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Document Sheet

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Nile basin wetlands of transboundary significance: inventory, baseline study and framework management plan

Ecosystem Services Assessment

Technical Report: Ecosystem services assessment functions in the Nile DSS

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List of Acronyms

DNP	Dinder National Park
DSS	Decision Support System
ES	Ecosystem Services
MEA	Millenium Ecosystem Assessment
NBI	Nile Basin Initiative
TEEB	The Economics of Ecosystems and Biodiversity
TEV	Total Economic Value
VU	Vegetation Units
WP	Work Package

1. Executive Summary

This document comprises deliverable 3.1 “Ecosystem services assessment functions in the Nile DSS “ and deliverable 3.2b “Inventory: baseline ecosystem Services assessment to be integrated into the inventory/atlas” of the assignment: “Schedule 3 - Technical proposal by HYDROC” for the project “Nile Basin wetlands of transboundary significance: Inventory, Baseline Study and Framework Management Plan with a nested case study on the Sudd", contract no. 81225710.

The ecosystem services (ES) assessment is key to understand the benefits that wetlands provide. Even though it is a commonly used concept and powerful tool to socialize conservation and natural resources management, their evaluation so far is biased towards evaluating the ones that are easy to measure or the most “popular”. Besides this, different classification systems and valuation methods exist.

Here we follow the Millenium Ecosystem Assessment (MEA 2005) classification of Ecosystem Services (ES) along with the list of ES detected by Emerton (2018). The literature reviewed by Emerton (2018) with an economic valuation perspective are re-evaluated here with the objective of identifying and listing the existing ES in different vegetation units (VU) within the Nile basin, within each sub-basin, and within each wetland-group defined for this study.

The identified ES in each sub-basin and wetland group are discussed for each in its respective chapter. All 29 ES identified by Emerton (2018) were found in all the wetland groups and sub-basins of this study.

With this we also seek to translate the pressures on wetlands into changes in ecosystem services of wetlands. For this we also provide simple functions that describe the ES provisions in different vegetation units that can be integrated into the assessment routines to evaluate future scenario analyses.

2. Introduction

This document comprises deliverable 3.1 “Ecosystem services assessment functions in the Nile DSS “ and deliverable 3.2b “Inventory: baseline ecosystem Services assessment to be integrated into the inventory / atlas” of the assignment: “Schedule 3 - Technical proposal by HYDROC” for the project “Nile Basin wetlands of transboundary significance: Inventory, Baseline Study and Framework Management Plan with a nested case study on the Sudd", contract no. 81225710.

The ecosystem services (ES) assessment is key to understand the benefits that wetlands provide. However, there are still several classification systems, valuation methods, and assessment procedures of ES, each with its advantages and disadvantages. For the purposes of this study, the ES classification from the Millenium Ecosystem Assessment (MEA 2005) is used, and the list of ES is based on those detected by Emerton (2018). Emerton (2018) reviewed 206 documents with a focus on the economic valuation of ES used within those documents. Here, the same literature is reviewed with a focus on ES availability within the Nile sub-basins and within the wetland groups defined for this study. Based on the reviewed literature, the ES are exemplary described and listed for each of the wetland groups and sub-basins in cross tables.

The functions are additionally provided as an excel sheet. The aim here is to help translate pressures on wetlands into changes in ecosystem services of wetlands, which shall be used in further options assessments.

Furthermore, based on the spatial scale and modelling framework developed in Work Package 1 and 2, simple and robust functions that describe ES provisions are presented taking key scenario variables into account. The Nile DSS analyst at NBI, will integrate the assessment functions into the assessment routines of the Nile DSS as tools or scripts that will be used to evaluate such services in future scenario analyses.

2.1 Ecosystem Services

Ecosystem Services (ES) had been indirectly addressed for a long time, but the concept itself was coined until the 1980s by Ehrlich & Ehrlich (1981) broadly as the “indispensable free services” nature provides us. This was then popularized in the late 1990s and received more attention after Costanza *et al.* (1997) attempted to show the economic relevance of Ecosystem Services on a global scale. Since then, the concept has been further developed.

We can define ES as “the benefits people obtain from ecosystems”, either actively or passively, that support human well-being. These can range from water storage, flow and quality regulation, through watershed protection, drought mitigation, flood control and disaster risk reduction, to the generation of a wide range of goods, products and raw materials that underpin local livelihoods.

Wetland ecosystems, for example, deliver a wide array of ES, like fish, fresh water, water purification, coastal protection, recreation opportunities, among many others (MEA 2005).

It must be noted that the wide array of ES is interdependent, and the relationships are not always in a one-to-one fashion. In some cases, an ES is a product of two or more Ecosystem Functions; for example, primary production (process) maintains a viable fish population (function) which in turn provides us with food (service) (Costanza *et al.* 1997; De Groot *et al.* 2018). An ES can also provide more than the product itself, such as how food (provisioning service) provides nutrition, but also pleasure and social identity (cultural ES) (De Groot *et al.* 2018).

Even though the ES concept can be a powerful tool to socialize conservation and guide sustainable resource management (Jacobs *et al.* 2015; Grêt-Regamey *et al.* 2017), their evaluation so far is biased towards evaluating the ones that are easy to measure or the most "popular" (Grêt-Regamey *et al.* 2017). Another problem is that some ES might not be so obvious when they are not traded in conventional markets (De Groot et al 2018). A final important aspect to keep in mind is that most ES assessment approaches, including the ones within the literature assessed in this report, don't fully account for the role biodiversity plays in producing these ES, nor for the necessary ecosystemic *infrastructure* and connectivity that allows for the necessary ecosystem processes and functions (Potschin & Haines-Young 2016; La Notte *et al.* 2017; De Groot *et al.* 2018), and thus their interpretation must be kept in mind.

Besides the challenges mentioned above regarding the ES concept, the fact that many wetland ecosystems for some world regions are still under-represented must also be considered since their estimated value (for both marketed and non-marketed benefits) might be greater than what's currently estimated (MEA 2005). For simplicity purposes, throughout this document the term Ecosystem Services is used to refer to ecosystem services, goods, functions and processes alike and the ES classification used follows that of MEA (2005) as Provisioning, Regulating, Supporting and Cultural services.

3. Methods and Definitions

The current study builds up on the results of the NBI TEEB study. Therefore, coherent approaches and definitions are considered. “TEEB” stands for The Economics of Ecosystems and Biodiversity: a global initiative seeking to mainstream the value of biodiversity and ecosystem services into decision-making at all levels. The TEEB study orientates its definitions and approaches to the Millennium Ecosystem Assessment for Wetland ecosystem services (2005). The list of Ecosystem Services is based on key Ecosystem Services detected within the Study "Nile Basin Wetlands TEEB Scoping Report: Valuing & investing in wetlands as natural water infrastructure" by Emerton (2018). In total, 29 ES are considered in this report (listed in all tables below).

3.1 Literature review

The literature review covers all ten Nile Basin Initiative (NBI) countries (Burundi, Democratic Republic of Congo, Egypt, Ethiopia, Kenya, Rwanda, South Sudan, The Sudan, Tanzania and Uganda). From the 206 documents reviewed by Emerton (2018), 168 documents were available and analysed here. Three other documents about ES in the Sudd wetland group were added. In total, 172 documents are included in this analysis. From each document, information on the ES within their study sites was extracted considering:

a) which wetland group and sub-basin the study took place in,

b) the assessment method, and

c) the presence/absence of a total of 29 Ecosystem Services identified per Vegetation Unit.

The wetland groups targeted within this literature review are:

1. Lake Victoria wetlands
2. Kagera wetlands
3. Mara wetlands
4. Sio Nzoia Yala Nyando wetlands
5. Lake Kyoga wetlands
6. Semliki wetlands
7. Sudd wetlands
8. Bahr el Ghazal wetlands
9. Baro Akobo Sobat wetlands
10. Dinder wetlands
11. Lake Tana wetlands
12. Nile Delta wetlands.

Besides these, some documents referred to other wetlands (or other ecosystems) within the Nile basin not considered in the pre-established wetland groups, thus they were grouped only under the sub-basin to which they belong.

The used Vegatation units (VU) as defined in WP 1 and 2 consists of eight classes, represented by typical vegetation as an indicator for specific wetland condition combinations. They are:

- Open water (1)
- Permanent Swamps - Papyrus (2)
- Reeds (3)
- Grassland (4)
- Woodland/Forest (5)
- Agriculture (6)
- Urban (7)
- Other/Not Specified (0)

The Urban (7) Vegetation Unit is not considered in the Ecosystem Services analysis.

3.2 Data Analysis

The data extracted from the reviewed literature was compiled in an Excel matrix. The matrix considers the study location by country, sub-basin and wetland group; if mentioned in the study, it considers the vegetation units (as defined above). For each ES mentioned in each document, the matrix contemplates whether each of the 29 ES is available in the specified VUs or if that detail is not specified. In that case, when an ES was mentioned but not linked to a specific VU, the ES was assigned a "0", implying it is available in the overall study location but no specific information about the VUs is included in the study. Finally, the assessment method each document utilizes was also noted.

After extracting the information from all 172 documents, matrices were made for each sub-basin and each wetland group. Here, the availability/presence of ES was re-coded as follows: if an ES is available as found in the literature (coded with a "1"); whether it is potentially available based on expert judgement or if it was found in the same VU of other WG ("2"); if it is not applicable (for example, finding the ES "fish" in the VU "forest"; coded with a "0"); or if we cannot provide any information ("3"). One matrix (Table 3) is included for the entire Nile basin where a "1+" implies this ES was found in at least one sub-basin or wetland group and its potential availability based on expert judgement. Therefore, for the matrices delivered for each sub-basin and each WG, the "1+" category does not exist (table 1).

Table 1. List of attributes for all values used for the functions

Values: Attributes listed below	
0	not applicable
1+	Ecosystem Service available in NILE basin
1	Ecosystem Service available in this sub-basin/wetland
2	Ecosystem Service potentially available
3	not known

The resulting matrices are presented and discussed by sub-basin and wetland group.

Finally, to assess the *potential presence* of each ecosystem service (ES) after the implementation of new intervention measures, simple arithmetic relationships were established between the VU land cover and ES *based on the change in the Vegetation Unit (VU) availability (area).* One equation was formulated for each ES, considering the VU where they are currently available (according to literature), potentially available or not applicable. The equations are provided in detail below.

4. Results

Out of the 206 reviewed documents, 172 were applicable for our analysis. Out of these, 70 documents dealt with wetlands and other ecosystems outside the Nile Basin, and 102 documents inside the Nile Basin, presented here. Since the investigated literature did not contain information about Ecosystem Services for some wetland groups (see Table 2), information from the whole Nile basin was used to find potentially available ES. An overview of ES of the Nile Basin and more supporting informations on the literature study is to be found in deliverable 3.2a "Technical Report: Assessment methodology and overview for ecosystem service".

Table 2. Number of documents analyzed per sub-basin and wetland group

Total	**206**
Available References (TOTAL analyzed here)	**172**
References Outside Nile Basin	70
Inside Nile Basin	**101**
Lake Victoria Sub-Basin (LV)	**57**
Lake Victoria wetlands group	26
Kagera wetlands group	1
Mara wetlands group	10
Sio Nzoia Yala Nyando wetlands group	13
Victoria Nile Sub-Basin (VN)	**11**
Lake Kyoga wetlands group	4
Lake Albert Sub-Basin (LA)	**15**
Semliki wetlands group	14
Bahr el Jebel Sub-Basin (BJ)	**4**
Sudd Wetlands group	4
Bahr el Ghazal Sub-Basin (BG)	**0**
Bahr el Ghazal wetlands group	0
Baro-Akobo-Sobat Sub-Basin (BA)	**4**
Baro/Akobo Sobat Wetlands group	0
White Nile Sub-Basin (WN)	**1**
Blue Nile Sub-Basin (BN)	**10**
Dinder wetlands group	2
Lake Tana wetlands group	4
Tekeze-Atbara Sub-Basin (TA)	**10**
Main Nile Sub-Basin (MN)	**4**
Nile Delta wetlands group	1

4.1 The Nile River Basin

The Nile Basin covers eleven countries of Northeastern and Eastern Africa (Burundi, DR Congo, Egypt, Ethiopia, Kenya, Rwanda, South Sudan, The Sudan, Tanzania, Uganda, Eritrea). Flowing from the equatorial Lake Victoria north to the Mediterranean Sea with an approximate length of 6,695 km, the Nile river is the largest in Africa flowing over different types of ecosystems and providing important services and products to over 300 million people (Dumont 2009; NBI 2017). The Nile Basin is further divided in ten sub-basins (Figure 1).

The sources of the main Nile river are several, which come from different parts of the highlands of the basin. Rivers that feed Lake Victoria, like the Mara, Yala, and Nzoia rivers, are the most distant sources of the Nile. North of Lake Victoria the White Nile emerges, flowing through the Victoria Nile sub-basin (through Lake Kyoga) into Lake Albert. From Lake Albert the White Nile goes through the Bahr el Jebel sub-basin, where the Sudd wetlands slow it down due to the topography in this region. Overall the White Nile has a gentler slope than the Blue Nile. Other important tributaries that feed the White Nile before its confluence with the Blue Nile are the Bahr el Ghazal and the Baro-Akobo-Sobat rivers. These two sub-basins contribute a small amount of water annually to the White Nile, particularly during rainy season. The Blue Nile begins in the Ethiopian highlands, from Lake Tana. It flows into Sudan, merging with the White Nile at Khartoum. Up until this point, several wetlands can be found, like the Sudd and lake-shore wetlands. From here on, the Main Nile flows through a desert biome from Sudan into Egypt, with fewer wetlands restricted mostly to river shores. The Atbara river is the last main tributary to join the Main Nile, particularly important during the rainy season. The Nile then flows north until it reaches the Mediterranean Sea, where the Nile Delta wetlands are found (Dumont 2009; Green 2009; Hamza 2009; Vijverberg *et al.* 2009; NBI 2017).

Out of the 29 ES included in this analysis, all of them have been identified throughout the entire Nile basin in the different Vegetation Units considered (Table 3). More details on the ES for each sub-basin and wetland group can be found below.

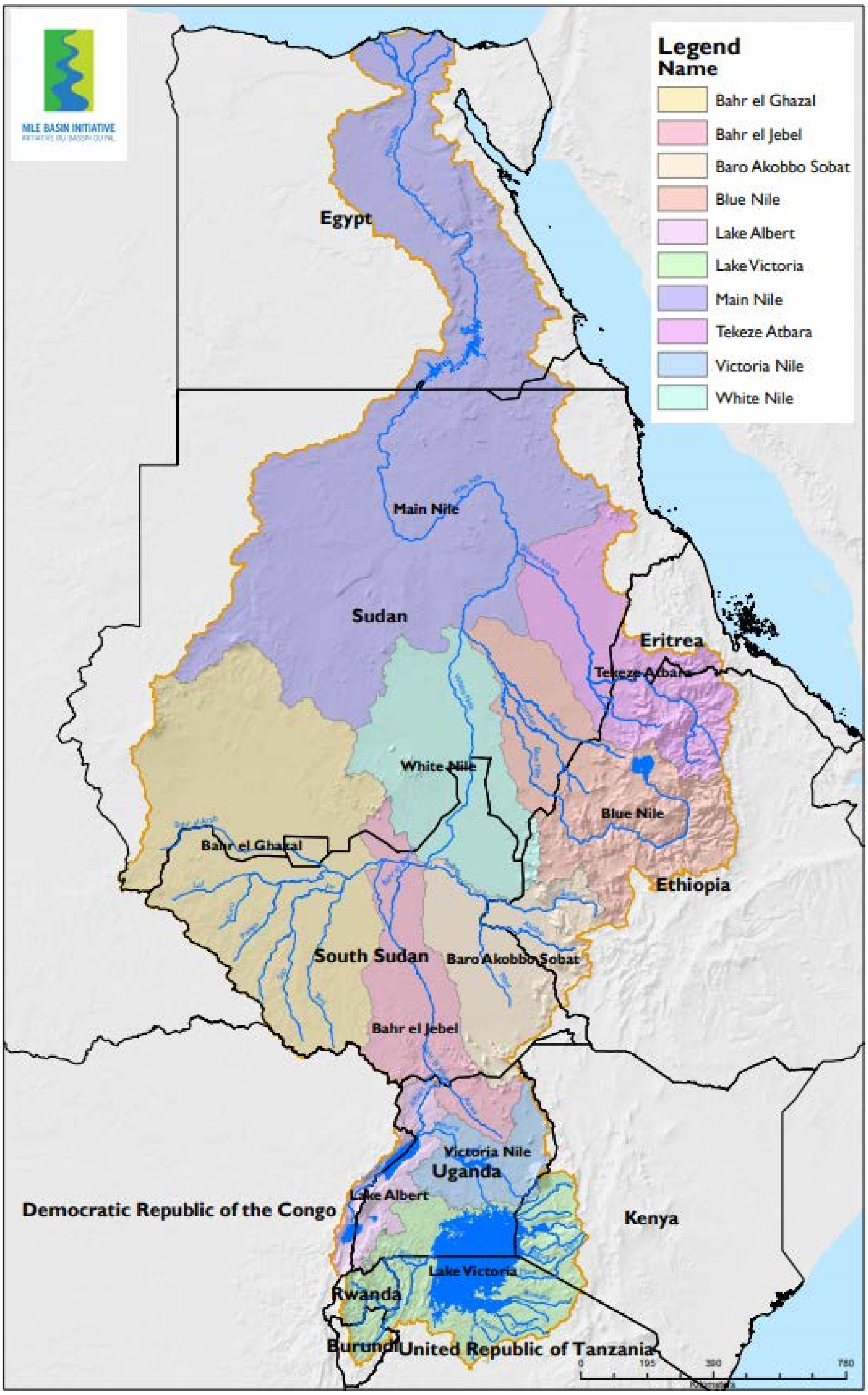

Figure 1. The Nile Basin depicting the 10 sub-basins (NBI 2017)

