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Nile Basin Wetlands Ecosystem Services Assessment Methodology

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On behalf of:
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Document Sheet

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The purpose of the technical report series is to support informed stakeholder dialogue and decision making in order to achieve sustainable socio-economic development through equitable utilization of, and benefit from, the shared Nile Basin water resources.

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List of acronyms

CICES	**Common International Classification of Ecosystem Services**
DPSIR	**Driver-Pressure-State-Impact-Response**
ES	**Ecosystem Service(s)**
MAES	**Mapping and Assessment of Ecosystems and their Services**
MEA	**Millennium Ecosystem Assessment**
MDGs	**Millennium Development Goals**
NA	**Not Applicable**
NBI	**Nile Basin Initiative**
PM	**participatory mapping**
SEEA	**System of Environmental and Economic Accounting**
TEEB	**The Economics of Ecosystems and Biodiversity**

Executive summary

Wetlands provide a wide range of ecosystem services (ES) that contribute to human well-being: For several thousand years, river landscapes have been used as settlement areas, infrastructure and production areas. They provide drinking and process water, flood control, draught mitigation, essential goods, products and raw materials for local livelihoods, offer recreational opportunities and have a cultural and aesthetic value.
During the last 50 years, globally, there was a dramatical decline in wetlands: at least one third of wetlands was lost since 1970. The primary direct and indirect drivers of the degradation of wetland ecosystems are population growth, economic development, the increasing intensification of freshwater (-resources) and land use. The associated changes lead to a shift in the available functions and the associated services of river landscapes and are the reasons why the degradation and loss of wetlands is more rapid than that of other ecosystems wetlands.

In order to counteract this development, there is a need to (1) identify and assess their (potential) availability as well as the actual demand and to (2) improve awareness of the importance of ecologically functional river landscapes. Decision-making process may benefit from the processes and the results of ecosystem service assessments (ES) since these approaches are fostering additional knowledge about the effects of management activities.

Recognizing this, during the last decades, assessing ecosystem services (ES) became increasingly popular. Nowadays they are often used to support decision making processes, such as land use planning procedures and to balance and evaluate (wet)land management options and practices. This is, because ES assessments highlight benefits (and disbenefits) and trade-offs between land-use options, ideally integrating different aspects, like biophysical, socio-cultural and economic approaches.

In the present document first, an **introduction on the ES concept** – including *common classification systems and indicator definitions* – is given: the most common and globally accepted definitions are given by the "Millennium Ecosystem Assessment" (MEA), the "Common International Classification of Ecosystem Services" (CICES) and the "Economics of Ecosystems and Biodiversity" (TEEB). All approaches provisioning (e.g. food or freshwater), regulating (e.g. climate regulation, erosion regulation) and cultural/social (e.g. recreation, education) services. The fourth group of supporting or habitat services as basic characteristics of ecosystems that produce ES are not considered as ES in CICES since this system only covers direct and final services that are used by humans. To foster basin wide comparability, the classification in the present study is in line with current activities in the NILE basin, i.e. the NBI TEEB study, and subsequently considers all 4 groups of ES.

Based on an extensive literature study of 101 references dealing with **ES in the Nile Basin**, it turned out, that provisioning services, which cover the most obvious direct benefits of ecosystems, are discussed and analysed by far most often (approx. 90% of the studies). Also, cultural and regulating services are considered in a high number of the analysed documents, whereas supporting services, covering benefits which are not used directly, only play a subordinate role.

When it comes to an **evaluation or assessment of** these **ES**, not only the technical application of different assessment methods is of importance, but also an *integrated framework* is required. This framework needs to consider not only ES potentials, but also drivers, pressures/stressors, states and responses of ecosystems as well as the actual supply, demand and flow (use) of ES. Therefore, besides the biophysical or economic dimensions, also socio-ecological aspects and frameworks should be to be taken into account. Against this background, and based on reviewed literature, a framework for a **participatory ES-assessment procedure** is recommended. This proposal consists of three consecutive steps. The first step (A) is the scoping phase, where the problem is defined and most relevant ES and

information needs are identified. The second step (B) is the actual assessment phase consisting again of four sub-steps and finally the (C) implementation phase which means the synthesis of gathered information to be integrated int decision making and management practices.

With respect to the technical part of ES-assessment, 168 studies were screened to gain an overview of **assessment methods** used in the countries of the Nile Basin Initiative (NBI). In total, 17 different methods, mainly (monetary) valuation methods, were used to assess ES, whereby socio-cultural and ecological approaches were less used. Due to the recommendation to integrate socio-cultural aspects into assessment procedures, additionally socio-cultural methods were listed and described in more detail. Also, two **best praxis examples** for integrative assessment procedures are given, which highlight the importance of participatory processes in ES assessments:
(1) "*Participatory mapping*" (PM) covers a wide range of technical expertise starting from point placement with e.g. stickers on printed maps up to digital mapping software (GIS) to draw polygons representing land (uses) units used for further (e)valuation processes. Using PM, enables decision makers to receive maps of ES also in regions of data scarcity. This method represents a relatively easy to handle and very comprehensible approach to identify and evaluate the different dimensions of ES by gathering perceptions and values and knowledge from (local) stakeholders to be used for land management decisions.
The (2) "*Ecosystem Service Matrix"* is an integrative approach consisting of six steps, covering the identification of the assessment purpose and available resources, the development of the matrix, the conduction of the actual assessment and finally the visualisation of the results to be integrated into decision making processes. This approach represents a potentially highly integrative and flexible method that can handle all types of ES, all levels of data availability and knowledge and can be applied by a wide range of scientific disciplines.

To support an assessment procedure leading into reasonable results that can be further used as a relevant basis for decision making processes it is **recommended**….

- **…to use a combination of methods**
- …to **combine biophysical and socio-cultural approaches**
- … to consider ES availability, potential and/or state and also **needs and the actual use**
- …to integrate a **participatory process** and to
- ….to include least a "**representative group**" covering all users (in the present case of the investigated Nile wetland) and concerned populations in the participatory process.
- …to hold the **complexity** of chosen methods **low**
- …to apply a comprehensive, transparent and adaptable **problem-oriented approach** to assess ES

1 Background & Introduction

1.1 The Ecosystem Services (ES) Concept

Wetlands provide a wide range of ecosystem services that contribute to human well-being (MEA 2005a): For several thousand years, river landscapes have been used as settlement areas, infrastructure and production areas. They provide drinking and process water, flood control, draught mitigation, essential goods, products and raw materials for local livelihoods, offer recreational opportunities and have a cultural and aesthetic value. Population growth, economic development, the increasing intensification of freshwater (-resources) and land use (infrastructure development, land conversion, water withdrawal, eutrophication and pollution, overharvesting and overexploitation, and the introduction of invasive alien species.) are the primary direct and indirect drivers of the degradation of wetland ecosystems. The associated changes lead to a shift in the available functions and the associated services of river landscapes and are the reasons why the degradation and loss of wetlands is more rapid than that of other ecosystems wetlands.

In order to counteract this development, there is a need to (1) identify and assess their (potential) availability as well as the actual demand and to (2) improve awareness of the importance of ecologically functional river landscapes. Decision-making process may benefit from the processes and the results of ecosystem service assessments (ES) since these approaches are fostering additional knowledge about the effects of management activities.

The concept of ES originated in the 1970s and gained importance in environmental discussions in the 1990s. According to the "Millennium Ecosystem Assessment", ES are the interface between ecosystems and human well-being and can be defined as the benefits that humans can derive from ecosystems (MEA 2005b). Some examples of these linkages between ES and certain components of human well-being (whereby it's important that intensity of linkages and the mediation potential are dependent on ecosystems and regions) are highlighted in Figure 1 (classification systems are described in Chapter 1.2). Vemuri and Costanza (2006) also found a significant relationship between natural capital (in terms of ES) and life satisfaction. The concept of ES thus also represents an important approach to making services and functions provided by ecosystems "tangible" and to communicating their significance to various stakeholder groups. Therefore the ES concept can also play an important role in knowledge transfer and in demonstrating the importance of ecologically functional river landscapes (e.g. Böck 2016); Poppe et al. 2016).

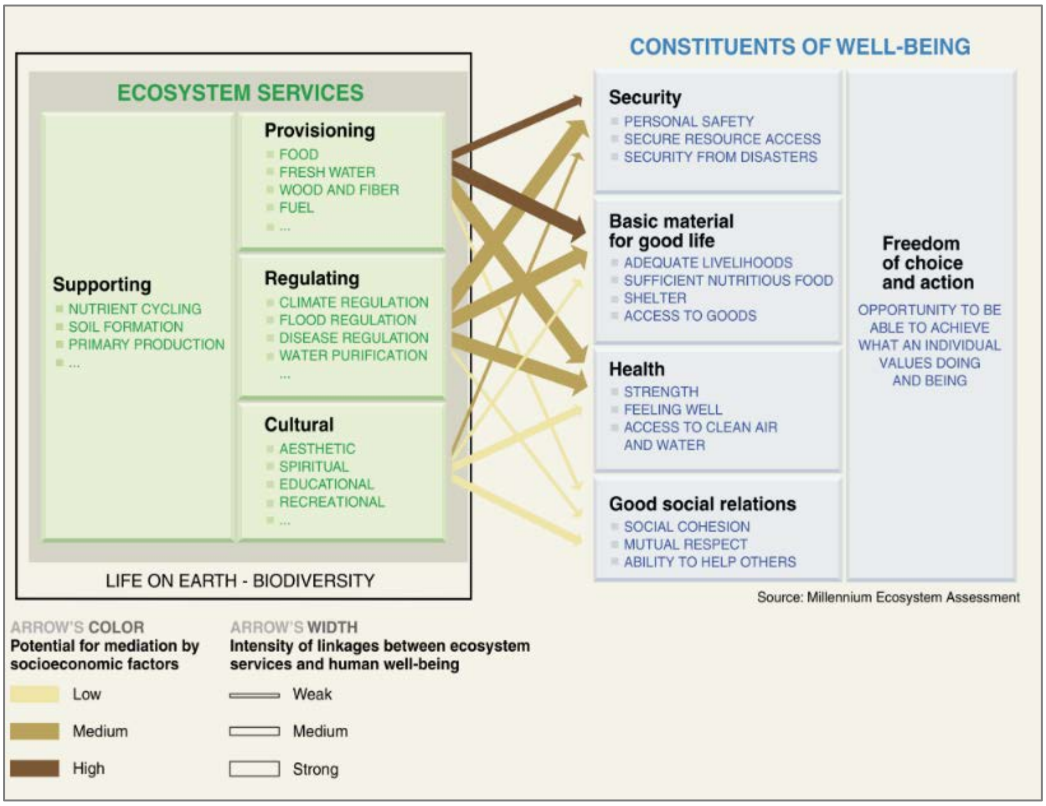

Figure 1: Array of aquatic ecosystem services and their relation to human well-being (MEA 2005b)

A crucial milestone in terms of ES evaluations was the publication of Costanza et al. (1997) in which the total value of all ES was given as 16-54 trillion $ per year. The Millennium Ecosystem Assessment (MEA 2005b) also had a lasting impact on the discussion on the assessment of ecosystems on the basis of the services they provide. The accompanying report (MEA 2005b) is probably the most cited literature source in this context to date. It draws attention to the fact that 60% of global ecosystems are already impaired in their function, which has both ecological and social consequences (Haines-Young and Potschin 2010). Other important steps were the TEEB initiative, which highlighted the economic benefits of biodiversity (TEEB 2010).

According to Turner et al. (2000), understanding the (spatial) relationships between surface water, wetland vegetation and other bio-physical parameters is very important, when it comes to wetland ecosystem services and their valuation, as they are often complex and ‘invisible’.
These authors also mention important ecological preconditions for the classification of ecosystem services and –goods in wetlands (Figure 2):

- Characteristics**:** A Combination of generic and site-specific features, including biological, chemical and physical ones
- Structure: Defined as the biotic and abiotic webs (e.g. vegetation- and soil type)
- Processes: Refer to the dynamics of transformation of matter or energy, i.e. interactions of hydrology and geomorphology, saturated soil and vegetation

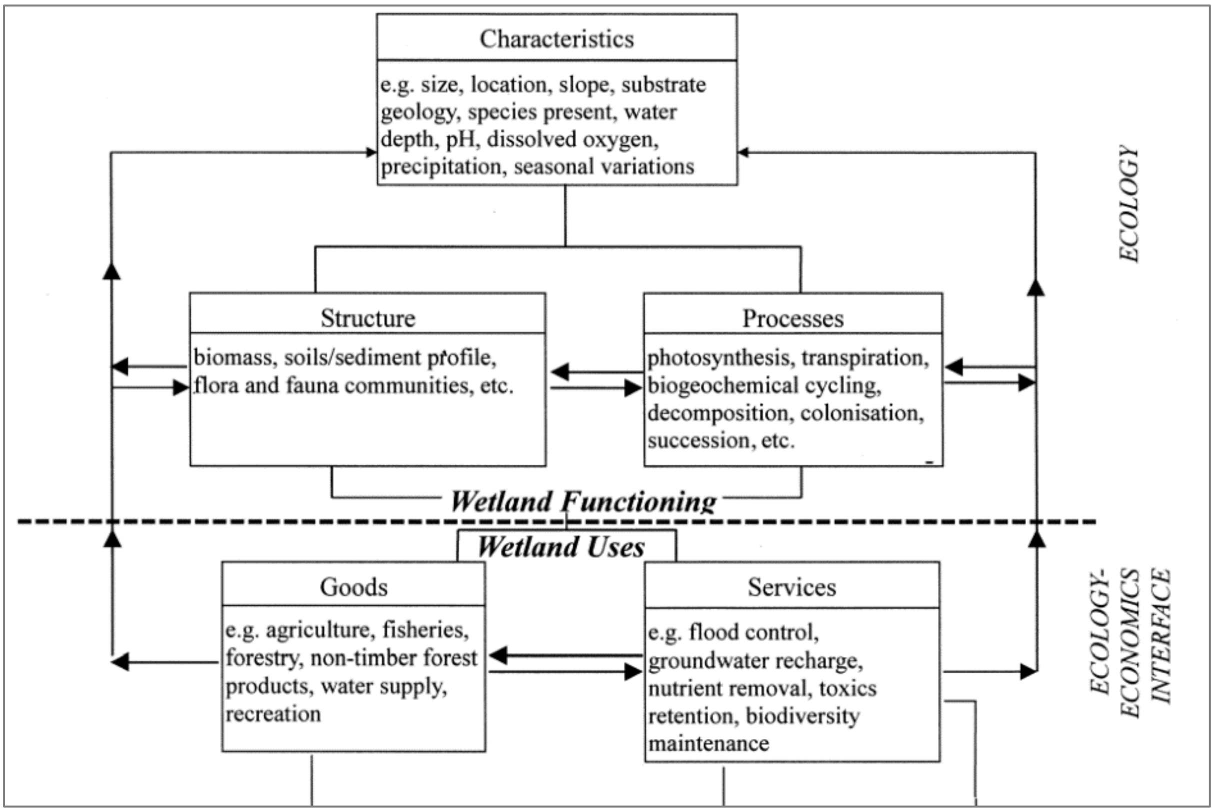

Figure 2: How wetland uses depend on wetland functioning (modified after Turner et al. 2000)

