the current study have not been captured due to scale issues. For updating the wetland database with regards to detail and accuracy, the management in a central location as well as the widespread dissemination to potential user groups and their information about the database utilization potential is essential. The database needs to be seen as a dynamic tool from which users and stakeholders can draw information but also as a platform to which users can feed back information in order to update and add detail. The database could be marketed as a free of charge and easy to use GIS tools for small scale users who in this way could utilize the benefits of the tool as a remote database.

The following steps are recommended for general accuracy updating of the wetland database:

- setup of the GIS database in a central location with defined use and access rules
- widespread distribution of the wetland inventory and information about its structure and utilization possibilities
- invitation to target stakeholders and potential user groups to use and help build the database
- schedule for continuous maintenance of the database to work in user feedback and data provided through surveys and local knowledge of these user groups

In addition to the described participatory updating of the database, structured campaigns could be launched to specifically improve the database for specific locations for which shortcomings or needs have been identified.

In addition to the centralized setup of the database, distribution to regional centres could be considered. Such distribution should be specific to each region (e.g. the regional Lake Victoria centre should only hold the Lake Victoria file subset) to allow easy synchronization with the master database. This setup would allow easier access for local users and promote regional ownership of the product leading to a potentially better acceptance, utilization and maintenance input of the individual involved groups.

More specific to Ethiopia, mapping would need to be conducted by a national mapping agency. The Central Statistic Agency (CSA) in collaboration with FAO is currently conducting a mapping exercise similar to what Africover has previously achieved; however, recent SPOT 5 images are being used for the land cover/land use mapping exercise. Spot 5 imageries are procured by the Government of Ethiopia. The maps will be used to increase the efficiency of agriculture survey and will also be the basis for estimating the maximum extent of cultivation by agricultural land type. It will provide layers of information that will assist CSA in the appropriate allocation of its sample survey and provide input to the development of a suitable assessment methodology. Agricultural strata will be related to land cover parameters which is one of the most useful and important sources of information required by decision makers and technicians involved in rural and urban development.

4.2 PERIODICAL UPDATE OF DATABASE

Second to the improvements in accuracy and in order to monitor trends and changing patterns, the wetland inventory should be periodically updated. The updates should be kept in separate layers allowing the detection of changes to the wetlands over time. Considering that not all information will be collected at comparable time intervals for the individual regions but through occasional updates by users, time windows like e.g. yearly intervals should be used for grouping information. In general the following issues should be taken into consideration:

- like-like comparison focusing on dry season images
- careful consideration of class definition
- collection of wetland attributes in line with the wetland extent

Considering the expected timeframes for changes it is advisable to carry out organized general updating exercises in 10 year intervals. For areas where changes may be introduced through strong drivers, updates tailored to the circumstances may be appropriate.

For long-term monitoring of wetlands, there is still a need to obtain baseline data. This is particularly true for Ethiopia as the method used for this project was struggling with details for the Ethiopian landscape. For monitoring and change detection, MODIS or MERIS may be a viable alternative, which could be followed by more detailed mapping of hotspots change. For that an understanding of seasonal and inter-annual variations need to be developed. This can be provided in part using some of the MODIS products.

4.3 GIS CAPABILITIES WITHIN THE NILE BASIN COUNTRIES

GIS capability within the Nile Basin countries was determined during the inception phase of the project. Knowledge about these capabilities was required to underpin responsibilities for future monitoring of wetland trends and future updating of the wetland inventory in the Nile Basin. The information was collected in the form of questionnaires which were evaluated and listed in Table 10.

The capability levels have been divided into the following categories:

1. Level 1 means establishment has started to build its GIS capabilities with no or low involvement in GIS or Remote Sensing (RS) projects.
2. Level 2 means establishment started to build its GIS capabilities with some low involvement in GIS or Remote Sensing (RS) projects
3. Level 3 means establishment has extensive GIS capabilities with great experience in GIS or Remote Sensing (RS) projects.

Table 10 List of GIS institutions within the Nile Basin countries

Country	Institution	Capability	Resources
Burundi	Geographical Information Centre	Level 1	Staff and software
	National Geographical Institute	Level 2	Staff, equipment, and software
DR Congo	Directorate of Forestry Inventory (in Ministry of Environment, Nature Conservation and Tourism)	Level 3	Staff, equipment, software and data
	National Geographic Institute (in Ministry of Scientific Resources)	Level 2	Staff, equipment, and software
	Agence Nationale de Météorologie et de Télédétection par Satellite (METELSAT)	Level 2	Staff, equipment, and software
Egypt	Ministry of environment	Level 3	Staff, equipment, software and data
	National Centre for Land Use	Level 2	Staff, equipment, and software
	The Egyptian Cabinet -Information and Decision Support	Level 3	Staff, equipment, software and data
	Ministry for Water Resources and Irrigation	Level 3	Staff, equipment, software and data
	Hydraulic Research Institute	Level 3	Staff, equipment, software and data
	Cairo and Ain Shams University	Level 3	Staff, equipment, software and data
Ethiopia	Central Statistical Agency (CSA)	Level 3	Staff, equipment, software and data
	Ethiopian Mapping Authority (EMA)	Level 3	Staff, equipment, software and data
	Environmental Protection Authority	Level 1	Policy issues, inventory, Ramsar
	Dept. of Earth Sciences, Addis Ababa University	Level 3	Staff, equipment, software and data

Country	Institution	Capability	Resources
	Dept. of Geography, Addis Ababa University	Level 3	Staff, equipment, software and data
	Ministry of Agriculture and Rural Development	Level 2	Data collection, studies, mapping
	Ethiopian Wildlife Conservation Org.	Level 2	Data collection, studies, mapping
	Ethiopian Wildlife and Natural History Society	Level 1	Focus on IBAs, wetland studies
	Ethiopian Wetlands Research Programme (EWRP)	Level 3	Detailed mapping, evaluation, dissemination
	Ethio-Wetland and Natural Resources Association (EWNRA)	Level 1	Information dissemination, capacity building
	Environmental Protection and Land Use Authority of Amhara Regional State (EPLUA)	Level 3	Staff, equipment, software and data
	FAO – Support to Food Security Information System	Level 3	Staff, equipment, software and data
Kenya	United Nations Joint Logistics Centre (UNJLC)	Level 3	Staff, software and data
	Ministry for Environment and Mineral Resources	Level 3	Staff, software, data, equipment
	Regional Centre for Mapping of Resources for Development (RCMRD)	Level 3	Staff, equipment and general data
	Global Land Cover Network	Level 3	Extensive database
	Lake Victoria Basin Commission	Level 2	Reports and access to data
	Lake Victoria Environmental Management Project (LVEMP)	Level 2	Reports and access to data
	International Centre for Research in Agroforestry (ICRAF)	Level 2	Hold some relevant data
	International Livestock Research Institute	Level 3	Staff, equipment, software and data
	United Nations Environment Program	Level 3	Staff, equipment, software and data
	Kenyan Wildlife Service	Level 2	Staff, equipment, software and data
Rwanda	Geographic Information Systems and Remote Sensing Regional Outreach Centre	Level 3	Staff, equipment, software and data
	Rwanda Environmental Management Authority (REMA)	Level 2	Staff, equipment, software
	Geographic Information Systems & Remote Sensing Research & Training Centre of the National University of Rwanda (CGIS-NUR)	Level 2	Staff, equipment, software and data
Sudan	University of Khartoum – Geography department	Level 2	Staff, software and basic data
	Remote Sensing Authority / National Research Centre	Level 3	Staff, software, equipment and data
	Ministry of irrigation and water resources	Level 1	Staff and software

Country	Institution	Capability	Resources
	Geological Department, Ministry of Energy and Mining	Level 2	Reports, equipment, data
	Survey Department, Ministry of Environment and Physical Development	Level 1	Staff, Equipment, Data
	National Forestry Corporation / Ministry of Agriculture and Forestry	Level 2	Reports, equipment, data
	Meteorological Unit of Juba Air Port	Level 1	Staff, software and basic data
	University of Juba	Level 1	Staff, software and basic data
	Office for the Coordination of the Humanitarian Affairs (OCHA)	Level 2	Staff , software and data
	Southern Sudan Wildlife Society	Level 2	Staff , software and data
	NBI	Level 1	Staff, software and basic data
Tanzania	Institute for Resource Assessment, University of Dar es Salaam	Level 3	Staff, equipment, software and data
	Sokoine University of Agriculture	Level 3	Staff, equipment, software and data
	Tanzania Natural Resources Information Centre (TANRIC)	Level 3	Staff, equipment, software and data
	National Environment Management Council (NEMC)	Level 2	Staff , software and data
	Tanzania National Parks (TANAPA)	Level 3	Staff, equipment, software and data
Uganda	NBI	Level 1	Have access to data through their members
	Wetlands Management Department	Level 2	Staff, equipment, software and data
	Makerere University	Level 2	Staff, equipment, software and data
	National Forest Authority	Level 3	Staff, equipment, software and data
	National Environmental Management Authority	Level 2	Staff, equipment, and software
	Bureau of Statistics	Level 2	Staff, equipment
	Directorate of Water Resources	Level 2	Staff, equipment, and software
	National Forest Authority	Level 3	Staff, equipment, and software
	Department of Geology and Surveys	Level 2	Staff, equipment, and software

Other identified international / regional institutions dealing with GIS / RS

- World Agro-forestry Centre, Nairobi, Kenya
- International Water Management Institute – Nile Basin and Eastern Africa Office, Addis Ababa, Ethiopia
- FAO Nile, Entebbe, Uganda
- Africover, Nairobi, Kenya

5. *Current Wetland Status and Trends*

The status and biodiversity of selected major wetlands of importance in the Nile Basin has been assessed and described based on literature resources as well as reports and narrative information from involved stakeholders. The wetlands are described in the sections below while most information has been stored in a geodatabase linking the wetland maps with their attributes including physical parameters, biodiversity information, transboundary issues, hotspots, threats, management challenges, monitoring strategies and recommendations. It is recommended to read the below descriptions and utilize the information contained in the geo-database in line with the RAMSAR guidelines (see web sites in Table 1).

With the scale of the Nile Basin, transboundary issues are of special concern and need to be tackled. Certain transboundary management and monitoring strategies have previously been in place. With regards to a wetland transboundary strategy, further details would need to be added and the efforts to be synchronized between the different countries. While a Nile Basin wide approach would be optimal, a first step focus could be on the coverage of certain important transboundary wetlands. It is important to understand that not the physical wetland boundaries are what need to be considered but that wetlands may be transboundary in nature through upstream influences related to hydrological, hydrodynamic and water quality aspects.

Examples regarding wetland management plans and related issues can be found at: http://www.ramsar.org/wurc/wurc_library.htm#nwps

Country specific descriptions of selected RAMSAR wetlands in the different Nile riparian countries are specifically listed and described on the RAMSAR website http://www.ramsar.org/profile/profile_index.htm. More detailed information has been included in the Annex 2 (extracts from Hughes et al., 1992, A Directory of Africa Wetlands).

5.1 IDENTIFIED WETLANDS

Table 11 provides a list of the major wetlands that have been identified and selected as of importance in the Nile Basin based on discussions with workshop group members. Further unnamed wetlands exist that could be captured during an updating exercises.

Table 11 List of major wetlands in the Nile Basin

Country	Name	River \ Lake	Town (near)
Burundi	Lake Tshohoha South	Akanyaru River	Bujumbura, Gitega
	Lake Katshamirinda	Akanyaru River	Muhinga, Kitega
	Lake Rhwihinda	Akanyaru River	Muhinga, Kitega
	Lake Rugwero	Nyawarungu River	Bujumbura, Muyinga
	Lake Kanzigiri	Lake Rugwero	Muhinga, Kitega
	Luvironza / Kayongozi / Ruvuvu System	Luvironza / Kayongozi / Ruvuvu System	Muyinga
	Akanyaru River	Akanyaru River	Muyinga
DRC	Lake Albert Swamps	Lake Albert	Bunia
	Lake Edward	Kazinga Channel	Lubero
	Semliki River	Semliki River	Bunia

Country	Name	River \ Lake	Town (near)
Egypt	Lake Manzala	Nile	Alexandria
	Lake Nasser	Nile	Aswan
	The Delta Proper	Nile	Alexandria
	Lake Maryut	Nile	Alexandria
	Lake Idku	Nile	Alexandria
	Lake Burullus	Nile Delta	Kafr El Sheikh
	Lake Bardawil	Nile Delta	Port Said
Ethiopia	Lake Tana	Lake Tana	Amhara Region
	Fogera floodplain marsh and swamps	Gumera River, Lake Tana Eastern shore	Fogera Woreda, South Gondar
	Dembia floodplain marsh and swamps	Dembia River, L Tana, northern valley	Dembia Woreda, North Gondar
	Bahir Dar Zuria marsh and swamps	Lake Tana, southern valley	Bahir Dar Woreda, West Gojam
	Dangela floodplain marsh and swamps	Kilti River, (L. Tana' s tributary)	Awi Zone, Dangela Wereda
	Gambela marsh and swamps	Baro, Akobo, Alwero and Gilo Rivers	Gambela Region
	Fincha'a-Chomen Lake marsh	Fincha'a–Chomen Reservoir	Fincha'a, Shambu, E Wellega
	Dabus River marsh and swamps	Dabus River floodplain	Nejo, W. Wellega, Oromiya Region
	Illubabor marsh and swamps	Valley bottom along numerous highland small streams	Illubabor Zone, Oromiya Region
	Abay and Beles River floodplains	Abay and Beles River (lower)	Benishangul-Gumuz Region,
Kenya	Winam Gulf swamps	Lake Victoria	Kisumu
	Lake Victoria East Shore	Lake Victoria	Kisumu
Rwanda	Upper Kagera lakes and swamps	Kagera River	Kigali, Kibungu
	Kamiranzovu Swamp	Lukarara River	Cangugu, Butare
	Lake Mohasi	Nyabugogo River	Kigali, Kibungu
	Rugezi Swamp	Hondo River	Biumba, Ruhengeri
	Mugesera Rugwero Swamp Complex	Nyawarungu River	Kigali, Kibungu
Sudan	Kenamuke/Kobowen Swamp	Kangen River, Sobat River	Juba
	Lotilla Swamps	Lotilla River	Pibor
	Badigeru Swamp	Kinyeti River	Juba, Bor
	Veveno/Adiet/Lilebook Swamps	Lotilla River	Bor, Pibor Post
	Nile Valley below Malakal	White Nile	Malakal
	Lake Ambadi	Bahr el Ghazal	Rumbek
	Lake Yirol	Yei River	Yirol, Shambe
	Lake Anyi	Yei River	Shambe
	Lake Nyiropo	Lau River	Shambe
	Lake Nubia/Nasser	Nile	Dongola
	El Roseires	Blue Nile	El Roseires

Country	Name	River \ Lake	Town (near)
	Sennar	Blue Nile	Sennar
	Kashm el Girba	Atbara	Kassala
	Bahr el Ghazal swamps	Bahr el Ghazal	Wau
	Machar marshes	Sobat River	Daga Post, Malakal
	Dinder Floodplains	Dinder River	Dinder Town
	Sudd swamp	Bahr el Jebel	Bor
	Gebel Aulia	White Nile	Khartoum
Tanzania	Kagera swamps	Kagera River	Mwanza
	Lake Vic. south shore swamps	Lake Victoria	Mwanza, Kagera
	Mara wetlands	Mara River	Mara
Uganda	Kafu System	Kafu River	Masindi
	Lake Wamala	Kibimba River	Kampala
	Lakes Bisina & Opeta	Lake Kyoga	Junja
	Kijanebalola Lake	Ruizi River	Mbarara
	Bunyoni Lake	Kabirita River	Mbarara
	Lake Albert	Albert Nile	Masindi, Hoima
	Lake Edward	Kazinga Channel	Fort Portal
	Lake Vic. north shore swamps	Lake Victoria	Entebbe, Jinja, Kampala, Masaka
	Lake Kyoga Kwani swamps	Lake Kyoga	Lira, Soroti, Mbale, Nakasongola
	Lake George swamps	Lake George	Kasese
	Albert Nile swamp	Albert Nile	Arua

5.2 SELECTED WETLANDS AND INDICATION OF THEIR BIODIVERSITY

This section focuses on ecological aspects, impacts and biodiversity trends with regards to the mapped wetlands based on historically available literature. Based on studies of these literature resources, the historical status as well as the development and derived actual and potential threats for the ecological balances have been assessed and described in line with identifying key animal and plant species for the individual exemplary wetlands, judging their resilience or fragility to changes in the wetlands. The following wetlands were included in the assessment; an overview about their characteristics is given in Table 12, the wetlands are shown in Figure 17.

1. Sio Malaba Malakisi
2. Mara Wetlands
3. Sudd Swamps
4. Nile Delta
5. Sobat–Machar/Gambela Marches
6. Ghazal Swamps
7. Kyoga Swamps
8. Albert Nile Swamps
9. Winam Gulf (Kisumu Bay)
10. Kagera Swamps
11. Lake Tana Wetlands Complex