Table 3. Present Ecosystem Services (ES) within the entire Nile Basin

0 = not applicable; 1+ = ES in the Nile Basin (according to literature); 2= ES potentially available in Nile Basin (expert judgement); 3 = Not Known

Ecosystem Services Category	Ecosystem Services	Open water (1)	Permanent Swamps - Papyrus (2)	Reeds (3)	Grassland (4)	Woodland/Forest (5)	Agriculture (6)	Other/Not Specified (0)
Provisioning ES	food - wild fish	1+	1+	1+	0	0	0	1+
	food - insects	2	2	2	2	1+	3	3
	food - wild game	1+	1+	1+	1+	1+	1+	1+
	food - fruits	0	1+	1+	1+	1+	1+	1+
	food - vegetables	0	1+	1+	1+	1+	1+	1+
	food - grains	0	1+	1+	1+	1+	1+	1+
	food - fodder and pasture (for livestock)	1+	1+	1+	1+	1+	1+	1+
	food - farmland (for crop cultivation)	3	1+	1+	1+	1+	1+	1+
	fresh water	1+	1+	1+	1+	1+	0	1+
	fuel/ fiber/ raw materials	3	1+	1+	1+	1+	1+	1+
	medicinal products	3	1+	1+	1+	1+	3	1+
	genetic materials	1+	1+	1+	1+	1+	3	1+
	Transport Infrastructure	1+	0	0	2	1+	0	1+
Regulating ES	waterflow regulation	1+	1+	1+	1+	1+	0	1+
	water purification/waste treatment	1+	1+	1+	1+	1+	0	1+
	erosion regulation	1+	1+	1+	1+	1+	0	1+
	maintenance of soil fertility	1+	1+	1+	1+	1+	0	1+
	natural hazard regulation	1+	1+	1+	1+	1+	3	1+
	climate regulation	1+	1+	1+	1+	1+	3	1+
	pollination	0	1+	1+	1+	1+	1+	1+
	biological control	1+	1+	1+	1+	1+	0	1+
Supporting ES	soil formation	2	1+	3	1+	1+	0	1+
	nutrient cycling	1+	1+	1+	1+	1+	0	1+
	maintenance of genetic diversity	1+	1+	1+	1+	1+	0	1+
Cultural ES	cultural/ spiritual/ inspirational	1+	1+	1+	1+	1+	1+	1+
	recreational	1+	1+	1+	1+	1+	1+	1+
	educational/research	1+	1+	1+	1+	1+	1+	1+
	aesthetic	1+	1+	1+	1+	1+	1+	1+

4.2 Lake Victoria Sub-Basin

The Lake Victoria region of the Nile Basin is formed by two sub-basins, the Lake Victoria sub-basin (described here) and the Victoria Nile sub-basin (described below). The Lake Victoria sub-basin comprises most of the lake's catchment area of transboundary nature shared by Kenya, Tanzania, Uganda, Rwanda and Burundi.

Many rivers feed Lake Victoria, some of which are discussed below, such as the Kagera, Mara, Yala, Nzoia and Sio rivers (NBI 2017). Besides the wetlands themselves (described herein), several of the analyzed documents also dealt with the ecosystem services provided by the forests and other terrestrial ecosystems located in the high parts of the basin which also provide important services that feed and protect the wetlands, such as water infiltration, water purification, erosion regulation, nutrient cycling, and maintenance of genetic diversity (Kulindwa 2006). The ES identified for the Lake Victoria sub-basin are further presented in Table 4.

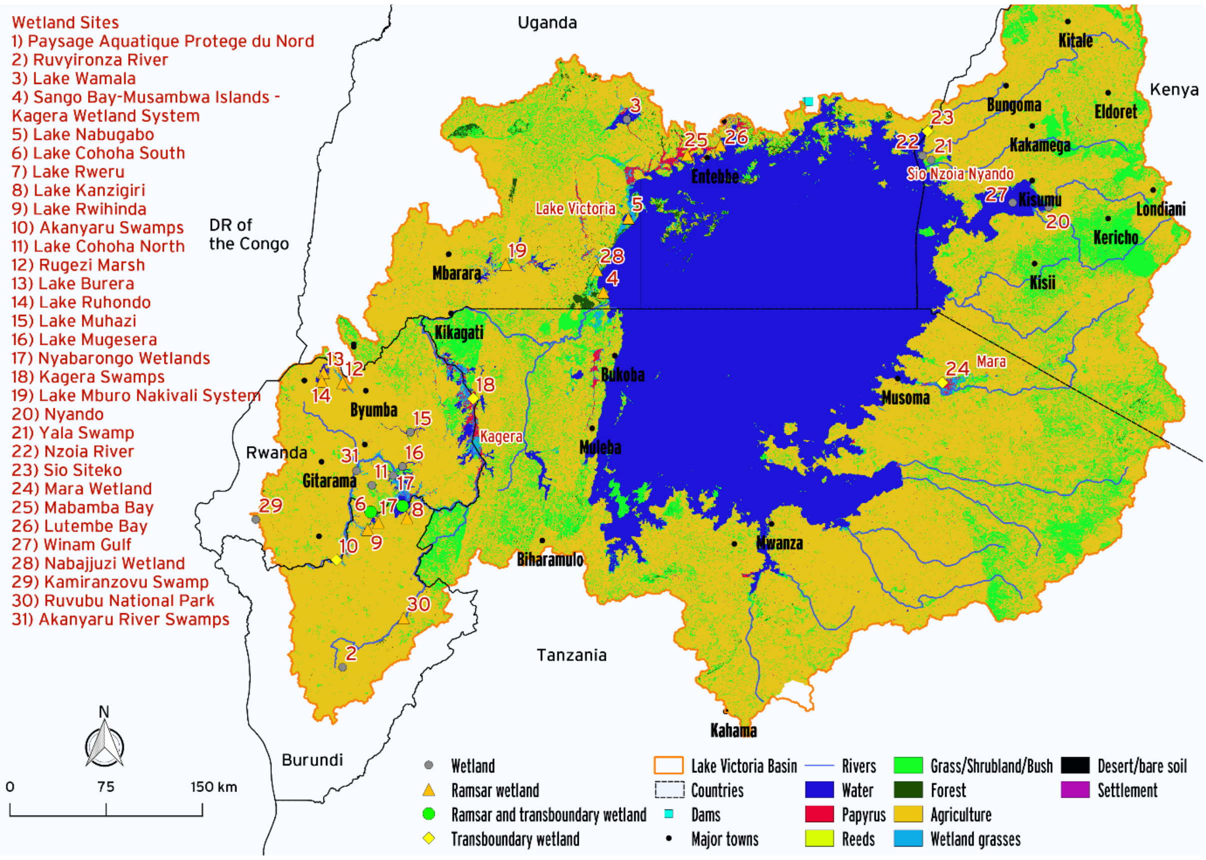

Figure 2. Lake Victoria Sub-basin depicting specific wetlands, vegetation units, identification of transboundary wetlands and Ramsar wetlands

Table 4. Present Ecosystem Services (ES) within the Lake Victoria Sub-Basin

0 = not applicable; 1 = ES in the Lake Victoria Sub-Basin (according to literature); 2= ES potentially available in the Lake Victoria Sub-Basin (based on Table 3 - expert judgement); 3 = Not Known

Ecosystem Services Category	Ecosystem Services	Open water (1)	Permanent Swamps - Papyrus (2)	Reeds (3)	Grassland (4)	Woodland/Forest (5)	Agriculture (6)	Other/Not Specified (0)
Provisioning ES	food - wild fish	1	1	1	0	0	0	1
	food - insects	2	2	2	2	1	3	3
	food - wild game	2	1	1	1	1	1	1
	food - fruits	0	1	1	1	1	1	1
	food - vegetables	0	1	1	1	1	1	1
	food - grains	0	1	1	1	1	1	1
	food - fodder and pasture (for livestock)	1	1	1	1	1	1	1
	food - farmland (for crop cultivation)	3	1	1	1	1	1	1
	fresh water	1	1	1	1	1	0	1
	fuel/ fiber/ raw materials	3	1	1	1	1	2	1
	medicinal products	3	1	1	1	1	3	1
	genetic materials	1	1	1	1	1	3	1
	Transport Infrastructure	1	0	0	2	1	0	1
Regulating ES	waterflow regulation	1	1	1	1	1	0	1
	water purification/waste treatment	1	1	1	1	1	0	1
	erosion regulation	1	1	1	1	1	0	1
	maintenance of soil fertility	1	1	1	1	1	1	1
	natural hazard regulation	1	1	1	1	1	3	1
	climate regulation	1	1	1	1	1	3	1
	pollination	0	1	1	1	1	1	2
	biological control	1	1	1	1	1	0	2
Supporting ES	soil formation	2	2	3	2	1	0	2
	nutrient cycling	1	1	1	1	1	0	1
	maintenance of genetic diversity	1	1	1	1	1	0	1
Cultural ES	cultural/ spiritual/ inspirational	1	1	1	1	1	1	1
	recreational	1	1	1	1	1	1	1
	educational/research	1	1	1	1	1	1	1
	aesthetic	1	1	1	1	1	1	1

4.2.1 Lake Victoria Wetlands

Within the analyzed literature, documents specific to the Lake Victoria wetlands focused mostly on the lake itself, the papyrus and reeds wetlands, and agricultural areas (*e.g.* Schuijt 2002; Kulindwa 2006; Simonit & Perrings 2011). Lake Victoria is an important ecosystem worldwide, and locally it is important for agriculture, industry, domestic water supply, fisheries and tourism. More specifically, the Lake Victoria wetlands provide food for the people living within these wetlands in the form of fish, fruits, vegetables, grains, and game, as well as indirectly by providing farmland and fodder for livestock. People also obtain raw materials for handcrafts or construction work, as well as medicinal products (Kakuru *et al.* 2013). Further, Kakuru *et al.* (2013) estimate the values of these provisioning services for some agroecosystems in the Uganda side of Lake Victoria. Fish spawning was valued at an approximate 363,815 US$/year, water for domestic use at 34 million US$/year, and livestock pastures at 4.24 million US$/year (Kakuru *et al.* 2013).

The open water areas are also employed for commercial and non-commercial transportation (Kulindwa 2006). Often mentioned was also the management and distribution of wild honeycombs within the local communities for the extraction of honey, mostly for subsistence consumption although commercial production also takes place (Okwi 2002; Langat & Chebwoiwo 2010; Kipkoech *et al.* 2011; Kakuru *et al.* 2013).

Although still little understood, regulating services are amongst the most important ones (Simonit & Perrings 2011). Flood control was estimated by Kakuru *et al.* (2013) at approximately 1.7 billion US$/year, and water regulation and recharge at 7.1 million US$/year for several Ugandan wetlands within the Lake Victoria.

In the last decades, protected areas have been established to protect other supporting services like biodiversity, its habitats, and genetic processes (Börner *et al.* 2009). Some examples are the Kakamega forest, Bujagali Falls Recreational Park and the Serengeti. This also provides recreation areas for local and international tourism, which add an important and valuable service for the local economy (Emerton and Mfunda 1999). For example, Bujagali Falls Recreational Park has been estimated to have a capital value of 1.3 million US$ (Buyinza *et al.* 2007).

Some of the analyzed documents dealt with specific wetlands within this group, like Mabamba Bay Wetland (Akwataireho 2009) and Nakivale Wetland (Adonia 2013) in Uganda. These specific examples estimated the economic value of some ecosystem services. For example, the Mabamba Bay wetland provides water for domestic purposes, supports wetland-edge cultivation, it is a source of fish for local consumption and commercial purposes, they're areas for recreation and tourism, source of sand for construction, water as means of transportation, source of handcraft materials like papyrus, and carbon storage services. Akwataireho (2009) estimated the annual total economic value (TEV) of these on approximately 3.6 million US$/year, of which only 8.9% corresponds to the non-marketable services. Adonia (2013) estimates, for lake Nakivale, that the poor land use practices cost an approximate 2.9 million US$/year, adding to the economic justification for wetland management, sustainable land use planning and restoration programs. The beneficiaries of all these services are at the household, local community, district, national and international levels (Akwataireho 2009; Adonia 2013). The ES identified for the Lake Victoria wetlands are further presented in Table 5.

Table 5. Present Ecosystem Services (ES) within the Lake Victoria Wetlands Group

0 = not applicable; 1 = ES in the Lake Victoria Wetlands Group (according to literature); 2= ES potentially available in Lake Victoria Wetlands Group (based on Table 3 - expert judgement); 3 = Not Known

Ecosystem Services Category	Ecosystem Services	Open water (1)	Permanent Swamps - Papyrus (2)	Reeds (3)	Grassland (4)	Woodland/Forest (5)	Agriculture (6)	Other/Not Specified (0)
Provisioning ES	food - wild fish	1	1	1	0	0	0	1
	food - insects	2	2	2	2	2	3	3
	food - wild game	2	1	1	1	1	2	1
	food - fruits	0	1	1	1	1	2	1
	food - vegetables	0	1	1	1	1	2	1
	food - grains	0	1	1	1	1	2	1
	food - fodder and pasture (for livestock)	1	1	1	1	1	1	1
	food - farmland (for crop cultivation)	3	1	1	1	1	1	1
	fresh water	1	1	1	1	1	0	1
	fuel/ fiber/ raw materials	3	1	1	1	1	2	1
	medicinal products	3	1	1	1	1	3	1
	genetic materials	1	1	1	1	1	3	1
	Transport Infrastructure	1	0	0	2	2	0	1
Regulating ES	waterflow regulation	1	1	1	1	1	0	1
	water purification/waste treatment	1	1	1	1	1	0	1
	erosion regulation	1	1	1	1	1	0	1
	maintenance of soil fertility	1	1	1	1	1	0	1
	natural hazard regulation	1	1	2	1	1	3	1
	climate regulation	1	1	1	1	1	3	1
	pollination	0	1	1	1	1	1	1
	biological control	2	1	1	1	1	0	1
Supporting ES	soil formation	2	2	3	2	1	0	1
	nutrient cycling	1	1	1	1	1	0	1
	maintenance of genetic diversity	1	1	1	1	1	0	1
Cultural ES	cultural/ spiritual/ inspirational	1	1	1	1	1	1	1
	recreational	1	1	1	1	1	1	1
	educational/research	1	1	1	1	1	1	2
	aesthetic	1	1	1	1	1	1	1

4.2.2 Kagera Wetlands

The Kagera river is in the west side of Lake Victoria, with three upper headstreams in Rwanda and Burundi, and flows through Tanzania and Uganda, where it discharges into Lake Victoria.

This river is a social-ecological hotspot that provides numerous ES but is also threatened mainly due to human activities. Among them land use cover change (mainly through urbanization and agricultural intensification), over harvesting, eutrophication, wetland degradation, invasive species, and the impacts that all these imply translating into habitat loss and changes in water quality (Khan *et al.* 2018). Although there is not one regional governing institution on natural resources management, there are several institutions and policies enforced towards these attempts, but mostly at national levels.

One of the most daunting challenges identified by Khan *et al.* (2018) is the "management of transboundary water resources under changing climatic conditions". This directly impacts food security and inidustrial development. Proper land use policies and watershed protection measures on a transboundary level are necessary to sustain ES and ecosystem resilience, with a particular interest in upstream human activities (Khan *et al.* 2018).

Although only one of the analyzed documents refer to this WG, it is mostly regarding the Rwandan section of the catchment. Some other potential ES include direct and indirect food sources (grains, fruit, game, fodder for livestock and farmland), fresh water for domestic use, and medicinal products. The role wetlands play for regulating waterflow, water purification, maintaining soil fertility and climate regulation are also potential services for this wetland group. The Kagera wetlands can also support wildlife and maintain genetic diversity, as well as cultural and recreational values. The ES identified for the Kagera wetlands are further presented in Table 6.

Table 6. Present Ecosystem Services (ES) within the Kagera Wetlands Group

0 = not applicable; 1 = ES in the Kagera Wetlands Group (according to literature); 2= ES potentially available in Kagera Wetlands Group (based on Table 3 - expert judgement); 3 = Not Known

Ecosystem Services Category	Ecosystem Services	Open water (1)	Permanent Swamps - Papyrus (2)	Reeds (3)	Grassland (4)	Woodland/Forest (5)	Agriculture (6)	Other/Not Specified (0)
Provisioning ES	food - wild fish	2	2	2	0	0	0	1
	food - insects	2	2	2	2	2	3	3
	food - wild game	2	2	2	2	2	2	2
	food - fruits	0	2	2	2	2	2	2
	food - vegetables	0	2	2	2	2	2	2
	food - grains	0	2	2	2	2	2	2
	food - fodder and pasture (for livestock)	2	2	2	2	2	2	1
	food - farmland (for crop cultivation)	3	2	2	2	2	2	1
	fresh water	2	2	2	2	2	0	2
	fuel/ fiber/ raw materials	3	2	2	2	2	2	2
	medicinal products	3	2	2	2	2	3	2
	genetic materials	2	2	2	2	2	3	2
	Transport Infrastructure	2	0	0	2	2	0	2
Regulating ES	waterflow regulation	2	2	2	2	2	0	1
	water purification/waste treatment	2	2	2	2	2	0	1
	erosion regulation	2	2	2	2	2	0	2
	maintenance of soil fertility	2	2	2	2	2	0	2
	natural hazard regulation	2	2	2	2	2	3	2
	climate regulation	2	2	2	2	2	3	1
	pollination	0	2	2	2	2	2	2
	biological control	2	2	2	2	2	0	2
Supporting ES	soil formation	2	2	3	2	2	0	2
	nutrient cycling	2	2	2	2	2	0	1
	maintenance of genetic diversity	2	2	2	2	2	0	2
Cultural ES	cultural/ spiritual/ inspirational	2	2	2	2	2	2	2
	recreational	2	2	2	2	2	2	2
	educational/research	2	2	2	2	2	2	2
	aesthetic	2	2	2	2	2	2	2

4.2.3 Mara Wetlands

The Mara wetlands are shared by Tanzania and Kenya on the Southeast side of Lake Victoria. The Mara Case Study within the Nile-Eco-VWU (2016) Guidelines mentions fishing and grazing as the most important socio-economic activity for the communities living nearby. Gichere (2016) estimates the value of fishing and livestock (fodder and water) in the Mara wetlands on the Tanzanian side in approximately 414,393 US$/year and 1 million US$/year, respectively. Other provisioning services include food in the form of game and land for crop cultivation. Medicinal resources and timber and non-timber products, like thatching grass, are also important provisioning services for the local communities (Nile-Eco-VWU 2016), although their economic value as estimated by Gichere (2016) in the Tanzanian section is approximately 12,275 US$/year and 556,518 US$/year, respectively. Honey production is also common in these wetlands although economically they play a minor role (Nile-Eco-VWU 2016; Gichere 2016).