1.2 Classification systems and Indicators of ES

When studying ES, the greatest challenges are the relatively high complexity of the ES concept on the one hand and on the other hand the need to develop standardized approaches that are as easy to apply as possible (Burkhard et al. 2014).
There is currently no generally used approach for classifying ecosystem services. The three best-known classification systems can be found in the "Millennium Ecosystem Assessment Report" (MEA 2003, 2005b, a), the "Common International Classification of Ecosystem Services" (CICES, Haines-Young and Potschin 2013, 2018) and the study "The Economics of Ecosystems and Biodiversity" (TEEB 2010). A description of these three approaches can be found in the following sub-chapters 1.2.1 to 1.2.3. Most studies build on one of these systems and modify it to meet the respective requirements.

Ecosystem services are rarely analysed and evaluated directly, but usually indirectly via meaningful and robust indicators. An appropriate selection of these indicators is of crucial, as they play an important role in informing both the public and policymakers, not least in connection with river landscapes. Indicators can be used to inform about the condition and trends of ecosystems, which in turn supports prioritization attempts at management and political level (Van Oudenhoven et al. 2012). In addition, indicators can be used to evaluate measures and decisions taken, as they can be used to check the extent to which the desired objectives have been achieved. It is therefore important to use indicators that capture the relevant aspects - e.g. river management - as completely as possible and that are as easy as possible to apply in practical decision-making processes (Russi et al. 2013).

In the following sub-chapters, the three main classification-approaches are described in more detail. Whereby the focus of the ES- and indicator-lists lies on wetlands.

1.2.1 The Millennium Ecosystem Assessment – MEA

The Millennium Ecosystem Assessment was aiming at providing a better knowledge base for decisions concerning the protection of ecosystems and their services to humans. The MEA process was initiated to find an approach to achieve the Millennium Development Goals of the United Nations (MDGs; see https://www.un.org/millenniumgoals/).

Topics addressed in the MEA are primarily the identification and classification of ecosystems and their services, and the investigation of the interactions between ecosystem services and society. Furthermore, the development of indicators that describe the state of ecosystems, human well-being and interactions and the assessment of impacts that changes in ecosystems and ecosystem services have on society were discussed (MEA 2003).

ES were grouped into four categories: provisional, regulating, cultural and supporting services (see Table 1). In particular, the fourth group – those of the "basic supporting services" – are and have been critically discussed several times in the course of the further development of the ES concept, since their benefit for humans, in contrast to the other groups, is mostly indirect and they rather describe the basic characteristics of ecosystems (Carolli et al. 2017).

Table 1: Classification of ES provided by wetland ecosystems according to MEA 2005a, b

Category	Services	Comments and Examples
Provisioning	Food	production of fish, wild game, fruits and grains
	Fresh water	storage and retention of water for domestic, industrial and agricultural use
	Fiber and fuel	production of logs, fuelwood, peat, fodder
	Biochemical	extraction of medicines and other materials from biota
	Genetic materials	genes for resistance to plant pathogens, ornamental species, and so on
Regulating	Climate regulation	source of and sink for greenhouse gases; influence local and regional temperature, precipitation, and other climatic processes
	Water regulation (hydrological flows)	groundwater recharge/discharge
	Water purification and waste treatment	retention, recovery, and removal of excess nutrients and other pollutants
	Erosion regulation	retention of soils and sediments
	Natural hazard regulation	flood control, storm protection
	Pollination	habitat for pollinators
Cultural	Spiritual and inspirational	source of inspiration; many religions attach spiritual and religious values to aspects of wetland ecosystems
	Recreational	opportunities for recreational activities
	Aesthetic	many people find beauty or aesthetic value in aspects of wetland ecosystems
	Educational	opportunities for formal and informal education and training
Supporting	Soil formation	sediment retention and accumulation of organic matter storage,
	Nutrient cycling	storage, recycling, processing, and acquisition of nutrients

1.2.2 Common International Classification of Ecosystem Services – CICES

CICES was developed for supporting to the analyses and assessment of ES. It was developed as part of the work on the "System of Environmental and Economic Accounting (SEEA)" lead by the United Nations Statistical Division (UNSD). This system is now used as one of the main basis for the definition of indicators and the collection and assessment of ecosystem services (Haines-Young and Potschin 2018).

The first widely used version of the CICES classification was published in 2013 (V4.3). The MEA-approach (MEA 2003) was refined in order to solve some of the problems identified via literature research. A major difference to MEA is that ES are now grouped into only three "sections". Supporting services are not considered here, as they represent the basic characteristics of ecosystems that produce ES, but are not direct and final services that are used by humans. By leaving out these supporting services, also double counting should be avoided (Haines-Young and Potschin 2013). The CICES classification in its first version V4.3 has already been applied in the "MAES" process of the European Union ("Mapping and Assessment of Ecosystems and their Services" (Maes et al. 2014, 2016a). There the applicability of the CICES classification was tested for the first time in order to develop indicators for the evaluation of ES on a national and international level. The hierarchical structure of this system proved to be particularly advantageous in those cases where indicators were only available for higher levels. Though conducted on European level and the CICES system underwent a review process by 2018 (see below), this study provides a good basic guidance for a data driven way of choosing ES and potentially relevant indicators. ES of freshwater ecosystems and related indicators tested in this study are to be found in the Annex (Table 6).

As mentioned above, the CICES classification recently was reviewed and is now available in updated version V5.1 (Haines-Young and Potschin 2018). The 5-level hierarchical structure (section - division - group - class - class type) has been maintained, but the "division" has been differentiated in much more detail. For example, section "Cultural Services" was previously divided into only two divisions, and in the current version this section has a total of 17 divisions. Furthermore, “abiotic services” have been included. In this context, the most relevant division of the abiotic provisioning services is “water”, covering surface waters and groundwater used for nutrition, materials or energy. The complete classification including the five levels, short description of the classes and exemplary services and benefits can be found in the Annex (Table 7).

1.2.3 The Economics of Ecosystems and Biodiversity - TEEB

The global TEEB initiative was developed as a result of the G8+5 meeting of environment ministers in 2007. It was proposed to carry out a study to assess the economic impact on biodiversity loss. The aim of the study was to provide economically convincing arguments for nature conservation and climate protection.

The initiative is *“focused on ‘making nature’s values visible’. Its principal objective is to mainstream the values of biodiversity and ecosystem services into decision-making at all levels. It aims to achieve this goal by following a structured approach to valuation that helps decision-makers recognize the wide range of benefits provided by ecosystems and biodiversity, demonstrate their values in economic terms and, where appropriate, suggest how to capture those values in decision-making.”* (www.teebweb.org)

So, the TEEB approach aims to emphasize the global economic benefits of biodiversity and at the same time to highlight the increasing costs of biodiversity loss and ecosystem degradation. In this approach, the objective was not to develop new methods, but rather to synthesize existing approaches and to rely on existing knowledge and subsequently to establish a basis for assessing natural capital and ecosystem services flows.

In this approach, ecosystem services are given a monetary value. If this value is not available or unknown, it is defined and described differently. So, also qualitative and non-monetary values are recognised and considered. Also, the definition of monetary values of individual ecosystem services is seen as a major challenge(Ring et al. 2010). Russi et al. (2013) authored a report on water-related ES within the framework of the TEEB initiative in order to promote additional political and economic impulses and investments in conservation, restoration and meaningful use of wetlands. The report contains recommendations on how the value of water and wetlands may be considered in decision-making, as well as an exemplary list of water-related ES and indicators (Table 2).

Table 2: TEEB-based exemplary classification of ES and definition of indicators for wetland ecosystems (Russi et al. 2013)

	Ecosystem service	Example	Example Indicators
Provisioning Services	Food	Sustainably produced/harvested crops, fruit, wild berries, fungi, nuts, livestock, semi-domestic animals, game, fish and other aquatic resources etc.	Crop production from sustainable [organic] sources in tonnes and/or hectares; Livestock from sustainable [organic] sources in tonnes and/or hectares; Fish production from sustainable [organic] sources in tonnes live weight (e.g., proportion of fish stocks caught within safe biological limits)
	Water quantity	-	Total freshwater resources in million m^3
	Raw materials:	sustainably produced/harvested wool, skins, leather, plant fibre (cotton, straw etc.), timber, cork etc;	Timber for construction (million m3 from natural and/or sustainable managed forests)
		sustainably produced/ harvested firewood, biomass etc.	
Regulating Services	Climate/climate change regulation	carbon sequestration	Total amount of carbon sequestered/stored= sequestration/storage capacity per hectare x total area (Gt CO_2)
		maintaining and controlling temperature and precipitation	
	Moderation of extreme events	flood control	Trends in number of damaging natural disasters Probability of incident
		drought mitigation	
	Water regulation	regulating surface water runoff	Infiltration capacity/rate of an ecosystem (e.g. amount of water/ surface area) - volume through unit area/per time Soil water storage capacity in mm/m Floodplain water storage capacity in mm/m
		aquifer recharge	
	Water purification & waste management	decom- position/capture of nutrients and contaminants	Removal of nutrients by wetlands (tonnes or percentage) Water quality in aquatic ecosystems (sediment, turbidity, phosphorous, nutrients etc.)
		prevention of eutrophication of water bodies	
	Erosion control	maintenance of nutrients and soil cover	Soil erosion rate by land use type
		preventing negative effects of erosion (e.g. impoverishing of soil, increased sedimentation of water bodies)	
Cultural & Social services	Landscape & amenity values	amenity of the ecosystem	Changes in the number of residents and real estate values
		cultural diversity	
		identity	
		spiritual values	
		cultural heritage values	
	Ecotourism & recreation	hiking	Number of visitors to sites per year; Amount of nature tourism
		camping	
		nature walks	
		jogging	
		skiing	
		canoeing	
		rafting	
		recreational fishing	
		diving	
		animal watching	
	Cultural values and inspirational services	education	Total number of educational excursions at a site; Number of TV programmes, studies, books etc. featuring sites and the surrounding area; Number of scientific publications and patents

Currently a “Nile basin wetlands TEEB study” – coordinated by the NBI – is ongoing. This TEEB study seeks to bring wetland ecosystem values to the attention of river basin planners and managers, and to thereby promote better-informed, more effective, inclusive, equitable and sustainable conservation and development decision-making in the Nile River Basin (Emerton 2018a). In order to harmonize the present study with the TEEB study, this report builds up on the key wetland ecosystem services in the Nile Basin compiled for the TEEB Scoping Report 2018 (Emerton 2018a).

1.3 ES of the Nile Basin

Following the approach of the ”Nile Basin Wetlands TEEB Scoping Report” (Emerton 2018a) and the application for the Machar Marches (Mulatu et al. 2019a) and the Sudd wetland (Mulatu et al. 2019b) here, a list and a qualitative overview of relevant key-ecosystem services found in the investigated Nile Basin wetlands will be presented. The classification of the ES is based on the Millennium Ecosystem Service Assessment (MEA 2005a) and on definitions given by the TEEB initiative (TEEB 2018).

Due to its rich variety of ecosystems and natural resources, the Nile Basin delivers a crucial set of ES (Table 3), which is of substantial importance when it comes to socio-cultural, economic or natural systems and processes. The basins’ population is highly dependent on the biodiversity and flood plains, which further depends on the functional complex hydrology based on a high level of interconnectivity between floodplains, wetlands, swamps, lakes, highlands and the river’s drainage networks (NBI 2016; Emerton 2018a).