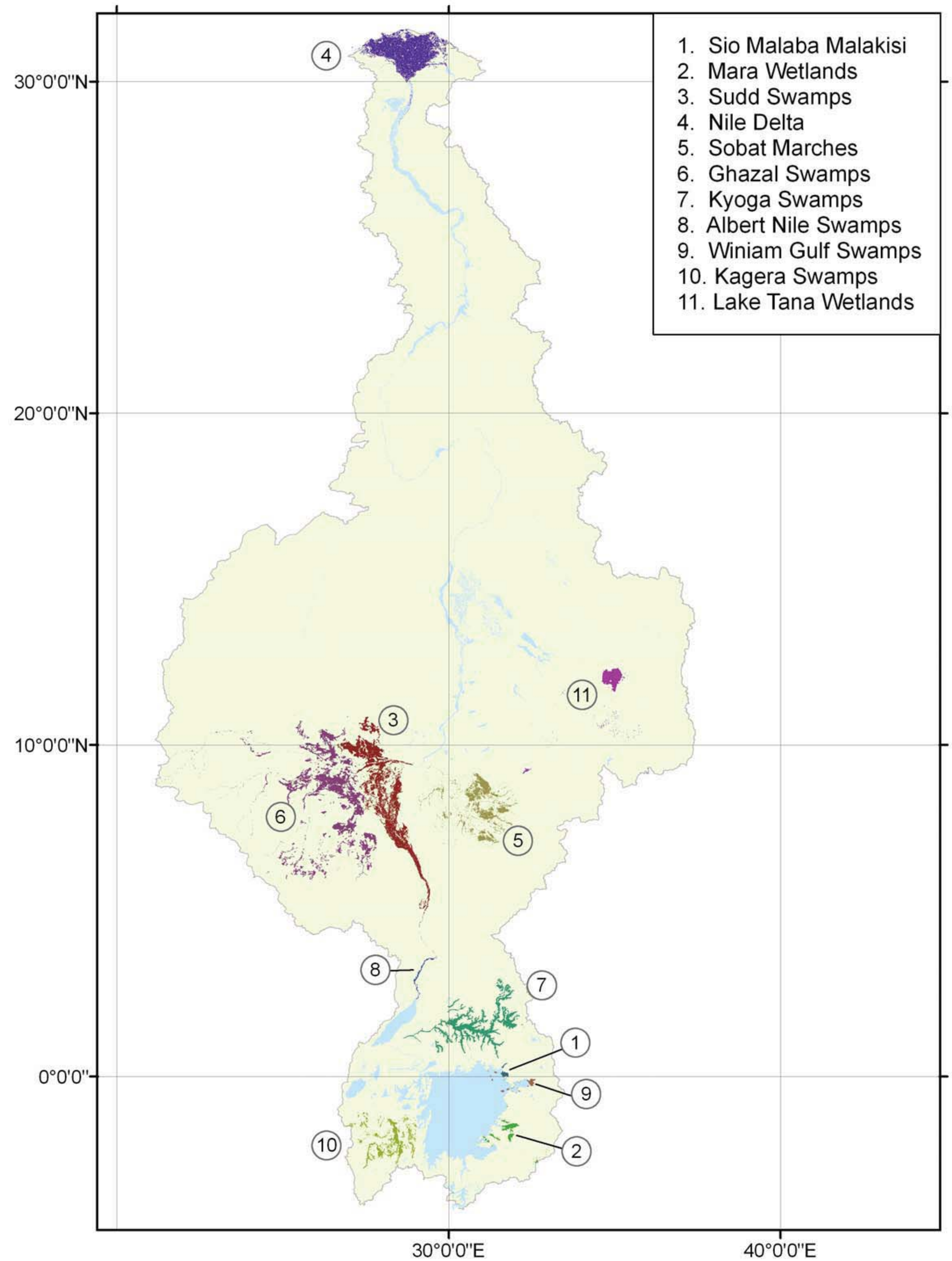

Figure 17 Selected wetlands within the Nile Basin

Table 12 Characterisation of selected wetlands

BioArealD'	Wetland	Coordinates	Ramsar Class (see table below)	Plant	Fish	Mammal	Reptile / Amphib	Bird	Invertebrate
1	Sio Malaba Malakisi	0°3' N/34°5'E	M, N, Tp, Ts	-	-	-	Nile Crocodile	-	-
2	Mara wetlands	1°49'S/34°14'E	M, N, Tp, Ts	Brachystegia, Isoberlinia and Julbernardia spp, often associated with Pterocarpus angolensis, Acacia-Comnziphora, Baphia massaiensis and Bussea massaiensis	Brachystegia, Isoberlinia and Julbernardia spp, often associated with Pterocarpus angolensis, Acacia-Comnziphora, Baphia massaiensis and Bussea massaiensis	-	Crocodile	Abundant Avifauna	Molluscs
3	Sudd Swamps	4°55'-9°37'N/29°59'-31°57'E	L, M, N, O, Tp, Ts	Cyperus papyrus, Phragnzites karka and Vossia cuspidata, Typha dontingensis, Eichhornia crassipes, Pistia stratiotes, Ceratophyllunz demersunz, Najas pectinata, Nymphaea lotus, Ottelia spp., Potamogeton spp., Trapa natans, Vallisneria spiralis, Oryza longistaminata, Echinochloa pyramidalis, Vossia cuspidata	Alestes dentex, Auchenoglanis biscutatus, Chelaethiops bibie, Citharinus citharus, Distichodus rostratus, Eutropius niloticus, Heterotis niloticus, Hydrocynus forskalii, Labeo niloticus, Lates niloticus, Micralestes acutidens, Mormyrus cashive, Oreochromis niloticus and Synodontis frontosus. Aplocheilichthys spp., Clarias spp., Epiplatys spp., Gymnarchus niloticus, Heterotis niloticus and Polypterus bichir	Alcelaphus buselaphus, Damaliscus korrigunz, D. lunatus, Hippopotamus amphibius, Hippotragus equinus, Kobus ellipsiprymnus, K megaceros, Loxodonta africana, Panthera pardus, Redunca redunca and Syncerus caffer.	Crocodylus niloticus, snakes, frogs	Alseonax aquatica, Balaeniceps rex, Necrosyrtes monachus, weavers, warblers, flycatchers, kingfishers, ducks, herons, ibises, egrets, storks, kites, crows and vultures	-
4	Nile Delta	30°07 '-31°36'N/29°53 ' - 32°31'E	F, M, N, O, Tp, Ts, 1	Phragmites australis, Typha capensis and Juncus tnaritimus	Anguilla spp., Mugil cephalus and Solea vulgaris	Lutra lutra and Vulpes vulpes, hippopotamus	Frogs, turtles, tortoises, Nile Crocodile	World's largest concentrations of little gulls and whiskered terns. Other birds making their homes in the delta include grey herons, Kentish Plovers, shovelers and cormorants. Also found are egrets and ibises.	-
5	Baro-Akobo-Sobat	8°27 ' -9°58'N/32°11' - 34°09'E	M, N, Tp, Ts	grassy floodplains and permanent herb swamps dominated either by papyrus along the innumerable watercourses, or by Phragmites and Typha away from them	The Baro-Akobo basin is apparently particularly rich in fish diversity (Golubtsov et al. 1995). The fauna is Nilo-Sudanic and is dominated by *Alestes, Bagrus, Barilius, Citharinus, Hydrocynus, Hyperopisus, Labeo, Malapterurus*, and *Mormyrus* genera.	Alcelaphus buselaphus, Damaliscus korrigunz, D. lunatus, Hippopotamus amphibius, Hippotragus equinus, Kobus ellipsiprymnus, K megaceros, Loxodonta africana, Panthera pardus, Redunca redunca and Syncerus caffer.	Crocodile	Abundant avifauna	-
6	Bahr el Ghazal	8°26'N/29°16'E	M, N, O, Tp, Ts	Cyperus papyrus, Phragnzites karka and Vossia cuspidata, Typha dontingensis, Eichhornia crassipes, Pistia stratiotes, Ceratophyllunz demersunz, Najas pectinata, Nymphaea lotus, Ottelia spp., Potamogeton spp., Trapa natans, Vallisneria spiralis, Oryza longistaminata, Echinochloa pyramidalis, Vossia cuspidata	Alestes dentex, Auchenoglanis biscutatus, Chelaethiops bibie, Citharinus citharus, Distichodus rostratus, Eutropius niloticus, Heterotis niloticus, Hydrocynus forskalii, Labeo niloticus, Lates niloticus, Micralestes acutidens, Mormyrus cashive, Oreochromis niloticus and Synodontis frontosus. Aplocheilichthys spp., Clarias spp., Epiplatys spp., Gymnarchus niloticus, Heterotis niloticus and Polypterus bichir. Nemacheilus abyssinicus is an endemic species found in the Baro-Akobo drainage basin	Alcelaphus buselaphus, Damaliscus korrigunz, D. lunatus, Hippopotamus amphibius, Hippotragus equinus, Kobus ellipsiprymnus, K megaceros, Loxodonta africana, Panthera pardus, Redunca redunca and Syncerus caffer.	Crocodylus niloticus, snakes, frogs	Alseonax aquatica, Balaeniceps rex, Necrosyrtes monachus, weavers, warblers, flycatchers, kingfishers, ducks, herons, ibises, egrets, storks, kites, crows and vultures	-
7	Kyoga swamps	0°33 ' -1°56'N/32°18 ' - 34°00 'E	L, O	Cyperus papyrus,	Fish fauna is nilotic: Oreochromis variabilis, Oreochromis esculentus, 0. leucostictus,0. niloticus and Tilapia zillii, Lates niloticus	Aonyx capensis, Atilax paludinosus, Hippopotamus amphibius and Lutra maculicollis, Tragelaphus spekei.	Crocodylus niloticus	Abundant avifauna	-

BioAreaID'	Wetland	Coordinates	Ramsar Class (see table below)	Plant	Fish	Mammal	Reptile / Amphib	Bird	Invertebrate
8	Albert Nile Swamps	1°01 ' -2°20 'N/30°23 ' -31°26 'E	L, O	Potamogeton schweinfurthii, P. pectinatus, Najas marina and Vallisneria aethiopica, Cyperus papyrus, Phragmites mauritianus, Vossia cuspidata, Cyclosorus striatus, Lemna paucicosta-Pistia stratiotes-Azolla nilotica association, Nymphaea calliandra, Najas marina, Nymphaea lotus, Vallisneria aethiopica, Ceratophyllum demersum, Utricularia thoningii, Nitzschia, Stephanotis, Anabaena sp.,	Lates niloticus, Bagrus, Heterobranchus, Lates, Alestes baremose, Citharinus citharus, Lates niloticus, Oreochromis niloticus, Lates microphthalmus, Hydrocynus vittatusm, H. forskalii,	Atilax paludinosus, Hippopotamus amphibius, Kobus ellipsiprymnus, K. kob, Loxodonta africana, Lutra maculicollis, Phacochoerus aethiopicus and Syncerus caffer.	Crocodylus niloticus	Buteo buteo, Chlidonias leucoptera, Ciconia ciconia, Crex crex, Cuculus canorus, Gallinago media, Gelochelidon nilotica, Lanius collurio, L. minor, Lynznocryptes minimus, Merops apiaster, Muscicapa striata, Pernis aprivorus, Phylloscopus trochilus, Porzana porzana, Riparia riparia, Tringa glareola and T. ochropus.	-
9	Winiam Gulf (Kisumu bay)	0°12'S/34°49'E	O	Cyperus papyrus, Ceratophyllum denzersunz and Potamogeton spp., waterlilies and Pistia stratiotes, Miscanthidium violaceum, Phragmites mauritanius, and Typha domingensis	Lates albertianus, Oreochromis leucosticta, 0. niloticus and Tilapia zillii, Barbus altianalis, Labeo victorianus, Mormyrus kannume, Oreochronzis esculentus and Schilbe mystus	Rodents, otters and Hippopotamus amphibius.	Water turtles, aquatic snakes, monitor lizards, Nile crocodile (Crocodylus niloticus), frogs	papyrus yellow warbler (*Chloropeta gracilirostris*), white-winged warbler (*Xenoligea montana*), papyrus gonolek (*Laniarius mufumbiri*), shoebill (*Balaeniceps rex*), Carruther's cisticola (*Cisticola carruthersi*), great egret (*Ardea alba*), Baillon's crake (*Porzana pusilla*), *Chlidonias leucopterus*, *Egretta garzetta*, *Phalacrocorax africanus*, *P. carbo*, *Larus cirrocephalus*	freshwater molluscs,
10	Kagera swamps	1°19'-2°1 1 'S/30°33'-31°01'E	M, N, Tp, Ts	Dryopteris gongylodes, Cyperus papyrus, Ipomoea fragrans, Polygonum spp., Echinochloa cruspavonis, Hydrocotyle ranunculoides, Leersia hexandra, Utricularia inflexa and Vossia cuspidata, Miscanthidium violaceum, Phoenix reclinata, Aeschynomene elaphroxylon, Dissotis incana, Ficus verruculosa, Myrica kandtiana, Lenzna paucicosta, Ludwigia stolonifera, Nynzphaea caerulea, N. nouchalii, Pistia stratiotes and Trapa natans, Ceratophyllum denzersunz, Myriophyllunz spicatum, Potantogeton pectinatus, Utricularia spp., and Vallisneria spiralis.	Labeo spp., Clarias spp., Bagrus spp., and Barbus spp.	Hippopotamus amphibius, Hippotragus equinus, Kobus ellipsipryinnus, Loxodonta africana, Panthera pardus, Phacochoerus aethiopicus, Redunca arundinum, Sylvicapra grimnzia, Syncerus caffer and Tragelaphus spekei, otters and rodents	Amphibians, crocodiles and water turtles are abundant, monitors, snakes,	Hippolais icterina, Hirundo rustica, Motacilla flava, Phylloscopus trochilus, Riparia riparia and Sylvia borin.	-
11	Lake Tana Wetlands Complex	11°35'-12°18'N/37°01'-37°35'E	O	Cyperus papyrus, with Echinochloa pyramidalis, E. stagnina, Polygonum barbatum, P. senegalense and Typha doiningensis. Floating leaved aquatics include Nymphaea caerulea, N. lotus and Pistia stratiotes, while the most important submerged species are Ceratophyllum demersunt and Vallisneria spiralis.	14 species of Barbus (of which B. affinis and B. intermedius are the most numerous), Discognathus quadriinaculatus and Varicorhinus beso. There are three clariids, Clarias anguillaris, C. mossanzbicus and the endemic C. tsanensis. Oreochromis niloticus is the only cichlid.	Otters, Rodents	-	Alopochen aegyptiaca, Bubulcus ibis, Egretta internzedia, Larus ichthyaetus, Plectropterus gambensis, Sarkidiornis melanota and Threskiornis aethiopica	Rich aquatic mollusc fauna

The following section provides a summary description of each of the selected wetland.

5.2.1 *Sio Malaba Malakisi*

The Sio-Malaba-Malakisi River Basin is located at the border between Kenya and Uganda. The Sio River originates at Mt. Elgon, flows along the Kenya-Uganda border, and finally discharges into Lake Victoria. The Sio catchment area is 1,334 Km^2. Catchment elevation is highest at the summit of Mt. Elgon (4,320 m) and lowest at the Sio River mouth (1134 meters; Lake Victoria). Mt. Elgon is also the source of the Malaba River which discharges into Lake Kyoga at the Mpologoma wetlands (950 meters). The Malaba catchment has an area of 1,750 Km^2.

Permanent water courses have cut steep-sided valleys that radiate from the caldera of Mt. Elgon. Afro-alpine heath and moorland occupy a small area around Mt. Elgon. Beyond the moorland, the area in the immediate vicinity of the mountain comprises national parks (in both Uganda and Kenya), several forest reserves, and the Chepkitale national reserve in Kenya (17,200 ha). However, large areas of forest cover surrounding the mountain in both countries have been lost to human settlements over the past 50 years, and the southern forest edge of Mt Elgon has been receding. Woodlands of different types occur in the areas forests have receded. These are interspersed with large tracts of small-scale farmland and grasslands. The low lying areas are dominated by large expanses of wetlands (WREM, 2008b)

The basin is used agriculturally with areas expanding at an alarming rate and suffers from environmental degradation, expanding settlements and deforestation. The development of sustainable development and management strategies is therefore important. The transboundary nature of the catchment increases the problems. Respective studies have been launched with e.g. the 2006 Sio-Malaba-Malakisi Transboundary Integrated Water Resources Management and Development project shared by Kenya and Uganda focusing on promoting development and reducing conflicts between communities using water resources of the basin.

Comparing descriptions given by historical maps and literature sources, the catchment is degrading with regards to its natural resources with the expanding population converting more and more land into urbanized or agricultural land. These changes make the basin vulnerable for hydro meteorological changes in the catchment including slope degradation, erosion, increased runoff and loss of flood retention potential as well as respective deterioration of water quality.

Following studies of WREM (2008b), the Sio-Malaba-Malakisi area boasts a dynamic ecosystem which is rich in fauna and flora. This abundance of species inhabits a highly diverse ecosystem and natural protected areas. In the upper catchment, the natural vegetation types include alpine moorland, bamboo forest, mountain forests, lowland forests and wooded grasslands. Mt. Elgon is part of the Eastern African High-Altitude Biodiversity Hotspot, and it contains a number of endemic, endangered and threatened fauna and flora.

On the Kenyan part of the Lake Victoria basin, the main wetlands occur in river mouths including the Yala, Nyando, Sondu Miriu, Oluch Kimira (Mogusi), Nzoia and Gucha Rivers. Wetlands also occur in the middle reaches of the Sio-Malaba-Malakisi rivers. However, wetlands near dams and rivers are threatened by drainage and siltation. The most prominent wetlands in Bungoma are Namilimo, Sibembe, Kayaya, Chebosi, Matulo, Ngwelo, Nang'eni, Khamoto, Bituyu, Tuti, Sio, Bukananachi, Wekelekha, Syoya, Lumboka, Lunao, Walatsi, Lidabo, Machusele, Bunambombu, Masusi, Masuno, Nabuto, Sikendaloba, Sichei A, Sichei B, Lurembe and Namiama. In Uganda, wetlands are estimated to cover about 13% of the total surface area including swamp (8,392 sq. km), swamp forest (365 sq. km) and zones with impeded drainage (20,392 sq. km).

Wetlands are classified depending on hydrological characteristics, soil, and vegetation types. In some cases, wetlands are classified using criteria for their ecological functions and their human value for products and services. In this study, wetland classification has been simplified to include aspects of the Ramsar Convention nomenclature. In Lakes Victoria and Kyoga, wetlands have been characterized according to their major vegetation types as follows:

- Papyrus (*Cyperus papyrus*) wetlands are found in association with *Phragmites*, *Typha*, *Ipomoea, Cyphostema,* and *Vossia* in the background and ferns *Polygonum* and *Cynodon)*
- *Phragmites mauritanius* wetlands are frequently on higher ground and in found in association with *Cyperus* and *Melanthera*
- *Vossia cuspidata* wetlands are seen with *Cyperus* in the background
- *Typha domingensis* wetlands are found with *Cyperus* and often in association with *Phragmites*l
- *Sesbania sesban/micrantha* wetlands are found in association with *Ambatch (Aeschynomene)* and *Kotschya Africana*
- *Eichhornia crassipes,* wetlands are found with water hyacinth in sheltered bays and often in association with *Cyperus, Typha and Vossia*
- *Lacustrine Papyrus/Vossia/Miscanthus or Phragmites* wetlands.

These wetlands have mixed nonligneous vegetation with *Cyperus, Vossia, Miscanthus,* or *Phragmites* in areas with perennially fluctuating water levels. The water in these wetlands is often covered with floating but anchored aquatic plants like *Nymphaea* and *Pistia* (water cabbage).

Wetlands have also been categorized into two broad categories, namely those associated with lakes (lacustrine) and those that are found along rivers (riverine).

Lacustrine Wetland around the Sio River Mouth

The wetlands surrounding the Sio River mouth are fringed by extensive wetland plants and are permanently flooded. The most common and dominant vegetation types include emergent *Cyperus papyrus, Phragmites muritianus, Vossia cuspidata and Sesbania sesban.* In the open waters, plants especially water hyacinth and the water lilies (*Nymphea sp)* occur in the shallow inshore zone (less than 4 meters deep) and along the river channel. The water hyacinth gets blown to the shore and covers the river mouth depending on the prevailing wind systems. When this occurs, the water hyacinth obliterates passage ways for boats and makes fishing hazardous. The wetland at the Sio River mouth has a rich biodiversity of fish. In this area fish feed, breed and shelter from predators. The most common fishes found here are *Clarias spp,* Nile tilapia, Nile perch, *Brycinus sp, Barbus spp, Labo victorianus,* mormyrids and Haplochromines. Fauna of this lacustrine wetland include monkeys, Sitatunga, hippopotamus, monitor lizards, birds including egrets, cormorants, kingfisher, fish eagle, cuckoo, weaver birds, and tern.

Floodplains in the Sio, Malaba, Manafwa and Mpologoma Rivers

The Sio River empties into Lake Victoria through a large riverine floodplain area. The river system is associated with an extensive temporary floodplain that extends upstream about 30 km and ranges between 5 km wide near the mouth to half a kilometre wide upstream near the Busia-Kisumu Road Bridge. The Malaba River wetland originates close to the Kenya-Uganda border post at Malaba Town. This wetland stretches down to the Jinja-Tororo road in the Butaleja and Bugiri districts before it empties into the Mpologoma River (Pallisa district) and finally Lake Kyoga in eastern Uganda. The dominant vegetation in the seasonal floodplain wetlands includes sedges, reeds, natural grasslands, bush and shrubs. Other common natural vegetation include *Laudetia, Marantocloa, Echinocloa, Afromomum, Typha, Miscanthus, Acasia spp, Albizia, Acassia, Euphorbia* and *Carica edulis, Hyperrhenia,* ferns, sedges and *Lantana camara* in disturbed areas. The seasonal wetlands have grasslands that provide good fodder for game and livestock. Converted zones on the wetland fringes consist of farmland for sugar cane, maize, potatoes, cabbages, tomatoes, yams, and rice are grown and livestock.

Wetland Reclamation for Agriculture

In the Sio Malaba Malakisi Uganda districts, many wetlands have been converted into agricultural use, particularly for rice growing. Conversion of wetlands to agriculture is between 16% to 32%. For Kenya, there are no details on wetlands conversion to agricultural land.

Regulation Policies for Wetlands Management

Wetlands regulations in Uganda include the Wetlands Policy of 1995, the Wetlands Regulations of 1995 and the National Environment (Wetlands, River Banks and Lake Shores Management) Regulations, No. 3/2000. In Kenya, similar regulations are being formulated but are not yet in place. The policy and regulations in Uganda provide for conservation and ensure: the sustainable use of wetlands for ecological and tourist purposes; wetlands fauna and flora habitat protection; regulated public use; and research activities. The policy and regulations operate on the following principles:

- Wetlands resource use in a sustainable manner compatible with the continued presence of wetlands and their hydrological functions and service
- Environmental impact assessment under the statute is mandatory for all wetlands activities with potential adverse impacts
- Special measures for protecting wetlands: international, national and local importance as ecological systems and habitat for fauna and flora species; cultural and aesthetic purposes; and hydrological functions
- Appropriate wetland use integration into the national and local resource management through awareness campaigns.

Wetlands as Fish Habitats

Wetlands are very important as fish habitats. Many fish breed in wetlands and return to the lake to feed and grow. After spawning, fish use wetlands as nursery grounds where young fish grow away from predators and are protected and by wetland vegetation. The following are the principal species of fish caught in riverine wetlands like those along Lake Kyoga and the great Mpologoma wetland:

- The Cichlidae including *Oreochromis* and *Tilapia*
- The Lepidosirenidae including *Protopterus aethiopicus*, the African Lung Fish
- The Clariidae including the Catfishes *Clarias*

- The Mormyridae including *Gnathonemus* and *Petrocephalus* species
- The *Marcusenius*
- The Cyprinidae including *Barbus*
- The Cyprinodontidae including *Aplocheilichthys*
- The Haplochromines
- The Haplotilapia
- The *Astatoreochromis*
- The Synodontidae including *Synodontis*
- The *Mastacembelus*.

5.2.2 Mara Wetlands

The Mara River basin covers an area of 13,504 km², of which approximately 60% is located in Kenya and 40% in Tanzania. From its sources in the Kenyan highlands i.e. the Mau Escarpment, the river flows for about 395 km and drains into Lake Victoria. With the upstream rive reaches originating from the Mau escarpment with forests and agricultural land, the Mara tributaries crosses the Kenyan rangelands, an open savannah grassland that is used by pastoralists, followed by the Kenyan Maasai Mara and Tanzanian Serengeti national reserves.

Finally the river meanders and splits into different streams which feed the downstream Mara wetlands. These streams and wetlands continue for about 70 kilometres downstream until Lake Victoria. According to WREM (2008) the wetlands expand to a maximum area during the Masika (long) rains due to high inflows while extending to about 45 km off the lake shores and shrink to the minimum area during the dry season. According to local inhabitants, the wetlands have expanded significantly in the early 1970s (around 1973-1974) by about 387% (Mati *et al*, 2005). In this part of the basin human and livestock densities are high and small-scale subsistence agriculture is the main land use. The river is also a vital source to grazing animals nearby.

During recent years the river regime has changed in a way that more and more peak flow events occur. These large peaks are connected to changes in land use in the catchments area. Decreasing vegetation covers are causing a faster run-off of rainwater. Near the river mouth in Tanzania, the rapidly fluctuating water levels in Lake Victoria of the previous century have further added to discharge difficulties of the Mara River. Consequently, floods have become more common and large parts of the Tanzanian Mara wetlands have become more permanent instead of temporary wetlands.