Important regulating services provided by the Mara wetlands are water purification and nutrient retention, particularly through the role of papyrus and reeds on nitrogen retention either through direct plant intake as well as by retaining sediment load (Nile-Eco-VWU 2016). Carbon sequestration is also an important regulating service, valued at approximately 835,989 US$/year (Gichere 2016). These wetlands also provide habitat for biodiversity. The rich biodiversity here places these wetlands on national and global importance for conservation (Nile-Eco-VWU 2016). The area is also known for tourism which can also generate relevant income for the local communities and the country through park entry fees, hunting charges and lodge and camp concessions (Emerton & Mfunda, 1999; Gichere 2016). The ES identified for the Mara wetlands are further presented in Table 7.

Table 7. Present Ecosystem Services (ES) within the Mara Wetlands Group

0 = not applicable; 1 = ES in the Mara Wetlands Group (according to literature); 2= ES potentially available in Mara Wetlands Group (based on Table 3 - expert judgement); 3 = Not Known

Ecosystem Services Category	Ecosystem Services	Open water (1)	Permanent Swamps - Papyrus (2)	Reeds (3)	Grassland (4)	Woodland/Forest (5)	Agriculture (6)	Other/Not Specified (0)
Provisioning ES	food - wild fish	1	1	1	0	0	0	1
	food - insects	2	2	2	2	2	3	3
	food - wild game	2	1	1	1	1	2	1
	food - fruits	0	1	1	1	1	2	1
	food - vegetables	0	1	1	1	1	2	1
	food - grains	0	1	1	1	1	2	1
	food - fodder and pasture (for livestock)	2	1	1	1	1	1	2
	food - farmland (for crop cultivation)	3	1	1	1	1	1	2
	fresh water	1	1	2	1	1	0	1
	fuel/ fiber/ raw materials	3	1	1	1	1	2	2
	medicinal products	3	1	1	1	1	3	1
	genetic materials	1	1	1	1	1	3	2
	Transport Infrastructure	2	0	0	2	2	0	2
Regulating ES	waterflow regulation	1	1	1	1	1	0	2
	water purification/waste treatment	2	1	1	1	1	0	2
	erosion regulation	2	1	1	1	1	0	2
	maintenance of soil fertility	2	1	1	1	1	0	2
	natural hazard regulation	2	2	2	2	1	3	2
	climate regulation	1	1	1	1	1	3	2
	pollination	0	2	2	1	1	2	1
	biological control	1	1	1	1	1	0	1
Supporting ES	soil formation	2	2	3	2	1	0	1
	nutrient cycling	1	1	1	1	1	0	2
	maintenance of genetic diversity	1	1	1	1	1	0	1
Cultural ES	cultural/ spiritual/ inspirational	1	1	1	1	1	1	2
	recreational	1	1	1	1	1	2	2
	educational/research	1	1	1	1	1	2	2
	aesthetic	1	1	1	1	1	2	2

4.2.4 Sio, Nzoia, Yala, Nyando wetlands

These rivers and wetlands are located in Kenya on the east side of Lake Victoria. According to the literature on these wetlands, they provide the local communities with several provisioning ecosystem services like direct forms of food (fish, game, vegetables, fruits, grains and potentially insects) and indirectly through fodder for livestock and farmland for crop cultivation (Abila 2002). The three most important products according to Schuijt (2002) are water (for cooking, washing, drinking and irrigation), fish, and agricultural grounds. Fishing provides fish for commercial and non-commercial purposes as well as creating other income generating activities like fish-net and boat repairing. They also provide raw materials for construction, medicinal products, genetic materials, and water as means for transportation (Abila 2002; Schuijt 2002).

Among the important regulating services, water purification is one of the main ones discussed for these wetlands due to the filtering effect of the swamps where most sediments are retained (Schuijt 2002; Simonit & Perrings 2011). Simonit & Perrings (2011) discuss the regulating services in the Yala catchment, which, although still little understood, are probably the most important ones when it comes to nutrient retention, erosion regulation, maintenance of soil fertility and water purification. These services are also key for sustaining other provisioning services, such as healthy fish populations. Modeling the interaction between fisheries and wetland conversion for agriculture, Simonit & Perrings (2011) estimated the value of these regulating services in about 3.86M US$/year (which comprises about 35% of the earnings when converting wetlands to farmland that could be offset through payment for ecosystem services mechanisms).

These are also important sites for biodiversity conservation, as they have a rich biodiversity and are habitat for endemic species, like the Sitatunga antelope (Schuijt 2002). Besides wildlife conservation, the loss of these wetlands would also imply the loss of some socio-cultural values and sites important for their spiritual, recreational and educational purposes. (Abila 2002; Ondiek *et al.* 2016). The ES identified for the Sio, Nzoia, Yala & Nyando wetlands are further presented in Table 8.

Table 8. Present Ecosystem Services (ES) within the Sio-Nzoia-Yala-Nyando Wetlands Group

0 = not applicable; 1 = ES in the Sio-Nzoia-Yala-Nyando Wetlands Group (according to literature); 2= ES potentially available in Sio-Nzoia-Yala-Nyando Wetlands Group (based on Table 3 - expert judgement); 3 = Not Known

Ecosystem Services Category	Ecosystem Services	Open water (1)	Permanent Swamps - Papyrus (2)	Reeds (3)	Grassland (4)	Woodland/Forest (5)	Agriculture (6)	Other/Not Specified (0)
Provisioning ES	food - wild fish	1	1	1	0	0	0	2
	food - insects	2	2	2	2	2	3	3
	food - wild game	2	1	1	2	2	1	1
	food - fruits	0	1	1	2	2	1	2
	food - vegetables	0	1	1	2	2	1	2
	food - grains	0	1	1	2	2	1	2
	food - fodder and pasture (for livestock)	2	1	1	2	1	1	2
	food - farmland (for crop cultivation)	3	1	1	2	1	1	2
	fresh water	1	1	1	2	1	0	2
	fuel/ fiber/ raw materials	3	1	1	2	1	2	2
	medicinal products	3	1	1	2	1	3	2
	genetic materials	2	1	1	2	1	3	2
	Transport Infrastructure	1	0	0	2	2	0	2
Regulating ES	waterflow regulation	2	1	1	2	1	0	1
	water purification/waste treatment	2	1	1	2	1	0	1
	erosion regulation	1	1	1	2	1	0	2
	maintenance of soil fertility	2	1	1	2	1	0	2
	natural hazard regulation	1	1	1	2	2	3	2
	climate regulation	1	1	2	2	1	3	2
	pollination	0	2	2	2	1	2	2
	biological control	2	2	2	2	2	0	2
Supporting ES	soil formation	2	2	3	2	1	0	2
	nutrient cycling	2	2	2	2	1	0	2
	maintenance of genetic diversity	2	2	2	2	2	0	2
Cultural ES	cultural/ spiritual/ inspirational	1	1	1	2	1	1	2
	recreational	1	1	1	2	1	1	2
	educational/research	1	1	1	2	1	1	2
	aesthetic	1	1	1	2	1	1	2

4.3 Victoria Nile Sub-Basin

The Lake Victoria region of the Nile Basin is formed by two sub-basins, the Lake Victoria sub-basin (described above) and the Victoria Nile sub-basin (described here). The Victoria Nile sub-basin is within Uganda territory, comprising the northernmost part of Lake Victoria. The Lake Victoria Nile leaves the lake near the town of Jinja flowing north until the swamp-lake Kyoga (wetland group described herein) and further north-west until it reaches the Lake Albert sub-basin (described later) (Dumont 2009).

Within the analyzed literature, one document provided a specific example of economic valuation of ecosystem services in a Natural Reserve within the Victoria Nile sub-basin. Upon the proposal of degazetting the Mabira Forest Reserve for sugar cane production, Moyini & Masiga (2011) estimated the total economic value (TEV) of conservation to support the conservation efforts and keep the protected area as such. The ecosystem services considered were fresh water, timber and non-timber forest products, medicinal products, water regulating and purification services, carbon sequestration, ecotourism and “option/existence values” (which includes the option of using the forest in the future, the cultural importance, and the intrinsic value of a forest and its wildlife). The TEV of the Reserve conservation was estimated in 45.1 million US$/year; in contrast, the sugar cane industry TEV was estimated on 29.9 million US$/year (Moyini & Masiga 2011).

Another often mentioned wetland within this sub-basin was Nakivubo Swamp, the largest wetland area in Kampala and one of the few remaining, since over ¾ of Kampala’s wetlands have been converted into urban or industrial zones. The wetland flows out into Murchinson Bay, Lake Victoria, through the Nakivubo river and other tributaries, which are the main carriers of Kampala’s wastewater (both partially treated and untreated) (Emerton 2003).

This wetland is dominated by papyrus, cat tails and reeds, which contribute to its high nutrient retention and water purification capacity (Emerton 2003). Emerton (2003) valued Nakivubo Swamp’s wastewater purification and nutrient retention services in between 1 – 1.75 million US$/year.

The main activity near Nakivubo wetlands is agriculture, mainly sugar cane and coco yams. Other provisioning services used include sand and clay for brick making, papyrus for mat construction and other handcrafts, fish, fodder, and water for agriculture and car washing (Nile-Eco-VWU). The ES identified for the Victoria Nile sub-basin are further presented in Table 9.

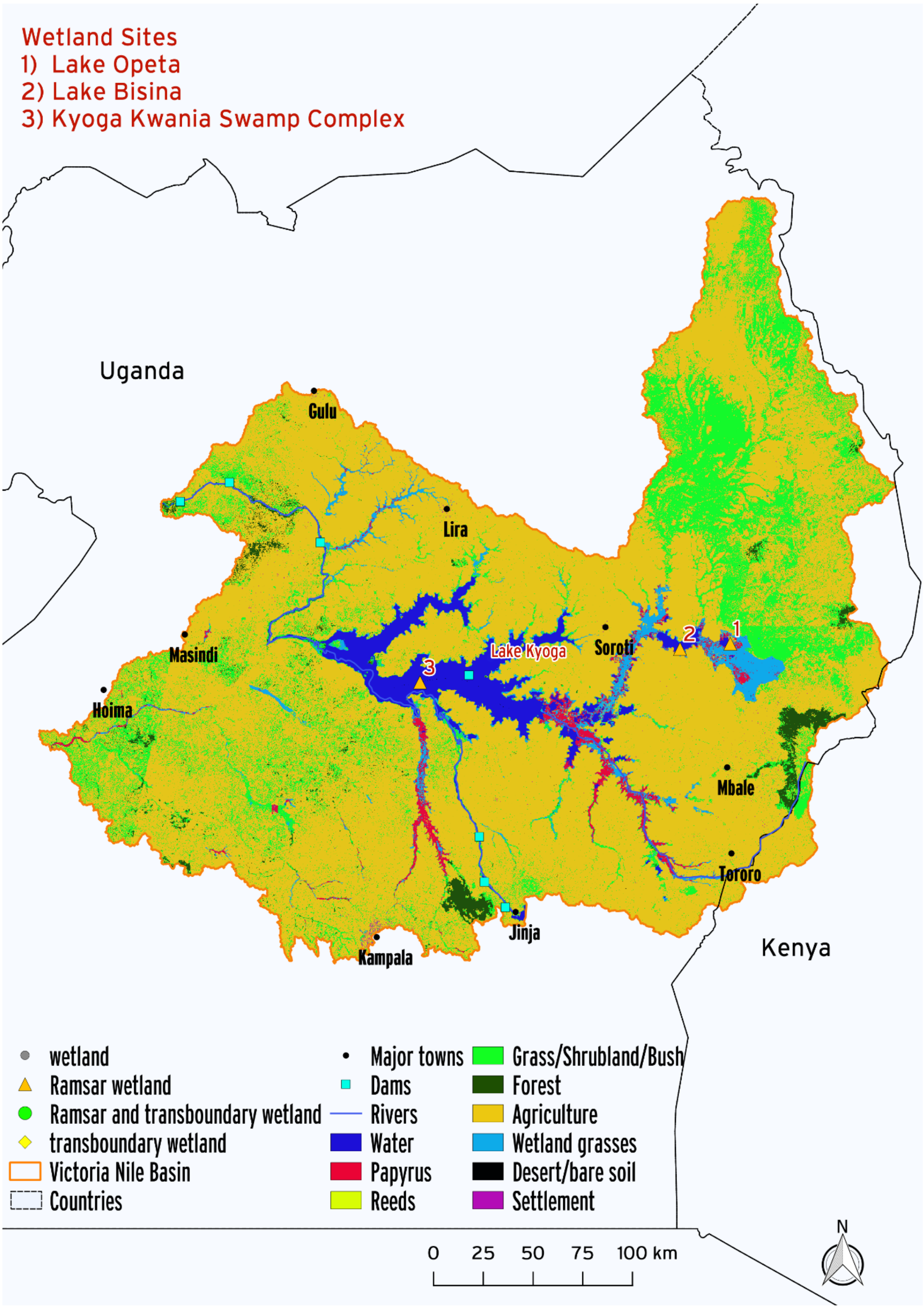

Figure 3. Victoria Nile Sub-basin depicting specific wetlands, vegetation units, identification of transboundary wetlands and Ramsar wetlands

Table 9. Present Ecosystem Services (ES) within the Victoria Nile Sub-Basin

0 = not applicable; 1 = ES in the Victoria Nile Sub-Basin (according to literature); 2= ES potentially available in the Victoria Nile Sub-Basin (based on Table 3 - expert judgement); 3 = Not Known

Ecosystem Services Category	Ecosystem Services	Open water (1)	Permanent Swamps - Papyrus (2)	Reeds (3)	Grassland (4)	Woodland/Forest (5)	Agriculture (6)	Other/Not Specified (0)
Provisioning ES	food - wild fish	1	1	1	0	0	0	1
	food - insects	2	2	2	2	2	3	3
	food - wild game	1	1	1	1	1	2	1
	food - fruits	0	1	1	1	1	2	1
	food - vegetables	0	1	1	1	1	2	1
	food - grains	0	1	1	1	1	2	1
	food - fodder and pasture (for livestock)	2	1	1	1	1	2	1
	food - farmland (for crop cultivation)	3	1	1	1	2	1	1
	fresh water	1	2	2	2	2	0	1
	fuel/ fiber/ raw materials	3	1	1	1	1	2	1
	medicinal products	3	1	1	1	1	3	1
	genetic materials	2	2	2	2	2	3	1
	Transport Infrastructure	1	0	0	2	2	0	1
Regulating ES	waterflow regulation	1	1	1	1	1	0	1
	water purification/waste treatment	1	1	1	1	1	0	1
	erosion regulation	2	1	1	1	1	0	1
	maintenance of soil fertility	1	1	1	2	2	0	1
	natural hazard regulation	1	1	1	2	2	3	1
	climate regulation	2	2	2	1	1	3	1
	pollination	0	2	2	2	2	2	2
	biological control	2	2	2	1	2	0	2
Supporting ES	soil formation	2	2	3	2	2	0	2
	nutrient cycling	2	2	2	2	2	0	1
	maintenance of genetic diversity	2	2	2	1	1	0	1
Cultural ES	cultural/ spiritual/ inspirational	1	1	1	1	1	2	1
	recreational	1	2	2	1	1	2	1
	educational/research	2	2	2	1	2	2	2
	aesthetic	2	2	2	2	2	2	1

4.3.1 Lake Kyoga

Lake Kyoga is a shallow lake north of Lake Victoria, receiving its main inflow from Lake Victoria and to a lesser extent from other tributaries from Mount Elgon and Karamoja. This lake discharges into Lake Albert (described in the next section). The lake is very sensitive to the flood pulse, splitting into a series of satellite lakes with papyrus swamps during low water conditions (Green 2009; Rebelo & McCartney 2012).

Not that much literature was available for lake Kyoga, but we know it provides an important habitat for wildlife, and several regulating services like waterflow and erosion regulation, water purification, maintains soil fertility, climate and natural hazard regulation. Lake Kyoga also provides food in the forms of fish, game, fodder for livestock and farmland, as well as fresh water, medicinal products, raw materials for construction and handcrafts, and water as a means of transportation (Karanja *et al.* 2001). The ES identified for the Lake Kyoga wetlands are further presented in Table 10.