Table 3: Key Ecosystem Services of the Nile basin according to the NBI TEEB study (Emerton 2018a; Mulatu et al. 2019a, b)

ES group	ES	Examples
Provisioning	Food	Wild fish, insects, wild game, fruits, vegetables and grains, as well as provision of fodder and pasture for livestock production and farmland for crop cultivation, supporting both subsistence- level and commercial-industrial production and consumption
	Fresh water	Storage and retention of water for domestic, industrial, agricultural and hydropower uses.
	Fuel and fibre	Timber, polewood, fuelwood, thatch and handicraft materials, supporting both subsistence-level and commercial-industrial production and consumption
	Medicinal products	Wild plant and animal products used as traditional remedies as well as providing the raw materials for the pharmaceutical industry
	Genetic materials	Materials used for medical, pharmaceutical, agricultural, nutritional, cosmetic and other applications; resistance to plant pathogens; ornamental species; etc.
Regulating	Waterflow regulation	Stabilisation of flows, groundwater recharge/discharge
	Water purification and waste treatment	Retention, recovery, and removal of excess nutrients and other pollutants
	Erosion regulation	Control of runoff, soil stabilisation, sediment and silt trapping
	Maintenance of soil fertility	Retention of soil moisture, maintenance of soil structure and quality, supply of soil nutrients required to support plant growth and agriculture.
	Natural hazard regulation	Drought mitigation, flood control, storm protection, landslide control, etc.
	Climate regulation	Source of and sink for greenhouse gases, moderation of local and regional temperatures, precipitation, and other climatic processes
	Pollination	Habitat for bird, bat, mammal and insect pollinators important for cultivated crops and wild species
	Biological control	Control of pests and diseases through the activities of predators and parasites such as birds, bats, flies, wasps, frogs and fungi
Supporting	Soil formation	Sediment retention and accumulation of organic matter
	Nutrient cycling	Storage, recycling, processing, and acquisition of nutrients
	Habitat for species	Space, materials and conditions that flora and fauna need to survive or are essential for key stages of their lifecycle (breeding, feeding, migratory, etc.), including rare, endangered and endemic species and those of special cultural or commercial importance
	Maintenance of genetic diversity	High numbers of plant and animal species, enhancing the robustness of the system as well as providing the basis for well-adapted cultivars and livestock, and a gene pool for further local-level and industrial product development.
Cultural	Cultural, spiritual and inspirational	Source of traditional knowledge, sacred sites, customary practices and knowhow; spiritual and religious significance and inspiration; national or international heritage and iconic status
	Recreational	Opportunities for leisure and tourism
	Educational and research	Space, species and natural processes to support and inform formal and informal education and training, generate knowledge and learning
	Aesthetic	Visual and artistic beauty and appreciation of wetland landscapes, species and cultural elements

To be in line with the current NBI TEEB study, the definitions of ES in the present document are widely taken over from this study. Only the ES "food" was differentiated in more detail and "others" were added where found in literature.

Through an extensive literature study of the documents used in the TEEB study (Emerton 2018b) and additional references the presence and the potential availability of ES in the Nile basin and its wetlands was analysed. Out of 206 known references, 171 were available and screened for the current study. Altogether 101 documents dealt with ES in the Nile Basin and therefore were considered in the analyses. The considered documents are listed separately in the list of references.
All ES groups were covered in these studies (usually more than one group was investigated), whereas provisioning services were covered by almost 90% of the analysed studies (88 out of 101), followed by regulating (n=77) and cultural (n=73) services. With only 46 studies, supporting services played a relatively subordinate role (Figure 3).

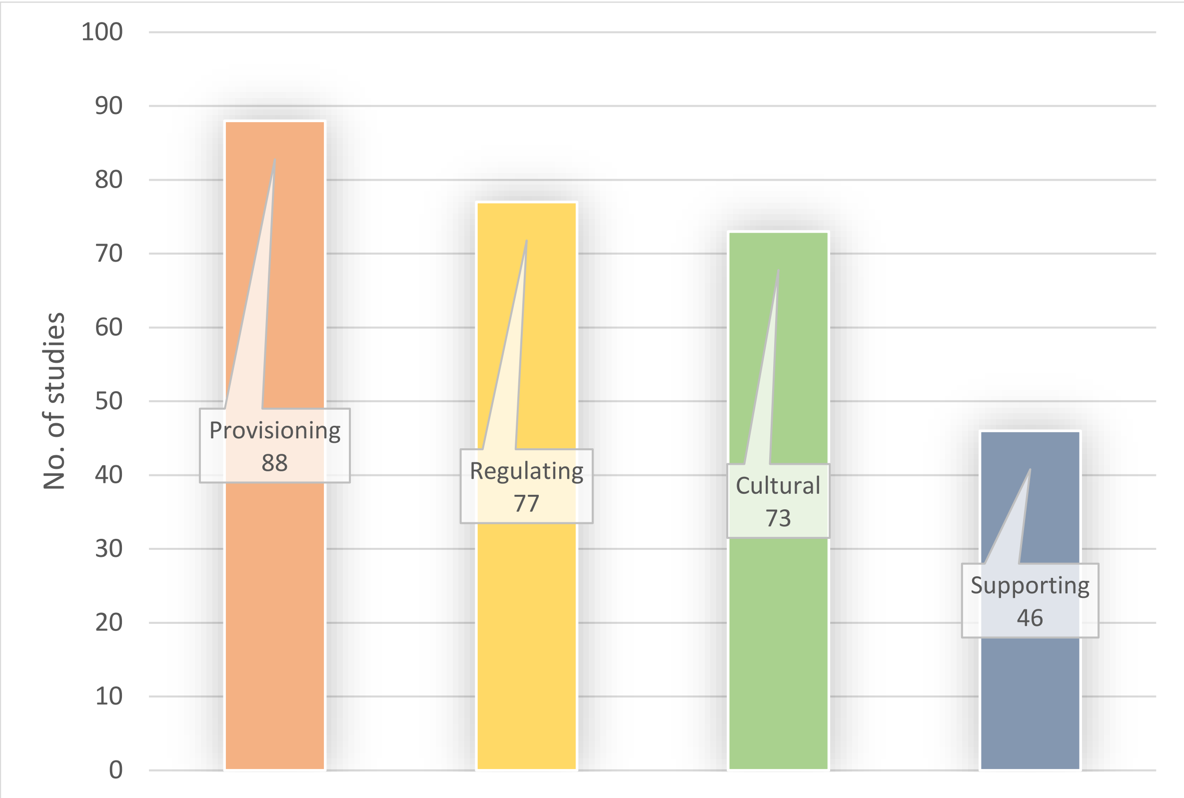

Figure 3: Number of studies dealing with ES groups within the Nile basin (N=101).

Out of the 30 ES included in this analysis, all of them have been identified throughout the entire Nile basin in the different Vegetation Units considered. Only the “other” regulating ES “air quality regulating” was highlighted, but not linked directly to any Unit (see

Table 4).

Table 4. Presence of Ecosystem Services in areas within the Nile Basin: 0 = not applicable; 1+ = Ecosystem Service available in NILE basin (according to literature); 2 = Ecosystem Service potentially available in Nile basin (expert judgement); 3 = not known

ES group	ES	Open water (1)	Permanent Swamps - Papyrus (2)	Reeds (3)	Grassland (4)	Woodland/ Forest (5)	Agri-culture (6)	Other / Not Specified (0)
Provisioning	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 & 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/ fibre/ 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+
	Other Provisioning ES (text)*	3	3	3	1+	1+	3	1+
Regulating	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+
	Other Regulating ES (text)**	3	3	3	3	3	3	3
Support-ing	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	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+

* e.g. honey, gum arabic ** e.g. air quality regulation

2 Assessment methods: a review-based framework

Over the past few decades, environmental, ecological and social scientists as well as economists associated with those research fields have developed a quite high number of methods for measuring the value that people obtain from diverse ecosystems and related services. The following chapters give an overview about the general procedures when assessing (wetland) ES. Steps and frameworks to be considered are described, recently common and accepted methods and techniques for ES valuation and assessment are listed and their essential features are summarised. Since the present document focusses on non-monetary, preferably participatory approaches, two examples of relatively easy understandable and applicable methods are presented in more detail. Finally, these points lead to recommendations for an integrated framework for wetlands ES assessments.

2.1 Assessing ES – background and general procedure

An evaluation of ES usually requires an integrated framework considering not only ES potentials, but also drivers, pressures/stressors, states and responses of ecosystems[1] as well as the actual supply, demand and flow (use) of ES. Therefore, not only biophysical or economic dimensions should be to be taken into account, but also socio-ecological aspects and frameworks. In particular socio-cultural dimensions are often neglected, since "valuation" increasingly tends to be used and performed rather in a monetary sense and ES assessments aiming at supporting decisions in environmental planning often focus on biophysical and economic indicators. Due to the fact, that the ES-concept is an anthropocentric concept, neglecting social and cultural factors and human-nature relationships, assessments may lead to incomplete and therefore unsatisfactory results in terms of applicability and implementability and consequently often do not fulfil the expectations of decision makers (Santos-Martín et al. 2017).

According to Vihervaara et al. (2017), aside from the need to integrate more than one dimension and particularly consider socio-cultural aspects, it's inevitable to detect and specify the intentions and underlying reasons to initiate an ES assessment process (e.g. policy questions, scope of the assessment,…). Following this, aspects to measure as well as evaluation methods need to be defined. Based on relevant (scientific) literature, a set of appropriate indicators has to be chosen (cf. also chapter 1.2). The selection of one or a set of indicators finally depends on external and internal factors like purpose, target audience, data availability, scale, level of expertise needed, etc.. Supported by these indicators, it's possible to investigate the state and/or trend on ecosystems and associated services. When choosing on more indicators, it has to be kept in mind, that they are also used to communicate the characteristics, status and trends of ES. Therefore, they should be chosen against the background, that they support (not exclusively, but also) policy makers to understand the condition and trends of ES. ES indicators do not only give information on the quantity, quality or condition of an ecosystem (service), but ecosystem degradations and associated changes need to be measured, since these aspects cause changes in the potential and flow of ES. With respect to biophysical quantifications of ES, a variety of methods exists for measuring and subsequently (e)valuate these indicators. Approaches range from direct measurements (gathering primary data in the field) and indirect measurements (remote methods and use of existing data) to modelling techniques of varying complexity. Underlying reasons for choosing a particular method or a combination of methods are likely the same as for the choice of certain indicators, but additionally

[1] For detailed information on the driver-pressure-state-impact-response model (DPSIR) see deliverable 6.1. "Technical paper: Management and development options for Nile Basin wetlands: Description of policy choices and framework for their assessment" of the present project. Exemplary DPSIR models for different management scenarios for Nile basin wetlands see deliverable 6.2. "Technical Paper: Scenario study of the management options for Nile Basin wetlands and their assessment".

depend on the type of the indicator itself. Figure 4 gives a rough outline of the here described steps and dependencies.

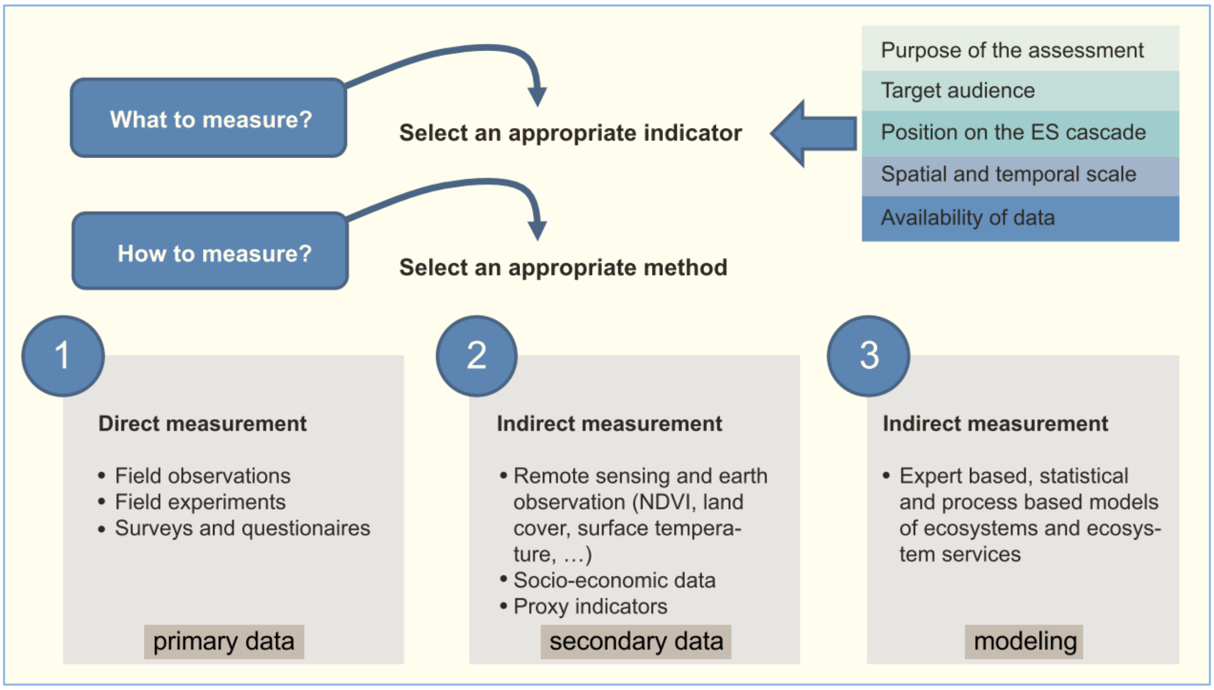

Figure 4: Steps, influencing factors and methodological approaches to be basically considered when aiming at a biophysical quantification of ES (adapted from Vihervaara et al. 2017).

In order to improve the applicability of ES assessments, Förster et al. (2015) developed a problem orientated approach - an framework for ES assessments covering all steps from the beginning (definition of problems) to the final implementation phase. Though this approach does not address wetland ES in particular, it describes the stepwise procedures in a comprehensible way and additionally is adaptable to fit certain purposes and needs (in this case to be applicable in the context of wetland ES). Additionally, the proposed steps are highly flexible in their sequence since feedback loops are possible and recommended in iterative processes. Förster et al. (2015) highlighted that "*assessments of ecosystem services (ES), that aim at informing decisions on land management, are increasing in number around the globe. Despite selected success stories, evidence for ES information being used in decision making is weak, partly because ES assessments are found to fall short in targeting information needs by decision makers*." The need to integrate socio-ecological aspects into the assessment process is also in line with the detected neglect of socio-cultural factor sand resulting insufficiencies discussed above. This also applies for the conclusion that "*monetary valuation of ES is not necessarily required or useful in every decision context*" (Förster et al. 2015).