The two main wetlands in the basin are the Enapuiyapui and Masurura swamps in Kenya and Tanzania, respectively. These wetlands are productive ecosystems providing environmental goods and services including water storage, flood control, water filtration, water recharge and discharge, nutrient cycling, pollution control, wildlife habitats and landscaping. In addition, they provide non-use existence value benefits. Much like other sensitive ecosystems, the wetlands are under threat from agro-chemical pollution and soil erosion. Forest encroachment and destruction for farming are also threatening these wetlands. Deliberate efforts are needed to protect the wetlands and their biodiversity and to sustain the goods and services they offer. There are also plans to divert water from the Mara River in Kenya that may drastically alter the swamp's ecology (BirdLife International. 2009h).

Developments can be summarized as follows:

- Forests and savannah grasslands have been cleared and turned into land for agriculture, charcoal burning and overgrazing
- Grazing resources have been reduced in favour of cultivation areas
- Rapid population growth and high rates of immigration demand land
- Deforestation leads to increased runoff, erosion and eutrophication
- agricultural land area has increases significantly over the last years, forests and savannah grasslands are reducing
- Destruction of closed forests in favour for tea plantations.
- sharp increases in flood peaks, reduction in base flows,
- Wildlife such as hippos can only swim knee-deep in the dry-season, due to the low flows of the Mara River.
- There has been increased sedimentation of downstream wetlands, causing them to expand thereby forcing farmers and livestock to abandon formerly arable lands.

In order to cope with the changes and deteriorating conditions, especially also considering the transboundary challenges of the wetland, the Mara Transboundary Integrated Water Resources Management and Development project, shared between Tanzania and Kenya, has been launched in January 2006.

5.2.3 Sudd Swamps

The Sudd of Southern Sudan is a massive wetland area of approximately 30,000 km^2 but strongly varying in size depending on the inflow conditions. It is located at the Bahr el Jebel, the upper tributary of the White Nile between Mongalla and Malakal in Southern Sudan. In the swamps, the Bahr el Jebel bifurcates into multiple parallel channels feeding a wide swamp area. In the Sudd, every gradation from riverine to lacustrine conditions may be found. Long term variations in the amount of water discharged from the East African lakes are the main source of changes in the swamp system having a serious impact on habitats and plant composition in the channels, lagoons, papyrus and seasonal floodplain areas.

Regarding vegetation composition, *Cyperus papyrus* is dominant at riversides, forming a riparian belt which extends right through the swamps. *Phragmites communis* and *Vossia cuspidata* are associated with the papyrus and in places *Phragmites* dominates swamps behind the papyrus. Elsewhere, *Typha doningensis* forms enormous pure stands behind the papyrus, and this species has probably shown the greatest increase since the water level rise of 1961-62. Next to these indigenous species, *Eichhornia crassipes,* occupies more and more areas of the Sudd, replacing other sloating species. *Oryza longistaminata* is the predominant floodplain grass, with *Echinochloa pyramidalis* and *Vossia cuspidata* are most widespread associates.

The Sudd is home to a large variety of fish species, providing feeding areas on the seasonal floodplains during the flood season. In the permanent swamps plankton is abundant, in addition other aquatic and transitional species like molluscs, frogs, snakes, Nile Crocodiles *(Crocodylus niloticus)*, hippopotamus (*Hippopotamus amphibious)* and elephant (*Loxodonta Africana)* can be found in the swamps and the floodplains boast numerous Buffalo (*Syncerus caffer),* and antelopes including Tiang, *(Damaliscus korrigum Tiang),* and Oribi *(Ourebia ourebi)* during the dry season. The herbivores are followed by feline predators. Sitatunga (*Tragelaphus spekei)* and the Nile lechwe *(Ontragus megaceros)* can be found in the swamps in the dry season. The Sudd is important for migratory birds' species include weavers, warblers, flycatchers, kingfishers, ducks, herons, ibises, egrets, storks, kites, crows and vultures. Even the rare Crowned Crane (*Balearica pavonina*) can be found in the swamps. The Sudd swamps hold by far the largest population of *Balaeniceps rex (*shoebill stork). Aerial surveys in 1979-1982 counted a peak of 6,407 individuals. The site is probably also important for *Aythya nyroca* and, on passage, for *Falco naumanni*. In addition to those listed below, three species characteristic of the Sahel biome (A03) and five of the Somali-Masai biome (A08) have also been recorded.

The Sudd swamps have come under considerable pressure during the last years. Hunting of mammals has been uncontrolled during civil war times and with the peace returned the inflow of large numbers of refugees as well as their cattle herds put pressure on the natural resources of the Sudd area due to competition for grazing, deforestation, urbanisation and infrastructural activities. Fishing has traditionally been conducted using spears on the floodplains as well as nets in the lagoons. The pressures and techniques used for fishing can be expected to change with the influx of returnees. Considering these pressures, programs for the sustainable use of the Sudd´s resources are urgently needed, especially considering the need for over-arching interdisciplinary and multiple stakeholder approaches.

5.2.4 Nile Delta

The Nile Delta in Egypt with its length of 175 km and width of some 263 km at the sea is located at the mouth of the Nile at the Mediterranean coast. The Nile here is divided into the Rosetta (western) and Damietta (eastern) branches. Several major canals and numerous streams branch off from these main channels. A number of small lakes occur in the delta, many representing sections of abandoned river channel. Since the construction of the Aswan High Dam the delta is no longer subject to annual flooding, and much of the marshland has been reclaimed for agriculture. Of the persisting marshland, most is associated with the lakes and lagoons along the seashore. Coastal erosion is increasing with the Aswan Dam impounding most of the silt coming down the River Nile and the integrity of the delta lakes is threatened.

The delta wetlands have coastal fresh water floras and faunas. *Phragrnites australis, Typha capensis* and *Juncus tnaritimus* are common here, together with some small sedge. While having grown in abundance in earlier years, papyrus is now virtually absent from the delta. The delta is home to several fish species and an abundant avifauna.

Lake Burullus, a large, shallow, fresh-to-brackish coastal lagoon located between the two Nile branches forming the delta. It is elongate in shape extending for about 54 km from east to west with a width of 6-21 km and an estimated average depth of 75-100 cm. The lake is separated from the sea by a broad, dune-covered sandbar, which varies in width from a few hundred meters in the east to 5 km in the west. There are some 50 islands scattered throughout the lake with a total area of 0.7 km². On average, 50-70 million m³ of slightly saline, nutrient-rich water enters the lake annually from the south via six drains. Bughaz El Burullus, located in the north-east corner of the lake, is the only direct connection between Burullus and the Mediterranean. Salinity in the lake decreases towards the south and west as the distance from the Bughaz increases, becoming fresh near the outflows of drains and canals that flow into the lake from the south. Consequently, the north shores of the lake are dominated by saltmarshes and mudflats, while the southern shore is bordered by an extensive fringe of reed-swamps (mainly *Phragmites* and *Typha*), which currently covers more than 25% of the lake area. Lake Burullus has abundant submerged vegetation, dominated by *Potamogeton*, which is densest in the southern portion of the lake. Burullus is by far the least disturbed and damaged of the delta wetlands and its environs still retain some aspects of wilderness, which have been lost throughout most of the delta.

Compared to former times, most of the delta has been reclaimed and is used agriculturally. A major threat is that with increased irrigation water demands from river and groundwater pumping as well as with the construction of the High Aswan Dam the upper delta has tended to become progressively more saline. This is due in part to the intrusion of seawater, but also to the use of artificial fertilisers in the lower Nile Valley to compensate for the loss of silt which used to be deposited by the flood each year. By contrast the delta lakes have become less saline due to increased drainage from irrigation schemes.

Almost all the vegetation in the Delta is xerophytic. Aquatic plants are well represented. Reed and swamp types occupy a considerable area of the northern lakes. Salt marsh plants are more prominent than in any other part of the country. Five distinct communities of plant can be named which are dominated by *Zygophyllum aegyptium*, *Arthrocnemum macrostachyum, Halocnemum strobilaceum, Juncus acutus* and *Juncus rigdus*. The associated species are *Juncus sublatus* and *Tamarix nilotica* as perennial, *Lotus halophilus, Salsola kali* and *Polypogon viridus* as annuals. The large Manzala coastal lagoon supports beds of *Ceratophyllum demersum, Potamogeton crispus,* and *P. pectinatus* around the southern shore as well as dense phytoplankton. Other typical species found here are *Najas pectinata, Eichhornia crassipes*, and *Cyperus* and *Juncus spp.* that grow along lake shores (Hughes and Hughes 1992). The salt tolerant *Halocnemum spp.* and *Nitraria retusa* grow in marshes along the Mediterranean coast.

The delta can be divided ecologically into four main habitats: salt marsh, sand formation, reed swamp and fertile non-cultivated land. In each habitat, vegetation types can be distinguished based on the dominance of single plant species. The salt marsh habitat comprises five such communities dominated by: *Zygophyllum aegyptium, Inula crithmoides, Arthrocnemum macrostachyum, Juncus acutus* and *Halocnemum strobilaceum*. The vegetation of the sand formation includes 11 communities dominated by: *Elymus farctus ssp. farctus, Alhagi graecorum, Cynodon dactylon, Heliotropium curassavicum, Stipagrostis lanata, Thymelaea hirsuta, Moltkiopsis ciliata, Asparagus stipularis* and *Pancratium maritimum* (sand dunes), *Cressa cretica* and *Phragmites australis* (sand flats). The reed swamp habitat is dominated by *Typha domingensis*. Other species are *Cyperas articulatus* and *C. lavigatas*. On the other saline fringes of these swamps many halophytes are growing e.g. *Juncus rigidus, J. acutus* and *Tamarix tetragyna.* In the fertile non-cultivated land *Alhagi graecorum, Cynodon dactylon* and *Heliotropium curassavicum* are the dominants.

Marine fish are found in the delta, such as *Anguilla* spp., *Mugil cephalus* and *Solea vulgaris*. Financially important species in the lakes and lagoons include *Oreochromis niloticus*, *O. aureus*, *O. galilaeus*, *Tilapia zillii* and *Clarias* spp. (Hughes and Hughes 1992).The most economically important fish species are tilapia species (*Oreochromis niloticus, O. aureus, Sarotherodon galilaeus,* and *Tilapia zillii*) and freshwater species (*Bagrus bayad, Lates niloticus, Barbus* spp*., Clarias* spp*. and Mugil* spp.).

The ecoregion provides habitat for one endemic frog, *Bufo kassasii.* Aquatic reptiles include *Varanus niloticus* and *Crocodylus niloticus* as well as two marine turtles which breed at Lake Bardawil in the Delta, the endangered loggerhead (*Caretta caretta*) and the endangered green turtle (*Chelonia mydas*). The African softshell turtle (*Trionyx triunguis*) was once found in the Delta but has been eradicated from Egypt. The remaining Mediterranean population is considered to be critically endangered (Schleich et al.1996). The endangered Egyptian tortoise, *Testudo kleinmanni*, lives in the dunes and islets of this ecoregion.

Mammals endemic to the ecoregion include a member of the white-toothed shrew genus, *Crocidura floweri*. European mammals found here include the otter (*Lutra lutra*) and the red fox (*Vulpes vulpes*). Healthy populations of swamp cat (*Felis chaus*) can be found around Lake Manzala.

For birds, including migratory species, the Nile Delta is suitable for breeding, resting and as a rich feeding ground. Thousands of birds are wintering in the northern lakes or crossing the Delta to farther south. Lake Manzala and Lake Burullus are probably the most important breeding site in the Western Palearctic, Breeding waterbirds in lake Manzala include Little Grebe, Little Bittern, Water Rail, Moorhen, Purple Gallinule, Collared Pratincole, Kentish Plover, and Spur-winged Plover. Other waterbirds include shoveler (*Anas clypeata*), teal (*A. crecca*), wigeon (*A. penelope*), garganey (*A. querquedula*), grey heron (*Ardea cinerea*), pochard (*Aythya ferina*), ferruginous duck (*A. nyroca*), Kentish plover (*Charadrius alexandrinus*), and cormorant (*Phalacrocorax carbo*) (Hughes and Hughes, 1992). Reed beds and salt marshes hold a variety of other breeding birds including Pied Kingfisher, and warbler species. In a recent survey conducted in 2007 in the North Eastern Delta, almost 9000 individuals were recorded. Species that pass through the Nile Delta Flooded Savannah ecoregion include white stork (*Ciconia ciconia*), black stork (*Ciconia nigra*), European crane (*Grus grus*) and white pelican (*Pelecanus onocrotalus*), as well as numerous birds of prey, including short-toed eagle (*Circaetus gallicus*), booted eagle (*Hieraaetus pennatus*), steppe eagle (*Aquila nipalensis*), lesser spotted eagle (*Aquila pomarina*), steppe buzzard (*Buteo buteo*), honey buzzard (*Pernis apivorus*) and levant sparrowhawk (*Accipter brevipes*).

Burullus is one of Egypt's most important wetland for wintering waterfowl, holding a total of 98,887 in winter 1989/90, the second-largest concentration recorded in Egypt that winter. The lake supports the largest numbers of some wintering waterfowl in the country, including *Anas penelope*, *Anas clypeata*, *Aythya nyroca*, *Aythya ferina*, *Fulica atra* and *Tringa totanus*. Burullus is one of the most important wintering grounds for *Aythya nyroca* in the eastern Mediterranean. Because of its relative isolation, Burullus is also an important breeding site for several waterbirds and wetland species. About 35 species of birds are known to breed, of which the most prominent are *Tachybaptus ruficollis*, *Ixobrychus minutus*, *Porphyrio porphyrio*, *Sterna albifrons*, *Charadrius alexandrinus*, *Vanellus spinosus*, *Glareola pratincola*, *Caprimulgus aegyptius*, *Ceryle rudis*, *Centropus senegalensis* and *Acrocephalus stentoreus*. The endemic delta subspecies of *Calandrella rufescens* (*Calandrella rufescens nicolli*) probably has its largest population in the vicinity of Burullus (BirdLife International 2009).

5.2.5 Machar Marches and Gambela Marshes

The Machar Marshes are part of the larger Baro-Akobo-Sobat system wetlands and are located in the south eastern part of southern Sudan and western Ethiopia between the Bahr el Jebel and the Ethiopian Highlands, to the north of the River Sobat. With the ‘Sudd’ and Bahr el Ghazal swamps, the Machar marshes form the largest tropical wetlands in the world. They have an area of approximately 1 million ha of which over half is located in Sudan and half in Ethiopia.

Waters from the lower Baro are both feeding the Machar marshes as well as the marshes stretching across the Gambela plains. Permanent and seasonally inundated areas of marsh and swamps form the wetland complex found across most of the Gambela plains stretching along all its main rivers including the Alwero, the Gilo and the Akobo. Mapping of land cover based on early 2000 Landsat images (WBISPP 2005) identified permanent and seasonal marshes and swamps, and permanent water bodies, covering an area of approximately 240,000 ha. These areas of wetlands have been mapped as part of this project.

The Machar Marshes comprise a vast area of swamps and seasonal floodplains interlaced by an intricate reticulate system of watercourses and various waterbodies. The wetlands are partly fed by sheet flows, overland flows and spill that are generated from the highly seasonal and variable runoff from the Ethiopian Highlands which leaves the defined watercourses when entering the plains.

Further to the south-west, a lesser known area covered with extensive wetlands is found between the Akobo and the Pibor and in connection with a spillway linking the two rivers. There is an area of approximately 230,000 ha of permanent inundated swamp and 250,000 ha of seasonally inundated swamp associated with the spillway (ENTRO 2007b).

The hydrophytic plant community of the Machar and Gambela marshes and swamps is typically dominated by papyrus sedge, common cattail and common perennial reed (*Phragmites karka*), *Cyperus papyrus* forming tall stands along the innumerable watercourses, fringing numerous waterlogged and permanently inundated areas. Away from the deeper area, *Typha domingensis* dominates. Emergent *Vossia cuspidata* (hippo grass) is the dominant fixed-floating species.

Grassy floodplains form an important habitat. The seasonally flooded grasslands are dominated by *Oryza longistaminata* and by *Echinochloa pyramidalis*. The grass composition varies along an inundation gradient. The seasonally river-flooded grassland forms the '*toich'*, which yields dry season grazing areas important to the Nuer and Dinka agro-pastoralists. Yield is affected by the duration, timing and intensity of the flood. There are two types: *Oryza longistaminata* (wild rice) dominant and *Echinochloa pyramidalis* dominant. Oryza dominated grassland forms up to 90 % of the standing crop. Echinochloa forms a year-round pasture. Seasonally Rain-fed Grasslands are divided into three groups: *Echinochloa haploclada* grassland, *Sporobolus pyramidalis* Grassland, and *Hyparrhenia rufa* grassland (ENTRO 2007b).

Riparian forests species include: *Celtis kraussiana, Ficus sycomorus, Mimusops kummel, Tamarindus indica, Maytenus senegalensis, Kigelia aethiopum, Syzygium guineense* and Acacia spp. (ENTRO 2007b).

The Machar Marshes and represents an area of importance for biodiversity conservation. Wetlands flooded grassland mosaic (described above) maintains important population of large mammal species that are making annual migration in these seasonal grasslands, including two emblematic species for this area, the white-eared kob (*Kobus kob leucotis*) and the Nile Lechwe (*Kobus megaceros*); both are species listed by IUCN as threatened. Sitatunga (*Tragelaphus spekei)* – the most aquatic of the antelopes, with long, splayed hooves adapted for walking in swamps – and the

Nile Lechwe *(Kobus megaceros)* can be found in the swamps in the dry season. The Nile Lechwe, endemic to the 'Sudd', the Machar Marshes and some tributaries of the Sobat, moves according to flood cycle (Green and El-Moghraby 2009).

Elephant (*Loxodonta Africana)*, Buffalo (*Syncerus caffer),* tiang hartebeest, *(Damaliscus korrigum Tiang),* and the oribi antelope *(Ourebia ourebi)* extend their range up to the river's edge during the dry season. The herbivores are followed by feline predators. Hippopotamus (*Hippopotamus amphibious)* are quite frequent and the region harbours large populations of the Nile crocodile, *(Crocodylus niloticus)*. (El-Moghraby 2006, as cited in El-Moghraby in press).

According to local informants, crocodiles have been observed in the low-gradient sections of Baro River, upstream of the Baro 2 dam site. The monitor lizard probably also occurs along the river. Locals refer to an animal called "hola bishani" (meaning literally "sheep of the water" in Oromo language). The animal is known to feed on head of fish which are caught in gillnets set overnight. This could probably be the African clawless otter (*Aonyx capensis*), and this would be confirmed by the presence of mussel shells noted by local fishers along the river bank (Fitiwe in press).

The White-eared Kob range is found further away from the permanent swamp. This antelope makes long seasonal migrations over hundreds of kilometres, from wet season quarters in southern grasslands east of Bor and Juba to spend the dry season near the River Sobat (Fryxell 1987). The Kob feeds in the grasslands, mainly on Hyparrhenia and associated grasses. Carnivores in the swamps are lesser known. The marsh mongoose, *Atilax paludinosus*, is seen occasionally, and is probably quite common. It will eat almost anything it can catch, including fish, such as *Protopterus* and *Clarias*, as well as crabs and mussels (Green and El-Moghraby 2009).

Birds - The region represents a major flyway for migratory birds to the African continent. The extensive areas of swamp habitat are home to some 43 species of mammals and an IBA team recorded 230 species of birds (EWNHS 1996). There are two threatened bird species: the Shoebill, also called the whale-headed stork (*Balaeniceps rex*), and the Basra Reed Warbler (*Acrocephalus griseldis*) last recorded in 1976. The shoebill *Balaeniceps rex* is an iconic bird for the region. Its lifestyle is linked strongly to aspects of swamp ecology. The shoebill avoids the main channels and very tall vegetation, preferring smaller channels and pools, frequently surrounded by Typha. Its diet consists mainly of the air-breathing fishes *Protopterus*, *Polypterus* and *Clarias* (Green and El-Moghraby 2009).

EWNHS (1996) excerpt from the section on the Baro River, Site: ET040

> "In the dry season, when the Baro River is low, huge numbers of storks and other water birds (including pelicans, herons, egrets, etc.) gather to rest on sandbars in the river. A flock of 500 *Glareola nordmanni* (black-winged pratincole), apparently wintering, was noted at Jikawo in January 1970. *Balaeniceps rex* was recorded from swamps 20 km west of Gambella in the early 1960s, and was also found 60 km west of the western perimeter of Gambella National Park, west of Gog, in 1973. *Glareola nordmanni* and *Balaeniceps rex* are both considered Globally threatened (Global IBA Category A1).There is an unconfirmed 1996 report of *B. rex* breeding in the vicinity of Nasir in West Nile province, Sudan, adjacent to Jikawo, and large numbers have been reported from the Baro river system in Sudan, suggesting that the species may be present on the Ethiopian side of the border close to Nasir. During March 1976, thousands of *Anastomus lamelligerus* were recorded

> between Itang and Jikawo, and similar numbers of *Ciconia abdimii* were found between Pukwo and Jikawo. The latter species is thought to be an irregular non-breeding visitor."