Table 10. Present Ecosystem Services (ES) within the Kyoga Wetlands Group

0 = not applicable; 1 = ES in the Kyoga Wetlands Group (according to literature); 2= ES potentially available in Kyoga Wetlands Group (based on Table 3 - expert judgement); 3 = Not Known

Ecosystem Services Category	Ecosystem Services	Open water (1)	Permanent Swamps - Papyrus (2)	Reeds (3)	Grassland (4)	Woodland/Forest (5)	Agriculture (6)	Other/Not Specified (0)
Provisioning ES	food - wild fish	1	1	1	0	0	0	1
	food - insects	2	2	2	2	2	3	3
	food - wild game	1	1	1	2	2	2	1
	food - fruits	0	2	2	2	2	2	1
	food - vegetables	0	2	2	2	2	2	1
	food - grains	0	2	2	2	2	2	1
	food - fodder and pasture (for livestock)	2	1	1	1	2	2	1
	food - farmland (for crop cultivation)	3	1	1	2	2	2	1
	fresh water	1	2	2	2	2	0	1
	fuel/ fiber/ raw materials	3	1	2	2	2	2	1
	medicinal products	3	2	2	1	2	3	1
	genetic materials	2	2	2	2	2	3	1
	Transport Infrastructure	1	0	0	2	2	0	2
Regulating ES	waterflow regulation	2	1	1	1	2	0	1
	water purification/waste treatment	2	1	1	2	2	0	1
	erosion regulation	2	1	1	1	2	0	1
	maintenance of soil fertility	1	1	1	2	2	0	1
	natural hazard regulation	1	1	1	2	2	3	1
	climate regulation	2	2	2	1	2	3	1
	pollination	0	2	2	2	2	2	2
	biological control	2	2	2	1	2	0	2
Supporting ES	soil formation	2	2	3	2	2	0	2
	nutrient cycling	2	2	2	2	2	0	1
	maintenance of genetic diversity	2	2	2	1	2	0	1
Cultural ES	cultural/ spiritual/ inspirational	2	2	2	1	2	2	1
	recreational	2	2	2	1	2	2	1
	educational/research	2	2	2	2	2	2	2
	aesthetic	2	2	2	2	2	2	1

4.4 Lake Albert Sub-Basin

Lake Kyoga (described above) flows into the Lake Albert sub-basin, specifically into the Northeast part of Lake Albert. Currently, Lake Edward and Lake Albert are connected through the Semliki River (Dumont 2009; Rebelo & McCartney 2012).

Most of the documents pertaining this sub-basin dealt with biodiversity conservation in protected forest areas in the Albertine Rift Forests, like the Bwindi Impenetrable Forest National Park and Volcanoes National Park (Bush 2009; Bush *et al.* 2012). Particularly important for this region is the economic return of biodiversity conservation through mountain gorilla (*Gorilla beringei beringei*) eco-tourism (Bush 2009).

Besides tourism, these forests provide food, fodder for livestock and farmland, fresh water, medicinal products and genetic materials (Bush *et al.* 2004; Bush 2009; MacLean *et al.* 2010). Particularly important for the region is the use of wood for domestic energy consumption, so the proper valuation and conservation of forests is key given the regions' role in carbon sequestration and the importance of soil conservation (MacLean *et al.* 2010). The ES identified for the Lake Albert sub-basin are further presented in Table 11.

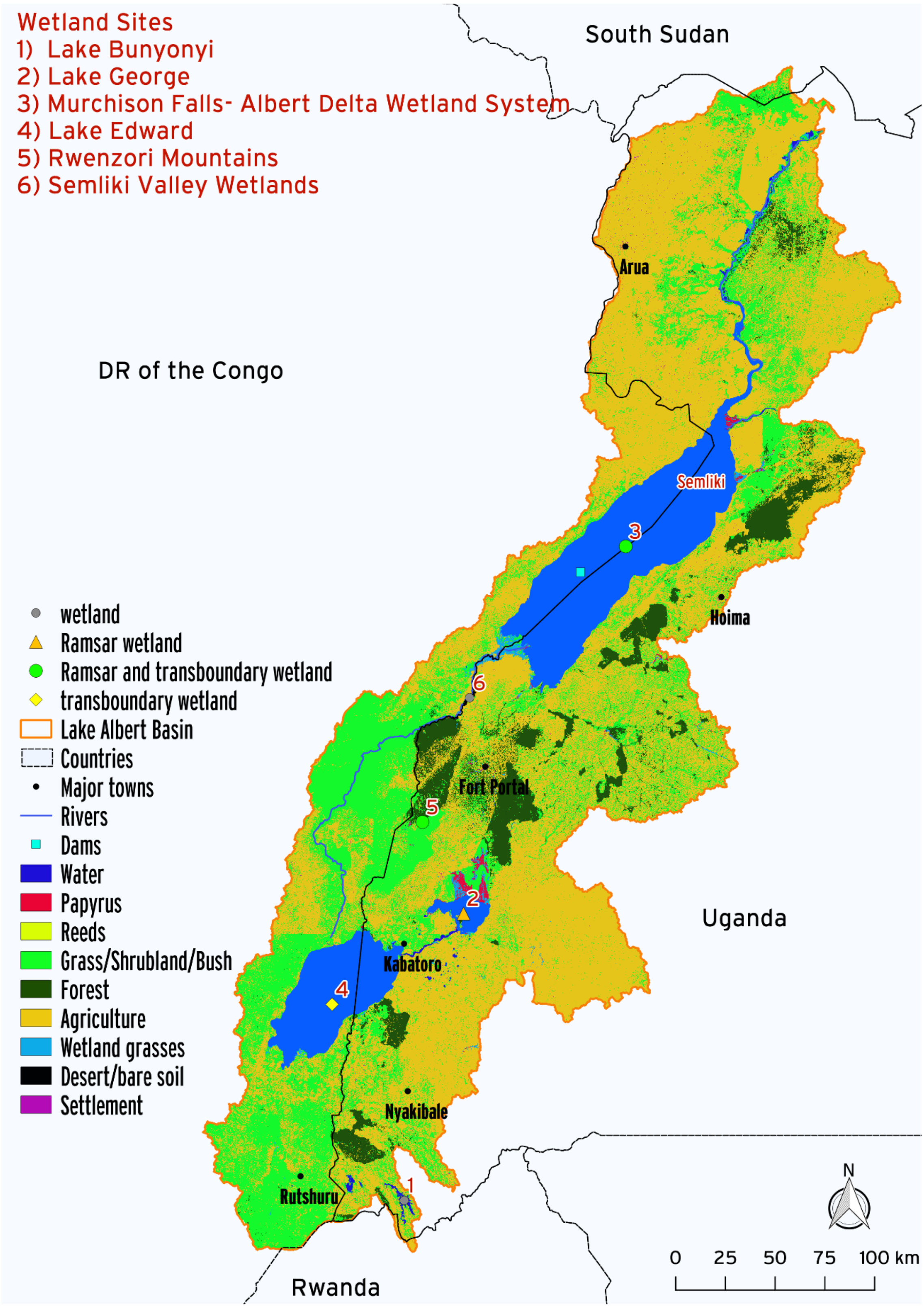

Figure 4. Lake Albert Sub-basin depicting specific wetlands, vegetation units, identification of transboundary wetlands and Ramsar wetlands

Table 11. Present Ecosystem Services (ES) within the Lake Albert Sub-Basin

0 = not applicable; 1 = ES in the Lake Albert Sub-Basin (according to literature); 2= ES potentially available in the Lake Albert Sub-Basin (based on Table 3 - expert judgement); 3 = Not Known

Ecosystem Services Category	Ecosystem Services	Open water (1)	Permanent Swamps - Papyrus (2)	Reeds (3)	Grassland (4)	Woodland/Forest (5)	Agriculture (6)	Other/Not Specified (0)
Provisioning ES	food - wild fish	1	1	2	0	1	0	1
	food - insects	2	2	2	2	1	3	3
	food - wild game	2	2	2	1	1	2	1
	food - fruits	0	2	2	2	1	2	1
	food - vegetables	0	2	2	2	1	2	1
	food - grains	0	2	2	2	1	2	1
	food - fodder and pasture (for livestock)	2	2	2	1	1	2	1
	food - farmland (for crop cultivation)	3	1	2	1	1	2	1
	fresh water	2	2	2	2	1	0	1
	fuel/ fiber/ raw materials	3	1	2	1	1	2	1
	medicinal products	3	2	2	1	1	3	1
	genetic materials	2	2	2	2	1	3	1
	Transport Infrastructure	2	0	0	2	1	0	2
Regulating ES	waterflow regulation	2	2	2	1	1	0	1
	water purification/waste treatment	2	1	2	2	1	0	1
	erosion regulation	2	1	2	1	1	0	1
	maintenance of soil fertility	2	2	2	2	1	0	2
	natural hazard regulation	2	2	2	2	1	3	1
	climate regulation	2	1	2	1	1	3	1
	pollination	0	2	2	2	2	2	2
	biological control	2	2	2	1	2	0	2
Supporting ES	soil formation	2	2	3	2	2	0	2
	nutrient cycling	2	2	2	2	2	0	2
	maintenance of genetic diversity	2	2	2	1	1	0	1
Cultural ES	cultural/ spiritual/ inspirational	2	2	2	1	1	2	1
	recreational	2	2	2	1	1	2	1
	educational/research	2	2	2	2	1	2	1
	aesthetic	2	2	2	2	1	2	2

4.4.1 Semliki Wetlands

Only one of the analyzed documents was specific to this wetland group region, but as before, it's focused on the Murchinson-Semliki forests and not directly on the wetlands. However, forests play an important role for water infiltration and purification. Besides this, they provide food in the form of game, fruits, vegetables, grains, fodder for livestock and farmland, timber and non-timber forest products, and genetic materials. Other regulating and supporting services include natural hazard and climate regulation, maintenance of soil fertility and they also support wildlife and the maintenance of genetic diversity. This region is also important for cultural, recreational and educational values (Akwetaireho *et al.* 2011). The ES identified for the Semliki wetlands are further presented in Table 12.

Table 12. Present Ecosystem Services (ES) within the Semliki Wetlands Group

0 = not applicable; 1 = ES in the Semliki Wetlands Group (according to literature); 2= ES potentially available in Semliki Wetlands Group (based on Table 3 - expert judgement); 3 = Not Known

Ecosystem Services Category	Ecosystem Services	Open water (1)	Permanent Swamps - Papyrus (2)	Reeds (3)	Grassland (4)	Woodland/Forest (5)	Agriculture (6)	Other/Not Specified (0)
Provisioning ES	food - wild fish	1	1	2	0	1	0	1
	food - insects	2	2	2	2	2	3	3
	food - wild game	2	2	2	1	1	2	1
	food - fruits	0	2	2	2	1	2	1
	food - vegetables	0	2	2	2	1	2	1
	food - grains	0	2	2	2	1	2	1
	food - fodder and pasture (for livestock)	2	2	2	1	1	2	1
	food - farmland (for crop cultivation)	3	1	2	1	1	2	1
	fresh water	2	2	2	2	1	0	1
	fuel/ fiber/ raw materials	3	1	2	1	1	2	1
	medicinal products	3	2	2	1	1	3	1
	genetic materials	2	2	2	2	1	3	1
	Transport Infrastructure	2	0	0	2	2	0	2
Regulating ES	waterflow regulation	2	2	2	1	1	0	1
	water purification/waste treatment	2	1	2	2	1	0	1
	erosion regulation	2	1	2	1	1	0	1
	maintenance of soil fertility	2	2	2	2	1	0	2
	natural hazard regulation	2	2	2	2	1	3	1
	climate regulation	2	1	2	1	1	3	1
	pollination	0	2	2	2	2	2	2
	biological control	2	2	2	1	2	0	2
Supporting ES	soil formation	2	2	3	2	2	0	2
	nutrient cycling	2	2	2	2	2	0	2
	maintenance of genetic diversity	2	2	2	1	1	0	1
Cultural ES	cultural/ spiritual/ inspirational	2	2	2	1	1	2	1
	recreational	2	2	2	1	1	2	1
	educational/research	2	2	2	2	1	2	1
	aesthetic	2	2	2	2	1	2	2

4.5 Bahr el Jebel Sub-Basin

The Bahr el Jebel sub-basin in South Sudan comprises the upper reach of the White Nile river (Rebelo & McCartney 2012). This river is fed primarily by the outflow at Lake Albert. The literature considered so far for this sub-basin focuses specifically on the Sudd wetlands, described below. The ES identified for the Bahr el Jebel sub-basin are further represented in Table 13. This table also represents the ES identified for the Sudd wetlands (described below) since the same four references were the only ones considering this sub-basin.

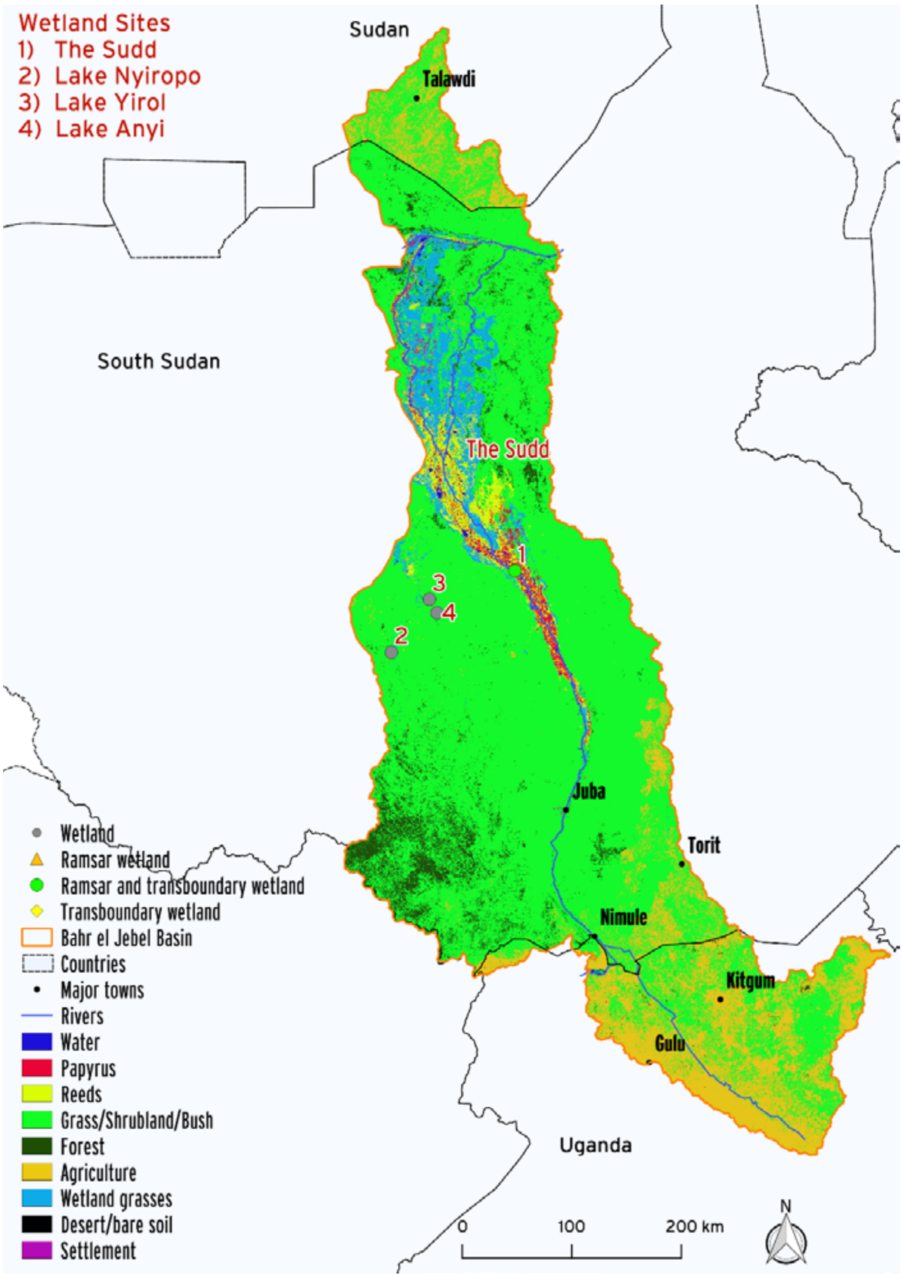

Figure 5. Bahr El Jebel Sub-basin depicting specific wetlands, vegetation units, identification of transboundary wetlands and Ramsar wetlands

Table 13. Present Ecosystem Services (ES) within Bahr El Jebel Sub-Basin

0 = not applicable; 1 = ES in Bahr El Jebel Sub-Basin (according to literature); 2= ES potentially available in Bahr El Jebel Sub-Basin (based on Table 3 - expert judgement); 3 = Not Known

Ecosystem Services Category	Ecosystem Services	Open water (1)	Permanent Swamps - Papyrus (2)	Reeds (3)	Grassland (4)	Woodland/Forest (5)	Agriculture (6)	Other/Not Specified (0)
Provisioning ES	food - wild fish	1	1	1	0	0	0	2
	food - insects	2	2	2	2	2	3	3
	food - wild game	2	1	1	1	1	2	2
	food - fruits	0	2	2	2	1	2	2
	food - vegetables	0	2	2	2	2	2	2
	food - grains	0	2	2	2	2	2	2
	food - fodder and pasture (for livestock)	2	1	1	1	1	2	2
	food - farmland (for crop cultivation)	3	1	1	1	1	2	2
	fresh water	1	1	1	2	2	0	2
	fuel/ fiber/ raw materials	3	2	1	2	1	2	2
	medicinal products	3	2	2	2	1	3	2
	genetic materials	2	2	2	2	2	3	2
	Transport Infrastructure	1	0	0	2	2	0	2
Regulating ES	waterflow regulation	2	1	1	1	1	0	2
	water purification/waste treatment	2	1	1	1	1	0	2
	erosion regulation	2	2	2	2	2	0	2
	maintenance of soil fertility	2	2	2	2	2	0	2
	natural hazard regulation	2	1	1	1	1	3	2
	climate regulation	1	1	1	1	1	3	2
	pollination	0	2	2	2	2	2	2
	biological control	2	2	2	2	2	0	2
Supporting ES	soil formation	2	2	3	2	2	0	2
	nutrient cycling	2	2	2	2	2	0	2
	maintenance of genetic diversity	2	2	2	2	2	0	2
Cultural ES	cultural/ spiritual/ inspirational	1	1	1	1	1	2	2
	recreational	1	1	1	1	1	2	2
	educational/research	1	1	1	1	1	2	2
	aesthetic	2	2	2	2	2	2	2

4.5.1 Sudd Wetlands

The Sudd wetland is the largest freshwater wetland in the Nile Basin and an ecosystem of worldwide importance (Riak 2006; Rebelo & McCartney 2012; Rebelo & El-Moghraby 2016; Gowdy & Lang 2016). The area supports a diverse range of habitats (*e.g.* open water, swamps, seasonally flooded grasslands, floodplain woodlands) which are highly dependent on the annual flood pulse (Rebelo & McCartney 2012). The area also supports great biodiversity and at least three different tribes (Dinka, Nuer and Shilluk tribes) that live in the Sudd and its surroundings (Rebelo & McCartney 2012), who temporarily migrate with the wet-dry season as the Sudd floods to make use of the products and services this ecosystem provides (Riak 2006; Gowdy & Lang 2016).