The framework proposed by Förster et al. (2015) consists of three phases (A to C) and five main steps. Not only the information on ES is structured with respect to land use problems identified by stakeholders, also information needs are targeted by decision makers and possible management options are determined (Figure 5):

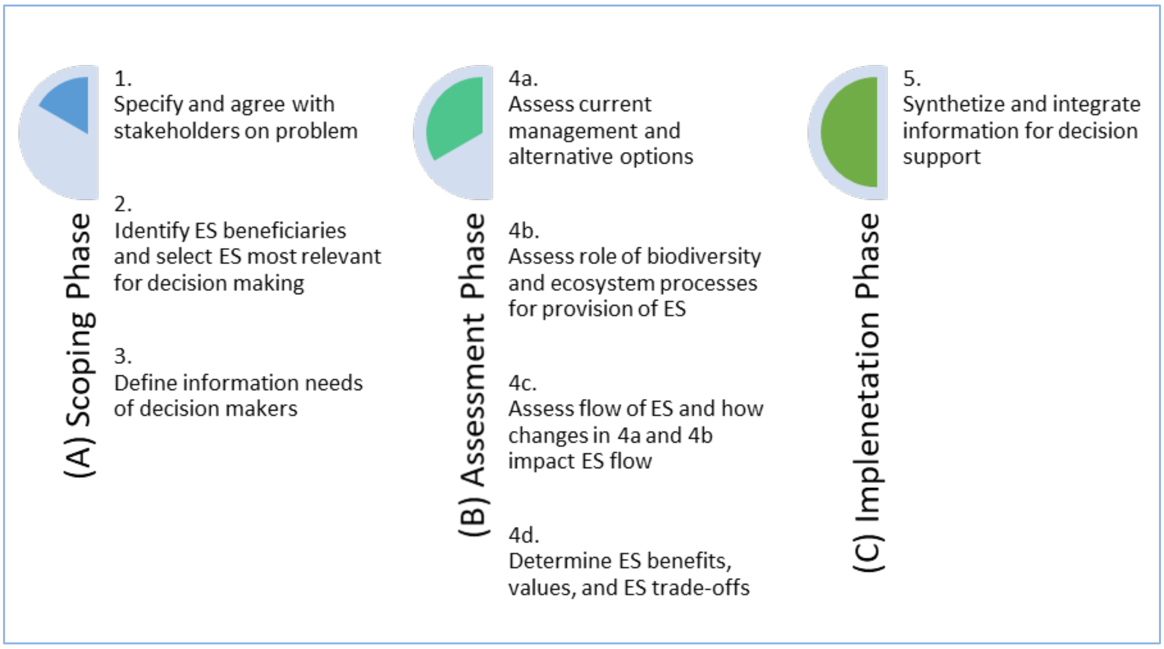

Figure 5: The problem-oriented framework for assessing ES after Förster et al. (2015)

(A) Scoping Phase:

(1) *Specify and agree with stakeholders on problem:*
The first step comprises a consultation of experts and stakeholders, as well as a screening of relevant literature and data in order to identify land-use associated problems, drivers and impacts. To determine the focus of the involved parties, also the socio-cultural background has to be considered by looking into the distribution of (dis)benefits and the impacts on power relations.

(2) *Identify ES beneficiaries and select ES most relevant for decision making*
The second step aims at a prioritization of ES to be in line with affected stakeholders and the previously defined problem(s). To cover most possible interests and the distribution of (dis)benefits, a high variety of stakeholders – covering all persons who have a personal or professional interest on the subject – needs to be integrated. So the considered stakeholders must represent all sectors of the affected population as well as decision makers and experts/researchers.

(3) *Define information needs of decision makers*
For this step, it's crucial to detect knowledge gaps of decision makers that lead to associated gaps in decision processes. By doing this, it's possible to ensure that assessments deliver relevant information that will be picked up for decision processes. The delivery of information required for a specific decision is ensured by the choice of appropriate indicators and methods, whereby these choices also depend on carefully defined and considered information needs. Additionally, to avoid insufficient results and/or an inappropriate use of the results, expectations of stakeholders on ES assessments – in particular on limits and capabilities – need to be kept realistic.

(B) Assessment phase

(4) *Analyze ES within social-ecological context and impacts of changes, e.g., in land use, policies, climate, on ES flow, benefits, and trade-offs.*

a. Assess current management and alternative options
This step meets the above articulated need to consider socio-cultural aspects: An understanding of the current (land)management culture (policies and practices) within their socioeconomic and cultural context is a crucial prerequisite for the identification of alternative options. This point has a clear connection to Step 1 of the scoping phase (A), since it also depends on the depends ability of the different stakeholder groups and beneficiaries to influence land-use decisions, which land use options are currently implemented and who subsequently earns the resulting ES benefits. An important point here is, that ES are generated via social, cultural and economic processes (within the ecological limitations of a landscape). So power relations, property and access rights, investments of time, labour, and resources need to be considered thoroughly.

b. Assess role of biodiversity and ecosystem processes for provision of ES'
Followed by the prioritization of ES and the investigation of *social* aspects (management practices) the *ecological* aspects need to be examined. The second step of the assessment phase is the definition and analyses of ecological processes and biodiversity indicators, relevant for the provision f the defined ES. This includes not only de identification of indicators but also appropriate measurement actions (see above and Figure 4) and the detection and description of relevant drivers. As in previous steps, for these procedures it's important to take several sources and levels of knowledge and expertise into account.

c. Assess flow of ES and how changes in 4a and 4b impact ES flow
This step consists of an integrative analysis of the previous assessment steps. Here, the interconnection of social (4a) and ecological (4b) aspects is assessed and their importance for the production and use of ES is identified. Since these relationships between ecological factors and ES provision (just as socio-ecological systems in general) are usually of characterize by a high level of complexity, often proxy indicators or modelling techniques are applied (in those cases, where direct measurements are not possible). To ensure / test the transferability of proxy indicators, and to check the accuracy of developed models, it's important to conduct additional validation actions (also by follow-up field surveys).

d. Determine ES benefits, values, and ES trade-offs
For a successful assessment of ES, it's crucial to tailor the (values to be assessed, as well as the used indicators to each specific decision. Values (social, spiritual, cultural, economic,…) that are attached to biodiversity an ES are manifold and highly dependent on the stakeholders and their perception and their place in the socio-cultural system, in other words, if they gain benefits from ES or suffer from disbenefits. Therefore an economic assessment may not always be the first choice (see also above), and alternative methods may be more suitable for considering social and cultural aspects in decision processes.

(C) Implementation phase
Finally, the gathered information is synthesised and integrated into decision making and management practices.

2.2 Methodological approaches for assessing ES

For compiling an overview of assessment methods regarding ecosystem services of wetlands in Africa, focussing on countries of the Nile Basin Initiative (NBI) and Eritrea, a total of 168 studies was analysed. 98 studies dealt with ES within the Nile basin wetlands (respective documents are listed and marked in the list of references included in the analyses). The remaining documents covered countries sharing the basin, but areas located outside or approaches at lager scales. Most of the documents were selected based on the NBI TEEB study (Emerton 2018b). Additionally assessment methods, mainly socio-cultural methods, were added since they are often neglected, according to Burkhard and Maes (2017).

Most of the African studies dealt with ES assessment in Tanzania, Uganda and Ethiopia. All other countries were only covered by less than 10 % of the analysed studies (Figure 6). Therefore, it has to be highlighted, that the overview of methods is not fully representative for NBI countries.

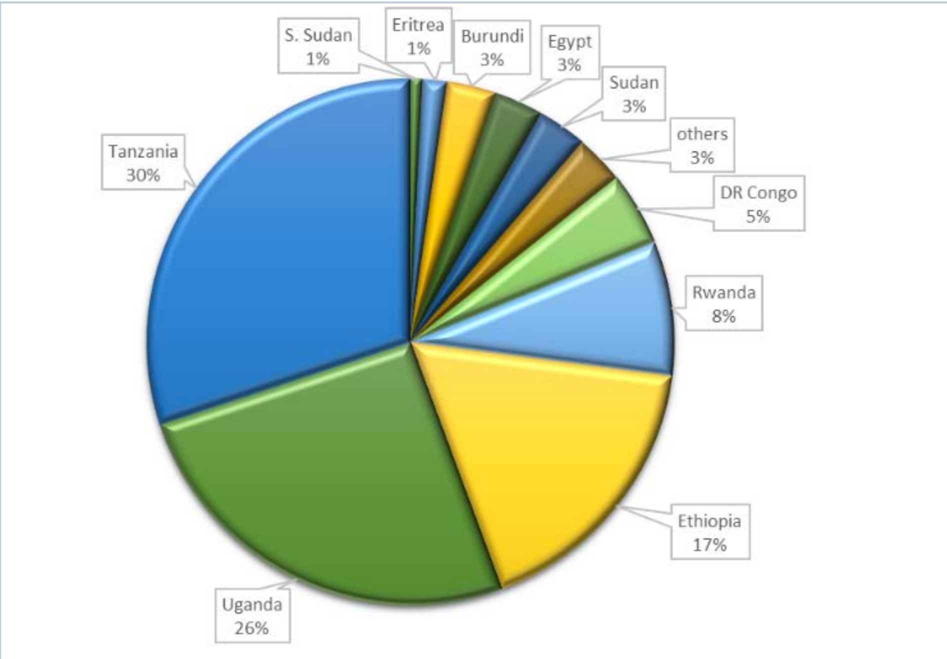

Figure 6: Countries covered by the analysed references regarding assessment methods of ES

The analyses of the 168 studies showed that 17 different methods, mainly (monetary) valuation methods, were used to assess ES, whereby socio-cultural and ecological approaches were less used (Figure 7). A method was rarely used exclusively but usually a combination of approaches was applied (Figure 8): more than 50 % of the studies used two or three methods for ES valuation.

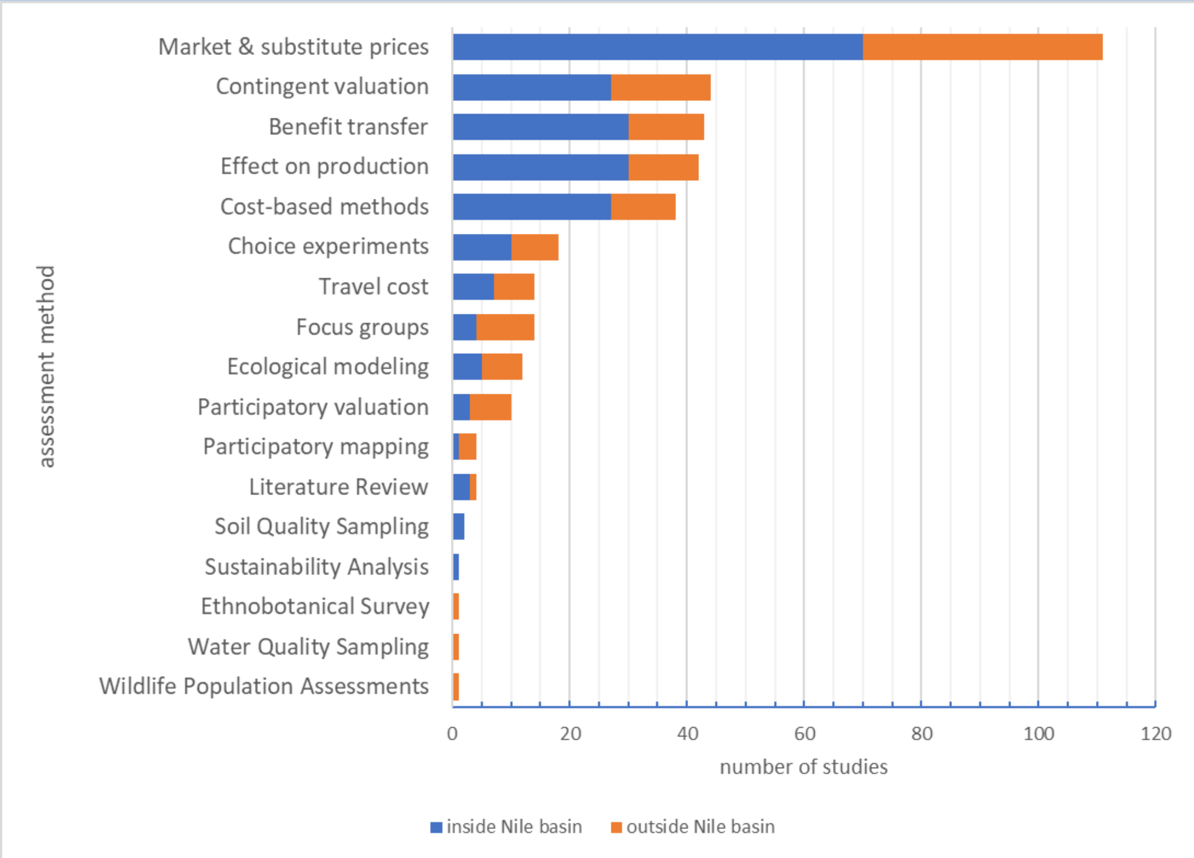

Figure 7: Number of documents and number of used methods within each study, differentiated between studies dealing within and outside the Nile basin wetlands.