EWNHS (1996) excerpt from the section on the Gambela National Park, Site: ET042

> "More than 230 species have been recorded in the park. *Balaeniceps rex* was recorded in the early 1960s, 20 km west of Gambella. There are recent anecdotal reports of the species breeding in the Akobo area, suggesting that it may be present seasonally in swamps within the park. *Acrocephalus griseldis* was recorded regularly between 1969 and 1976, but its current status is unknown. Sudan–Guinea Savannah biome species include: *Merops bulocki*, *Eremomela pusilla*, *Cisticola ruficeps*, *C. troglodytes*, *Plocepasser superciliosus*, *Lagonosticta larvata* and *Vidua interjecta*, the last-named being known in Ethiopia only from around Gambella. Three Afrotropical Highlands and four Somali–Masai biome species have been recorded. Other species include *Platalea leucorodia* (rarely recorded from the south and west of Ethiopia), *Kaupifalco monogrammicus* (little-known in Ethiopia), *Campethera cailliautii* and *Acrocephalus melanopogon*. The only Ethiopian record of *Vanellus crassirostris* is from Gambella."
>
> The Sudan–Guinea Savannah biome species are well represented with 11 of the 16 species known from Ethiopia recorded at this site.

Bird species recorded from Boma National Park include: Shoebill (*Balaeniceps rex*), Abyssinian Scimitarbill (*Rhinopomastus minor*), Hemprich's Hornbill (*Tockus hemprichii*), Boran Cisticola (*Cisticola bodessa*), Rufous Chatterer (*Turdoides rubiginosa*), White-rumped Babbler (*Turdoides leucopygia*), Kenya Violet-backed Sunbird (*Anthreptes orientalis*), Golden Pipit (*Tmetothylacus tenellus*). This list includes all 'Biome-restricted species (IBA – A3) with the exception of the Shoebill (BirdLife International 2009d).

Fish - Golubtsov in 1989 recorded the presence of 92 fish species belong to 51 genera and 23 families (ENTRO 2007b). Some of the fish species found in the Alwero reservoir include: *Barbus* spp., *Citharinus* spp., *Clarias* spp., *Gymnarchus niloticus, Heterotis niloticus*, *Labeo* spp., *Oreochromis niloticus*, and *Polypterus bichir Gymnarchus niloticus,* (EPA 2003). Fish catch composition from commercial fisheries (reported by Itang Cooperative) in 1994 was dominated by *Lates niloticus* (Nile perch), 41 % and *Polypterus bichir* (Nile bichir) 14%. The remaining species, ranked by total weight, included, *Bagrus* spp., *Heterotis niloticus*, *Clarias gariepinus*, *Distichodus* sp., *Gymnarchus niloticus*, *Barbus* spp., *Synodontis* spp., *Hydrocynus* sp., *Citharinus* sp., and *Tilapia nilotica* (Abrha and MoWR 2005)

Malacofauna - The Malacofauna of this region is exclusively Afrotropical. It is an impoverish version of the fauna of Lake Chad and it shows only a modest relationship to the fauna of the Great Lakes. The list includes 13 gastropod species, only one, *Gabbiella schweinfurthi* may be endemic (Brown, 1994; as cited in Van Damme and Van Bocxlaer, 2009); 11 bivalve species were found; only the iridinid *Chambardia marnoi* is likely distinctive and confined to this part of the Nile.

Benthos - The benthos of the Sobat River is similar to that of the White Nile. The clayey bottom of the bed was sparsely populated by Chironomidae (*Polypedilum* sp., *Clinotanypus* sp., *Stictochironomus* sp., *Cryptochironomus* sp.) and Trichoptera. The total biomass of the benthos in the middle of the river was about 0.2 g m^{-2}. But near the mouth of the Sobat, large zones were invaded by the big bivalve, *Etheria elliptica*. The

colonies of these molluscs provided a habitat for a rich fauna of Ephemeroptera and Trichoptera. The genera *Amphipsyche*, *Cheumatopsyche*, *Aethaloptera* and *Ecnomis* predominated. In the same place *Eupera parasitica* (Mollusca) was found (El-Shabrawy and Fishar 2009).
Biodiversity characteristics of the Gambela and Boma National Parks are presented next.

Gambela Park

This extensive area of swamp habitats are home to some 43 species of mammals and an IBA team recorded 230 species of birds (EWNHS 1996). There are two near threatened bird species: the Shoebill, also called the whale-headed stork (*Balaeniceps rex*), last recorded in 1961, and the Basra Reed Warbler (*Acrocephalus griseldis*) last recorded in 1976.

The park is rich in wildlife species and is known in particular for its species of importance for conservation including two endemic species (Sudan and Ethiopia southern marsh) the Nile lechwe (*Kobus megaceros)*, white eared kob (*Kobus kob leucotis*) and home of the whale-headed stork (*Balaeniceps rex*), the latter being endangered and may be only found in this region as its last refuge. The White Eared Kob migrates every year between the Sudd in Sudan and the Gambela Marshes. An inventory of large mammals found some 88 species of 9 Orders and 28 Families (Lavrenchenko et al. 1989). Other species include elephant, topi and road antelope. In smaller numbers Lion, leopard, Lelwel hartebeest and Buffalo are also found.

Boma National Park (Sudan)

The Boma National Park includes numerous wetlands. A major wildlife inventory was undertaken in 1980 and provided a baseline for the 2001 study (Deng 2001). With the exception of population estimates for Reedbuck, Ostrich and Eland populations the 2001 estimates suggest that there has been a massive decline in nearly all animal species. The most affected were the White-eared Kob and the Mongalla Gazelle. A summary is provided in Table 13. The big increase in hunting has caused the migratory routes of White-eared Kob and Elephant to change over 20 years (Deng 2001 , as cited in ENTRO 2007b).

Table 13 Comparison of wildlife population estimates of the years 1980 and 2001

Species	2001 count wet season	1980 count wet season	1980 count dry season
White-eared Kob	176,120	680,716	849,365
Lesser Eland	***21,000***	2,612	7,839
Oribi	3,920	2,939	2,264
Reedbuck	***28,840***	2,000	3,000
Road Antelope	1,960	2,059	3,085
Mongalla Gazelle	280	5,933	21,678
Warthog	280	293	4,868
Ostrich	3,640	1,306	2,151
Tiang	N.S.	24,078	29,460
Lelwel Hartebeest	5,600	8,556	47,148
Zebra	N.S.	24,078	29,460
Buffalo	N.S.	2,965	11,179
Giraffe	N.S.	4,605	9,028
Waterbuck	N.S.	620	2,462
Steinbuck	N.S.	292	1,981
Grants Gazelle	N.S.	1,222	1,811

Elephant	N.S.	1,763	2,179

Source: Deng 2001 and Fryxell 1983 for the 1980 survey data, as cited in ENTRO 2007b.
N.S.: Not seen

Two population of antelope, the lesser eland and reedbuck are in marked increase, their numbers increasing by an order of magnitude between the two studies.

Development Issues, impact on Biodiversity and Trends

The Sobat region including the Machar Marshes and the marshes from the Gambela plains are moderately utilized and pressures on this system have not yet build up to critical levels compared to other regions. The current environmental pressures from local communities including the small-scale farmers, agro-pastoralists and various pastoralist groups on the land, and in particular the wetlands are moderate. These communities have developed complex livelihood systems involving crop and livestock production and fishing (ENTRO 2007b). Wetland habitats main use comprises cattle grazing during the dry season as well as hunting and fishing on a currently sustainable level. This is vast area and much of the natural vegetation is in relative better condition compare to other sub-basin, and some parts are kept in relatively near pristine conditions. There are additional difficulties in establishing infrastructure projects due to the isolation and the remaining mines from recent conflicts. As a result information about the area is scant; the difficulty with accessing this relatively underdeveloped and politically volatile area makes it hard to carry out comprehensive surveys and much is left to be done.

Complex hydrological conditions characterising this sub-basin need to be better understood and links between ecosystems functioning and the rich biodiversity found in the region needs to be further investigated. The wetlands in particular with their distinctive flora and fauna are likely to be first impacted by changes in flow regimes. As indicated earlier, the highly variable hydrological nature of the system has also shaped the way in which local communities have developed their livelihood systems, hence changes in flow regimes will be far reaching.

Integrating conservation and development at the landscape scale in the sub-basin is necessary. With over 70 to 75 % flow contribution to the Sobat, the Baro catchment and changes that are in the planning in terms of hydropower development need to be closely monitored. Rapid increase in population both on the Baro headwaters in the Ethiopian highlands as well as in the lowlands is putting the watershed under accrued stress on the environment and biodiversity. Deforestation, land cover changes, soil degradation, wetland over-drainage, constitutes some of the major threats to the region.

Hydropower development on the Baro (Baro 1 and Baro 2):

The amount of excess water from the Baro that spills to the Machar marshes will likely decrease as a result of changes in hydrological alteration following the establishment of dams on the catchment. Studies found that the amount of spill will be reduced by about 20% (Norplan et al. 2006). This will affect the extent of flooding area, and in particular the “toich” grassland, which are likely going to shrink by about 12 % (ENTRO 2007b).

The Machar Marshes Canal Scheme:

This is a water diversion scheme along the Sobat River which aims to providing “new water” for downstream user, by building a canal to collect spill from the Sobat that partly flows to the Machar Marshes, water to be redirected to the White Nile. Annual benefits estimated from a number of studier vary greatly

> and estimates from recent study (Waterwatch 2006, as cited in ENTRO 2007b) are more conservative revising initial estimates of 4.4 km³ down to 0.96 km³.
>
> The 'marginal' benefits from the scheme should be weighed against the potential loss of such an important wetland. With all the spill and inflow redirected into the canal, the Machar Marshes would be effectively dry out apart from some localized flooding from local rainfall (Howell and Lock 1993, as cited in ENTRO 2007b).

The lesser known Pibor-Akobo wetlands present similar characteristics to those found in Machar Marshes and as such they are likely to experience the same environmental challenges resulting from hydropower development as well as from oil development schemes. This is a large area, somewhat larger than the Machar Marshes, but which is poorly understood and has limited information regarding its biodiversity. Vast herds of white-eared kob (Kobus Kob leucotis) are known to be using the area as part of their migratory routes. The Nile lechwe (Kobus megaceros) was also found in the area (ENTRO 2007b).

The steady development of irrigated agriculture in the area, which is mainly for industrial crops like sugar-cane and cotton, and the application of fertilizers, herbicides and pesticides will result in the build-up of chemical residues in the soil and river/swamp water.

Impact from development activities associated with the oil industry includes:

- Oil exploration (cutting of seismic traces, test drilling, access road construction);
- Extraction (infrastructure development, oil wells spills, water contaminations) are causing severe environmental and social impact;
- Alteration of drainage patterns resulting from poorly designed road. Roads act as a dam when culverts are not able to cope with excess water.

Sustainable traditional hunting practices have, now been disrupted with the introduction of firearms resulting in increased hunting pressure.

A detailed understanding of the hydrology and a full inventory and assessment of the status of habitats and biodiversity is therefore required.

Institutional Development

(Source: ENTRO 2007b). Over the last 20 years, civil wars, from both sides of the Sudan-Ethiopia border have left significant scars. The impact on the infrastructure and socio-economic activities is major, adding to the risk of societal breakdown affecting the communities.

The development of mechanisms for coordination between the two countries sharing the sub-basin, Ethiopia with its four Regional States and the ten States in Sudan, will help address upstream – downstream linkages as well as the management of trans-regional land uses, especially forests and wetlands.

Coordination of sub-basin management will require the development of an institution in each country, which is able to influence, and where necessary control, the actions of agencies within the regional governments. To that effect, Ethiopia is currently working on the publication of the "River Basins organizations Proclamation".

In Sudan the Southern Sudan administration is only just establishing itself and it may be some time before River Basin Authorities become a priority. The establishment of a Southern Commission on Natural Resources Management should be prioritized. The Commission would take responsibility for preparing an inventory of natural resources, designing a strategy for their rehabilitation and long-term sustainable management. Additionally the Commission would clarify the powers and responsibilities of the National Government, the Government of Southern Sudan, state and communities with respect to rights pertaining to and management of natural resources.

The development of policies that will address gaps in particular issues concerning biodiversity considerations in development planning should be a priority. In order to cope with the changes and deteriorating conditions, especially also considering the transboundary challenges affecting the wetlands, the region could benefit from establishing a comprehensive, transboundary integrated water resources management system; an initiative shared between Sudan and Ethiopia.

5.2.6 Ghazal Swamps

The Bahr el Ghazal system in Southern Sudan is a widespread swamp and floodplain area extending through major parts of the Bahr el Ghazal catchment being virtually continuous from Meshra' er Shoul through Lake Ambadi to Lake No and the confluence with the Bahr el Jebel. The swamps that are intermeshed wuíth the watercourses are responsible to the nearly total evaporation of the waters collected in the Ghazal catchment. The vegetation as well as fauna can be described similarly to that of the Sudd area. The area has been affected by civil war for many years leading to an uncontrolled use of the natural resources including hunting and the return of refugees now imposes further pressures that need to be dealt with. In general the Bahr el Ghazal can be treated similar to the Sudd system. During the wet season the boundaries in-between the two can not been distinguished.

5.2.7 Kyoga-Kwani Swamps

The Kyoga-Kwani Swamps fringe the shores of Lake Kyoga and Lake Kwani in Uganda, a shallow dendritic valley system, part of which is permanently flooded to form a series of shallow lakes, which have a combined maximum open water surface of 3500 km^2, and 2200 km^2 of permanent swamps. The system is part of the Victoria Nile which flows through the south western end of Lake Kyoga, and then receives the discharge of Lake Kwania 32 km downstream. The system owes its existence to the upwarping of the western edge of the Lake Victoria basin, which has reduced the gradient and rate of flow in rivers flowing west, causing ‘ponding' and turning them into sluggish swampy tracts.

The lakes themselves are very shallow with a mean depth of 3 m and maximum depth of 11 m in Lake Kyoga, making them very responsive to inflow related water level fluctuations. Surface water levels can fluctuate by as much as 3.8 m during a year. The shallow tributaries that feed the lakes are covered by extensive swamps. The swamp belts reach widths of 20 km and extend up several side valleys. The principal inflow to Lake Kyoga is from the Victoria Nile coming from Lake Victoria. Changes in lake outflow therefore have a major impact in the lake hydrology. Other tributaries have a much smaller influence. Being a very shallow lake with respectively low volume, water quality is a concern and agricultural practices have a direct effect in the lake nutrient balance.

The lake margins as well as the swamps are dominated by papyrus; seasonal floodplains carry grasses with some trees in less deeply inundated areas. During water level fluctuations the floating papyrus vegetation often detaches to produce floating islands. There are extensive and dense carpets of floating macrophytes along the fringes of the open water, and beds of submerged macrophytes throughout the lakes. Due to this floating vegetation the outlets of the lakes are prone to clogging what leads to further changes in water level and interruption of navigation. The swamps are predominantly dense papyrus *Cyperus papyrus*, broken in parts by pools of water forming sudds (clumps of floating papyrus). Sometimes these sudds open up completely, forming small lakes. Some lakes, like Nawampasa, are very shallow and covered by water-lilies *Nymphaea*, with short sedges (dominated by *Cyperus*) occupying the drier parts of the fringing papyrus swamp. These shallow areas are important for both waterbirds and surrounding fishing communities.

The Doho Rice Scheme in eastern Uganda was formerly a seasonal wetland on the River Manafwa flood-plain. Doho Rice Scheme is an area of intensive irrigated rice cultivation with adjacent areas of natural wetland, mainly in the south. The swamps immediately to the north of the scheme have also been drained for rice-growing by independent farmers referred to as 'outgrowers'. The swamps to the north form part of the Lake Kyoga complex. All of the rice-fields have irrigation channels which supply water to the rice-paddies from River Manafwa. Rice cultivation has not destroyed the wetland, but has changed the character and flora of most of the area from a natural ecosystem to a managed artificial environment. The remaining natural vegetation consists of reeds *Phragmites*, floating grass *Vossia* and various species of sedge (Cyperaceae), including papyrus *Cyperus papyrus*. Wet grasslands dominate seasonal swamps. The rice scheme is not a protected area. Management falls under the Ministry of Agriculture, Animal Industry and Fisheries, whose interest is rice production. There is currently minimal use of herbicides, pesticides and fertilizers, but this may increase with decreasing soil productivity. However, pesticides have been used as a means of killing ducks and other birds for food. This is dangerous and an awareness campaign is needed. However, the transformation from wetland to rice scheme has created conditions favourable for some species, particularly waders, whilst destroying the habitats of others. This wetland forms part of the Lake Kyoga basin and more research, especially in the remaining intact swamps, could reveal other species of interest at the site, especially papyrus endemics. The area is also important for breeding *Balearica regulorum*, and other species such as *Ardea melanocephala*, *Threskiornis aethiopicus* and *Platalea alba* breed in Busolwe, a nearby trading centre. Recently, over 800 nests of *Bubulcus ibis* were recorded at the heronry. The rice scheme is an important site for some migratory species and big congregations are occasionally recorded. Species such as *Himantopus himantopus*, *Limosa limosa* and *Tringa erythropus* are sometimes numerous

The fish fauna in Lake Kyoga is nilotic. There was no effective barrier separating the fish faunas of Lakes Kyoga and Victoria until the Owen Falls Dam was completed in 1954, thus the fish fauna of the lakes in the complex is similar to that of the inshore waters of Lake Victoria. By contrast the Murchison Falls have always been a barrier to interchange between these lakes and Lake Albert.

The presence of the Nile crocodile in the Lake Kyoga swamps has been dramatically decreased and is at the point of extinction as a result of systematic killing with the human population increasing around the lakeshores. The avifauna remains abundant. On the mammal side hippopotamus can be found in the swamps while elephant populations have been largely diminished. The lake is strongly used for fisheries with the wetlands along the lakeshores acting as breeding habitats.

The area is remote and poorly known, and therefore needs further investigation. The use of firearms to hunt *Balaeniceps rex* needs to be discouraged through a public-awareness campaign which, in addition to stressing the global significance of the species, should address some of the negative cultural beliefs, such as the bird being a bad omen for fishermen (BirdLife International, 2009i).

5.2.8 Albert Nile Swamps

Lake Albert, shared between Uganda and Congo, lies between two parallel escarpments in the Western Rift Valley. Due to the incised geography, the lake is subject to violent windstorms which cause the upwelling of bottom waters, but even without these happenings, the lake is generally well mixed. During calm periods, which frequently occur between November and February, a degree of stratification develops and dissolved oxygen levels fall, but not deleteriously for the fauna. The lake is fed by the Semliki and the Victoria Nile which form swamp deltas into the lake.

There are extensive stands of *Cyperus papyrus* and *Phragmites mauritianus* in the river deltas of the lake. Aquatic meadows of *Vossia cuspidata* flourish on the lakeward side of the papyrus swamp. The lake boasts a variety of fish species. Nile Crocodiles still exist and can be found in increasing numbers down the Albert Nile and in the related swamps. The Avifauna of the lake is rich. Mammals occurring in the swamps and along the lake include hippopotamus and buffalo, their numbers are anyhow reducing.

5.2.9 Winam Gulf (Kisumu Bay)

Winam Gulf is located in the Kisumu Bay, part of Lake Victoria in Kenya. It is comparatively shallow, having a maximum depth of 35 m and a mean depth of 6 m. It is fringed by papyrus swamps parts of which may become dislodged and can be found as floating islands.

Dunga (or Tako river mouth) is a wetland situated about 10 km south of Kisumu town on the shores of Winam Gulf. *Cyperus papyrus* stands stretched along the shore in a strip that varies in width from about 50 to 800 m. A number of streams drain into the lake through the swamp, the main one being Tako river. The swamp is predominantly Papyrus (*Cyperus papyrus*) which forms distinctive habitat. It is also richly endowed with Lake Victoria Basin macrophytes such as *Miscanthidium violaceum*. Bird fauna is abundant in Winam Gulf with Lake Victoria Basin biome species having been recorded here. The birds include the restricted range endemics like the globally threatened Papyrus, Yellow Warbler (*Chloropeta gracilirostris*), the near threatened Papyrus Gonolek (*Linarius mufumbiri*), White Winged Warbler (*Bradypterus carpalis*), Carruthers's Cisticola (*Cisticola carruther*) and Papyrus Canary (*Serinus koliensis*) (IUCN RED LIST and the Kenya IBA directory). This is one of the most reliable sites in Kenya for the scarce and threatened *Chloropeta gracilirostris*, which is often seen along the lakeward side of the swamp. All but one of Kenya's nine Lake Victoria Basin biome species have been recorded here, and it is especially important for *Laniarius mufumbiri* (relatively common), *Bradypterus carpalis* and *Serinus koliensis*, all papyrus endemics. Other threatened and endemic wildlife is found in the wetlands which are known to be important refuges for a number of the lake's endemic haplochromine fish species.

The fish fauna is essentially nilotic but there are also many endemics. Certain fish species including *Lates albertianus, Oreochromis leucosticta, Oreochromis niloticus* and *Tilapia zillii* had been introduced into the lake before 1962, and are now widely distributed but have had a serious impact on other endemic species which they replaced. Certain other species which are common in the lake are comparatively scarce in Winam Gulf, e.g. *Barbus altianalis, Labeo victorianus, Mormyrus kannume, Oreochronzis esculentus* and *Schilbe mystus.* Many of the Equatorial East African animals occur in, or on the shores, of the Kenyan part of Lake Victoria, including water turtles, aquatic snakes, monitor lizards, crocodiles, rodents, otters and hippopotamus.

Conservation issues - Population pressure is significantly increasing at the bay so that wetland areas that have previously been excluded from settlements come under increasing pressure. Industrial fishing in the lake increases. There is some evidence to suggest that Winam Gulf is currently being overfished with the catch numbers still rising. Major towns put particular strain on the wetlands. Papyrus harvesting is often excessive and unsustainable. The incoming streams bring pollution in the form of sewage and solid wastes from nearby residential estates. Lake Victoria's papyrus swamps are under increasing pressure in general. Water hyacinth *Eichhornia crassipes* has infested much of the Winam Gulf. By preventing fishermen from fishing, it forces them to seek other forms of livelihood. Often, the only alternative available is to harvest papyrus, or to clear it in order to cultivate crops. The gulf urgently requires formal protection, as it has no conservation status at present. The site is already a popular area for recreation. Its proximity to Kisumu gives it potential for environmental education and bird tourism focused on the papyrus endemics.