The Sudd contributes provisioning ecosystem services in the form of food (fish, game and fruits), freshwater, building materials, and medicinal products. Particularly important are the diversity of vegetation communities that are heavily used for grazing, especially the seasonally river-flooded grassland ("toich" in the local Dinka language), which is the most productive for year-round grazing caused by the high protein content of the dead grass. Further the flooded areas are an important freshwater source for livestock during the dry season. The Sudd as a water source is also important for other wildlife during the dry season (Riak 2006).

Fishing is also an important seasonal activity and source of food as fish migrate to the nutrient-rich floodplains. It is the second most important occupation of the inhabitants of the wetlands, in particular for the Shilluk and Nuer tribes, and is typically conducted seasonally alternately with crop production and livestock-rearing (Rebelo & McCartney 2012). Many fish species migrate from the surrounding rivers to the nutrient-rich floodplains to feed and breed during the seasonal floods and therefore play an important role in the life cycles of many fish species identified in the wetland. The different habitat types ranging from open water, riverine, lacustrine to palustrine offer ideal conditions for over hundred species of fish (Riak 2006).

Subsistence hunting is also important to the Nilotes of the Sudd catchment. Crop production is not a significant occupation although some subsistence agriculture is carried out in the highland areas during the wet season (Rebelo & El-Moghraby 2016). The tree vegetation is an important source of firewood and building poles (Riak 2006). The wetland is used as well for commercial and non-commercial navigation (Rebelo & El-Moghraby 2016).

Besides these products and supporting biodiversity, the Sudd also provides regulating ecosystem services such as the regulation of water flow, nutrient retention, purification of water, and providing climatic and natural hazard regulation. The socioeconomic benefits of the wetland to the communities living in its catchment are considered as immense (Rebelo & El-Moghraby 2016).

Ultimately, the Sudd has very important cultural values for the local tribes, from sacred wildlife species (*e.g.* Nile lechwe (*Ontragus megaceros*), the shoebill stork (*Balaeniceps rex*), and the crowned crane (*Balearica pavonina*)) to important ritual places, used for the initiation of relationships and dancing leading to courtship and marriage (Rebelo & El-Moghraby 2016). According to Gowdy & Lang (2016), if properly managed, the Sudd wetland can greatly contribute to the sustainable economic development of South Sudan.

4.6 Bahr el Ghazal Sub-Basin

The Bahr el Ghazal sub-basin is the Westernmost part of the Nile river basin, consisting of several small tributaries flowing down from the border of the Congo-Nile basins. This sub-basin is part of Sudan and South Sudan. The Bahr el Ghazal is a seasonal stream that flows East to meet the Bahr el Jebel river (White Nile) (Dumont.2009). This river has a negligible contribution, discharge-wise, as most of it evaporates before reaching the Nile (Rebelo & McCartney 2012).

Although no specific documents within the analyzed literature dealt with this sub-basin, a report by Ibnaof *et al*. (2013) studies the economic value of ecosystems and biodiversity within North Kordofan State, a State of Sudan located within the Bahr el Ghazal sub-basin. The main ecosystem uses considered are pastoralism, agriculture, fisheries, fresh water, fuelwood, carbon sequestration, water production, cultural and recreational values. The Gum Arabic (*Acacia senegal* & *Acacia sayal*) extraction and production is of particular interest for the region, with an approximate value of $65-$250M (Ibnaof *et al.* 2013).

4.6.1 Bahr el Ghazal wetlands

Although no particular document within the revised literature addressed the Bahr el Ghazal wetlands, Rebelo & McCartney (2012) state that the livelihood activities of Bahr el Ghazal are similar to those of the Sudd. Therefore, potential ecosystem services of these wetlands are fish resources, subsistence hunting, fruits and other food sources, fresh water, fuelwood, building materials and medicinal products. Potential regulating and supporting services include the regulation of water flow, nutrient retention, water purification, natural hazard and climate regulation, and potentially important cultural values of the locals. The potential ES identified for the Bahr el Ghazal sub-basin and wetlands are further presented in Table 14.

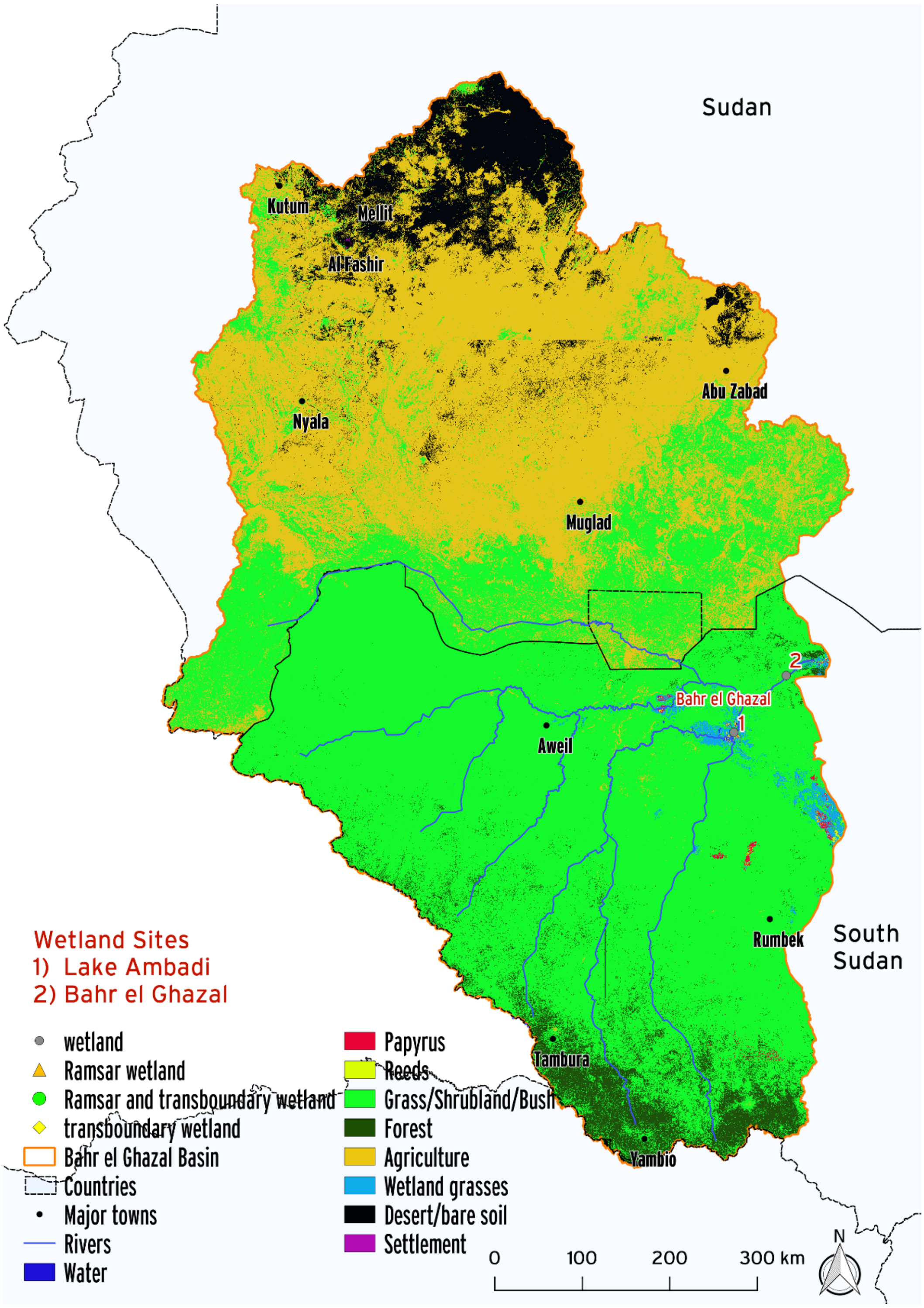

Figure 6. Bahr el Ghazal Sub-basin depicting specific wetlands, vegetation units, identification of transboundary wetlands and Ramsar wetlands

Table 14. Present Ecosystem Services (ES) within the Bahr El Ghazal Sub-Basin AND Bahr El Ghazal Wetlands Group

0 = not applicable; 1 = ES in the Bahr El Ghazal Sub-Basin AND Bahr El Ghazal Wetlands Group (according to literature); 2= ES potentially available in Bahr El Ghazal Sub-Basin AND Bahr El Ghazal Wetlands Group (based on Table 3 - expert judgement); 3 = Not Known

Ecosystem Services Category	Ecosystem Services	Open water (1)	Permanent Swamps - Papyrus (2)	Reeds (3)	Grassland (4)	Woodland/Forest (5)	Agriculture (6)	Other/Not Specified (0)
Provisioning ES	food - wild fish	2	2	2	0	0	0	2
	food - insects	2	2	2	2	2	3	3
	food - wild game	2	2	2	2	2	2	2
	food - fruits	0	2	2	2	2	2	2
	food - vegetables	0	2	2	2	2	2	2
	food - grains	0	2	2	2	2	2	2
	food - fodder and pasture (for livestock)	2	2	2	2	2	2	2
	food - farmland (for crop cultivation)	3	2	2	2	2	2	2
	fresh water	2	2	2	2	2	0	2
	fuel/ fiber/ raw materials	3	2	2	2	2	2	2
	medicinal products	3	2	2	2	2	3	2
	genetic materials	2	2	2	2	2	3	2
	Transport Infrastructure	2	0	0	2	2	0	2
Regulating ES	waterflow regulation	2	2	2	2	2	0	2
	water purification/waste treatment	2	2	2	2	2	0	2
	erosion regulation	2	2	2	2	2	0	2
	maintenance of soil fertility	2	2	2	2	2	0	2
	natural hazard regulation	2	2	2	2	2	3	2
	climate regulation	2	2	2	2	2	3	2
	pollination	0	2	2	2	2	2	2
	biological control	2	2	2	2	2	0	2
Supporting ES	soil formation	2	2	3	2	2	0	2
	nutrient cycling	2	2	2	2	2	0	2
	maintenance of genetic diversity	2	2	2	2	2	0	2
Cultural ES	cultural/ spiritual/ inspirational	2	2	2	2	2	2	2
	recreational	2	2	2	2	2	2	2
	educational/research	2	2	2	2	2	2	2
	aesthetic	2	2	2	2	2	2	2

4.7 Baro Akobo Sobat Sub-Basin

Another major tributary of the White Nile, flowing from the Southeast, is the Sobat river (Dumont 2009). The Sobat is formed at the confluence of the Baro and Akobo rivers. It is along these rivers that the Machar marshes are formed. The ES identified for the Baro Akobo Sobat sub-basin are further presented in Table 15.

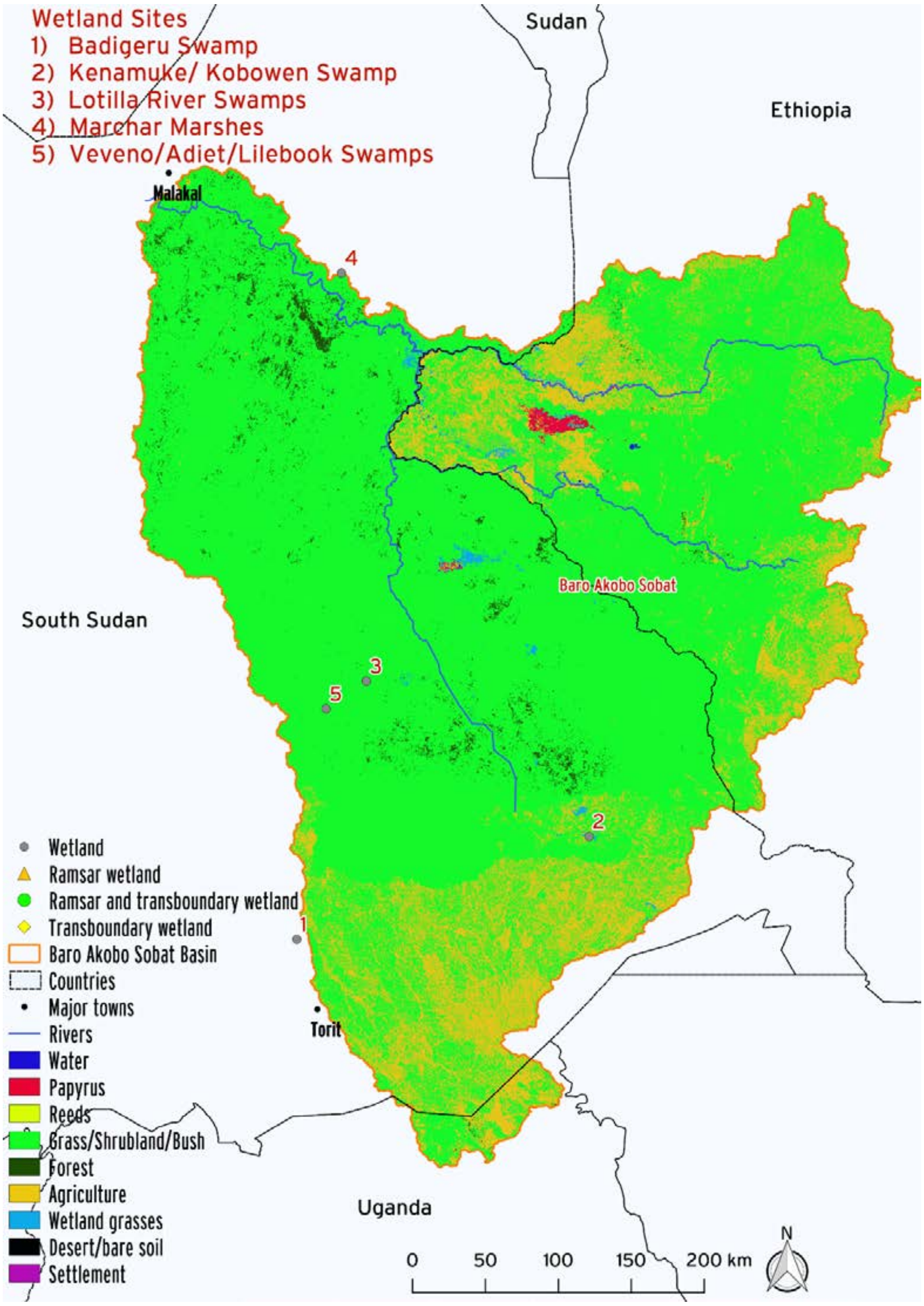

Figure 7. Baro Akobo Sobat Sub-basin depicting specific wetlands, vegetation units, identification of transboundary wetlands and Ramsar wetlands

Table 15. Present Ecosystem Services (ES) within the Baro Akobo Sobat Sub-Basin

0 = not applicable; 1 = ES in Baro Akobo Sobat Sub-Basin (according to literature); 2= ES potentially available in Baro Akobo Sobat Sub-Basin (based on Table 3 - expert judgement); 3 = Not Known

Ecosystem Services Category	Ecosystem Services	Open water (1)	Permanent Swamps - Papyrus (2)	Reeds (3)	Grassland (4)	Woodland/Forest (5)	Agriculture (6)	Other/Not Specified (0)
Provisioning ES	food - wild fish	2	2	2	0	0	0	2
	food - insects	2	2	2	2	1	3	3
	food - wild game	2	2	2	2	1	2	2
	food - fruits	0	2	2	2	1	2	2
	food - vegetables	0	2	2	2	1	2	2
	food - grains	0	2	2	2	1	2	2
	food - fodder and pasture (for livestock)	2	2	2	2	1	2	1
	food - farmland (for crop cultivation)	3	2	2	2	2	2	2
	fresh water	2	2	2	2	2	0	1
	fuel/ fiber/ raw materials	3	2	2	2	1	2	1
	medicinal products	3	2	2	2	1	3	1
	genetic materials	2	2	2	2	1	3	2
	Transport Infrastructure	2	0	0	2	2	0	2
Regulating ES	waterflow regulation	2	2	2	2	1	0	1
	water purification/waste treatment	2	2	2	2	1	0	1
	erosion regulation	2	2	2	2	1	0	1
	maintenance of soil fertility	2	2	2	2	1	0	1
	natural hazard regulation	2	2	2	2	1	3	2
	climate regulation	2	2	2	2	1	3	1
	pollination	0	2	2	2	1	2	1
	biological control	2	2	2	2	2	0	1
Supporting ES	soil formation	2	2	3	2	1	0	2
	nutrient cycling	2	2	2	2	1	0	2
	maintenance of genetic diversity	2	2	2	2	1	0	1
Cultural ES	cultural/ spiritual/ inspirational	2	2	2	2	1	2	1
	recreational	2	2	2	2	1	2	1
	educational/research	2	2	2	2	2	2	2
	aesthetic	2	2	2	2	1	2	2

4.7.1 Baro-Akobo-Sobat Wetlands (Machar marshes)

The Machar marshes are a large wetland complex of lakes and floodplains in Eastern Sudan and Western Ethiopia. These are fed by local precipitation, inflows from the Ethiopian highlands and flood pulses from the Baro, Akobo and Sobat rivers (Dumont 2009; Rebelo & McCartney 2012).