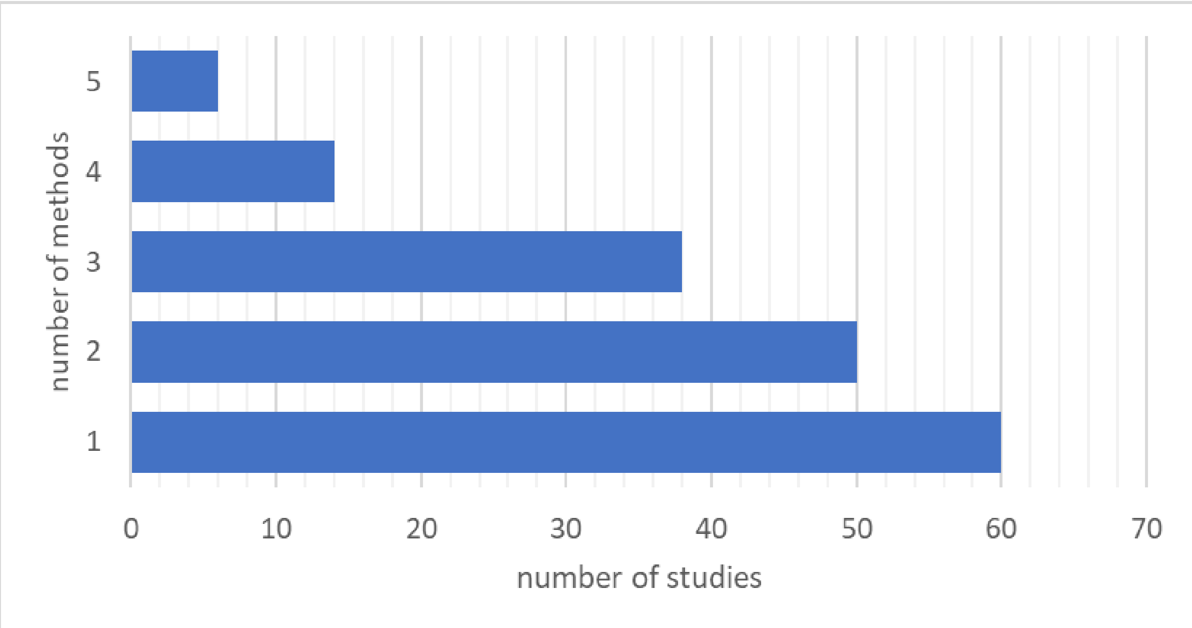

Figure 8: Number of Studies (N=168) and number of used methods within each study

Choosing a certain method or a combination of assessment methods is mainly a question of the general conditions and background of the evaluation. Thus, there is no general rule, which method or technique to apply. The decision depends on various factors, like aims, topics, focussed ES, involved and affected people, as well as e.g. availability, needs and gaps of data and expertise.

The following Table 5 gives an overview of common and economic and socio-cultural valuation methods. It covers the main identified techniques in used in Nile basin countries as well as the state of the art of additional social / participatory approaches. Of course, socio cultural approaches may also cover monetary valuations by participants, but the distinction of the general approaches was driven by the underlying concept of gathering information.

The list is not exhaustive, but includes all main techniques that are generally accepted by scientists and practitioners from environmental, socio-ecological and economic sectors. Biophysical quantifications are left aside here, since addressed in chapter 2.1. Strictly and mainly biological/ecological assessment methods are also not described here, since they need a high level of specialist knowledge for defining indicators, measurement techniques, analyses and interpretation. Nonetheless these aspects are not of less importance when evaluating the ecological potential or state of ecosystems with respect to ES.

Table 5: List and description of common used economic and socio-cultural approaches to investigate/assess/valuate ES

General approach	Method	Sources *	Description
Economic	Market & substitute prices	***Emerton*** 2018c	Market price techniques look at what it costs to buy or sell a particular good or service, and relate this to the quantity consumed or produced. Market price techniques are typically cheaper, simpler and less data-intensive to apply and analyse than other valuation methods. They usually require only rudimentary surveys, or rely on secondary sources.
Economic	Contingent valuation	***Emerton*** 2018c	Contingent valuation methods, value recreation and tourism, or to gauge *willingness to pay and* accept *compensation* for the provision of ecosystem services. People are asked directly what they would be willing to pay for an ecosystem service, or how much they would need to be compensated for its loss.
Economic	Benefit transfer	***Emerton*** 2018c	Benefit transfer represents a fairly straight forward technique that can be applied in situations where technical capacity, data, time and other resources are limited. It transfers the findings of studies carried out elsewhere to the service or site that is of interest. Though relatively simple on the first sight, this method is often applied incorrectly (e.g. failures to adjust data from earlier studies for the effects of inflation, or to account for differences in purchasing power parity when using value estimates from different countries).
Economic	Effect on production	***Emerton*** 2018c	Effect on production methods are usually used in the context of regulating services. These techniques establish a dose-response relationship which traces the contribution of ecosystem services to marketed outputs or production processes. Crucial points when applying this method are the availability of credible biophysical data scientifically substantiated assumptions.
Economic	Cost-based methods	***Emerton*** 2018c	Cost-based methods assess how much an ES saves people in terms of reduced expenditures, decreased losses or lower damages. They too are most commonly applied to regulating services Crucial points are the same as for effect on production methods.
Economic	Travel cost	**Emerton** 2018c; *Christie* et al. 2012; *Emiru and Gemechu* 2017	Here, data on the costs of travel to a natural resource are used to evaluate the recreational benefits of that. This approach Includes e.g. travel expenses, the length of the trip, the amount of time spent for the trip. If non-use values are significant, the travel cost method alone will underestimate the benefits of preserving the site and hence the researcher will use a combination with other methods of valuation in order to estimate the total economic value of the site.
Economic / Socio cultural	Choice experiments	***Emerton*** 2018c	Choice experiments are a related technique which weigh up people's (economic) preferences for different ecosystem attributes and features. Gathering of data may happen via interviews (hypothetical preferences) or real data on actual choices/decisions. This method has become much more widespread over recent years.
Socio-cultural	Focus groups	**Emerton** 2018c; *Kaplowitz and Hoehn* 2001	Focus groups are group discussions designed to learn about subjects' perceptions on a defined area of interest. They involve as many as 12 participants and are conducted by a skilled moderator using a discussion guide. Focus groups rely on the dynamics of group interaction to reveal participants' similarities and differences of opinion

Socio-cultural	Participatory / deliberative valuation	**Emerton** 2018c; *Christie* et al. 2012; *Fontaine* et al. 2014; *Santos-Martín* et al. 2017	These methods focus on the integration of knowledge systems, disciplines and diverse data. Potential aims of valuating of the social dimension are to gather information on what local actors value in their living environment and why it is important to them. Additionally, these approaches lead to a better understanding of mindsets of different groups of people when valuing ES and to information on affected and involved stakeholders. Participatory and deliberative approaches combine stated preference valuation methods (covering e.g. face-to-face interviews, open discussion, structured ranking, valuation workshops, citizens' juries, photo-voice, map description) with elements of deliberative processes from political science. The challenge with the social valuation of ES is to deal with a variety of stakeholders who may have different views, values and interests. Typically, the valuation process is administered through small group activities in which participants are provided with time for reflection, information gathering and group deliberation before valuing that good. Deliberative methods can address ethical beliefs, moral commitments and social norms and are often used in combination with other approaches (e.g. mapping or monetary valuation). In its basic format, deliberation is used to engage and empower non-scientific participants by addressing issues of low public knowledge of complex environmental goods.
Socio-cultural	Participatory mapping	***Emerton*** 2018c; *Santos-Martín* et al. 2017	Participatory mapping focusses on the integration of knowledge-systems, disciplines and diverse data. This technique assesses the spatial distribution of ES according to the perceptions and knowledge of stakeholders via workshops and/or surveys. This technique facilitates the participation of various stakeholders integrating their perceptions, knowledge and values in maps of ES.
Socio-cultural	Preference assessment	*Santos-Martín* et al. 2017	This is a direct consultative method that assesses the individual and social importance of ES by analysing motivations, perceptions, knowledge and associated values of ES. Data is collected through free-listing exercises, ecosystem service ranking, rating, or other selection mechanisms. Examples for integrated preference assessment valuation are techniques for weighting the preferences related to impacts on the ecosystem service of different management alternatives such as multi-criteria analyses.
Socio-cultural	time use method	*Santos-Martín* et al. 2017	Here, hypothetical scenarios for willingness to give up time are created. This method estimates the value of ES by asking people how much time they are willing to dedicate for a change in the quantity or quality of a given ecosystem service. This method is not only a non-monetary metric, but also a way of measuring the willingness to actively contribute to nature conservation through practical actions. (cf. contingent valuation / willingness to pay)
Socio-cultural	Photo-elicitation surveys	*Santos-Martín* et al. 2017	These surveys seek to uncover the socio-cultural value of ES by translating people's visual experiences, perceptions and preferences of landscapes into ES values. This technique is useful for eliciting socio-cultural values of ES as it uses a communication channel (i.e. photographs) which is easily understood by multiple social actors
Socio-cultural	Narrative methods	*Santos-Martín* et al. 2017	These methods are mainly used to collect qualitative data. By using narrative methods (e.g. structured to unstructured interviews, focus groups [s. there], participant observation, content analysis, recording of events, etc.), participants can articulate the heterogeneous values of ES through their own stories and direct actions.
Socio-cultural	Scenario planning	*Santos-Martín* et al. 2017	Like participatory valuation (see there) this method focusses on the integration of knowledge systems, disciplines and diverse data. It combines various tools and techniques (e.g. interviews, brainstorming or visioning exercises, often complemented with modelling) to develop plausible and internally consistent descriptions of alternative futures, where values of ES can be elicited

* Sources are covering the references (**bold**) from which the approaches were gathered and partly reviewed as well the documents (*italic*) that were cited in the method-descriptions – underlying sources of those are to be found in the respective document

2.3 Detailed examples

The following two methodological approaches are practical examples for integrative assessment procedures which highlight the importance of participatory processes in ES assessments. Regarding level of expertise, depending on the defined problems, practices and assessment purposes, multiple types of knowledge can be integrated.

2.3.1 Participatory mapping (PM)

Using participatory mapping, enables decision makers to receive maps of ES also in regions of data scarcity. The crucial factor here is to integrate stakeholders into the mapping process. Participatory mapping represents a relatively easy to handle and very comprehensible approach to identify and evaluate the different dimensions of ES. It can be a very effective method that can be used at several relevant spatial scales – mainly for local and regional, but partly also at national level. The requirements regarding data availability are rather medium and it can be used to uncover quantitative, as well as qualitative data. It's mainly used to integrate non-academic stakeholders and persons/experts covering other fields than the responsible researcher(s). Additionally, this method is not too resource consuming (with regard to time and money). With respect to TEEB-values, participatory mapping covers ecological and socio-cultural aspects, but assessing economic values is rather not expedient. Altogether this method has one of the highest integrative potentials of socio-cultural methods for assessing supply, demand and/or flow of ES (Santos-Martín et al. 2017).

By using this method, perceptions and values, as well as knowledge from (local) stakeholders can be gathered and further be used for land management decisions. Included people may cover local lay public but also stakeholders from various sectors and experts such as scientists and planning practitioners. From the technical point of view PM of ecosystem services coves a wide range of possibilities starting from point placement with e.g. stickers on printed maps up to digital mapping software (GIS) – often web based – to draw polygons representing land (uses) units used for further (e)valuation processes. Following analytical processes handle either only the PM data alone (analysing the informants and general spatial patterns) or include additional spatial/social/economic data (depending on assessment purpose and data availability; see Figure 9) (Fagerholm and Palomo 2017).

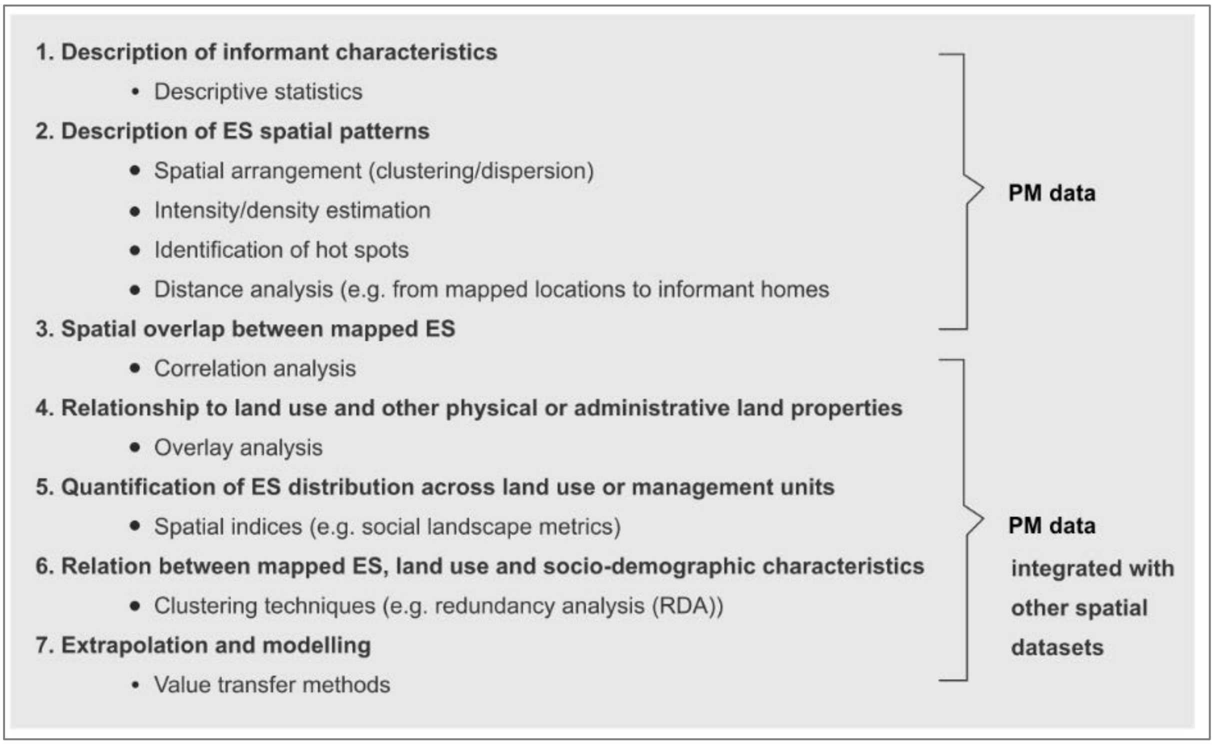

Figure 9: Potential analytical processes for analysing PM data – ranging from simple statistical methods to data integration and modelling; adapted from Fagerholm and Palomo (2017)

2.3.2 ES matrix

The so called "Ecosystem Service Matrix" is a potentially highly integrative and flexible method that can handle all types of ES, all levels of data availability and knowledge and can be applied by a wide range of scientific disciplines. The matrices are the result of an (assessment) process, which is very illustrative and comprehensible. Additionally this approach is applicable for a variety of purposes and varying complexity – from simple ES screening and as a communication tool for awareness raising up to sophisticated ES assessments like multidisciplinary ES quantification approaches (Burkhard 2017). Another advantage is it's high combination potential – matrix approaches can be used either as a stand-alone technique or it can be combined with almost all available assessment methods or even be the result of an alternative method, like e.g. participatory mapping (Priess and Kopperoinen 2017).