5.2.9.1 Kagera Swamps

The Kagera swamps and lakes fringe the Kagera River in Rwanda/Tanzania with an area of approximately 1500 km^2. Most of the wetlands lie on the Rwanda/Tanzania border between two ridges of low hills, below Rusumu Falls.

The Kagera River basin is comprised of two types of wetland ecosystems, those associated with lakes (*lacustrine*) –such as Lake Rweru, Cyohoha and Ihema swamps and those associated with rivers (*riverine*) such as the Nyabarongo, Mugesera and Akanyaru swamps as well as Upstream of the Rusumo Falls on the Kagera River. The wetlands provide potential areas for hunting / fishing, cultivation, livestock grazing and source of raw materials for construction and handcrafts. The wetland areas also play an important role in protecting the river and lakes from siltation/sedimentation and/or pollution due to their ability to filter sediments and retain nutrients and pollutants. They also help in the prevention of flood hazards, water flow regulation, drought alleviation, stabilization of the hydrological cycle, ground water recharge and maintaining the micro-climate. In addition, the wetlands provide a natural habitat for biological diversity and act as a source of genetic material for developing disease resistant varieties of crops through hybridisation. Wetlands ecosystems can also be utilized for waste water treatment, recreation and eco-tourism purposes.

The Kagera River, which delimits the Rwanda/Tanzania border, meanders along the centre of the flat bottomed valley for about 110 km, spilling over to inundate a swamp belt 2-18 km wide. The river is lined on each margin by a series of substantial lakes, 20 on the right bank being situated in Tanzania. The swamp belt is more extensively developed on the left bank, in Rwanda, where there are 21 lakes. The lakes lie partly in and partly out of the permanent swamp belt. Outside the permanent swamps some are fringed by seasonally inundated savannas. Very few of the lakes have permanent connections with the Kagera River, and in the past 30 years, the river has changed course and lost connection with lakes with which it formerly had continuity. Many small seasonal streams feed the lakes or swamps directly and flow twice a year during the rainy seasons, but the bulk of the riverine inflow is provided by the Kagera River which also rises in response to seasonal rains. The water level in the system has an annual amplitude of 1-1.5 m. During the dry season several of the lakes are isolated from the river.

The flora and fauna in the Kagera swamps is diverse with a variety of large mammals including hippopotamus, kob and buffalo having survived in the Kagera National Park covering to the northern half of the swamp complex. Amphibians, crocodiles and water turtles are abundant.

Over time, considerable pressure resulting from agricultural development and population growth has built up on the existing species with population growth in the local population increasing and more areas converted to agricultural land or taken over by human settlements, landfills and road construction. Population pressure results in cultivation of larger areas of wetlands without considering ecological balance, leading to environmental impacts e.g. upstream of Rusumu Wetland degradation leads to loss in groundwater recharge, decreased buffering capacity of wetland against floods, loss of filter functions to absorb and degrade pollutants and decrease in water quality, destruction of natural habitat for wetland related organisms and loss of biodiversity. There is no enforcement of laws to restrict development activities like cultivation, construction of houses, sand/clay mining in wetlands areas which are treated as public property. Lack of coordination and conflicting institutional policies within governments e.g. conversion of wetlands for urban expansion and conservation of wetland zones for the regulation of storm waters directly increase this conflict.

The biodiversity hotspots areas so far identified in the Kagera River basin cover a wide variety of areas with some of them containing endangered or unique species that have been listed under the Convention on International Trade on Endangered Species (CITES) and the World Conservation Union-IUCN.

In the Kagera River basin, wetland areas are associated with open lakes and river systems that are covered by vegetation, mainly papyrus grass and tree swamps. The wetland areas have been described as important habitats for protection of birdlife in the Kagera River basin. These include Mugesera, Kagera, Nyabarongo, Rugezi and Akanyaru Wetlands. These wetlands support a number of globally threatened species and restricted range of species such as water turtles, crocodiles, monitor lizards, snakes, otters and variety of water birds, including herons, egrets, ducks, warblers and weavers. In addition, some 180 bird species have been identified in the wetland habitats, including six European migrants (FAO, 2000).

Little detail is known of the avifauna of the site. *Chloropeta gracilirostris* has been recorded from papyrus swamps along the Ruvubu River, which flows north into the Kagera River. There are no records from within the IBA site, but it is likely to occur. During the 1990s, up to 50 *Balaeniceps rex* were estimated to remain in the area although there has been only one record from the Tanzanian part of the swamps. *Gallinago media* has been recorded once from flooded grassland along the north-western shore of Lake Rushwa and it is likely that similar habitats in the IBA are seasonally important for this passage migrant. *Laniarius mufumbiri* has been recorded throughout the course of the Kagera River and along the Ruvubu River to the south. Observations and ringing in 1987 and 1993 suggest it is not uncommon. It is unclear if

Lybius rubrifacies, the distribution of which defines the 'Dry woodlands west of Lake Victoria' Secondary Area, occurs at the site. There is little suitable habitat along the lake shore, but it is likely to occur in the hills overlooking the swamps. While only four species of the Lake Victoria Basin biome are known to occur at the site, it is possible that up to a further five may be present.

The Rugezi Wetland contains several species listed under CITES, these include marsh grass such as *Cyperus latifolius, Cyperus papyrus* and *Miscanthus violceus*. This wetland is also comprised of 19 animal species**,** which are associated with marsh plants like Grauer's scrubwarbler *(Bradypterus graueri)*. About 3000 species of animals in this wetland are considered to be endangered, hence need protection. Rugezi is estimated to have more than 10,000 species of birds and some of the bird species such as *Bostrichia hagedesh, Aonyx capensis* and *Threskion thides aethiopius* are listed by CITES as protected species.

Akagera is known to support important unique biological diversity in the basin. It constitutes an important reservoir for biological diversity with more than 500 species of birds, 9 amphibians and 23 species of Reptiles. The site contains species of marsh buck or sitatunga *Tragelaphus spekii,* which are also listed under CITES. Four species of mammals that have been listed under CITES include African elephants *(Loxodonta Africana),* buffaloes *(Sincerus caffer),* leopards *(Panthera leo)* and marsh buck *(Tragelaphus oryx)*.

Mugesera/Rweru Complex is an important principal habitat of endemic species, including *Bradypterus caupalis, Laniarius mufumbiri, Casticola carruthersii* and other protected species of marsh bucks or sitatunga *(Tragelaphus spekii* and spotted-neck otter *(Lutra maculicolis)*-which are fish–eating small mammals.

Lake Ihema, Hago and Ruanyakiziga contain large number of wild pigs *(Potamochoerus porcus)* and marsh bucks *(Tragelaphus spekii)*, which are considered to be important species listed under CITES and IUCN. There are some carnivorous animals like blotched / spotted genet *Genetta tigrina)*, which are also listed under IUCN. The Ihema Lake comprises of 34 species of Reptiles with 21 Genera and 9 Families. The lake also contains some fish species *(Astatoreochromis alluandi)*, which are also listed by CITES as protected species. Lake Ihema vegetation is dominated by giant marsh grass *(Cyperus papyrus, Potamogeton Sp.*and *Phragmites)*, which constitute an important source of detritus to the Akagera River. The littoral vegetation is characterized by herbaceous plants *(Aeschynomena elasphroxylon* and giant grass species *(Poaceae* and *Cyperaceae)*, which provide an important habitat and potential source of nutrients to fish. The hippopotamus *(Hippopotamus amphibious)* is the dominant large mammals in the lake.

Other important wetland areas include: Lake Rwihinda (Burundi), Ruvubu Wetlands and Akanyaru Valleyon on the Burundian side; The Rusumo Swamps (Upstream of Rusumo Falls), Lake Ihema, Lake Cyohoha, Lake Rugweru, Lake Mugesera, Bugesera Wetlands on the Rwanda side; and Minziro-Sango Bay Swamp Forest in Uganda.

5.2.10 Lake Tana Wetlands Complex

Lake Tana (Figure 18) is the largest lake in Ethiopia located on the northern plateau part of the Ethiopian highlands. The lake wetlands have ben selected to provide an in-depth evaluation of available biodiversity resources with respective listings of species (see also Annex 3) as an illustration of the current body of knowledge available from the literature.

Lake Tana is shallow with an average depth of 9.5 m and contains half the country's freshwater resources (ENTRO 2007a). There are 37 islands in the lake many supporting large colonies of birds.

The regional capital of Amhara, Bahir Dar, with ca 180,000 inhabitants is located on the southern border of the lake. The major habitats found around Lake Tana are farmland, grassland, forest, rocky areas, marsh, and reedbeds. Decreasing water retention capacity is occurring, making the area prone to inundation (NBI in press). Around the lake and its catchment, including the town of Bahir Dar, live about 2.5 million people. The area around the lake has been cultivated for centuries. This lake and adjacent wetlands provide directly and indirectly a livelihood for more than 500,000 people within the basin (Vijverberg et al. 2009), not counting the tens of millions of people living in the lower reaches of the Nile River Basin.

Lake Tana is bordered by wetlands all around most of its shore and floodplains, with the exception of the northeast region. They consist of permanent and seasonal marshes and swamps as well as areas regularly inundated which forms an extensive network connected to the lake at the height of the rainy season. Wetland habitats connected to the lake are propitious nurseries for fish inhabiting the lake. They also serve as breeding ground for avian and terrestrial fauna and as such are responsible for maintaining a rich biodiversity.

The entire Lake Tana wetland complex area including the largest part of the lake, with a surface area of 304,000 ha, along with its marginal floodplains, adding another 45,000 ha (Asmelash 2004), forms an imposing area of wetlands. It is usually cited as the largest in Ethiopia (NBI in press, Vijverberg et al. 2009). However, the delineation of wetland area is often open to interpretation.

Previous studies conducted in the Lake Tana Sub-basin found that the aquatic fauna diversity was poor (MoWR 2007). However, the available baseline data for aquatic biota has remained scant to date, with the exception of fishes (Eastern Nile Power Program 2007). This situation should be rectified with the recent assessment of the wetlands and biodiversity in the Lake Tana Sub-basin. This in-depth integrated analysis of the Lake Tana`s importance in the region was carried out by local experts. The study was mandated by the Nile Basin Initiative, Nile Transboundary Environment Action Project (NTEAP) (NBI in press).

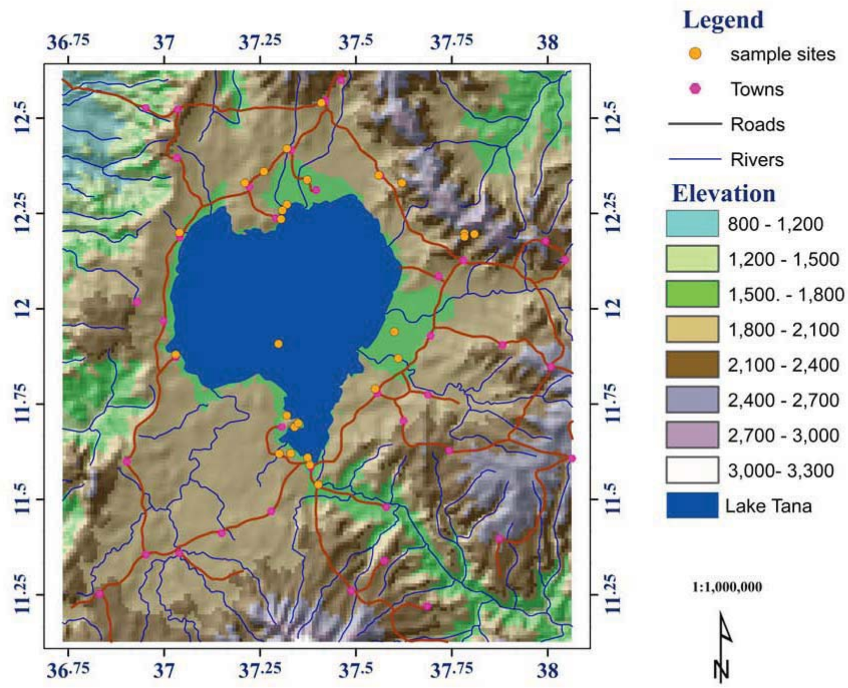

Figure 18 Map of Lake Tana sub-basin[9]

Biodiversity

The description of the biodiversity of Lake Tana draws extensively from the findings of the study that investigated the Lake Tana Sub-basin biodiversity. For the avifauna, the main source of data came from the comprehensive bird survey conducted by BirdLife International and their partners in Ethiopia, the Ethiopian Wildlife and Natural History Society, (EWNHS 1996). There are 69 designated Importance Bird Area[10] in Ethiopia. Information derived from the IBA's survey was complemented with the findings and analysis from the Lake Tana Sub-basin investigation (Wambura and NBI in press).

The next section discusses each group separately. Plants are presented first followed by mammals, birds, reptiles and amphibians, and finally fishes.

Plants (with a focus on hydrophytic species) - One of the most striking features of Lake Tana is the overwhelming presence of extensive *Papyrus* beds from which the local boats, 'tankwa', are made. Other large plants in the reedbeds are *Typha*, *Echinochloa* spp. grasses and *Polygonum* among many others. Several aquatic plants, including *Nymphaea coerulea*, *N. Lotus*, *Pistia statiotes* are noticeable.

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[9] Figure 9 shows the general impression of the landscape. Areas in green surrounding the lake indicate the presence of wetlands. The Fogera Plains corresponds roughly with the large patch east of the lake. Locations of vegetation sampling stations are shown. (source Woldu and NBI in press)

[10] Birdlife International's Important Bird Areas programme (IBAs) uses four categories for selecting priority sites: the presence of one or more threatened species; the presence of a group of species with a restricted range belonging to an Endemic Bird Area (EBA); the presence of a group of species restricted to a biome and the presence of a large number of individuals.

The riparian area along the eastern and southern region of the lake is dominated by papyrus reed beds 4 m tall (*Cyperus papyrus*), common cattail (*Typha domingensis*) and common reed (*Phragmites karka*). *Persicaria senegalensis*, hippo grass (*Vossia* spp.), bulrush (*Scirpus* spp.), and *Nymphaea lotus* are common throughout (Muluneh 2005). Submerged and floating vegetation of the lake shore and rivers occurs around the *Cyperus* and *Typha* beds. It is well represented in wetlands around the northern side of the town of Bahir Dar (Woldu and NBI in press). Common submersed macrophytes are *Ceratophyllum demersum* and *Vallisneria spiralis*.

The immense popularity of the two dominant plants found in L. Tana`s wetlands, *Typha* and *Cyperus*, for human use, mainly for building boats, for roofing material, for thatching, and for mating, is putting the wetlands at risk. However, the draining of wetlands for agricultural purposes presents the greatest risk to this important ecosystem.

Further inland sedges, reed grasses and bulrushes area found, along with swamp grasses such as *Echinochloa* spp. and *cynodon aethiopicus* that is grazed during the dry season (EWNHS 1996). Wetlands of the Fogera Plains that used to cover large areas are currently in transformation. Crop cultivation is progressively replacing permanent and temporary wetland plants. The remaining wetlands are dominated by various species of the Cyperaceae Family and by *Echinochloa staginana* (Woldu and NBI in press). A list of wetland species occurring in permanent and seasonal swamps are shown in Table 14.

Population of *Oryza longistaminata*, one of the wild rice species occurring in Ethiopia, are found in wetlands of L. Tana. This constitute the northern limit of Oryza`s distribution (Woldu and NBI in press).

Further at field the mixed forests comprise figs, *Syzygium guineense*, *Cordia africana*, *Albizia* spp., *Prunus africana* and the endemic *Millettia ferruginea* as common trees, a well-developed shrub layer and woody climbers. Huge figs, *Ficus vasta*, are also found as isolated trees in farmland and on the lake shore.

Table 14 List of major wetland species recorded from the Fogera plains (source: Getachew and Kagnew 2004, as cited in Shewaye in press)

Permanent swamp	Seasonal Swamp
Centrostachyus aquatica	*Aerva* sp.
Cyperus rotundus	*Aeschynomene schimperi*
Echinochloa colona	*Centrostachyus aquatica*
Echinochloa stagnina	*Cyperus distans*
Ipomoea aquatica	*Cyperus flavesens*
Lagarosiphon sp.	*Cyperus mundtii*
Nymphaea nouchali	*Cyperus polystachyos*
Persicaria glabra	*Cyperus rotundus*
Persicaria senegalensis	*Digitaria* sp.
Ranunculus sp.	*Echinochloa colona*
Sacciolepis africana	*Echinochloa haploclada*
	Echinochloa stagnina
	Hygrophila schulli
	Ipomea aquatica

Permanent swamp	Seasonal Swamp
	Otetelia ulvifolia
	Panicum coloratum
	Persicaria senegalensis
	Ranunculus sp.
	Sacciolepis africana
	Sesbania sp.
	Vigna vexillata
	Zannichellia palustris

It should be noted that *Cyperus papyrus*, most common sedge in and around Lake Tana as well as cattails (*Typha domingensis)* were found in the Fogera plains.

Mammals - A recent survey of mammals inhabiting Lake Tana catchment area recorded 30 species, mostly found around marginal patches of relatively undisturbed habitats, forests, woodlands, and wetlands. The list of mammals is presented in Table 15. Aquatic mammals include among others otter and the Hippopotami, the latter are mainly restricted to the river mouth of the Abay (Blue) Nile River. Other wildlife species reported in the region include vervet monkey, Anubis baboon, hyenas, mongoose and various rodents (Bakuneeta and NBI, in press).

Birds - The Lake Tana Sub-basin investigation reported a total of 215 species among 59 families of which 83 species were typical wetland species (Frances and Aynalem 2007, cited in Vijverberg 2009). Regular seasonal migrant species accounted for about a third of the total. The list of globally threatened birds encountered during the survey include the Egyptian vulture, the white-headed vulture, the great spotted eagle, the imperial eagle, the lesser kestrel and the wattled crane. Both vultures are endangered whereas the remaining four are classified as vulnerable (Warungu and NBI in press). Additionally, the list of Globally Threatened birds recorded from the “Bahir Dar – Lake Tana” IBA (ET007) and “Fogera Plains” IBA (ET006) includes the Wattled Crane (*Grus carunculatus*), the Lesser Flamingo (*Phoeniconaias minor*), and the Pallid Harrier (*Circus macrourus*), found in both sites; the Rouget's Rail (*Rougetius rougetii*) was only recorded in ‘Bahir Dar – Lake Tana (EWNHS 1996). The list of bird associated with the tree Biome-restricted assemblages for Ethiopia found in Lake Tana Sub-basin is presented in Table 16. There are three biome-restricted (A3) assemblages of international importance in Ethiopia (EWNHS 1996): the Afrotropical Highland Biome (ATHP), the Somali-Maasai Biome (SMB), and the Sudan and Guinea Savannah Biome (SGSB). Piscivorous species include residents such as African spoonbill (*Platalea alba*), yellow-billed stork (*Mycteria ibis*), pied kingfisher (*Ceryle rudis*), giant kingfisher (*Megaceryle maxima*), little grebe (*Tachybaptus ruficollis*), great white pelican (*Pelecanus onocrotalus*), great and long-tailed cormorants (*Phalacrocorax carbo*, and *P. africanus*), African darter (*Anhinga rufa*), many species of herons (*Ardeola* spp., *Egretta* spp., and *Ardea* spp.), and African fish eagle (*Haliaeetus vocifer*). Distribution of piscivorous birds is closely associated with the wetlands and inshore zones of the lake. Grey crowned crane (*Balearica regulorum*), common crane (*Grus grus*), greater flamingo (*Phoenicopterus ruber*), African open-billed stork (*Anastomus lamelligerus*), woolly-necked stork (*Ciconia episcopus*), sacred ibis (*Threskiornis aethiopica*), glossy ibes (*Plegadis falcinellus*), Hadada ibis (*Bostrychia rara*), hamerkop (*Scopus umbretta*), Egyptian goose (*Alopochen aegypticus*), spur-winged goose (*Plectropterus gambensis*) and the African pygmy goose (*Nettapus auritus*) are the most conspicuous non- piscivorous aquatic birds. Palaearctic migrants include osprey (*Pandion haliaetus*), great blackheaded, lesser black-backed and herring gulls (*Larus ichthyaetus*, *L. fuscus*, and *L. argentatus*), and whiskered and white-winged black terns (*Chlidonias hybridus* and *C. leucopterus*) (Nagelkerke 1997, cited in Vijverberg 2009).