None of the analysed documents dealt with this wetland group specifically nor within the sub-basin. However, we can take from Rebelo & McCartney (2012) that the Machar Marshes floodplains are used for grazing, hunting and fishing. The use of these wetlands in Sudan is not so intensive due to the low population density, but they are more utilized in Ethiopia for fresh water, fisheries, construction m aterials, medicinal plants, grazing and cultivation (Rebelo & McCartney 2012).

Given its dense papyrus areas (Rebelo & McCartney 2012), potentially these wetlands serve regulating purposes like waterflow and erosion regulation, water purification, maintenance of soil fertility, natural hazard and climate regulation. Other potential supporting and cultural services might include wildlife habitat and the maintenance of genetic diversity and recreation and educational purposes. The ES identified for the Baro Akobo Sobat wetlands are further presented in Table 16.

Table 16. Present Ecosystem Services (ES) within the Baro Akobo Sobat Wetlands Group

0 = not applicable; 1 = ES in the Baro Akobo Sobat Wetlands Group (according to literature); 2= ES potentially available in Baro Akobo Sobat Wetlands Group (based on Table 3 - expert judgement); 3 = Not Known

Ecosystem Services Category	Ecosystem Services	Open water (1)	Permanent Swamps - Papyrus (2)	Reeds (3)	Grassland (4)	Woodland/Forest (5)	Agriculture (6)	Other/Not Specified (0)
Provisioning ES	food - wild fish	2	2	2	0	0	0	2
	food - insects	2	2	2	2	2	3	3
	food - wild game	2	2	2	2	2	2	2
	food - fruits	0	2	2	2	2	2	2
	food - vegetables	0	2	2	2	2	2	2
	food - grains	0	2	2	2	2	2	2
	food - fodder and pasture (for livestock)	2	2	2	2	2	2	2
	food - farmland (for crop cultivation)	3	2	2	2	2	2	2
	fresh water	2	2	2	2	2	0	2
	fuel/ fiber/ raw materials	3	2	2	2	2	2	2
	medicinal products	3	2	2	2	2	3	2
	genetic materials	2	2	2	2	2	3	2
	Transport Infrastructure	2	0	0	2	2	0	2
Regulating ES	waterflow regulation	2	2	2	2	2	0	2
	water purification/waste treatment	2	2	2	2	2	0	2
	erosion regulation	2	2	2	2	2	0	2
	maintenance of soil fertility	2	2	2	2	2	0	2
	natural hazard regulation	2	2	2	2	2	3	2
	climate regulation	2	2	2	2	2	3	2
	pollination	0	2	2	2	2	2	2
	biological control	2	2	2	2	2	0	2
Supporting ES	soil formation	2	2	3	2	2	0	2
	nutrient cycling	2	2	2	2	2	0	2
	maintenance of genetic diversity	2	2	2	2	2	0	2
Cultural ES	cultural/ spiritual/ inspirational	2	2	2	2	2	2	2
	recreational	2	2	2	2	2	2	2
	educational/research	2	2	2	2	2	2	2
	aesthetic	2	2	2	2	2	2	2

4.8 White Nile Sub-Basin

The White Nile sub-basin begins where the Bahr el Jebel River and Baro-Akobo-Sobat River converge. The Sudd provides the base flow for this sub-basin and the Sobat river contributes seasonally. This sub-basin lies within Ethiopia, Sudan and South Sudan. This region provides a long stretch of navigable waters due to the relatively stable flow and flat slope (NBI 2017). No specific wetland group was considered within this sub-basin, and within the analyzed literature only one document dealt partly with this sub-basin. The ES identified for the White Nile sub-basin are further represented in Table 17.

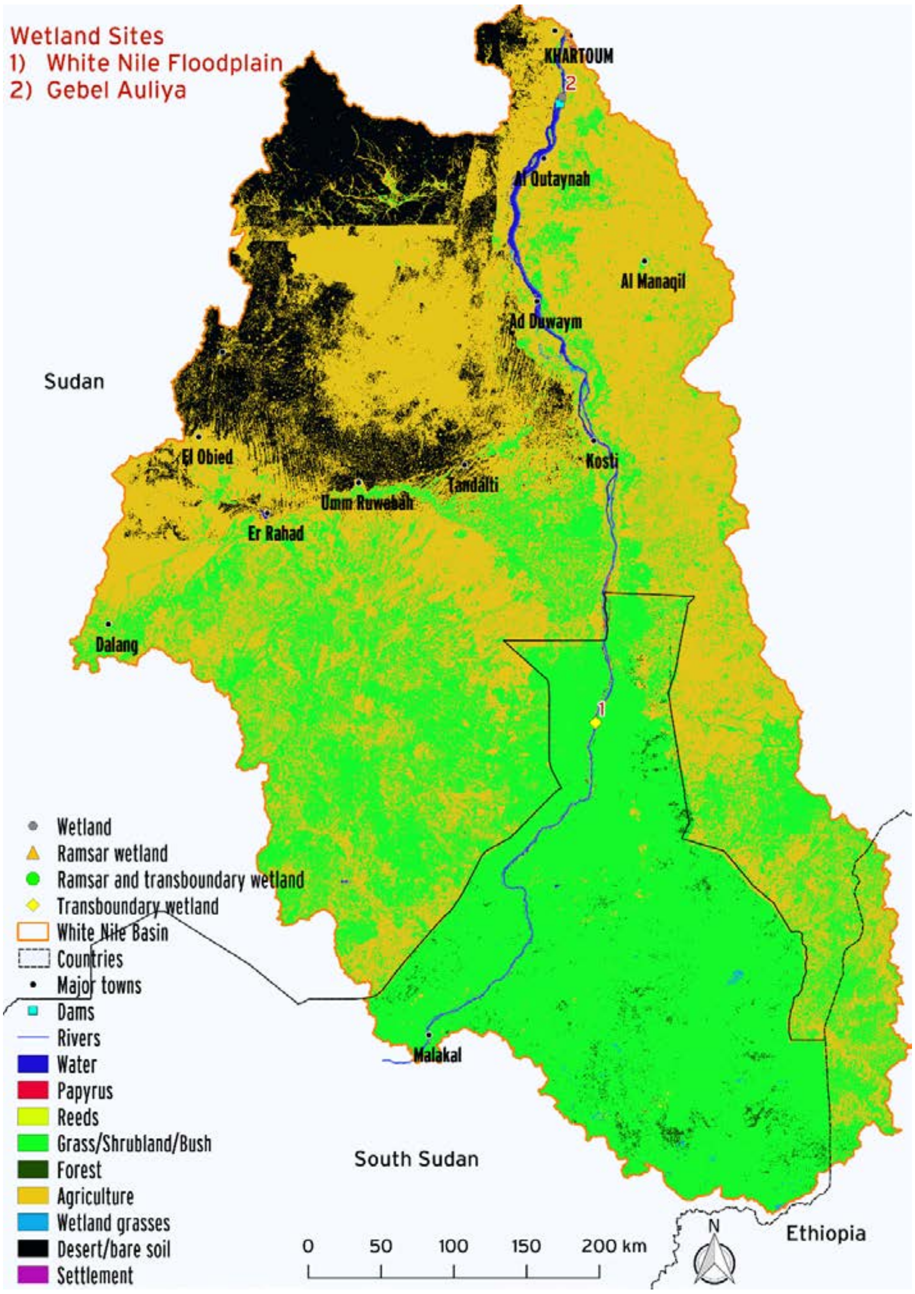

Figure 8. White Nile Sub-basin depicting specific wetlands, vegetation units, identification of transboundary wetlands and Ramsar wetlands

Table 17. Present Ecosystem Services (ES) within the White Nile Sub-Basin

0 = not applicable; 1 = ES in White Nile Sub-Basin (according to literature); 2= ES potentially available in White Nile Sub-Basin (based on Table 3 - expert judgement); 3 = Not Known

Ecosystem Services Category	Ecosystem Services	Open water (1)	Permanent Swamps - Papyrus (2)	Reeds (3)	Grassland (4)	Woodland/Forest (5)	Agriculture (6)	Other/Not Specified (0)
Provisioning ES	food - wild fish	2	2	2	0	0	0	2
	food - insects	2	2	2	2	2	3	3
	food - wild game	2	2	2	2	2	2	2
	food - fruits	0	2	2	2	2	2	2
	food - vegetables	0	2	2	2	2	2	2
	food - grains	0	2	2	2	2	2	2
	food - fodder and pasture (for livestock)	2	2	2	1	1	2	2
	food - farmland (for crop cultivation)	3	2	2	1	1	2	2
	fresh water	2	2	2	1	1	0	2
	fuel/ fiber/ raw materials	3	2	2	2	1	2	2
	medicinal products	3	2	2	2	1	3	2
	genetic materials	2	2	2	2	2	3	2
	Transport Infrastructure	2	0	0	2	2	0	2
Regulating ES	waterflow regulation	2	2	2	1	1	0	2
	water purification/waste treatment	2	2	2	2	2	0	2
	erosion regulation	2	2	2	1	1	0	2
	maintenance of soil fertility	2	2	2	1	1	0	2
	natural hazard regulation	2	2	2	2	2	3	2
	climate regulation	2	2	2	2	2	3	2
	pollination	0	2	2	2	2	2	2
	biological control	2	2	2	2	2	0	2
Supporting ES	soil formation	2	2	3	2	2	0	2
	nutrient cycling	2	2	2	1	1	0	2
	maintenance of genetic diversity	2	2	2	2	2	0	2
Cultural ES	cultural/ spiritual/ inspirational	2	2	2	2	2	2	2
	recreational	2	2	2	1	1	2	2
	educational/research	2	2	2	1	1	2	2
	aesthetic	2	2	2	2	2	2	2

4.9 Blue Nile Sub-Basin

The Blue Nile and its main tributaries, Dinder and Rahad rivers, flow out of Lake Tana in the central Ethiopian highlands towards the Northwest until the confluence with the White Nile at Khartoum (Sudan). In contrast with the White Nile profile, the Blue Nile flows through a very steep area so its flow is torrential, and the discharge contribution of the Blue Nile system is about twice that of the White Nile system (Dumont 2009; NBI 2017). Tesfaye *et al.* (2016) valued the main ecosystem services of the Blue Nile Basin in Ethiopia (of provisioning and regulating services) in approximately 52 million US$ for 2011, concluding also that this could be way higher if proper water resources management was enforced. The ecosystem services included were irrigation water, fisheries resources, energy production and commercial navigation (Tesfaye *et al.* 2016). The ES identified for the Blue Nile sub-basin are further presented in Table 18.

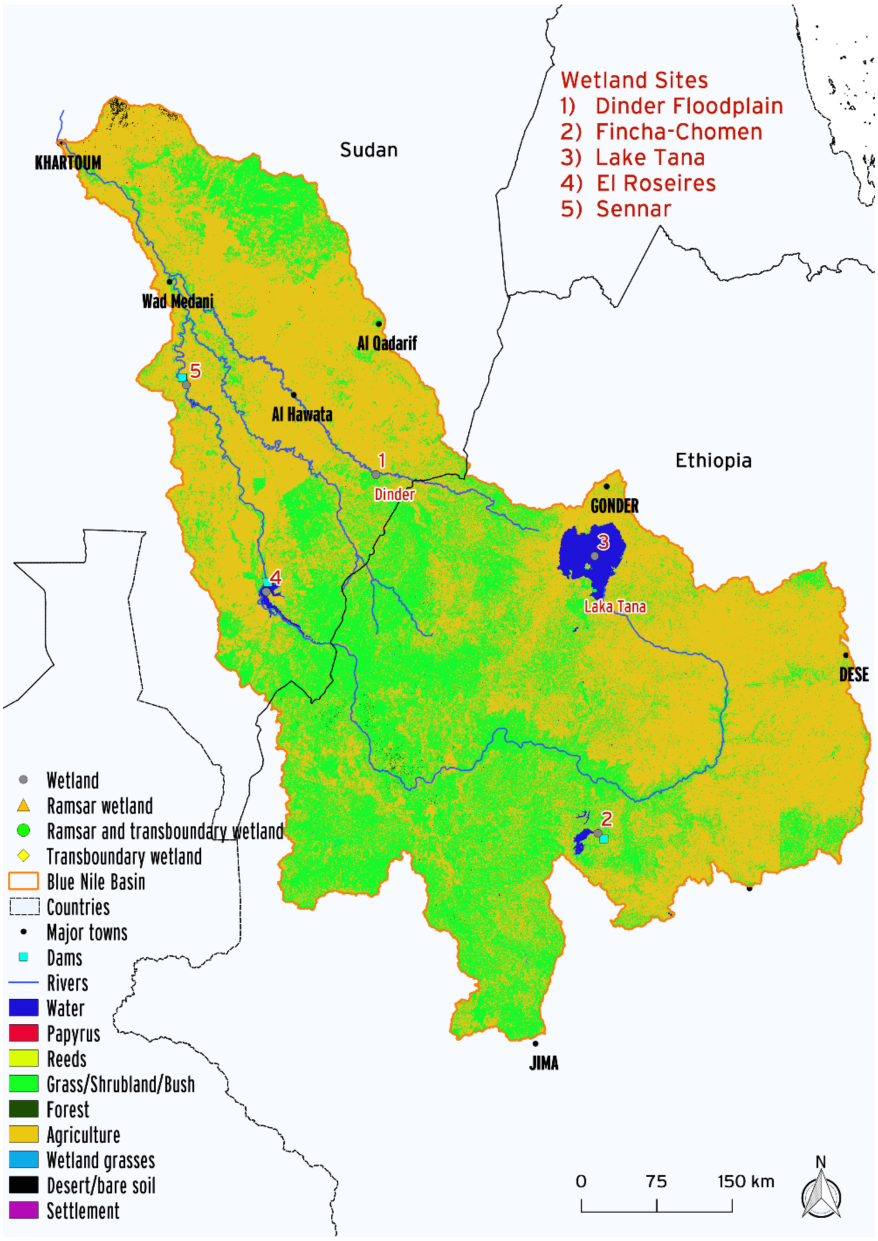

Figure 9. Blue Nile Sub-basin depicting specific wetlands, vegetation units, identification of transboundary wetlands and Ramsar wetlands

Table 18. Present Ecosystem Services (ES) within the Blue Nile Sub-Basin

0 = not applicable; 1 = ES in Blue Nile Sub-Basin (according to literature); 2= ES potentially available in Blue Nile Sub-Basin (based on Table 3 - expert judgement); 3 = Not Known

Ecosystem Services Category	Ecosystem Services	Open water (1)	Permanent Swamps - Papyrus (2)	Reeds (3)	Grassland (4)	Woodland/Forest (5)	Agriculture (6)	Other/Not Specified (0)
Provisioning ES	food - wild fish	1	1	1	0	0	0	1
	food - insects	2	2	2	2	1	3	3
	food - wild game	2	1	1	1	1	2	1
	food - fruits	0	1	2	1	1	2	1
	food - vegetables	0	1	2	1	1	2	1
	food - grains	0	1	2	1	1	2	1
	food - fodder and pasture (for livestock)	2	1	1	1	1	1	1
	food - farmland (for crop cultivation)	3	1	2	1	1	1	1
	fresh water	1	2	2	1	1	0	1
	fuel/ fiber/ raw materials	3	1	1	1	1	1	1
	medicinal products	3	1	1	1	1	3	1
	genetic materials	1	1	1	1	1	3	2
	Transport Infrastructure	1	0	0	2	2	0	1
Regulating ES	waterflow regulation	1	1	1	1	1	0	1
	water purification/waste treatment	2	1	1	1	1	0	1
	erosion regulation	2	1	1	1	1	1	1
	maintenance of soil fertility	2	1	1	1	1	1	1
	natural hazard regulation	2	2	2	1	1	3	2
	climate regulation	2	2	2	1	1	3	1
	pollination	0	2	2	2	1	2	1
	biological control	2	2	2	2	2	0	1
Supporting ES	soil formation	2	2	3	2	1	0	1
	nutrient cycling	1	1	1	1	1	1	2
	maintenance of genetic diversity	1	1	1	1	1	0	1
Cultural ES	cultural/ spiritual/ inspirational	1	1	1	1	1	2	1
	recreational	1	1	1	1	1	2	1
	educational/research	1	1	1	1	1	2	2
	aesthetic	1	1	1	1	1	2	2

4.9.1 Tana Wetlands

Lake Tana is Ethiopia's largest lake and contains about half the country's freshwater. During the rainy season, the surrounding (papyrus) swamps are connected with the main lake, and this acts as nurseries for most fish populations in the lake and breeding areas for birds and mammals (Vijverberg *et al.* 2009). Besides habitat for wildlife, the human population also makes use of the fishing resources for commercial and non-commercial purposes. Some species are preferred over others (like *Barbus* over catfish) for cultural and religious reasons. This lake also provides area for crop cultivation and fresh water for agriculture and cattle. People also use it as means for transportation (Agimass & Mekonnen 2011).

Regulating services, like waterflow regulation and water purification, are also important and are being lost due to wetland conversion and loss of plant cover, increasing the silt inflow into the lake (Agimass & Mekonnen 2011). Other potential ecosystem services of Lake Tana are natural hazard and climate regulation, soil formation, nutrient cycling, maintenance of genetic diversity, and recreational and educational values. The ES identified for the Lake Tana wetlands are further represented in Table 19.