Basically, the technical aspect of the matrix approach consists of 10 steps (Figure 10). The first six steps are related to the assessment purpose and available resources (data, expertise, time,..). During this phase it's crucial to include relevant stakeholders in the process. The development of the matrix and the conduction of the assessment itself takes place during steps 7 to 9. Finally, the results usually are transferred to a comprehensible map – for interpretation, communication, and e.g. application of the results as a basis for a decision-making process. The visual results of the process and its steps are demonstrated in Figure 11 (Burkhard 2017).

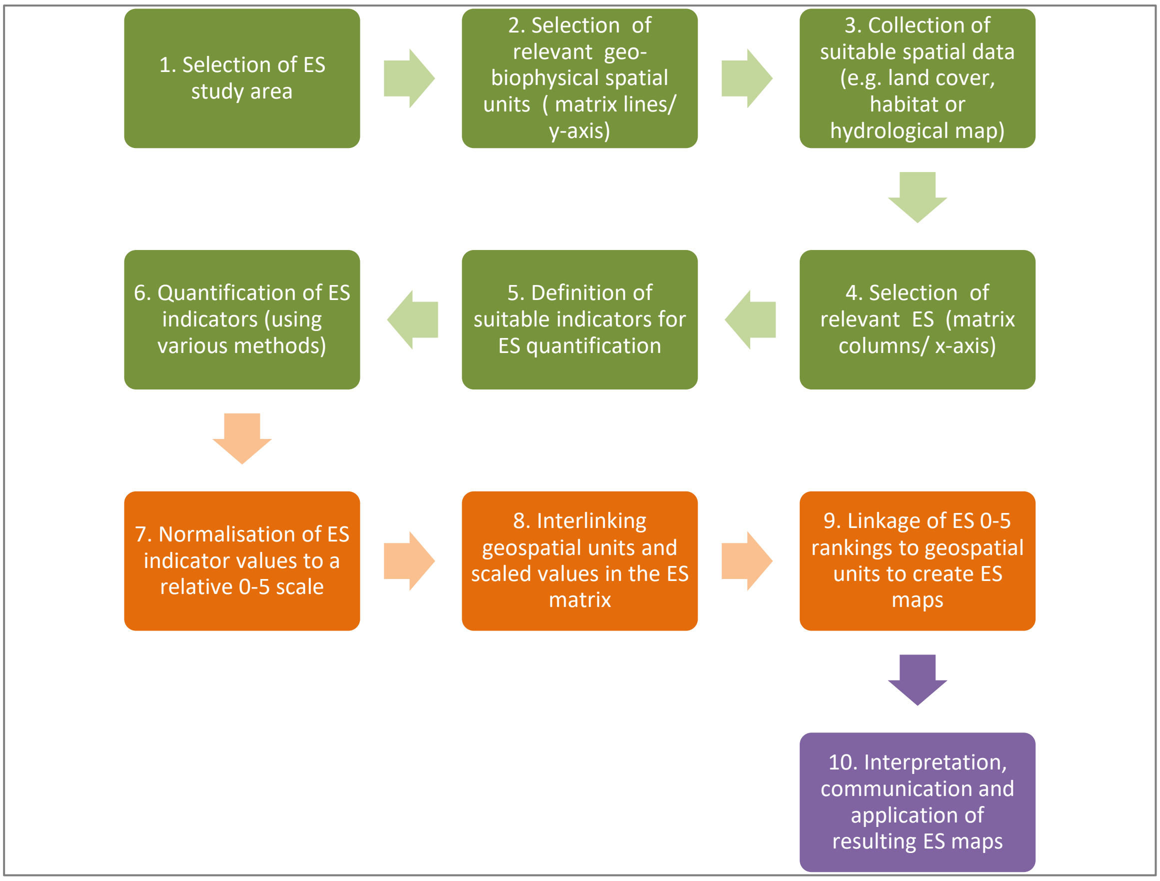

Figure 10: Technical steps of the ES matrix approach (after Burkhard 2017)

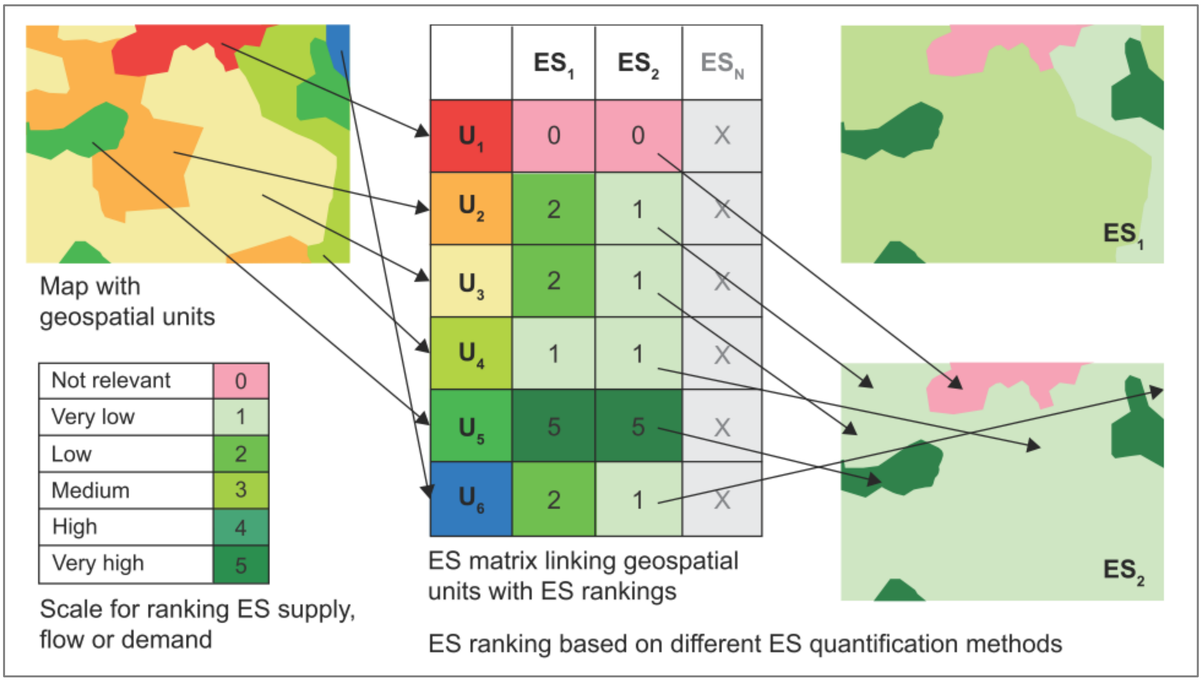

Figure 11: Relevant elements of the ES matrix and resulting maps (Burkhard 2017).

2.4 Recommendations for an integrated framework for ES assessment

Based on the findings and examples above, some aspects that should be taken into account when initiating an ES assessment process can be summarized. Considering the following points clearly supports an effective and expedient assessment procedure leading into reasonable results that can be further used as a relevant basis for decision making processes.:

- Using more than one (e)valuation-method (biophysical, socio-cultural, economic) or better using a **combination of methods** to avoid imbalance/bias.

- Regarding the point above, it's recommended to **combine biophysical and socio-cultural approaches.** Economic valuations can be integrated as well, but need to be handled with care and only used when reasonable.

- 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, therefore participation is crucial!

- When it comes to "**participation**", depending on the planned intensity of integrating the general public into management processes, there are several principles to be considered. An exemplary procedure for a participatory process, using the matrix-approach and involving experts and other stakeholders is given by e.g. Campagne and Roche (2018). An important aspect to consider is the correct definition of "stakeholders": this term includes all people who have a personal or professional interest in the project, who impacts or is impacted by an assessment process and management decisions. Stakeholders therefore are habitants, experts, researchers, politicians, people from administration, etc. Of course, not all stakeholders can be involved in each single phase, but at least a "**representative group**" may be identified via a stakeholder analysis and included in crucial steps. It consists usually of a minimum of 25 people covering all users (in the present case of the investigated Nile wetland) and concerned populations. It should be representative in terms of wetland relation, location, age, gender and activity (Ferrand et al. 2017).

- The **complexity** of chosen methods should be held **low** – in particular, when local stakeholders (public) are included. The more complex the methods and results are, the more important is their translation. Following this, it can be ensured, that the process is transparent and the results are comprehensible.

- Förster et al. (2015) developed a comprehensive, transparent and adaptable **problem-oriented approach** to assess ES. This framework serves as a comprehensible and useful template for ES assessment processes. An example framework for the *technical* part of ES assessments was given in the EU-project MARS ("Managing Aquatic Ecosystems and Water Resources under Multiple Stress"; Figure 12; Grizzetti et al. 2015). Based on this structure, drivers, pressures relationships, ecosystem status and ES can be sketched, whereby this framework is only a basic example that may be adapted according to a specific case!

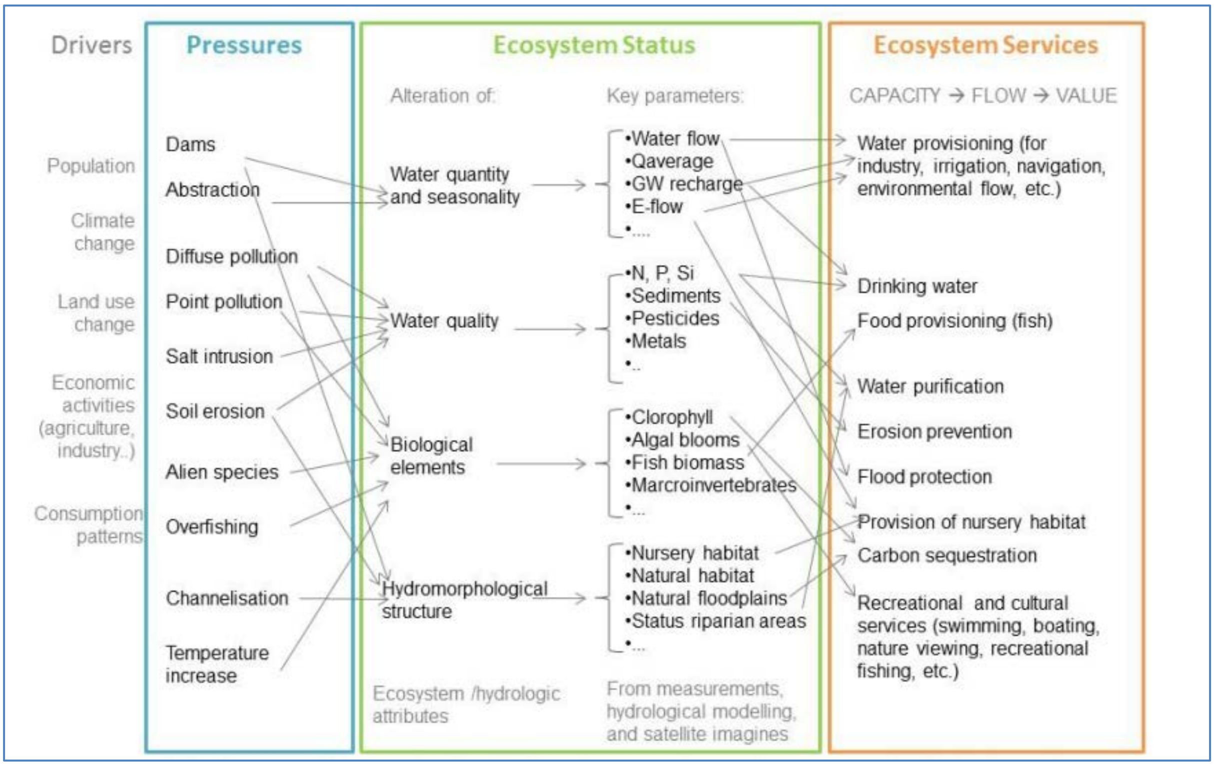

Figure 12: An exemplary framework for water ES assessment proposed within the MARS project (Grizzetti et al. 2015)

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4 Annex

Table 6: Ecosystem Services (after CICES VC4.3) and related indicators of freshwater ecosystems used in the project "Mapping and Assessment of Ecosystems and their Services" (Maes et al. 2016b)