Table 15 List of mammal species recorded in Lake Tana sub-basin

Species	Zeiger	Tera Gedam	Kunzila	Delgi	Gorgora	Bahir Dar Univ.	Gerima wetland	SNP	Total
Vervet monkey	25	8	4	2	15	18	9	5	86
Colobus guereza	1		2		3				6
Olive Baboon		2			8				10
Gelada Baboon								375	375
Anubis Baboon						3	1		4
Bushpig	2				1				3
Dik-dik	1				2				3
Bushbuck	1							5	6
Bush Duiker		1		1					2
African Civet	1			1	1				3
Porcupine			2		2				4
Hyaena (+)	1		1	1	1				4
Leopard (+)	1			1	1				3
Tree Hyrax	1				1				2
Rock Hyrax		1			2				3
Hippo	4		3	2	2	3	1		15
B. mongoose		1		2	1				4
Marsh Mongoose	1			1	2				4
W.B. Hedgehog		1			3				4
Common Jackal					2				2
Abyssinian Hare		4	1		2	1			8
Honey Badger			1		1				2
Oribi					2				2
Bats		2		10	5				8
Wild Cat						1			1
C. Porcupine	1								1
Ethiopian Wolf								2	2
Walia ibex								25	25
Klipspringer								15	15
Mole Rat								13	13
Total	**41**	**20**	**14**	**21**	**57**	**26**	**11**	**440**	**143**

Legend: (+) identification from tracks. **SNP**: Simien National Park

Table 16 ‘Biome-Restricted’ (A3) bird assemblages compiled from the Lake Tana sub-basin survey (Nov-21 to Dec-02, 2007)

Common Name	ATHP	SMB	SGSB
Wattle Ibis	✓		
Blue-winged Goose	✓		
Shelley’s Starling		✓	
Slender-billed Starling	✓		
Fischer’s Starling		✓	
Green-backed Eremomela			✓
Pale Chanting Goshawk		✓	
Black-winged Lovebird	✓		
White-cheeked Turaco	✓		
White-bellied Go-away Bird		✓	
Banded Barbet	✓		
Black-billed Wood Hoopoe		✓	
White-winged Cliff-chat	✓		
Rueppell’s Robin Chat	✓		
Hemprich’s Hornbill		✓	
Golden Pipit		✓	
Abyssinian Catbird	✓		
Taita Fiscal		✓	
African Citril	✓		
Blue-capped Cordon-bleu		✓	
Brown-rumped Seed-eater	✓		
Purple Grenadier		✓	
Baglafecht Weaver	✓		
Grey-headed Silverbill		✓	
Abyssinian Black-headed Oriole	✓		
Total	**13**	**11**	**1**

Source: adapted from Warungu and NBI (in press)

The general trend regarding the birds ‘most at risk’ for this region has not been re-assessed since the work of published in by EWNHS in 1996. These birds are likely to be affected by the general tendency towards fragmentation and overall loss of their critical habitats, including wetlands. Wetlands and riverine ecosystems serve as wintering or passage grounds for most migrant birds (Warungu and NBI in press).

Despite the significant habitat degradation, birdlife along Lake Tana and its wetlands is rich and diverse. A recent survey around Bahir Dar IBA found c. 83 birds that were typical wetland species (Frances and Aynalem 2007, cited in Vijverberg 2009). Piscivorous species include residents such as African spoonbill (*Platalea alba*), yellow-billed stork (*Mycteria ibis*), pied kingfisher (*Ceryle rudis*), giant kingfisher (*Megaceryle maxima*), little grebe (*Tachybaptus ruficollis*), great white pelican (*Pelecanus onocrotalus*), great and long-tailed cormorants (*Phalacrocorax carbo*, and *P. africanus*), African darter (*Anhinga rufa*), many species of herons (*Ardeola* spp., *Egretta* spp., and *Ardea* spp.), and African fish eagle (*Haliaeetus vocifer*).

Distribution of piscivorous birds is closely associated with the wetlands and inshore zones of the lake. Grey crowned crane (*Balearica regulorum*), common crane (*Grus grus*), greater flamingo (*Phoenicopterus ruber*), African open-billed stork (*Anastomus lamelligerus*), woolly-necked stork (*Ciconia episcopus*), sacred ibis (*Threskiornis aethiopica*), glossy ibes (*Plegadis falcinellus*), Hadada ibis (*Bostrychia rara*), hamerkop (*Scopus umbretta*), Egyptian goose (*Alopochen aegypticus*), spur-winged goose (*Plectropterus gambensis*) and the African pygmy goose (*Nettapus auritus*) are the most conspicuous non- piscivorous aquatic birds.

Palaearctic migrants include osprey (*Pandion haliaetus*), great blackheaded, lesser black-backed and herring gulls (*Larus ichthyaetus*, *L. fuscus*, and *L. argentatus*), and whiskered and white-winged black terns (*Chlidonias hybridus* and *C. leucopterus*) (Nagelkerke 1997, as cited in Vijverberg 2009).

EWNHS (1996) excerpt from the section on Bahir Dar – Lake Tana, Site: ET007

> "This site is particularly important for water birds, some of which occur in large numbers. In combination, numbers are thought to exceed 20,000 seasonally. A detailed count was made in December 1993. Species that occurred in particularly high numbers included *Phalacrocorax carbo*, *Anhinga rufa* (98+), *Mesophoyx intermedia*, *Threskiornis aethiopicus*, *Dendrocygna bicolor* and *D. viduata*. Other water birds of interest noted in substantial numbers include *Anastomus lamelligerus* and *Grus grus*. *Grus pavonina*, *Larus ichthyaetus*, *Larus cachinnans* and *Egretta gularis* occur in smaller numbers, and both *Botaurus stellaris* and *Podica senegalensis* have been recorded. In addition Bahr Dar has the most northerly records in Ethiopia of *Sarothrura rufa*. A number of globally threatened species occur: *Grus carunculatus*, seen irregularly in small numbers; *Phoenicopterus minor*, whose numbers fluctuate unpredictably; *Rougetius rougetii*, resident in small numbers; *Circus macrourus*, fairly common during migration time, with a few over wintering; and *Aquila clanga*, recorded at the site but rare.
>
> A survey in March 1996 recorded 217 species, and more are known to occur. *Asio abyssinicus*, *Parus leuconotus*, *Serinus xanthopygius* and *Lybius undatus* are notable among the Afrotropical Highlands biome species. In addition, two Sudan-Guinea Savannah biome species have been recorded. Other species of interest include *Nectarinia kilimensis*, which has been reported on a number of occasions, and *Lagonosticta rufopicta*, which is fairly common. *Ceratogymna brevis* nests in the large figs around the lake, including in the grounds of the larger hotels in Bahr Dar, and both *Picoides obsoletus* and *Cisticola eximia* are known from the area to the west of Lake Tana."

EWNHS (1996) excerpt from the section on Bahir Dar – Lake Tana, Site: ET006

> "This site is important for a number of globally threatened species: *Falco naumanni* and *Circus macrourus*, which occur on spring and autumn migration; *Grus carunculatus*, which is uncommon; and *Phoenicopterus minor*, whose numbers fluctuate unpredictably. A survey in March 1996 found *Gallinago media* in the swampy grasslands, and it may also be expected on autumn migration when the habitat would be more suitable. The marshes are important for water birds including *Grus pavonina* and *G. grus*, and may also be suitable for *Sarothrura rufa* and *Sarothrura ayresi*. Fig trees at the site are popular with

Poicephalus flavifrons. In addition, one species of the Sudan-Guinea Savannah biome occurs."

Reptiles and Amphibians - The available information about the herpetofauna of the area is very poor and scattered. A survey of amphibians from Lake Tana sub-basin yielded a total of 17 species among 9 genera and 5 families (Table 17). Three species were among the Ranidae (true frog) family are endangered (Saber and NBI in press). Information on amphibians is however relatively limited. According to the IUCN Red List of Threatened species for Lake Tana associated wetlands, the area was classified as 'Data Deficient' in 2006.

Table 17 Amphibian species surveyed from Lake Tana sub-basin (source: Saber and NBI in press)

FAMILY	GENUS	SPECIES
PIPIDAE	*Xenopus*	*Xenopus clivii*
BUFONIDAE	*Bufo*	*Bufo Garmani*
		Bufo kerinyagae
		Bufo regularis
		Bufo sp.
RANIDAE	*Rana*	*Rana angolensis*
	Ptychadena	*Ptychadena anchietae*
		Ptychadena neumanni (E)
		Ptychadena porosissima
		Ptychadena pumilio
		Ptychadena wadei (E)
	Cacosternum	*Cacosternum boettgeri*
	Phrynobatrachus	*Phrynobatrachus minutus* (E)
		Phrynobatrachus natalensis
HYPEROLIIDAE	*Leptopelis*	*Leptopelis bocagii*
	Hyperolius	*Hyperolius balfouri*
HEMISIDAE	*Hemisus*	*Hemisus marmoratus*

(E): endemic species.

The reptile fauna of Lake Tana Sub-basin includes 3 important orders. Squamata (lizards and snakes) forms the larger group of the three with 33 species. Crocodilia and Testudines are both represented by a single genus *Crocodylus niloticus* and *Geochelon pardalis* (leopard tortoise) respectively. The largest reptiles are the Nile Monitor (*Varanus niloticus*) and a python (*Python sebae*). The list of reptiles sampled from Lake Tana Sub-basin is presented in Table 18.

Table 18 Reptilian species composition recorded from Lake Tana sub-basin (source Saber and NBI in press)

ORDER	FAMILY	SPECIES
SQUAMATA	AGAMIDAE	*Acanthocercus cyanogaster* (RE)
		Agama doriae
		Agama sp.
	CHAMAELEONIDAE	*Chamaeleo affinis* (E)
		*Chamaeleo africanus**
		*Chamaeleo gracillis**
	GEKKONIDAE	*Hemidactylus laticaudatus* (RE)
		Hemidactylus sp.
		Lygodactylus somalicus
	SCINCIDAE	*Chalcides ragazzii*
		Lygosoma sp.
		Mabuya isselii (RE)
		Mabuya maculilabris
		Mabuya quinquetaeniata
		Mabuya varia
		Mabuya wingatii (RE)
	VARANIDAE	*Varanus niloticus**
		Rhinotyphlops somalicus (E)
		Typhlops lineolatus
	BOIDAE	*Python sebae**
	COLUBRIDAE	*Coluber florulentus*
		Crotaphopeltis hotamboeia
		Dasypeltis scabra
		Lamprophis fuliginosus
		Lycophidion capense
		Meizodon regularis
		Natriciteres olivacea
		Philothamnus battersbyi
		Psammophis sibilans
		Psammophis sp.
		Pseudoboodon lemniscatus (RE)
		*Dendroaspis polyepis**
		*Naja haje**
CROCODILIA	CROCODYLIDAE	*Crocodylus niloticus**
TESTUDINES	TESTUDINIDAE	*Geochelone paradalis**

(E): endemic species, (RE): regional endemic
The asterisks '*' denotes Species listed in CITES (the Convention on International Trade in Endangered Species of Wild Fauna and Flora).

One species was found under the category "Critically Endangered", the python. This species is losing ground due to habitat loss and from human persecution, suffering from 'negative press' as the usual suspect to blame for the killing of domestic animals (goats and sheep). The Nile crocodile, water snake and Nile monitor are regarded as "Vulnerable". The high number of endemic species should also be noted.

The fish community of the lake is dominated by cyprinid fishes represented by four genera. The lake has 27 fish species of which 20 are endemic (e.g. *Labeobarbus* spp., *Barbus* spp., *Garra* spp.) to the Lake catchment (Vijverberg et al. 2009). *Labeobarbus* has 15 endemic species out of 16 present. The lake has one cichlid, *Oreochromis niloticus* (Nile tilapia), one representative of the catfish family (Clariidae), *Clarias gariepinus* (African catfish), and Beso (*Varicorhinus beso*). All three are commercially important fish species and, along with 8 of the 15 *Labeobarbus* species, are known to spawn in the wetlands, which act as nurseries (NBI in press). A lesser known species, *Nemacheilus abyssinicus* (Balitoridae) is a loach primarily found in small streams of the Lake Tana catchment.

Fish - The fish community of Lake Tana is dominated by cyprinid fishes represented by four genera (e.g. *Labeobarbus* spp., *Barbus* spp., *Garra* spp.) The lake has 27 fish species in total of which 20 are endemic to the Lake catchment (Vijverberg et al. 2009). Labeobarbus has 15 endemic species out of 16 present. The lake has one cichlid, *Oreochromis niloticus* (Nile tilapia), one representative of the catfish family (Clariidae), *Clarias gariepinus* (African catfish), and Beso (*Varicorhinus beso*). Beso and *Garra dembeensis* are commonly found in rivers and lakes of the Ethiopian Highlands, whereas *G. Regressus* and *G. Tana* are endemic species of the lake (Dejen and NBI in press). Table 19 lists 25 out of the 27 species. Additional species include the lesser known species, *Nemacheilus abyssinicus* (Balitoridae) is a loach primarily found in small streams of the Lake Catchment and *Labeobarbus degeni* (Dejen and NBI in press). The list of fish species recorded from Lake Tana is presented in Table 19.

The fish fauna of Lake Tana consists in part of resilient, flexible species such as *O. Niloticus* and short lived, small-sized diploid, the African Barbus, as well as species-rich, endemic and ecologically specialized group of fish (hexaploid large *Labeobarbus*, *syn. Barbus*). Wetlands are important habitats supporting many of Lake Tana's fish fauna. Wetlands are spawning ground as well as acting as nursery habitat for juveniles. There are eight riverine spawners, almost all among the large barbs (*Labeobarbus*), mainly using Gumara and Dirma River (de Graaf 2003).

Table 19 List of fish fauna from Lake Tana and Gumara River, their diets and endemic status (Sources: MoWR 2007, Dejen 2003)

Family	Genera	Species	Remarks
1. Cyprinidae	*Varicorhinus*	*V. beso*	
	Garra	*G. quadrimaculata*	
		G. dembeensis	
		G. regressus	
		G. tana	
	Labeobarbus	*L. acutirostris*	Endemic and Piscivorous[1]
		L. dainellii	Id
		L. gorguari	Id
		L. longissimus	Id
		L. macrophtalmus	Id
		L. megastoma	Id

Family	Genera	Species	Remarks
		L. platydorsus	Id
		L. truttiformis	Id
		L. brevicephalus	Id
		L. crassibarbis	Endemic and non-Piscivorous[2]
		L. gorgorensis	Id
		L. nedgia	Id
		L. surkis	Id
		L. tsanensis	Id
		L intermedius	Id
	Barbus	*B. humilis*	Large African Barbus
		B. pleurogramma	Id
		B. tanapelagius	Id
2. Clariidae	*Clarias*	*C. gariepinus*	African catfish – Omnivore; moderately resilient to fishing pressure
3. Cichlidae	*Oreochromis*	*O. niloticus*	Tilapia – Planktivore; opportunist and most resilient to fishing pressure

[1] Food specialists (narrow preferences) and riverine spawners, highly vulnerable to fishing pressure, especially when targeted during spawning periods.
[2] Lacustrine spawners, highly vulnerable to fishing pressure

Development and Conservation Issues, Impact on Biodiversity and Trends

The management of the Lake Tana wetland complexes presents an overwhelming challenge. Recent assessments of the current situation are raising concerns about the state of environment (NBI *in press*). Wetlands degradation is widespread and for some areas it is beyond repair. Large swaths of land are converted for human use. Pressures and threats confronting the wetlands are varied and almost all types of threats are represented in this vast region. Lack of awareness is probably the overarching threats for any wetland areas, here and beyond, compounding both the socio-economic as well as the institutional and policy environment.

Environmental degradation resulting from expanding agriculture activities is a confronting reality resulting from an ever increasing population pressure, and this especially acute for agricultural-based economies. This in combination with unabated deforestation along the steep slopes characterising the surrounding watersheds present an imminent risk to the ecosystems with a steady deterioration of soil conditions. An increase in the sediment load directly impacts on the wetlands by an acceleration of the sedimentation process.

The plant biodiversity and the landscape in general has long been shaped by human presence and its wide ranging influence in the region, however there are new threats emerging. Over harvesting of wetland plants as well as unregulated fishing practises are direct causes to the loss of biodiversity. In areas where wetlands have been transformed to agricultural lands, the biodiversity has been completely transformed from wetland species to cropland species. Problems linked to the presence of invasive species are also creeping up. In some areas drained wetlands are harbouring pest birds, which are being attracted by a *Hygrophilla auriculata*, a weed that proliferates in degraded wetlands (Woldu and NBI in press)

Urban encroachment, pollution, and alteration of the hydrology of the lake and its tributaries are also compounding factors. The town of Bahir Dar is one of the numerous towns rapidly expanding. Their impact on the natural environment will be far reaching. This and the alteration of the lake hydrological regimes that will result from the development of hydropower projects is most likely going to have a large-scale ecological implications (Woldu and NBI in press).

Fisheries Decline

The major reason for the collapse of these fish species is due to destructive fishing during their spawning season. These species form aggregations in the river mouths in August–September, during which period they are targeted by the commercial gillnet fishery. Overfishing of *Labeobarbus* by traditional fishermen and opportunistic farmers has reduced their population number to a very low level. This species is particularly vulnerable near and at river mouths and upstream on and near the spawning grounds. Additionally destruction of spawning grounds by farmers who build small scale irrigation channels for their agricultural lands contributes to the reduced recruitment. It is clear that in case of the migrating labeobarbs recruitment-overfishing is taking place and that the seven species of this unique species flock are in danger of becoming extinct (Vijverbert et al. 2009).

In a recent study Dejen et al. (2006) suggested that *Barbus tanapelagius* would be a better target for the lake's fisheries. This would help alleviate pressure on juvenile large barbs since the *B. tanapelagius* utilizes different areas of the lake.

Hippo Sanctuary

A programme to manage the hippo population (*Hippopotamus amphibious*) in Lake Tana, near Gerima wetland, is examined (NBI in press). As the hippo habitat is increasingly being threatened with development projects, the Department of Wildlife, Wetlands and Forests of Bahir Dar University should explore the possibility of starting a Hippo Sanctuary in the land between the out-of-town Campus. This may require the University to acquire more land and as the populations could increase with time.

Conservation Initiatives

A number of large-scale conservation initiatives would help improve the environmental situation and curb the rate of habitat loss and ecosystem degradation:

- Designating the Lake and its associated wetlands, particularly around the Fogera Plains should be considered. However, Ethiopia needs first to ratify the Convention on Wetlands of International Importance especially as Waterfowl Habitat (Ramsar Convention);
- Designating the lake as UNESCO Biosphere Reserve would require that the lake be legally protected by proclamation of a National Park (Woldu and NBI in press)

Institutional Development

The Development activities around the Lake Tana sub-basin fall under different regimes and mandates and are not coordinated under one roof to the detriment of biodiversity conservation. This awkward situation puts the protection of biodiversity and habitat loss at a risk since it does not appear as a priority to decision makers nor to the communities living around them (NBI in press).

New local civic society has recently been formed (February 2007. The Lake Tana Environmental Protection Society was established with the principal aim of raising awareness on Lake Tana and its surroundings. The society intends to involve the community, institutions and individual members, with a strong focus on professional commitment. This society should help raise awareness about the importance of the lake to all levels of government (Woldu and NBI in press).

Buffer zones, corridor and passages in wetlands and lake's edge have not been recognised – no legislation exists to address this matter.

The role and linkages between institutions and communities in the sub-basin should be better defined within a legal framework, including legislations and laws rather than cultural and institutional norms only.
The creation and institutionalization of a Lake Tana Basin Organization and Blue Nile Basin Organization to coordinate and take charge of the ecological en economic concerns in the two basins is being suggested (NBI in press). Both organizations would act as a centralized institution.

5.3 WETLANDS PATTERN "TREND" AND CHANGE ANALYSIS

A wetland "trend" analysis has been carried out for selected wetlands in the Nile Basin. To utilize information dating as far back as possible, Russian as well as English topographical maps of the 1950's were used to digitize the wetlands shown on these maps. The resulting areas and patterns were compared with the wetlands mapped from the Landsat images/NDVI and changes in-between the years derived and shown in Table 20.

Table 20 Comparison of wetland areas derived from historical maps and derived from the Landsat NDVI analysis derived in the study

	Historical map area (km^2)	Landsat mapped area (km^2)	Area change (km^2)	Area change historic = 100%
Albert Nile	980.1	630.8	-349.3	64 %
Bahr el Ghazal Swamps	18748.1	28340.9	9592.8	151 %
Kagera Swamps	4831.1	6225.8	1394.7	129 %
Kyoga Swamps	13730.3	14220.2	489.9	104 %
Mara Wetlands	1849.2	1581.8	-267.4	86 %
Nile Delta	21017.7	19850.9	-1166.8	94 %
Sio Malaba Malakisi	420.3	431.0	10.7	103 %
Sobat Marches	12007.8	10662.7	-1345.1	89 %
Sudd Swamps	18109.4	25166.4	7057.0	139 %
Winam Gulf	498.1	262.8	-235.3	53 %
Lake Tana Wetlands	3215.9	3130.6	-85.3	97 %

Evaluating these results, the strong dependence of the wetlands on the hydrological situation and the large potential range of possible size fluctuations with the different seasons and over different years needs to be understood and considered. Results shown in Table 20 therefore should be seen as an indication of potential changes in wetland size, which, depending on drivers and pressures can considerably vary. More detailed observations are needed to get a better picture of the hydrology or climate related trends in the wetlands.

The results shows increasing wetland sizes for the Equatorial Lakes, and large natural swamps like the Sudd and Bahr el Ghazal, and decreasing areas for the Mara Wetlands, Winam Gulf and the Nile Delta, the latter most likely caused by anthropogenic pressures. The decrease in size in the Baro-Akobo-Sobat may be related to mapping inaccuracies. Visual comparisons of the change pairs are shown in Figures 19 to 29. Issues that need to be considered include among others artificial decline in water levels leading to a decrease of wetland areas, population pressure, conversion to farmland or climate change factors. Based on the unknown conditions in deriving the historical maps that were utilized for the comparison, the results anyhow carry a high uncertainty.