Table 19. Present Ecosystem Services (ES) within the Lake Tana Wetlands Group

0 = not applicable; 1 = ES in the Lake Tana Wetlands Group (according to literature); 2= ES potentially available in Lake Tana Wetlands Group (based on Table 3 - expert judgement); 3 = Not Known

Ecosystem Services Category	Ecosystem Services	Open water (1)	Permanent Swamps - Papyrus (2)	Reeds (3)	Grassland (4)	Woodland/Forest (5)	Agriculture (6)	Other/Not Specified (0)
Provisioning ES	food - wild fish	1	1	2	0	0	0	1
	food - insects	2	2	2	2	2	3	3
	food - wild game	2	2	2	2	2	2	2
	food - fruits	0	2	2	2	2	2	2
	food - vegetables	0	2	2	2	2	2	2
	food - grains	0	2	2	2	2	2	2
	food - fodder and pasture (for livestock)	2	1	2	2	2	1	1
	food - farmland (for crop cultivation)	3	1	2	2	1	1	1
	fresh water	1	2	2	2	2	0	1
	fuel/ fiber/ raw materials	3	1	2	2	1	1	2
	medicinal products	3	2	2	2	2	3	2
	genetic materials	2	2	2	2	2	3	2
	Transport Infrastructure	1	0	0	2	2	0	1
Regulating ES	waterflow regulation	2	2	2	2	2	0	1
	water purification/waste treatment	2	2	2	2	2	0	2
	erosion regulation	2	2	2	2	1	1	1
	maintenance of soil fertility	2	2	2	2	1	1	2
	natural hazard regulation	2	2	2	2	2	3	2
	climate regulation	2	2	2	2	2	3	2
	pollination	0	2	2	2	2	2	2
	biological control	2	2	2	2	2	0	2
Supporting ES	soil formation	2	2	3	2	2	0	2
	nutrient cycling	2	2	2	2	1	1	2
	maintenance of genetic diversity	2	2	2	2	2	0	2
Cultural ES	cultural/ spiritual/ inspirational	2	2	2	2	2	2	2
	recreational	1	1	2	2	2	2	1
	educational/research	2	2	2	2	2	2	2
	aesthetic	2	2	2	2	2	2	2

4.9.2 Dinder Wetlands

The Dinder wetlands are located along the tributaries of the Blue Nile, at the floodplains between the Dinder and Rahad rivers in the Sudan side of the basin (Rebelo & McCartney 2012). The Dinder National Park (DNP), at the border between Sudan and Ethiopia, lies along an ecotone of two important floristic and faunal regions, reason for its rich biodiversity (Nile-Eco-VWU).

The DNP thus provides habitat for wildlife and the maintenance of genetic diversity. In it live important primate species like the baboon (*Papio anubis*) and husser monkey (*Cercopithecus aethiops*). It also hosts endangered species, like the Arabian bustard (*Ardeotis arabs*). Some fowl species are also an important source of food for the local people (Nile-Eco-VWU).

The main provisioning services of the Dinder wetlands are fresh water, farmland along the riverbanks, food (wild fruits like Nabag (*Ziziphus spp*)), timber, and non-timber forest products (particularly *Ziziphus* leaves for handcrafts for household use and for sale) (Nile-Eco-VWU). These wetlands are also an important source of water and nutritious grasses for livestock, particularly during the dry season (Rebelo & McCartney 2012).

They also provide important regulating services like air quality regulation, water purification and regulation, climate and erosion regulation, soil formation, pollination, biological control, and nutrient cycling. There are important cultural aspects as well rooted in the areas' cultural diversity, and some important species like the Saaf (*Ziziphus spp*) which is used in a ritual manner as a protection symbol. There are important archaeological sites, and the DNP is also an important area for recreation and education opportunities (Nile-Eco-VWU). The ES identified for the Dinder wetlands are further presented in Table 20.

Table 20. Present Ecosystem Services (ES) within the Dinder Wetlands Group

0 = not applicable; 1 = ES in the Dinder Wetlands Group (according to literature); 2= ES potentially available in Dinder Wetlands Group (based on Table 3 - expert judgement); 3 = Not Known

Ecosystem Services Category	Ecosystem Services	Open water (1)	Permanent Swamps - Papyrus (2)	Reeds (3)	Grassland (4)	Woodland/Forest (5)	Agriculture (6)	Other/Not Specified (0)
Provisioning ES	food - wild fish	1	1	1	0	0	0	1
	food - insects	2	2	2	2	2	3	3
	food - wild game	2	1	1	1	1	2	1
	food - fruits	0	1	2	1	1	2	1
	food - vegetables	0	1	2	1	1	2	1
	food - grains	0	1	2	1	1	2	1
	food - fodder and pasture (for livestock)	2	1	1	1	1	1	2
	food - farmland (for crop cultivation)	3	2	2	1	1	1	2
	fresh water	1	2	2	1	1	0	1
	fuel/ fiber/ raw materials	3	1	1	1	1	2	2
	medicinal products	3	1	1	1	1	3	1
	genetic materials	1	1	1	1	1	3	2
	Transport Infrastructure	2	0	0	2	2	0	2
Regulating ES	waterflow regulation	1	1	1	1	1	0	2
	water purification/waste treatment	2	1	1	1	1	0	2
	erosion regulation	2	1	1	1	1	0	2
	maintenance of soil fertility	2	1	1	1	1	0	2
	natural hazard regulation	2	2	2	1	1	3	2
	climate regulation	2	2	2	1	1	3	2
	pollination	0	2	2	2	2	2	1
	biological control	2	2	2	2	2	0	1
Supporting ES	soil formation	2	2	3	2	2	0	1
	nutrient cycling	1	1	1	1	1	0	2
	maintenance of genetic diversity	1	1	1	1	1	0	1
Cultural ES	cultural/ spiritual/ inspirational	1	1	1	1	1	2	2
	recreational	1	1	1	1	1	2	2
	educational/research	1	1	1	1	1	2	2
	aesthetic	1	1	1	1	1	2	2

4.10 Tekeze-Atbara Sub-Basin

After the White Nile and Blue Nile converge in Khartoum (Sudan), the Atbara river is the next tributary that joins the Main Nile in Sudan. This river contributes particularly after the summer floods (August-September) before it dries up again (Dumont 2009). This sub-basin is shared amongst the countries of Eritrea, Ethiopia and Sudan.

Although no specific wetland groups of interest for this study are within this sub-basin, some of the literature analyzed included studies on forest and woodland areas within this sub-basin that provide important ecosystem services to the local communities and for the wetlands downstream. Particularly the administrative sub-zone Dighe (Eritrea) is relevant for its biodiversity richness and socio-economic importance, which is threatened by forest clearings for commercial agriculture and resettlements (Aria 2005). These forests provide ecosystem products in the form of food like game, fruits, grains, fodder for livestock and farmland, as well as fresh water, timber and medicinal products. They also provide regulating and supporting services like waterflow regulation, water purification, erosion regulation, maintenance of soil fertility, natural hazard regulation, climate regulation, pollination, nutrient cycling and habitat for species (Aria 2005; Mekuria *et al.* 2011; Aymeric *et al.* 2014; Atnafu 2014).

Atnafu (2014) considers specifically the importance of this forests in Ethiopia, particularly the Semien Mountains National Park, as an important conservation zone for the Walia ibex (*Capra walie*). This National Park provides habitat for this and other wildlife species, thus aids in maintaining genetic diversity, and provides recreational opportunities. The ES identified for the Tekeze-Atbara sub-basin are further presented in Table 21.

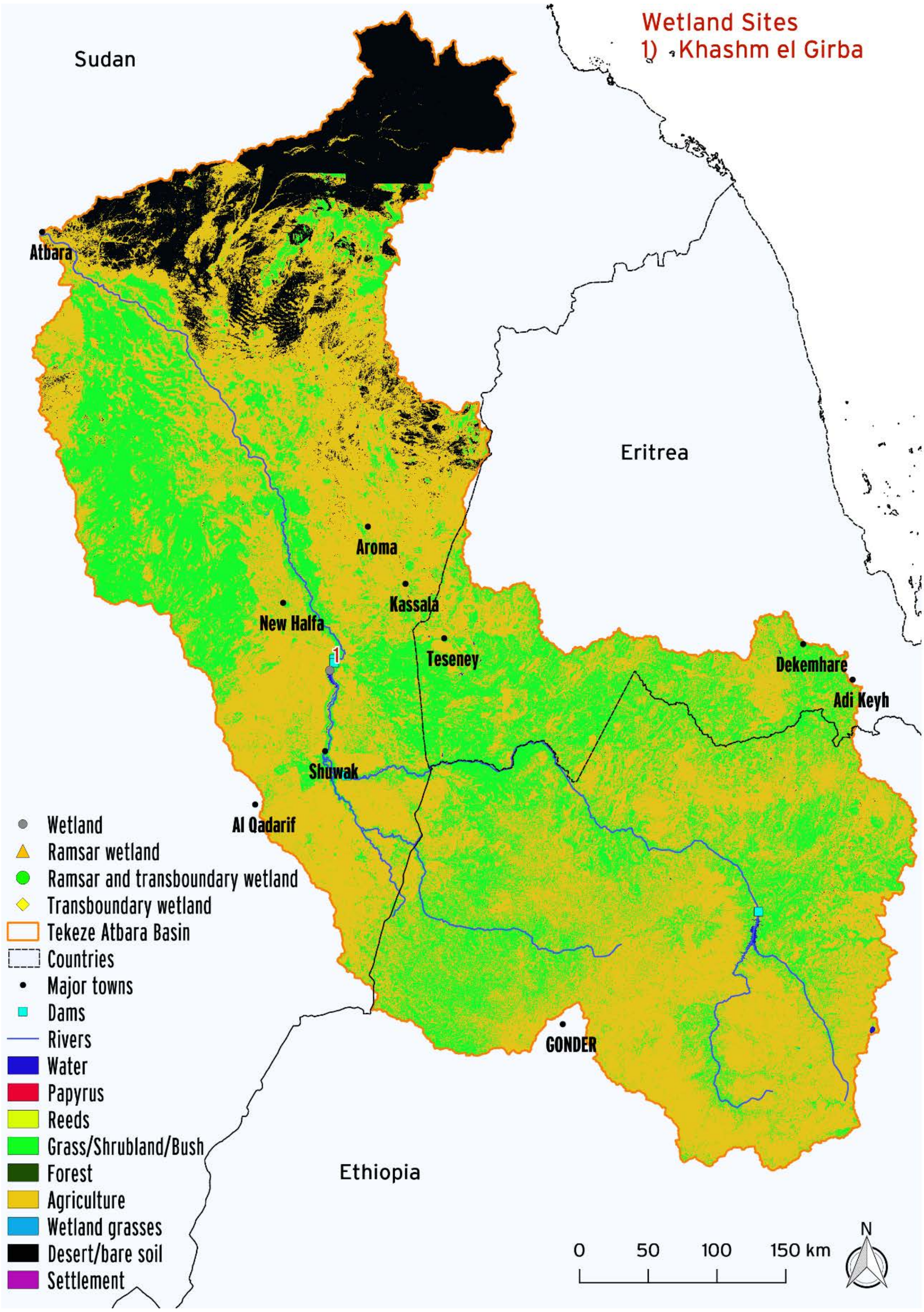

Figure 10. Tekeze Atbara Sub-basin depicting specific wetlands, vegetation units, identification of transboundary wetlands and Ramsar wetlands

Table 21. Present Ecosystem Services (ES) within the Tekeze Atbara Sub-Basin

0 = not applicable; 1 = ES in Tekeze Atbara Sub-Basin (according to literature); 2= ES potentially available in Tekeze Atbara Sub-Basin (based on Table 3 - expert judgement); 3 = Not Known

Ecosystem Services Category	Ecosystem Services	Open water (1)	Permanent Swamps - Papyrus (2)	Reeds (3)	Grassland (4)	Woodland/Forest (5)	Agriculture (6)	Other/Not Specified (0)
Provisioning ES	food - wild fish	2	2	2	0	0	0	1
	food - insects	2	2	2	2	1	3	3
	food - wild game	2	2	2	2	1	2	2
	food - fruits	0	2	2	1	1	2	1
	food - vegetables	0	2	2	2	1	2	2
	food - grains	0	2	2	1	1	2	1
	food - fodder and pasture (for livestock)	2	2	2	1	1	1	1
	food - farmland (for crop cultivation)	3	2	2	1	1	1	1
	fresh water	2	2	2	1	1	0	1
	fuel/ fiber/ raw materials	3	2	2	1	1	2	1
	medicinal products	3	2	2	1	1	3	1
	genetic materials	2	2	2	2	1	3	1
	Transport Infrastructure	2	0	0	2	2	0	2
Regulating ES	waterflow regulation	2	2	2	2	1	0	1
	water purification/waste treatment	2	2	2	2	1	0	1
	erosion regulation	2	2	2	1	1	0	1
	maintenance of soil fertility	2	2	2	1	1	0	1
	natural hazard regulation	2	2	2	2	1	3	2
	climate regulation	2	2	2	1	1	3	1
	pollination	0	2	2	2	1	2	1
	biological control	2	2	2	2	2	0	1
Supporting ES	soil formation	2	2	3	1	1	0	2
	nutrient cycling	2	2	2	2	1	0	2
	maintenance of genetic diversity	2	2	2	1	1	0	1
Cultural ES	cultural/ spiritual/ inspirational	2	2	2	1	1	2	1
	recreational	2	2	2	1	1	2	1
	educational/research	2	2	2	2	1	2	2
	aesthetic	2	2	2	1	1	2	2

4.11 Main Nile Sub-Basin

The Main Nile Sub-Basin begins where the White Nile and Blue Nile converge in Khartoum (Sudan) flowing North through Sudan and Egypt until it disembogues in the Mediterranean Sea. Historically, flood recession farming was common all along the Nile river floodplains, but after the completion of the second Aswan Dam in 1970 the loss of seasonal flood pulse and wetland habitats allowed year-round agriculture (Dumont 2009; Rebelo & McCartney 2012). Since then this is the most important agricultural region of Egypt (Rebelo & McCartney 2012). The ES identified for the Main Nile sub-basin are further presented in Table 22.

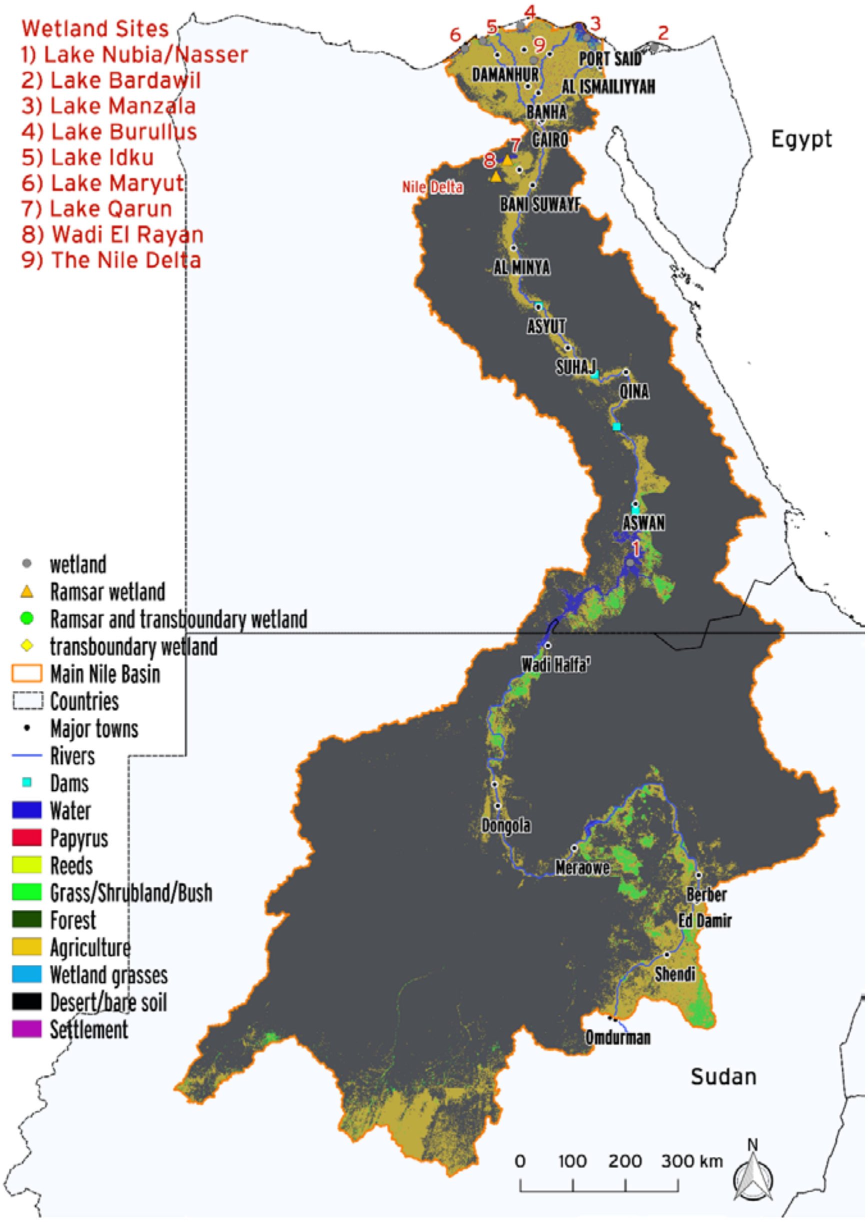

Figure 11. Main Nile Sub-basin depicting specific wetlands, vegetation units, identification of transboundary wetlands and Ramsar wetlands

Table 22. Present Ecosystem Services (ES) within the Main Nile Sub-Basin

0 = not applicable; 1 = ES in Main Nile Sub-Basin (according to literature); 2= ES potentially available in Main Nile Sub-Basin (based on Table 3 - expert judgement); 3 = Not Known

Ecosystem Services Category	Ecosystem Services	Open water (1)	Permanent Swamps - Papyrus (2)	Reeds (3)	Grassland (4)	Woodland/Forest (5)	Agriculture (6)	Other/Not Specified (0)
Provisioning ES	food - wild fish	1	1	1	0	0	0	1
	food - insects	2	2	2	2	2	3	3
	food - wild game	2	1	1	1	1	2	1
	food - fruits	0	1	2	1	1	2	1
	food - vegetables	0	1	2	1	1	2	1
	food - grains	0	1	2	1	1	2	1
	food - fodder and pasture (for livestock)	2	1	1	1	1	1	1
	food - farmland (for crop cultivation)	3	2	2	1	1	1	1
	fresh water	1	2	2	1	1	0	1
	fuel/ fiber/ raw materials	3	1	1	1	1	2	1
	medicinal products	3	1	1	1	1	3	1
	genetic materials	1	1	1	1	1	3	1
	Transport Infrastructure	2	0	0	2	2	0	2
Regulating ES	waterflow regulation	1	1	1	1	1	0	1
	water purification/waste treatment	2	1	1	2	1	0	1
	erosion regulation	2	1	1	1	1	0	1
	maintenance of soil fertility	2	1	1	1	1	0	1
	natural hazard regulation	2	2	2	2	2	3	1
	climate regulation	2	2	2	2	1	3	1
	pollination	0	2	2	2	2	2	1
	biological control	2	2	2	2	2	0	1
Supporting ES	soil formation	2	2	3	2	2	0	1
	nutrient cycling	1	1	1	1	1	0	1
	maintenance of genetic diversity	1	1	1	1	1	0	1
Cultural ES	cultural/ spiritual/ inspirational	1	1	1	1	1	2	1
	recreational	1	1	1	1	1	2	1
	educational/research	1	1	1	1	1	2	1
	aesthetic	1	1	1	1	1	2	1

4.11.1 Nile Delta

The Nile builds a flat, triangular delta of about 25,000 km^2 (Hamza 2009; Dumont 2009) comprising natural and artificial freshwater and brackish wetlands, lakes and intertidal zones. The region near the Nile Delta is one of the most industrialized, populated and cultivated areas in Egypt, holding over 60% of the country's population (Rebelo & McCartney 2012). This area is also a source of oil and natural gas (Hamza 2009; Dumont 2009). Some of the existing wetlands in the delta are threatened by urban development, agricultural activities and illegal fish farms (Nile-Eco-VWU 2016).