<table>
<tr><th>Division</th><th>Group</th><th colspan="2">Class</th><th>Lakes</th><th>Rivers</th><th>Ground water</th><th>Wetlands</th></tr>
<tr><td rowspan="9">Nutrition</td><td rowspan="6">Biomass</td><td colspan="2">Cultivated crops</td><td colspan="4"></td></tr>
<tr><td colspan="2">Reared animals and their outputs</td><td colspan="4"></td></tr>
<tr><td colspan="2">Wild plants, algae and their outputs</td><td colspan="2">● Wild plants used in gastronomy, cosmetic, pharmaceutical uses (data on industries collecting the plants)</td><td></td><td>see lakes and rivers</td></tr>
<tr><td colspan="2">Wild animals and their outputs</td><td colspan="2">● Fish production (catch in tonnes by commercial and recreational fisheries)
● Number of fisherman and hunters of waterfowls (anglers, professional and amateur fishermen)
● Status of fish population (Species composition, Age Structure, Biomass kg/ha)</td><td></td><td>see lakes and rivers</td></tr>
<tr><td colspan="2">Plants and algae from in-situ aquaculture</td><td colspan="4"></td></tr>
<tr><td colspan="2">Animals from in-situ aquaculture</td><td colspan="2">● Freshwater aquaculture production (e.g. sturgeon and caviar production)</td><td></td><td></td></tr>
<tr><td rowspan="3">Water</td><td>Surface water for drinking</td><td rowspan="3">● Water exploitation index (WEI)</td><td colspan="2">● Water consumption for drinking
● Surface water availability
● Water abstracted</td><td></td><td>● Nitrate-vulnerable zones</td></tr>
<tr><td rowspan="2">Ground water for drinking</td><td colspan="2" rowspan="2"></td><td rowspan="2">● Ground water bodies
● Ground water abstraction</td><td rowspan="2"></td></tr>
<tr></tr>
<tr><td>Materials</td><td>Biomass</td><td colspan="2">Fibres and other materials from plants, algae and animals for direct use or processing</td><td colspan="3"></td><td>● Wood produced (tons or volume) by riparian forest
● Surface of exploited wet forests (e.g. poplars) and reeds</td></tr>
</table>

<table>
<tr><th>Division</th><th>Group</th><th colspan="2">Class</th><th>Lakes</th><th>Rivers</th><th>Ground water</th><th>Wetlands</th></tr>
<tr><td rowspan="4"></td><td rowspan="2"></td><td colspan="2">Materials from plants, algae and animals for agricultural use</td><td colspan="4"></td></tr>
<tr><td colspan="2">Genetic materials from all biota</td><td colspan="4"></td></tr>
<tr><td rowspan="2">Water</td><td>Surface water for non-drinking purposes</td><td rowspan="2">● Water exploitation index (WEI)</td><td colspan="2">● Water use per sector
● Surface water availability
● Water abstracted
● Volume of water bodies</td><td></td><td>● Surface of flood-prone areas</td></tr>
<tr><td>Ground water for non-drinking purposes</td><td colspan="2"></td><td>● Ground water bodies
● Ground water abstraction</td><td></td></tr>
<tr><td rowspan="3">Energy</td><td rowspan="2">Biomass-based energy sources</td><td colspan="2">Plant-based resources</td><td colspan="2"></td><td></td><td>● Firewood produced by riparian forests</td></tr>
<tr><td colspan="2">Animal-based resources</td><td colspan="4"></td></tr>
<tr><td>Mechanical energy</td><td colspan="2">Animal-based energy</td><td colspan="4"></td></tr>
<tr><td rowspan="5">Mediation of waste, toxics and other nuisances</td><td rowspan="2">Mediation by biota</td><td colspan="2">Bio-remediation by micro-organisms, algae, plants, and animals</td><td colspan="2" rowspan="3">● Indicators on water quality (microbiological data for bathing waters, BOD5 nitrate concentration, phosphate concentration, oxygen conditions, saprobiological status)
● Nutrient loads
● Ecological status
● Trophic status
● Area occupied by riparian forests
● Number and efficiency of treatment plants
● Waste treated</td><td rowspan="3">● Indicators on groundwater quality (NO3, pesticide, trace metals, emerging pollutants, etc. evolution in GW)</td><td rowspan="3">● Carbon storage per unit of area
● Potential mineralization or decomposition
● Ecological status
● Nutrient concentration
● Nutrient retention</td></tr>
<tr><td colspan="2">Filtration/sequestration/storage/accumulation by micro-organisms, algae, plants, and animals</td></tr>
<tr><td rowspan="3">Mediation by ecosystems</td><td colspan="2">Filtration/sequestration/storage/accumulation by ecosystems</td></tr>
<tr><td colspan="2">Dilution by atmosphere, freshwater and marine ecosystems</td><td colspan="4"></td></tr>
<tr><td colspan="2">Mediation of smell/noise/visual impacts</td><td colspan="4"></td></tr>
<tr><td rowspan="4">Mediation of flows</td><td rowspan="2">Mass flows</td><td colspan="2">Mass stabilisation and control of erosion rates</td><td></td><td></td><td rowspan="4">● GW level evolution</td><td></td></tr>
<tr><td colspan="2">Buffering and attenuation of mass flows</td><td colspan="2">● Sediment retention</td><td>● Sediment retention</td></tr>
<tr><td rowspan="2">Liquid flows</td><td colspan="2">Hydrological cycle and water flow maintenance</td><td></td><td></td><td></td></tr>
<tr><td colspan="2">Flood protection</td><td colspan="2">● Holding capacity flood risk maps</td><td>● Water holding capacity of soils</td></tr>
</table>

Division	Group	Class	Lakes	Rivers	Ground water	Wetlands
			● Conservation of river and lakes banks			● Floodplains areas (and record of annual floods) ● Area of wetlands located in flood risk zones ● Conservation status of riparian wetlands
	Gaseous / air flows	Storm protection				● Conservation status of wetlands
		Ventilation and transpiration				
Maintenance of physical, chemical, biological conditions	Lifecycle maintenance, habitat and gene pool protection	Pollination and seed dispersal			● GW level	
		Maintaining nursery populations and habitats	● Biodiversity value (Species diversity or abundance, endemics or red list species and spawning location) ● Ecological status Morphological status			
	Pest and disease control	Pest control	● Alien species (Introduced riparian and aquatic plants ● Number of introduced aquatic invertebrates ● Number of introduced vertebrates in rivers and riparian areas			***see lakes and rivers***
		Disease control				
	Soil formation and composition	Weathering processes	● Fluvisols surface			● Hydromorphic soils (Presence/absence) Surface of floodplains
		Decomposition and fixing processes				● Potential mineralization, decomposition, etc.
	Water conditions	Chemical condition of freshwaters	● Chemical status ● Ecological status		● Indicators of GW quality	● Chemical status ● Ecological status ● Potential of water purification of wetlands
		Chemical condition of salt waters				

Division	Group	Class	Lakes	Rivers	Ground water	Wetlands
	Atmospheric composition and climate regulation	Global climate regulation by reduction of greenhouse gas concentrations	● C sequestration (Annual increase in ● Carbon sequestration in living biomass of riparian forest ● Carbon sequestered by plantations of *Populus* ● Organic carbon stored in fluvisols)		● C sequestration (Evolution of annual volumes of CO_2 injected, ● Number of sites for CO_2 deep injections	***see rivers and lakes***
		Micro and regional climate regulation			● GW level	
Physical and intellectual interactions with biota, ecosystems, and land-/seascapes [environmental settings]	Physical and experiential interactions	Experiential use of plants, animals and land-/seascapes in different environmental settings	● Number of visitors (to National Parks including lakes or rivers) ● National Parks and Natura 2000 sites ● Known bird watching sites Waterfowl			● Number of visitors (waterfowl hunters and fishermen ● Visitors to National Parks or protected areas including wetlands) ● Known bird watching sites ● Waterfowl ● Tourism revenue
		Physical use of land-/seascapes in different environmental settings	● Number of visitors ● bathing areas and Number beaches ● Fishing reserves ● Fish abundance ● Fish monetary value from angling ● Number fishing licenses ● Quality of fresh waters for fishing		● Number of visitors (to thermal mineral and mud springs and beaches to Natural Reserve areas) speleology sites	● Number of visitors (waterfowl hunters and fishermen) ● Number of fishing licenses ● Tourism revenue
	Intellectual and representative interactions	Scientific	● Monitoring sites (by scientists) ● Number of scientific projects articles, studies ● Classified sites (world heritage, label European tourism)			
		Educational	● Number of visitors ● National Parks and Natura 2000 sites			
		Heritage, cultural	● Number of visitors ● Natural heritage and cultural sites ● Number of annual cultural activities organised			

Division	Group	Class	Lakes	Rivers	Ground water	Wetlands
		Entertainment	● Number of visitors ● Surface or number of wetlands located next to a bike path			
		Aesthetic	● Number of visitors ● Contrasting landscapes (lakes close to mountains) ● Proximity to urban areas of scenic rivers or lakes			
Spiritual, symbolic and other interactions with biota, ecosystems, and land-/seascapes [environmental settings]	Spiritual and/or emblematic	Symbolic	● National species or habitat types		● Number of visitors (to places where springs and streams with GW origin made them historic and religious sites)	● National species or habitat types
		Sacred and/or religious	● Sacred/religious sites (catastrophic events, religious places)			● Sacred/religious sites (catastrophic events, religious places)
	Other cultural outputs	Existence	● Number of visitors (to National Parks including lakes) ● Number of fishing licenses		● Number of visitors (to hot mineral spring waters)	***See rivers and lakes***
		Bequest	● Number of associations registered on animals, plants, environment, naturism			***See rivers and lakes***

Table 7: CICES classification of Ecosystem Services, V5.1 (divisions/groups “others” left out) (Haines-Young and Potschin 2018)

Section	Division	Group	Class	Class type	Simple descriptor	Example Service	Example Goods and Benefits
Provisioning (Biotic)	Biomass	Cultivated terrestrial plants for nutrition, materials or energy	Cultivated terrestrial plants (including fungi, algae) grown for nutritional purposes	*Crops by amount, type (e.g. cereals, root crops, soft fruit, etc.)*	*Any crops and fruits grown by humans for food; food crops*	*Standing wheat crop before harvest (Proxy for: ecosystem contribution to growth of harvestable wheat)*	*Harvested crop; Grain in farmer's store; flour, bread*
			Fibres and other materials from cultivated plants, fungi, algae and bacteria for direct use or processing (excluding genetic materials)	*Material by amount, type, use, media (land, soil, freshwater, marine)*	*Material from plants, fungi, algae or bacterial that we can use*	*Harvestable surplus of annual tree growth*	*Processed timber (Volume of harvested wood)*
			Cultivated plants (including fungi, algae) grown as a source of energy	*By amount, type, source*	*Plant materials used as a source of energy*	*Standing crop of Miscanthus at time of harvest*	*Energy production*
			Plants cultivated by in- situ aquaculture grown for nutritional purposes	*Plants, algae by amount, type*	*Plants that are cultivated in fresh or salt water that we eat*	*Harvestable surplus of seaweed biomass in situ*	*Vitamin supplement*
			Fibres and other materials from in-situ aquaculture for direct use or processing (excluding genetic materials)	*Plants, algae by amount, type*	*Plants that are cultivated in fresh or salt water that we can use as a material*	*Harvestable surplus of seaweed biomass in situ*	*Seaweed as an insulating material*
			Plants cultivated by in- situ aquaculture grown as an energy source	*Plants, algae by amount, type*	*Plants that are cultivated in fresh or salt water that we can use as an energy source*	*Harvestable surplus of seaweed biomass in situ*	*Seaweed as a source of energy*
		Reared animals for nutrition,	Animals reared for nutritional purposes	*Animals, products by amount, type (e.g. beef, dairy)*	*Livestock raised in housing and/or grazed outdoors*	*Increase in weight or numbers of cattle herd per year [previously the grass feeding these animals was considered the final service]*	*Meat produced at abattoir, eggs, milk sold on farm or in shops*

		materials or energy	Fibres and other materials from reared animals for direct use or processing (excluding genetic materials)	*Material by amount, type, use, media (land, soil, freshwater, marine)*	*Material from animals that we can use*	*Harvestable number and quality of animal skins in herd*	*Hide products*
			Animals reared to provide energy (including mechanical)	*By amount, type, source*	*Animal materials used as a source of energy or for traction*	*Volume of dung or number of animals used for traction*	*Cooking fuel or Haulage*
		Reared aquatic animals for nutrition, materials or energy	Animals reared by in-situ aquaculture for nutritional purposes	*Animals by amount, type*	*Animals that are cultivated in fresh or salt water that we eat.*	*Harvestable stock of bivalves*	*Seafood (e.g. mussels)*
			Fibres and other materials from animals grown by in-situ aquaculture for direct use or processing (excluding genetic materials)	*Animals by amount, type*	*Animals that are cultivated in fresh or salt water that we can use as a material.*	*Harvestable pearls produced by oyster beds*	*Pearls used for adornment*
			Animals reared by in-situ aquaculture as an energy source	*Animals by amount, type*	*Animals that are cultivated in fresh or salt water that we can use as a source of energy.*	*Biogas from aquaculture waste*	*Energy production*
		Wild plants (terrestrial and aquatic) for nutrition, materials or energy	Wild plants (terrestrial and aquatic, including fungi, algae) used for nutrition	*Plants, algae by amount, type*	*Food from wild plants*	*Harvestable volume of wild berries or wild mushrooms, OrBenthic macroalgae (e.g. Dulse, Laminaria (Kelp)) and macrophytes (e.g. Salicornia and other saltmarsh plants) harvested in the shallow sublittoral and/or littoral zone*	*Berries as food or for the production of jam*
			Fibres and other materials from wild plants for direct use or processing (excluding genetic materials)	*Plants, algae by amount, type*	*Materials from wild plants*	*Harvestable volume of reeds Or Macroalgae used for thickening agents, agar and superconductor electrodes*	*Roofing material*