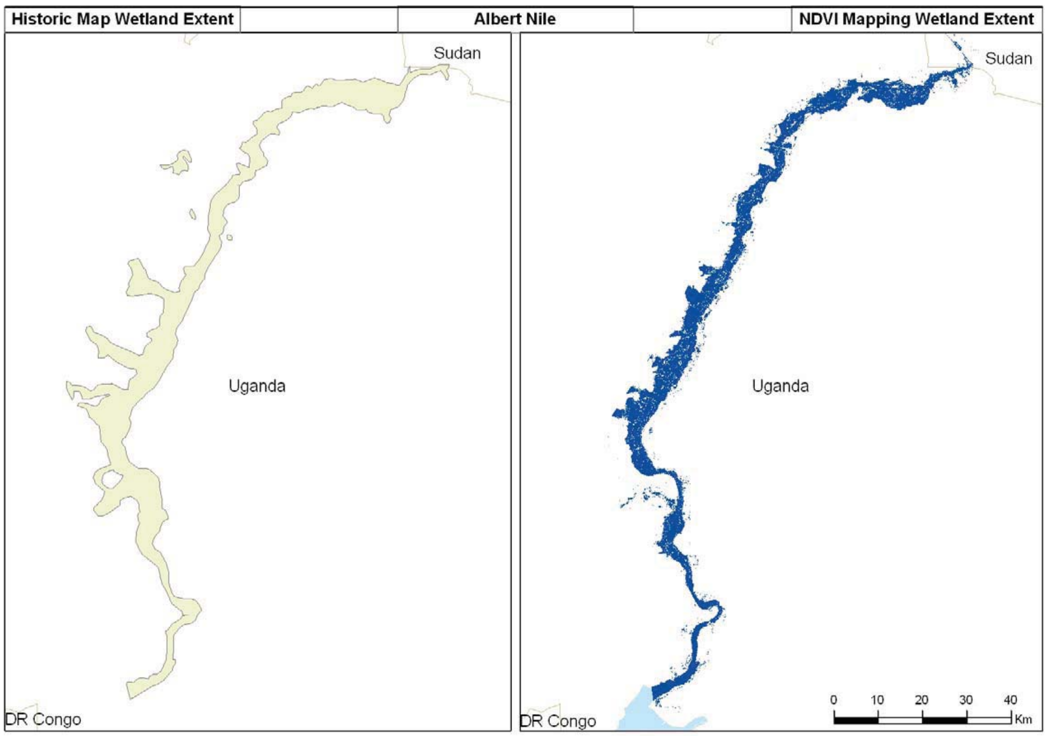

Figure 19 Changes in wetland patterns on the Albert Nile between the 1950es and the 1980es-1990es between historical map and remote sensing derived wetland data

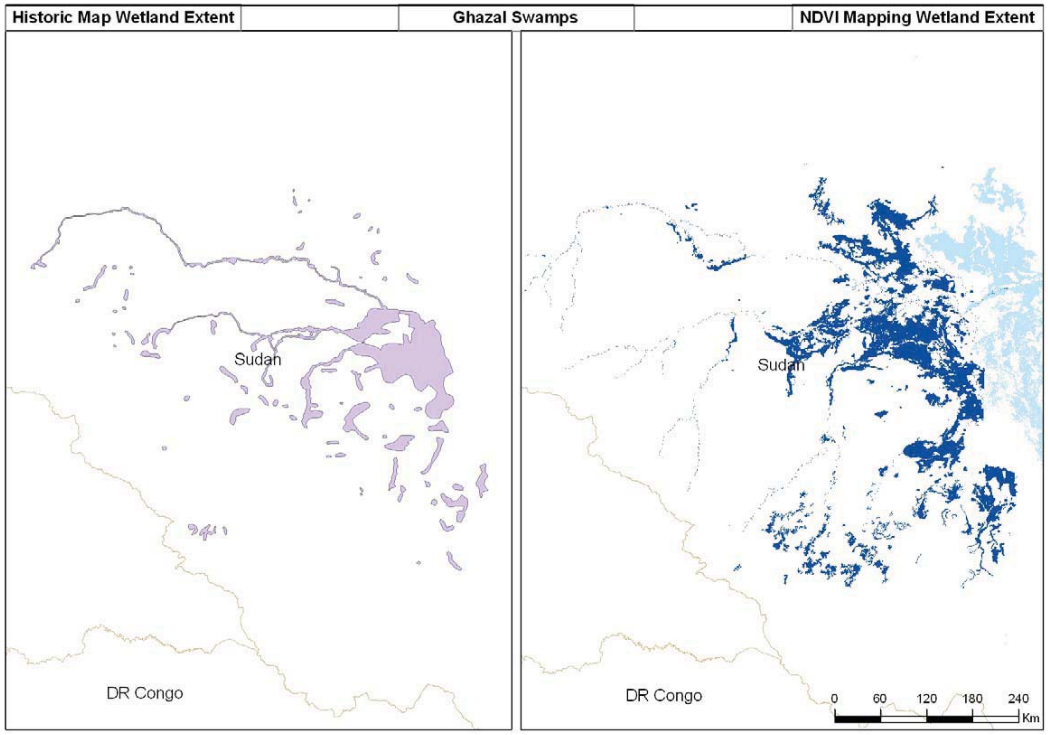

Figure 20 Changes in wetland patterns in the Bahr el Ghazal swamps between the 1950es and the 1980es-1990es between historical map and remote sensing derived wetland data

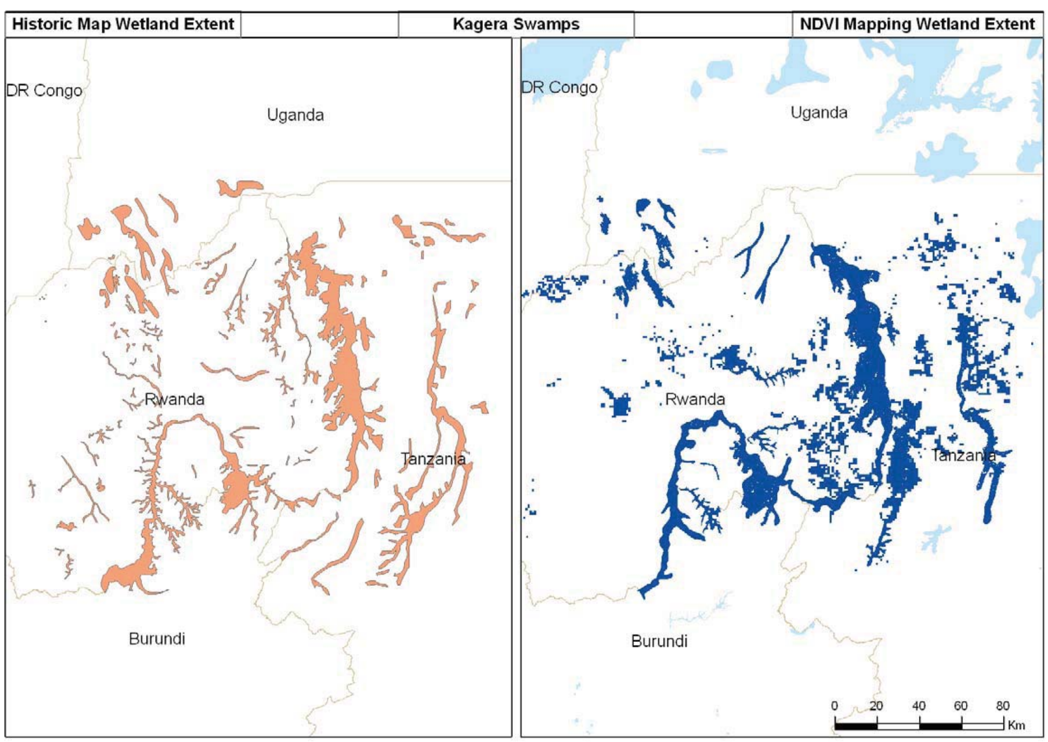

Figure 21 Changes in wetland patterns in the Kagera swamps between the 1950es and the 1980es-1990es between historical map and remote sensing derived wetland data

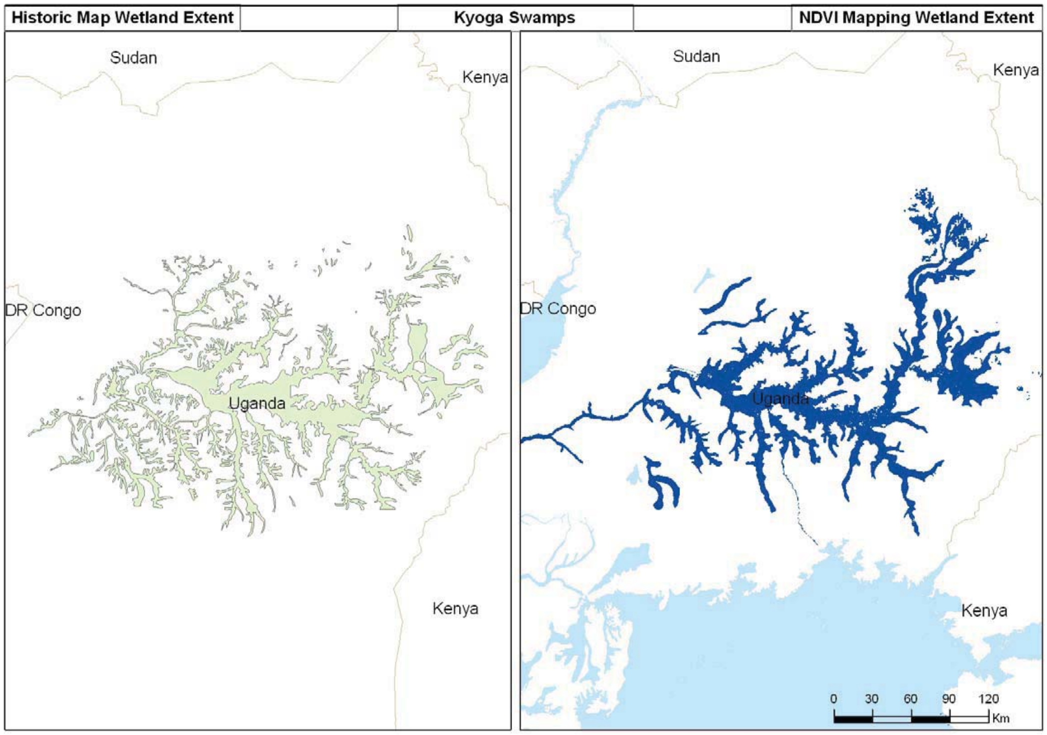

Figure 22 Changes in wetland patterns in the Kyoga swamps between the 1950es and the 1980es-1990es between historical map and remote sensing derived wetland data

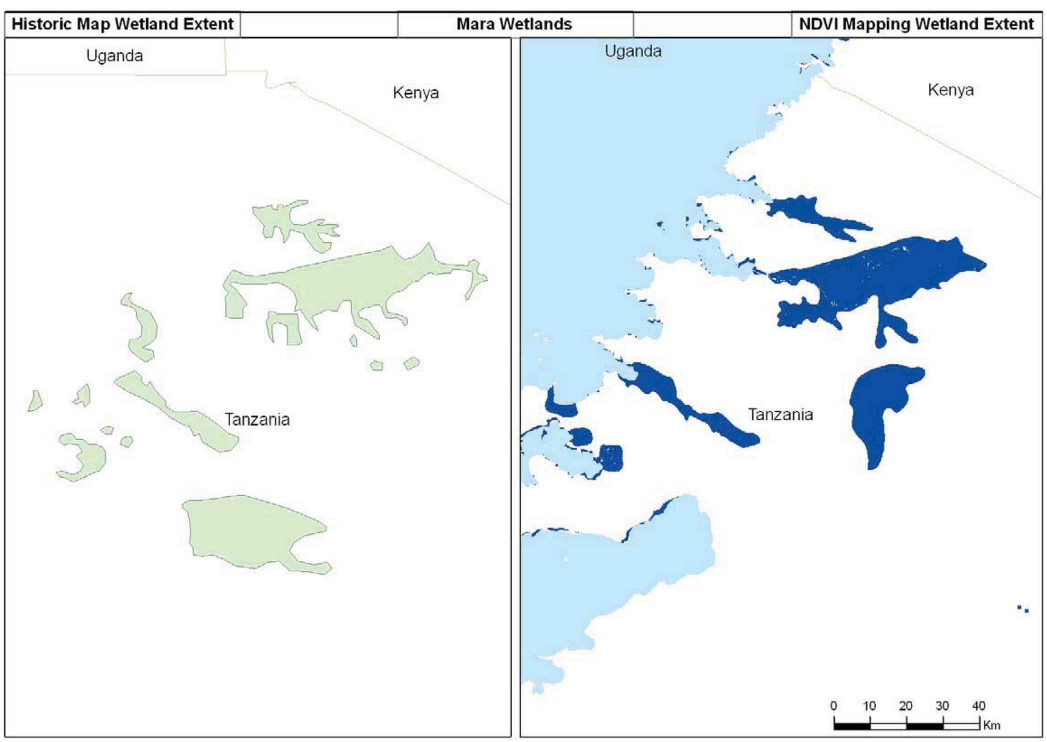

Figure 23 Changes in wetland patterns in the Mara wetlands between the 1950es and the 1980es-1990es between historical map and remote sensing derived wetland data

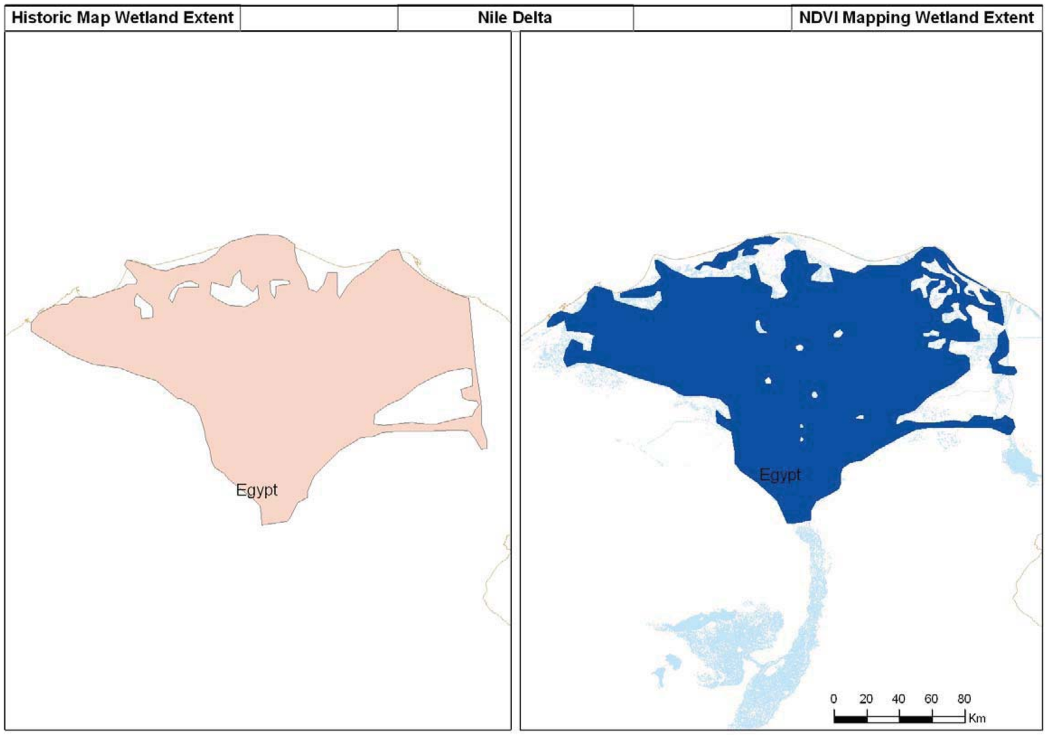

Figure 24 Changes in wetland patterns in the Nile Delta between the 1950es and the 1980es-1990es between historical map and remote sensing derived wetland data

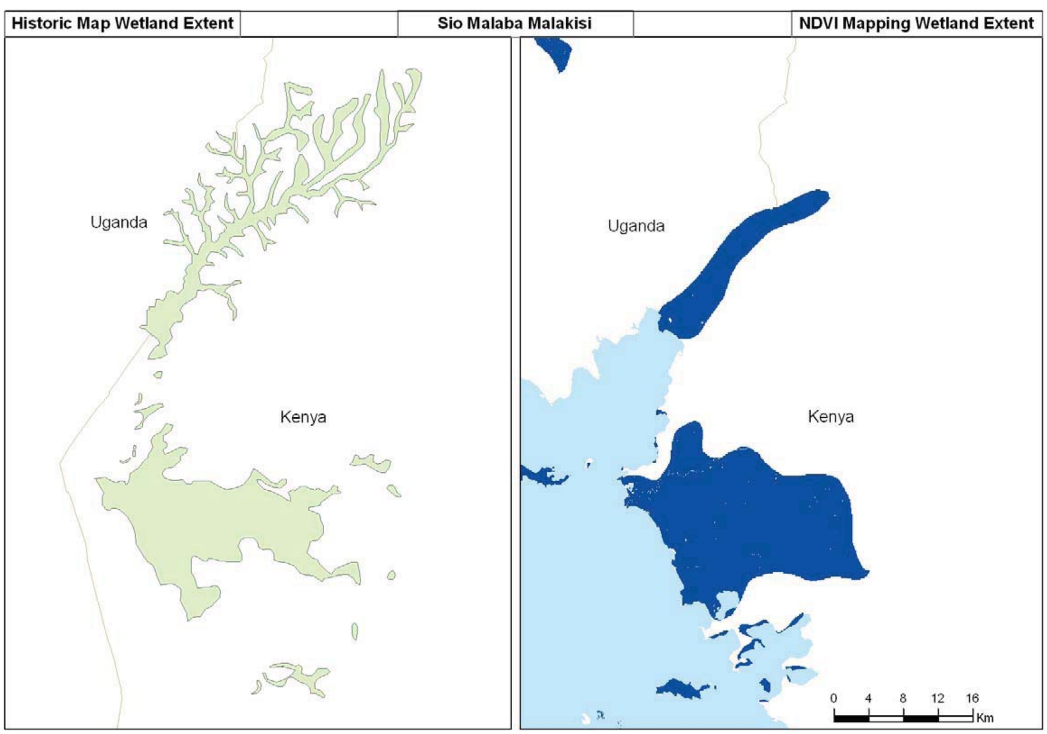

Figure 25 Changes in wetland patterns in the Sio-Malaba-Malakisi swamps between the 1950es and the 1980es-1990es between historical map and remote sensing wetland data

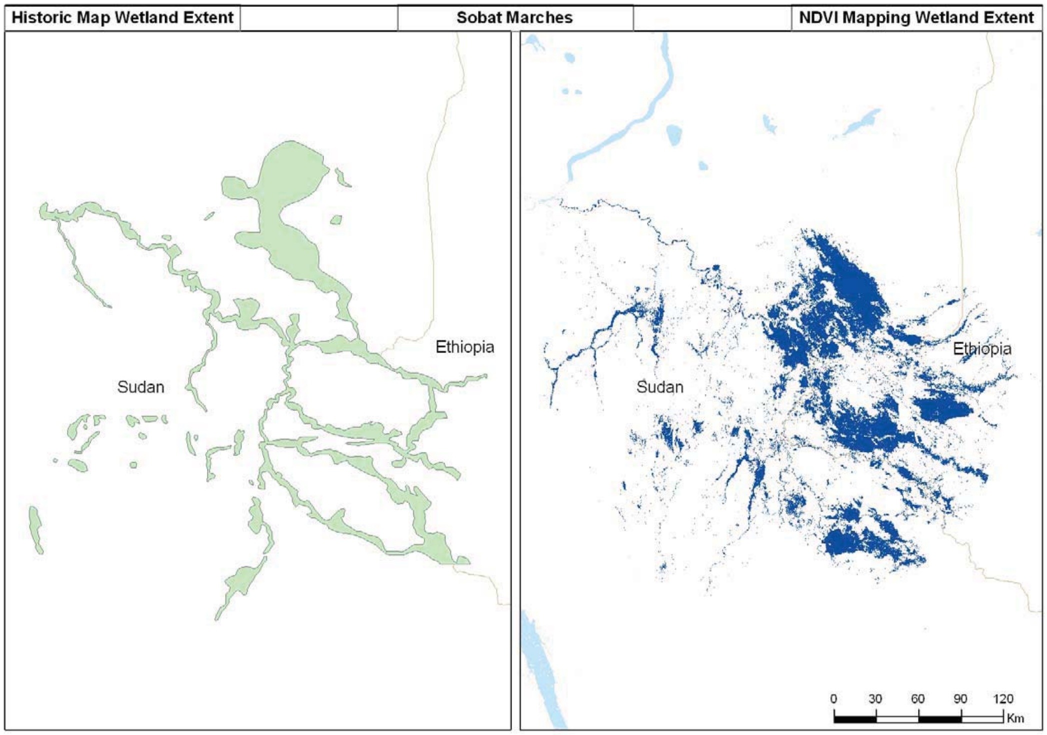

Figure 26 Changes in wetland patterns in the Sobat Marshes between the 1950es and the 1980es-1990es between historical map and remote sensing derived wetland data