As mentioned before, the High Aswan Dam influenced the summer floods, and it retains the nutrient-rich sediments no longer reaching the Nile delta. This has increased the need of large amount of artificial fertilizer for agriculture. The hydrological impacts have also led to decreasing the papyrus habitats and increasing salinity levels, affecting agriculture as well as fishes composition (Dumont 2009; Rebelo & McCartney 2012).

Within the analyzed literature, the Nile-Eco-VWU (2016) Guidelines is the only document specifically targeting a case study within the Nile Delta on the wetlands of Lake Burullus and its provisioning ecosystem services. The main resources the local communities depend on are the fishery resources, followed by agriculture (Nile-Eco-VWU 2016). Although aquaculture has been developed in the Nile delta (Rebelo & McCartney 2012), fisheries exploitation in Lake Burullus is still unsustainable, illegal fish farms have been established, and the annual fish catch from this lake has decreased over the past 10 years (Nile-Eco-VWU 2016).

Other provisioning services of Lake Burullus include provisioning of fresh water and grazing areas for buffaloes, cows, sheep, goats and camels along the lake's shores within the protected area. Hunting of birds, although illegal, is still a common activity. Salt extraction from the marshes and the use of several plants of economic importance (fuel, medicinal, food, building materials) are also products the local communities benefit from (Nile-Eco-VWU 2016).

Other potential ecosystem services not directly mentioned in the literature could be the use of water as a means of transportation, regulating services like water purification, natural hazard regulation, erosion regulation, pollination and biological control. The ES identified for the Lake Victoria sub-basin are further presented in Table 23.

Table 23. Present Ecosystem Services (ES) within the Nile Delta Wetlands Group

0 = not applicable; 1 = ES in the Nile Delta Wetlands Group (according to literature); 2= ES potentially available in the Nile Delta Wetlands Group (based on Table 3 - expert judgement); 3 = Not Known

Ecosystem Services Category	Ecosystem Services	Open water (1)	Permanent Swamps - Papyrus (2)	Reeds (3)	Grassland (4)	Woodland/Forest (5)	Agriculture (6)	Other/Not Specified (0)
Provisioning ES	food - wild fish	1	1	1	0	0	0	1
	food - insects	2	2	2	2	2	3	3
	food - wild game	2	1	1	1	1	2	1
	food - fruits	0	1	2	1	1	2	1
	food - vegetables	0	1	2	1	1	2	1
	food - grains	0	1	2	1	1	2	1
	food - fodder and pasture (for livestock)	2	1	1	1	1	1	2
	food - farmland (for crop cultivation)	3	2	2	1	1	1	2
	fresh water	1	2	2	2	1	0	1
	fuel/ fiber/ raw materials	3	1	1	1	1	2	2
	medicinal products	3	1	1	1	1	3	1
	genetic materials	1	1	1	1	1	3	2
	Transport Infrastructure	2	0	0	2	2	0	2
Regulating ES	waterflow regulation	1	1	1	1	1	0	2
	water purification/waste treatment	2	1	1	2	1	0	2
	erosion regulation	2	1	1	1	1	0	2
	maintenance of soil fertility	2	1	1	1	1	0	2
	natural hazard regulation	2	2	2	2	2	3	2
	climate regulation	2	2	2	2	1	3	2
	pollination	0	2	2	2	2	2	1
	biological control	2	2	2	2	2	0	1
Supporting ES	soil formation	2	2	3	2	2	0	1
	nutrient cycling	1	1	1	1	1	0	2
	maintenance of genetic diversity	1	1	1	1	1	0	1
Cultural ES	cultural/ spiritual/ inspirational	1	1	1	1	1	2	2
	recreational	1	1	1	1	1	2	2
	educational/research	1	1	1	1	1	2	2
	aesthetic	1	1	1	1	1	2	2

5. Nile DSS equation based funtions

To assess the *potential presence* of each ecosystem service (ES) after the implementation of new interventions, simple arithmetic relationships were established *based on the change in the Vegetation Unit (VU) availability (area).* One equation was formulated for each ES, considering the VU where they are currently available (according to literature), potentially available or not applicable.

$$A_{ESi} = \sum \left((VUi_0 - VUi_1) * x \right)$$

Equation 1. Basic form of the equations established (equations for each ES detailed below). A = Available Area for ESi. VUi_0 = Vegetation Unit Present Area. VUi1 = Vegetation Unit Area after intervention. X = binary variable (0|1) where 1 indicates VU where an ES might be available and 0 is non-applicable.

The resulting values must be interpreted carefully. It must be clear that **the result for each equation adds up to the *total available area* where an ES *is potentially available*.** It does not make a distinction between which specific Vegetation Units had a change in the area. This is due to the available type of data we have, merely the area of vegetation unit. This is irrespective of ES. Regarding ES, we have binary data (available/unavailable) per VU. This does not provide enough information to weigh each VU or VU-ES relationship differently.

For example, the ES "Fish" can only be available in VU1 (open water), VU2 (papyrus swamps) and VU3 (reeds), whereas the other VUs will not add any value to this equation. If there is a change in area from VU2 to VU1 (*i.e.* expansion of papyrus wetlands area, thus decreasing the open water area), the value will remain the same. However, if VU2 or VU3 are replaced with agricultural land (VU6), the value *will* show a difference (decreasing, in this hypothetical example). Therefore, the following equations indicate the total area available for an ES to be potentially present and should only be interpreted this way.

5.1 Arithmetic relationships for each ES

The used Vegetation units as defined in the introduction were used here as follows:

- VU1 = Open water
- VU2 = Permanent Swamps - Papyrus
- VU3 = Reeds
- VU4 = Grassland
- VU5 = Woodland/Forest
- VU6 = Agriculture

And where sub-indices:

$_0$ = area before implementation of measures (*e.g.* current area)

$_1$ = area after implementation of measures

Where the VUs apply equally to different ES, the equation is only presented once and the ES are listed beforehand in parenthesis.

Provisioning ES

Change of ES1 **(Fish)**

$$A_{ES1} = \big((VU1_0 - VU1_1) * 1\big) + \big((VU2_0 - VU2_1) * 1\big) + \big((VU3_0 - VU3_1) * 1\big) + \big((VU4_0 - VU4_1) * 0\big) + \big((VU5_0 - VU5_1) * 0\big) + \big((VU6_0 - VU6_1) * 0\big)$$

Change of ES2 **(Insects)**

$$A_{ES2} = \big((VU1_0 - VU1_1) * 1\big) + \big((VU2_0 - VU2_1) * 1\big) + \big((VU3_0 - VU3_1) * 1\big) + \big((VU4_0 - VU4_1) * 1\big) + \big((VU5_0 - VU5_1) * 1\big) + \big((VU6_0 - VU6_1) * 0\big)$$

Change of ES3, ES7 **(Wild Game, Fodder and Pasture)**

$$A_{ES3,7} = \big((VU1_0 - VU1_1) * 1\big) + \big((VU2_0 - VU2_1) * 1\big) + \big((VU3_0 - VU3_1) * 1\big) + \big((VU4_0 - VU4_1) * 1\big) + \big((VU5_0 - VU5_1) * 1\big) + \big((VU6_0 - VU6_1) * 1\big)$$

Change of ES4 – ES6 **(Fruits, Vegetables, Grains)**

$$A_{ES4,5,6} = \big((VU1_0 - VU1_1) * 0\big) + \big((VU2_0 - VU2_1) * 1\big) + \big((VU3_0 - VU3_1) * 1\big) + \big((VU4_0 - VU4_1) * 1\big) + \big((VU5_0 - VU5_1) * 1\big) + \big((VU6_0 - VU6_1) * 1\big)$$

Change of ES8 **(Farmland)**

$$A_{ES8} = \big((VU1_0 - VU1_1) * 0\big) + \big((VU2_0 - VU2_1) * 1\big) + \big((VU3_0 - VU3_1) * 1\big) + \big((VU4_0 - VU4_1) * 1\big) + \big((VU5_0 - VU5_1) * 1\big) + \big((VU6_0 - VU6_1) * 1\big)$$

Change of ES9 **(Fresh Water)**

$$A_{ES9} = \big((VU1_0 - VU1_1) * 1\big) + \big((VU2_0 - VU2_1) * 1\big) + \big((VU3_0 - VU3_1) * 1\big) + \big((VU4_0 - VU4_1) * 1\big) + \big((VU5_0 - VU5_1) * 1\big) + \big((VU6_0 - VU6_1) * 0\big)$$

Change of ES10 **(Fuel/Fiber/Raw Materials)**

$$A_{ES10} = \big((VU1_0 - VU1_1) * 0\big) + \big((VU2_0 - VU2_1) * 1\big) + \big((VU3_0 - VU3_1) * 1\big) + \big((VU4_0 - VU4_1) * 1\big) + \big((VU5_0 - VU5_1) * 1\big) + \big((VU6_0 - VU6_1) * 1\big)$$

Change of ES11 **(Medicinal Products)**

$$A_{ES11} = \big((VU1_0 - VU1_1) * 0\big) + \big((VU2_0 - VU2_1) * 1\big) + \big((VU3_0 - VU3_1) * 1\big) + \big((VU4_0 - VU4_1) * 1\big) + \big((VU5_0 - VU5_1) * 1\big) + \big((VU6_0 - VU6_1) * 0\big)$$

Change of ES12 **(Genetic Materials)**

$$A_{ES12} = \big((VU1_0 - VU1_1) * 1\big) + \big((VU2_0 - VU2_1) * 1\big) + \big((VU3_0 - VU3_1) * 1\big) + \big((VU4_0 - VU4_1) * 1\big) + \big((VU5_0 - VU5_1) * 1\big) + \big((VU6_0 - VU6_1) * 0\big)$$

Change of ES13 **(Transport Infrastructure)**

$$A_{ES13} = \big((VU1_0 - VU1_1) * 1\big) + \big((VU2_0 - VU2_1) * 0\big) + \big((VU3_0 - VU3_1) * 0\big) \\ + \big((VU4_0 - VU4_1) * 1\big) + \big((VU5_0 - VU5_1) * 1\big) + \big((VU6_0 - VU6_1) * 0\big)$$

Regulating ES

Change of ES14 – ES19 & 21 **(Waterflow Regulation, Water Purification/Waste Treatment, Erosion Regulation, Maintenance of Soil Fertility, Natural Hazard Regulation, Climate Regulation, Biological Control)**

$$A_{ES14-19,21} = \big((VU1_0 - VU1_1) * 1\big) + \big((VU2_0 - VU2_1) * 1\big) + \big((VU3_0 - VU3_1) * 1\big) \\ + \big((VU4_0 - VU4_1) * 1\big) + \big((VU5_0 - VU5_1) * 1\big) + \big((VU6_0 - VU6_1) * 0\big)$$

Change of ES20 **(Pollination)**

$$A_{ES20} = \big((VU1_0 - VU1_1) * 0\big) + \big((VU2_0 - VU2_1) * 1\big) + \big((VU3_0 - VU3_1) * 1\big) \\ + \big((VU4_0 - VU4_1) * 1\big) + \big((VU5_0 - VU5_1) * 1\big) + \big((VU6_0 - VU6_1) * 1\big)$$

Supporting ES

Change of ES22 **(Soil Formation)**

$$A_{ES22} = \big((VU1_0 - VU1_1) * 1\big) + \big((VU2_0 - VU2_1) * 1\big) + \big((VU3_0 - VU3_1) * 0\big) \\ + \big((VU4_0 - VU4_1) * 1\big) + \big((VU5_0 - VU5_1) * 1\big) + \big((VU6_0 - VU6_1) * 0\big)$$

Change of ES23 – ES24 **(Nutrient Cycling, Maintenance of Genetic Diversity)**

$$A_{ES23,24} = \big((VU1_0 - VU1_1) * 1\big) + \big((VU2_0 - VU2_1) * 1\big) + \big((VU3_0 - VU3_1) * 1\big) \\ + \big((VU4_0 - VU4_1) * 1\big) + \big((VU5_0 - VU5_1) * 1\big) + \big((VU6_0 - VU6_1) * 0\big)$$

Cultural ES

Change of ES25 – ES28 **(Cultural/Spiritual/Inspirational, Recreational, Educational/Research, Aesthetic)**

$$A_{ES25-28} = \big((VU1_0 - VU1_1) * 1\big) + \big((VU2_0 - VU2_1) * 1\big) + \big((VU3_0 - VU3_1) * 1\big) \\ + \big((VU4_0 - VU4_1) * 1\big) + \big((VU5_0 - VU5_1) * 1\big) + \big((VU6_0 - VU6_1) * 1\big)$$

5.2 Quantification of Key Ecosystem services

The above listed equations can futher be linked to quantifiable or measured values, *e.g.* kg of fish or tonnes of organic carbon/hectar. The results indicate potentially available services. Most of valuation studies for ES have a focus on socio-economical valuation of ES that are being exploited per household and are therefore not directly usable for an estimation of what is potentially available. Several factors are not considered, and the resulting limitations and simplifications must be accepted. Those are, for example:

- The given amount does not take into account of how much can be exploited for a sustainable use;
- No interactions between the vegetation units are considered (*e.g.* fish need different habitats to fulfill their lifecycle);
- Wetlands in the Nile basin are very diverse; ES may differ between the wetlands substantially as they have different biophysical characteristics, experience varied socioeconomic conditions and are faced with dissimilar management challenges;
- Most of the available studies indicate ES that are used by humans (and therefore is strongly correlated to population density) but do not give any details about the potential availability of the respective ES
- Most ES comprise a variety of different factors. By indicating one you run the risk to neglect the others. For example, the indication of tonnes of organic carbon/ha within the Regulating ES – Climate regulation is just a fraction of the total Climate regulation ES, Source of and sink for other greenhouse gases, moderation of local and regional temperatures, precipitation, and other climatic processes are not considered.

In Table 24. Examples of selected key ES and their quantification options, are provided. Once more informations are available, they can be easily adopted or linked to the equations.

Table 24. Examples of selected key ES and their quantification options

ES Type	**Quantification**	**Area**	**Reference**
Provision ES - Fish:	435–580 kg/ha	Sudd	Hickley, P., & Bailey, R. G. (1987).
Provision ES – fuel/ fiber/ raw materials:	papyrus raw materials 400 head loads / ha	Uganda	Kakuru et al. (2013)
Provision ES - fodder and pasture (for livestock):	Sheep: 7/km² Goats: 9/km² Cattle: 16/km²	Nile basin	Awulachew et al. (2013)
Regulating ES - Climate regulation	1,380-3,285 tonnes organic carbon/ha peatland	Nile basin	Elshehawi et al. (2019)
Regulating ES - water purification/ waste treatment	1 ha weltand provides water purification for approx. 1000 city residents	Kampala, Uganda	Calculated after Kansiime and Nalubega (1999)

6. Recommendations

Based on the findings and examples above, the listed limitations and some additional aspects should be taken into account especially when implementing the results into the DSS routines. The study of Ecosystem Services in itself has several limitations. The literature reviewed was focused on that from Emerton (2018), which focused mainly on studies that attempted to economically value or quantify the ES used by specific human communities. Therefore, we have not included studies that specifically focus on quantifying the extent of potentially available ES, or that evaluate the ecological or biological state of the natural communities that provide the ES. The evaluation of ES tends to be biased towards the “popular” ones, those that are easy to perceive, or those that are easy to measure (Grêt-Regamey *et al.* 2017). Often the focus is only set on the ES availability, potential and/or state, but also on the ES needs and flow (actual use) need to be considered. The ES concept is an anthropocentric one. We therefore suggest caution in the interpretation of our results, since the under-represented regions or ES might have a greater importance than what is currently known. It is also important to keep in mind that the presence/absence of an ES does not account for the necessary ecosystemic infrastructure and connectivity that allows an ES to continuously exist. In a next step, we recommend to add some weightening for each ES and VU wihthin the Arithmetic relationships developed in Chapter 5.1. Furthermore, a detailed literature review, with regional distinctions, on the quantification option (Chapter 5.2) is endorsed to get a more realistic picture for the DSS users.

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