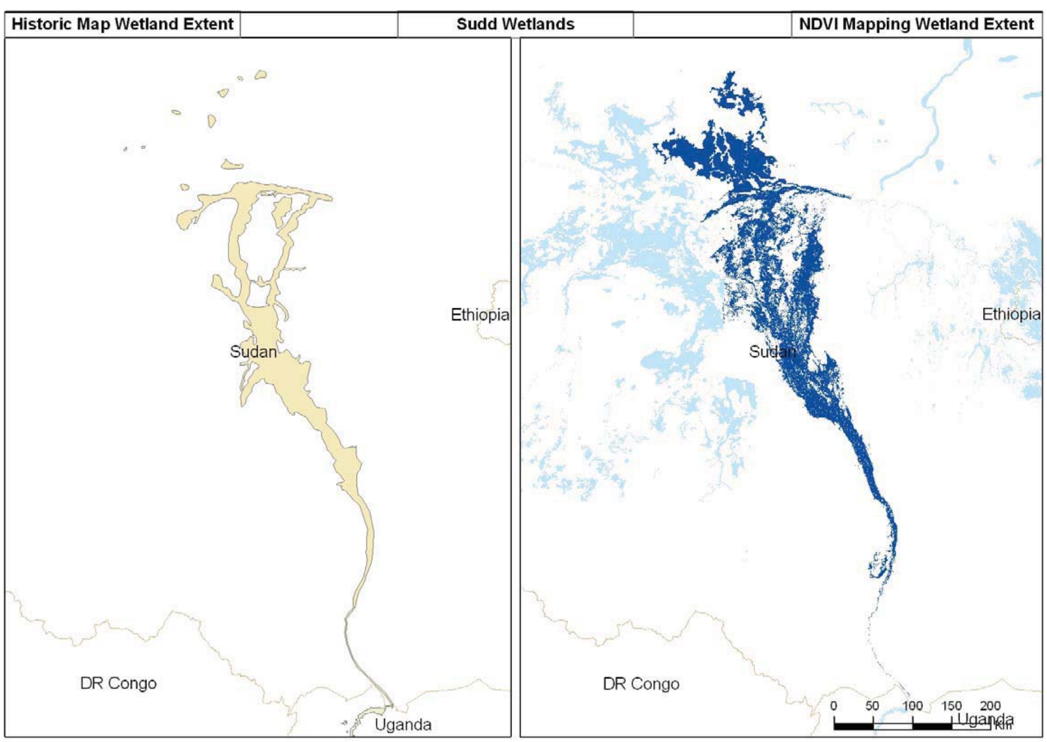

Figure 27 Changes in wetland patterns in the Sudd swamps between the 1950es and the 1980es-1990es between historical map and remote sensing derived wetland data

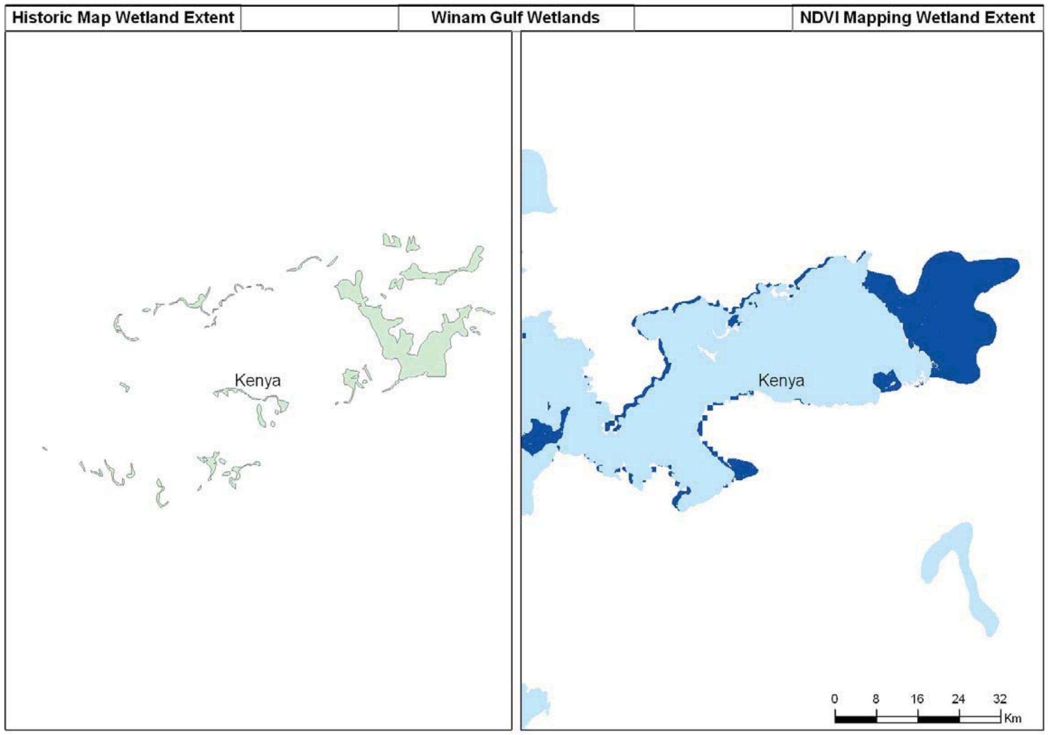

Figure 28 Changes in wetland patterns in the Winam Gulf between the 1950es and the 1980es-1990es between historical map and remote sensing derived wetland data

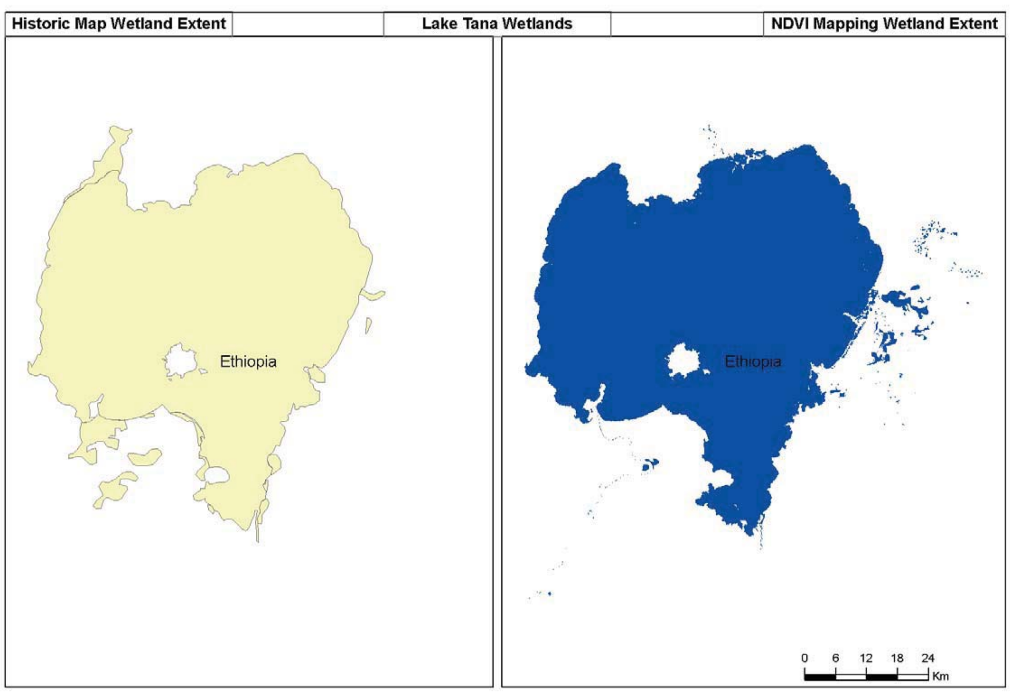

Figure 29 Changes in wetland patterns Lake Tana between the 1950es and the 1980es-1990es between historical map and remote sensing derived wetland data

6. Conclusions

The wetland inventory and mapping of the Nile Basin has been carried out using a combination of remote sensing, ground truthing and stakeholder consultation approaches. The following conclusions are drawn up based upon the work that has been undertaken:

- Wetlands in the Nile Basin have been mapped on a basin wide scale and their attributes described in a baseline inventory GIS database. This inventory and the surveys conducted for its setup are a starting point, representing a baseline state of the wetlands in the Nile Basin.

- A number of approaches were tested to select the most suitable one to map the wetlands. The Normalized Difference Vegetation Index (NDVI) has proved to give better results than other approaches hence it was used for this purpose.

- Wetland extents and outlines that have been detected using the remote sensing data and the NDVI approach are a snapshot based on dry season Landsat images that were used for this assignment. The representation of the wetlands can therefore deviate from what is actually found on ground at different points in time, especially as wetlands are dynamic ecosystems that change based on a variety of factors including hydrometeorologic, environmental and anthropogenic influences. Wetland attributes may also change in the same way as the physical wetland parameters.

- Landsat TM5 and ETM7 images were used successfully to obtain this baseline inventory. Advantages of using them are:
  - They are readily and freely available
  - They cover the whole of the Nile Basin
  - Their resolution (28 × 28 m) is suitable for mapping this large area.

  However, a problem that persists with the Landsat data is the Scan Line Corrector (SCL) failure that occurred in May 2003. This makes them unsuitable for use after this date as it is estimated that approximately 22% of any scene is affected leading by this problem. For the current study pre 2003 images were used for mapping.

- The GIS capabilities of number of institutions in the region have been determined as a part of this study. This shows a varying degree of capability levels between the Nile Basin countries. Knowledge about these capabilities will be important for future monitoring of wetland trends and future updating of the produced wetland inventory in the Nile Basin.

- Ground truthing information has been collected from various sources, mainly from the Africover ground photographs database, photos taken during a previous field campaigns in Uganda and Sudan and data including photographical evidence collected during a field campaign in Ethiopia as part of this study. This data was used to verify and improve the NDVI classification of the mapped wetlands. It can also be used in future wetlands studies in the Nile Basin for the same purpose.

- The wetlands data and information that was collected during this study are made available in two deliverables, a GIS geodatabase and in this report. The GIS geodatabase is set up as a tool that can provide wetland information to help wetland managers in decision making. It is structured to provide input that is suitable to be used in the NBI Water Resources Management Project (WRMP) Nile Decision Support System with minimum effort. The geodatabase architecture in which the collated information is stored has been also designed in a way to allow for future updates of the existing information.

- The Ramsar classification system has been used to classify the wetlands in the Nile Basin as it is found more suitable for this purpose other then other classification systems such as FAO Africover Land Cover Classification System.

- Looking into wetland "trends", a change analysis was carried out for a number of selected wetlands in the Nile Basin comparing their extent between the 1950es and the 1990es. The results show increased wetland sizes for the Equatorial Lakes and large natural swamps like the Sudd and Bahr el Ghazal. Decreased wetland areas were found for the Mara Wetlands, Winam Gulf and the Nile Delta, assumingly due to anthropogenic pressures.

- The Nile Wetlands that have been considered as example sites in this study are under considerable pressure. Human activities are significantly altering the natural environment. Undisturbed conditions are mostly found in areas where there is little human interference.

- Overall the Nile Wetlands that have been considered as example sites in this study are under considerable pressure. Especially population growth is significantly impacting on the balances that have been maintained. More stable conditions are mostly found in areas where there is little population pressure.

- The historical and mapped status of wetlands in the basin have been assessed during this study as well as the development and potential threats for their ecological balances in line with identifying key animal and plant species judging their resilience or fragility to changes in the wetlands.

- Output of this study has to be seen within the context of the large extent of the Nile Basin as a top level overview and starting point for further smaller scale detailed assessments.

The inventory can provide important information to researchers, policy- and decisionmakers by offering information about the existing wetland resources. The inventory can provide input to different audiences on the technical, managerial and political level and can support educated decisions based on its compiled knowledge database.

7. Recommendations

The wetland inventory produced within this project is a baseline survey of the wetlands in the Nile Basin including their location, physical parameters as well as certain attributes such as Ramsar classes. It is recommended to undertake the following actions to improve this mapping and inventory in the future:

- Long term maintenance of the wetland database through the following steps:
  - Setup of the GIS database in a central location with defined use and access rules
  - Widespread distribution of the wetland inventory and information about its structure and utilization possibilities
  - Development of a common system and processes for data exchange and handling of updated or additional data input
  - Nile Basin countries to discuss and agree protocols for data exchange
  - A system to include further data that is currently stored in national databases should be introduced. It is recommended that the national database coordinators are approached for this transfer
  - Coordinated data exchange and protocols to be observed by the host of the master database
  - Schedule for periodical maintenance of the database to work in user feedback and data provided through surveys and local knowledge of user groups.

  Stakeholder ownership, open utilization of the database, easy access for patching, and periodic maintenance projects are key aspects to maintain a valuable and up to date database

  Practicalities for future hosting, maintenance and upgrading of the database need to be discussed and agreed between the different Nile Basin countries. This will be important to secure the future of the database and long term success of the project.

- Remote sensing plays an ever increasing role in environmental assessment and management initiatives. It has been recognised that the need to develop techniques that can fill gaps in baseline wetland inventory should includes the application of remote sensing and GIS. It is therefore necessary to provide adequate training to those involved in running, maintaining and updating the GIS system to ensure that stakeholders are fully aware of the benefits of the system.

- More information in support of wetland management needs to be acquired at multiple scales from regional, national and local assessments. This information can guide policy-making and prioritization of responses to more local information on specific wetlands and guide management planning processes, including assessment and monitoring.

- Carry out multi-temporal analysis of wetlands location and extent to better study the system behaviour over different seasons and years. Define minimum and maximum wetland extents also related to the hydrology and flow events that drive the wetland systems. Such analysis will provide a better overview of the seasonal wetland patterns and on the aquatic characteristics. Using monthly images will be a suitable approach for closely assessing temporal changes in size and location.

- In line with wetland change analysis or detailed wetland trend analysis, assessments of the hydrological regimes, being a likely factor for changes in the wetlands should be conducted. With no relation to the hydrology found, other factors for investigation could include historical socioeconomic changes.

- The findings of the second stage updating exercise were evaluated and the wetland maps and GIS updated with the additional information accordingly. The approach helped to enhance the accuracy of the wetland maps and added additional information to the GIS database attribute layers. While the wetland maps and attribute information was enhanced in this way, constraints regarding fine scale accuracy and completeness of the attribute lists of the wetlands still exist as it could be expected for the basin wide approach. Future focused research and assessments in the individual swamps will need to bring further refinement and additional attribute information.

- Enhancing the Landsat satellite images derived wetlands with other sources of data to improve the results locally is recommended. An example of this is using the MODIS and Landsat satellite images by calculating the actual evapotranspiration to distinguish between open water and vegetation under different conditions. Using the high spatial resolution of Landsat with MODIS data will improve the quality of the wetland mapping. Other sources that are not based on optical sensors should also be explored.

- Findings of the second stage updating have also highlighted the need for more detailed wetland surveys of fine scale areas and individual wetlands. Comparison between the basin wide scaled maps generated by the basin wide approach with more detailed information has shown the need for finer resolution area specific approaches in order to increase accuracy. While such information was used to increased accuracy as far as available, the kind of information is lacking for many wetlands but could possibly be obtained over time by individual studies and be used for later updating exercises.

- It is recommended to carry out future studies with up to date data to identify new and monitor known hotspot areas and obtain a refined picture and understanding of issues in these hotspot areas as well as to learn lessons and improve future developments.

- Develop and implement wetlands strategies for the basin and improve institutional and community capacity to manage wetlands and networking among institutions. Information in support of wetland management needs to be acquired at multiple scales from regional, national and local assessments to guide policy-making and prioritization of responses.

- Consider climate change aspects in the wetland monitoring strategies and in the overall concept of wetland management. Climate change impacts on wetlands should be considered to judge their future vulnerability to changes which need to be included in decision making processes.

- For the last years wetlands have in many areas been seen as nuisances that disturb or inhibit human benefits. Wetlands have therefore been drained and converted and their function and biodiversity were lost. Considering ongoing research and initiatives, the importance of wetlands is anyhow seen by today’s scientists. Policies start to adapt and take consideration of the important wetland functions.

This process needs to be further supported and the conservation of wetlands as mayor biodiversity sites, breeding baskets and natural buffers for a variety of impacts needs to be strengthened and issues communicated to the involved communities.

- Consider the main challenges for wetlands management within the Nile Basin. The basin is vast in its extent, covers several countries, climatic regions and cultures with their different specific problems and focus of interest. As water politics in the basin have shown, problems and differing priorities can lead to tense situations and a good stakeholder involvement based on sound data for decision making is important for smooth discussion and implementation of policies. Management of wetlands is part of the issues of concern within the Nile Basin. With the wetlands being of transboundary dependency and influence, consideration of multiple stakeholder aspects and involvement of these is of so much more importance. Recent experience in the Lake Victoria Basin has also shown the need for long term sustainable approaches and decisions based on sound data evaluation considering a variety of aspects.

- Water quality and hydrological aspects as well as flow data have a significant impact on the wetlands but have not been tackled in this study. It is suggested to study these topics with regards to their interaction with the wetlands. Especially regarding decisions to be made on the river the influence of flows onto the wetlands as well as the influence of wetlands on altering flows is important information. As for the wetlands, knowledge of inflow and outflow quantities, inundation depth and inundation periods are important as these have a direct influence on the vegetation in the wetlands. Findings can readily be included in the database, would add to its information content and add value to decision makers.

- Socioeconomic aspects are important information for decision making and could be included in the database. Respective data may partly be available and could be collected in a data collection project. Other and especially wetland specific socioeconomic data may need to be collected in a purpose specific project.

- An important study in line with the recommended socioeconomic assessments would be an analysis of the dependency of community livelihoods on the wetlands. Such analysis would generate important decision support data when managing the wetlands. Results could be included in the inventory.

- For widespread implementation and use of the database it is recommended to specifically assess countries resources to work with the inventory. While technical knowledge and institutions may be available, capacities may be limited and concerns have been raised during previous consultations that resources may not be adequate. Suitable resources would therefore need to be found for the selected institutions in the different Nile Basin countries to work with the wetland inventory.

- For national and regional management efforts consider the key planning and decision making necessities including:
  - Stakeholder consultation and workshops, also considering indirect transboundary aspects
  - Community consultation and worshops
  - Weighing and prioritizing of multiple stakeholder aspects
  - Collection of sufficient base data for decision making

  - Long term data collection and monitoring strategy
  - Identification and focus on key issues
  - Sustanable long term approach for solution definition
  - Involvement of stakeholders in decision making process (participatory approach) and dissemination of results
  - Prioritization of win-win scenarios
  - Development of management plans agreed by all parties
  - Plan implementation including stakeholder briefings, transfer of ownership and responsibility, policy development, guideline development, coordination, and awareness raising
  - Post implementation monitoring

- Implement transboundary monitoring strategies looking specifically into hydrological and water quality parameters and observe biodiversity trends especially for hotspot areas. Long term data collection and monitoring considering cause-consequence chains can only be conducted if downstream impacts of upstream conditions or changes of conditions are sufficiently monitored. Inter-disciplinary relations as e.g. potentially between hydrology and water quality need to be considered, not only on a national but also on a transboundary level. Socioeconomic considerations need to be taken into account if e.g. hydropower aspects need to be considered. The development of a monitoring network should therefore always be based on a holistic problem approach covering its whole spatial as well as consequential parameter spectrum. The monitoring aspects are especially important for hotspot areas where biodiversity has already declined and careful monitoring is needed to observe trends. Careful definition of indicator species will be required in these areas in order to capture changes of conditions or impacts of anthropogenic developments. Long term monitoring results may also be used to extrapolate scenarios in order to forecast the impacts of certain development conditions. Implementation of the transboundary monitoring plans will require legislative acceptance of data sharing and the development of cooperation agreements.

- Mapping of biological resources is an important aspect. To achieve representative results, certain methodological concepts need to be adhered to as it is mostly impossible to count each and every individual of a species. This problem is usually solved by taking a number of samples from different locations of the habitat, making the necessary assumption that these samples are representative of the habitat in general. In order to be reasonably sure that the results from the samples do represent the habitat as closely as possible, careful planning beforehand is essential. Samples are usually taken using a standard sampling unit of some kind. This ensures that all of the samples represent the same area or volume (water) of the habitat each time. The usual sampling unit is a quadrate, the dimensions to be selected depending on the species to be counted. The purpose of using a quadrate is to enable comparable samples to be obtained from areas of consistent size and shape. Small quadrates are much quicker to survey, but are likely to yield somewhat less reliable data than large ones. However, larger quadrates require more time and effort to examine properly. A balance is therefore necessary between what is ideal and what is practical. There are three main ways of taking samples, including Random Sampling, Systematic Sampling (includes line transect and belt transect methods) and Stratified Sampling.
  - Random sampling is usually carried out when the area under study is fairly uniform, very large, and or there is limited time available. When using

random sampling techniques, large numbers of samples/records are taken from different positions within the habitat. Animals, and/ or plants inside the quadrats are counted, measured, or collected, depending on what the survey is for. This is done many times at different points within the habitat to give a large number of different samples

- Systematic sampling is when samples are taken at fixed intervals, usually along a line. This normally involves doing transects, where a sampling line is set up across areas where there are clear environmental gradients. For example you might use a transect to show the changes of plant species as you moved from grassland into woodland, or to investigate the effect on species composition of a pollutant radiating out from a particular source
- Stratified sampling is used to take into account different areas (or strata) which are identified within the main body of a habitat. These strata are sampled separately from the main part of the habitat

Many ecological surveys are carried out over extended periods of time, with sampling taking place at regular intervals within a particular habitat. In such cases, it is necessary to estimate the number of samples which should be taken at each sampling period. For Wetlands, considering their size, transect sampling may be suitable. More information can be found at http://www.countrysideinfo.co.uk/wetland_survey/biosampl.htm

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