			Wild plants (terrestrial and aquatic, including fungi, algae) used as a source of energy	*Material by type/source*	*Materials from wild plants, fungi and algae used for energy*	*Volume of harvested wood*	*Fuel wood*
		Wild animals (terrestrial and aquatic) for nutrition, materials or energy	Wild animals (terrestrial and aquatic) used for nutritional purposes	*Animals by amount, type*	*Food from wild animals*	*Harvestable surplus of cod population, or deer population*	*Cod liver oil, Venison joint*
			Fibres and other materials from wild animals for direct use or processing (excluding genetic materials)	*Material by type/source*	*Materials from wild animals*	*Reindeer skins* *Or* *Zooplankton – jellyfish used to produce collagen for various purposes*	*Hide products*
			Wild animals (terrestrial and aquatic) used as a source of energy	*By amount, type, source*	*Material from wild animals that can be used as a source of energy*	*Seal blubber used by traditional cultures in lamps* *Or* *Sand eels (Historical) or Cetaceans*	*Fuel source*
	Genetic material from all biota (including seed, spore or gamete production)	Genetic material from plants, algae or fungi	Seeds, spores and other plant materials collected for maintaining or establishing a population	*By species or varieties*	*Seed collection*	*Seeds or spores that we can harvest*	*Wild plant seed for commercial sale*
			Higher and lower plants (whole organisms) used to breed new strains or varieties	*By species or varieties*	*Plants. fungi or algae that we can use for breeding*	*Population of plant algae or fungi species used to in breeding programmes*	*Plant, algae or fungi species with novel characteristics that increase yields or reduce costs by resisting diseases or pests*
			Individual genes extracted from higher and lower plants for the design and construction of new biological entities	*Material by type*	*Genetic material from wild plants. fungi or algae that we can use*	*Harvestable share of population of plant species used to extract genes*	*Creation of artificial gene products*
		Genetic material	Animal material collected for the purposes of maintaining or establishing a population	*By species or varieties*	*Animals used for replenishing stock*	*Spat for fish and shellfish farms*	*Reduced costs of production*

		from animals	Wild animals (whole organisms) used to breed new strains or varieties	*By species or varieties*	*Wild animals that we can use for breeding*	*Population of animals used in breeding programmes*	*Animals with novel characteristics that increase yields or reduce costs by resisting diseases or pests*
		Genetic material from organisms	Individual genes extracted from organisms for the design and construction of new biological entities	*Material by type*	*The genetic information that is stored in wild animals that we can use*	*Harvestable share of population of a given species used to extract genes*	*Creation of a novel micro-organism to help produce a pharmaceutical product*
Regulation & Maintenance (Biotic)	Transformation of biochemical or physical inputs to ecosystems	Mediation of wastes or toxic substances of anthropogenic origin by living processes	Bio-remediation by micro-organisms, algae, plants, and animals	*By type of living system or by waste or subsistence type*	*Decomposing wastes*	*Bio-remediation of industrial wastes by disposal on agricultural land* *Or* *Bacteria such as Marionobacter that can break the oil down into simple monomers*	*Sustainable disposal of wastes*
			Filtration/sequestration/storage/accumulation by micro-organisms, algae, plants, and animals	*By type of living system, or by water or substance type*	*Filtering wastes*	*Dust filtration by urban trees* *Or* *Macrophytes, for example salt marsh grass, can trap particles in their roots, sequestering wastes/toxicants in the sediment (Govers et al. 2014)*	*Reduction in respiratory disease*
		Mediation of nuisances of anthropogenic origin	Smell reduction	By type of living system	Reducing smells	*Shelter belts that filter particulates that carry odours* *Or* *Birds, epifauna, infauna and bacterial communities contribute to this service by removing material such as*	*Reduction in nuisance effect of smells from animal lots*

						rotting algal mats, which is in the littoral zone or offshore but could potentially wash up on shore and produce olfactory and visual impacts	
			Noise attenuation	By type of living system	*Reducing noise*	*Shelter belts along motorways*	*Low noise environment*
			Visual screening	By type of living system	*Screening unsightly things*	*Shelter belts around industrial structures*	*Visual amenity*
	Regulation of physical, chemical, biological conditions	Regulation of baseline flows and extreme events	Control of erosion rates	*By reduction in risk, area protected*	*Controlling or preventing soil loss*	*The capacity of vegetation to prevent or reduce the incidence of soil erosion Or Macroalgae, microphytobenthos, macrophytes and biogenic reef structures (epifauna and infauna) all contribute through sediment stabilisation*	*Reduction of damage (and associated costs) of sediment input to water courses*
			Buffering and attenuation of mass movement	*By reduction in risk, area protected*	*Stopping landslides and avalanches harming people*	*The capacity of forest cover to prevent or mitigate the extent and force of snow avalanche*	*Reduction in cost to human lives and physical damage to infrastructure*
			Hydrological cycle and water flow regulation (Including flood control, and coastal protection)	*By depth/volumes*	*Regulating the flows of water in our environment*	*The capacity of vegetation to retain water and release it slowly, Or The capacity of mangroves to mitigate the effects of tsunamis Or Localised coastal influences on the hydrological cycle by phytoplankton producing Dimethylsulphide (DMS) and localised flow changes due to algal and higher plant structures. Macroalgae beds, such as a kelp forest,*	*Mitigation of damage as a result of reduced in magnitude and frequency of flood/storm events*

						macrophytes and biogenic reefs (epifauna and infauna) contribute to attenuation of wave energy and flood prevention	
			Wind protection	*By reduction in risk, area protected*	*Protecting people from winds*	*Wind breaks*	*Reduction in scale or frequency of damage to crops*
			Fire protection	*By reduction in risk, area protected*	*Protecting people from fire*	*The capacity of ecosystems to reduce the frequency, spread or magnitudes of fires. (e.g. wetland area between forests, or fire belt in woodland containing species of low combustibility)*	*Reduction in fire damage costs*
		Lifecycle maintenance, habitat and gene pool protection	Pollination (or 'gamete' dispersal in a marine context)	*By amount and pollinator*	*Pollinating our fruit trees and other plants*	*Providing a habitat for native pollinators Or In the context of societal efforts for the restoration of, for example, seagrass beds , it can be considered final since seed dispersal can occur through this service rather than artificially.*	*Contribution to yield of fruit crops*
			Seed dispersal	*By amount and dispersal agent*	*Spreading the seeds of wild plants*	*Acorn dispersal by Eurasian Jays*	*Tree regeneration in parkland*
			Maintaining nursery populations and habitats (Including gene pool protection)	*By amount and source*	*Providing habitats for wild plants and animals that can be useful to us*	*Important nursery habitats include estuaries, seagrass, kelp forest, wetlands, soft sediment, hard bottom, shell bottom and water column habitats. Floating seaweed clumps (macroalgae) form rafts under which juvenile fish aggregate e.g. in the North Sea in pelagic habitats*	*Sustainable populations of useful or iconic species that contribute to a service in another ecosystem.*

		Pest and disease control	Pest control (including invasive species)	*By reduction in incidence, risk, area protected by type of living system*	*Controlling pests and invasive species*	*Providing a habitat for native pest control agentsOrIn the Black Sea, the recovery of fish populations and an alien invader, the Beroe comb jelly, (both of whom predate nuisance alien comb jellies, Finenko et al.2009) may have been the most important contributing factors for the control of the Mnemiopsis leidyi alien comb jelly, which caused an ecosystem shift in the late 80s.*	*Reduction in pest damage to cultivated crop*
			Disease control	*By reduction in incidence, risk, area protected by type of living system*	*Controlling disease*	*Presence of native disease control agents such as microbial antagonists for the control of postharvest diseases*	*Reduction in disease damage due to harvested fruit or vegetables*
		Regulation of soil quality	Weathering processes and their effect on soil quality	*By amount/concentration and source*	*Ensuring soils form and develop*	*Inorganic nutrient release in cultivated fields*	*Maintenance of soil quality and hence capability of soil for human use.*
			Decomposition and fixing processes and their effect on soil quality	*By amount/concentration and source*	*Ensuring the organic matter in our soils is maintained*	*Decomposition of plant residue; N-fixation by legumes*	*Maintenance of soil quality; legumes used to increase/maintain N-levels in soil*

		Water conditions	Regulation of the chemical condition of freshwaters by living processes	*By type of living system*	*Controlling the chemical quality of freshwater*	*Use of buffer strips along water courses to remove nutrients in runoff*	*Reduced damage costs nutrient runoff from agroecosystems*
			Regulation of the chemical condition of salt waters by living processes	*By type of living system*	*Controlling the chemical quality of salt water*	Fish communities that regulate the resilience and resistance of coral reefs to eutrophication	*Health of coral reef and its benefits to people in terms of buffering wave action etc.*
		Atmospheric composition and conditions	Regulation of chemical composition of atmosphere and oceans	*By contribution of type of living system to amount, concentration or climatic parameter*	*Regulating our global climate*	*Sequestration of carbon in tropical peatlands*	*Climate regulation resulting in avoided damage costs Or Mitigation of impacts of ocean acidification*
			Regulation of temperature and humidity, including ventilation and transpiration	*By contribution of type of living system to amount, concentration or climatic parameter*	*Regulating the physical quality of air for people*	*Evaporative cooling provided by urban trees*	*Increased thermal comfort in cities*
Cultural (Biotic)	Direct, in-situ and outdoor interactions with living systems that depend on presence in the environmental setting	Physical and experiential interactions with natural environment	Characteristics of living systems that that enable activities promoting health, recuperation or enjoyment through active or immersive interactions	*By type of living system or environmental setting*	*Using the environment for sport and recreation; using nature to help stay fit*	*Ecological qualities of woodland that make it attractive to hiker; private gardens Or Opportunities for diving, swimming*	*Recreation, fitness; de-stressing or mental health; nature-based recreation*
			Characteristics of living systems that enable activities promoting health, recuperation or enjoyment through passive or observational interactions	*By type of living system or environmental setting*	*Watching plants and animals where they live; using nature to destress*	*Mix of species in a woodland of interest to birdwatchers Or Whales, birds, seals and reptiles can be enjoyed by wildlife watchers*	*Recreation, fitness; de-stressing or mental health; eco-tourism*

		Intellectual and representative interactions with natural environment	Characteristics of living systems that enable scientific investigation or the creation of traditional ecological knowledge	*By type of living system or environmental setting*	*Researching nature*	*Site of special scientific interest, Natura 2000 site*	*Knowledge about the environment and nature*
			Characteristics of living systems that enable education and training	*By type of living system or environmental setting*	*Studying nature*	*Site used for voluntary conservation activities*	*Skills or knowledge about environmental management*
			Characteristics of living systems that are resonant in terms of culture or heritage	*By type of living system or environmental setting*	*The things in nature that help people identify with the history or culture of where they live or come from*	*Sherwood Forest*	*Tourism, local identify*
			Characteristics of living systems that enable aesthetic experiences	*By type of living system or environmental setting*	*The beauty of nature*	*Area of Outstanding Natural Beauty; panorama site*	*Artistic inspiration*
	Indirect, remote, often indoor interactions with living systems that do not require presence in the environmental setting	Spiritual, symbolic and other interactions with natural environment	Elements of living systems that have symbolic meaning	*By type of living system or environmental setting*	*Using nature to as a national or local emblem*	*Bald Eagle*	*Social cohesion, cultural icon*
			Elements of living systems that have sacred or religious meaning	*By type of living system or environmental setting*	*The things in nature that have spiritual importance for people*	*Totemic species, such as the turtle*	*Mental well-being*
			Elements of living systems used for entertainment or representation	*By type of living system or environmental setting*	*The things in nature used to make films or to write books*	*Archive records or collections*	*Nature films*

Provisioning (Abiotic)	Water	Surface water used for nutrition, materials or energy	Surface water for drinking	*By amount, type, source*	*Drinking water from sources at the ground surface*	*Volume and characteristics of water from a natural springs*	*Potable water in public supply system*
			Surface water used as a material (non-drinking purposes)	*By amount & source*	*Surface water that we can use for things other than drinking*	*Temperature and volume of water that can be used for cooling or irrigation*	*Reduced energy costs; glass house cultivation*
			Freshwater surface water used as an energy source	*By amount, type, source*	*Hydropower*	*Hydraulic potential (Head)*	*HEP*
			Coastal and marine water used as energy source	*By amount, type, source*	*Wave or tidal power*	*Tidal velocity*	*Tidal power*
		Ground water for used for nutrition, materials or energy	Ground (and subsurface) water for drinking	*By amount, type, source*	*Dirking water from the below ground*	*Aquifer volume and characteristics*	*Potable water in public supply system; mineral water*
			Ground water (and subsurface) used as a material (non-drinking purposes)	*By amount & source*	*Sub-surface water that we can use for things other than drinking*	*Characteristics and volume of water that can be used for washing purposes*	*Reduced material costs*
			Ground water (and subsurface) used as an energy source	*By amount & source*	*Sub-surface water that we can use as a source of energy*	*Hot water and steam vents*	*Reduces energy costs*
	Non-aqueous natural abiotic ecosystem outputs	Mineral substances used for nutrition, materials or energy	Mineral substances used for nutritional purposes	*Amount by type*	*Minerals in our food*	*Salt*	*Dietary value*
			Mineral substances used for material purposes	*Amount by type*	*Natural inorganic materials from nature that we can use*	*Pigments*	*Decoration*
			Mineral substances used for as an energy source	*Amount by type*	*Natural inorganic materials from nature that we can use as an energy source*	*Uranium*	*Energy production*
		Non-mineral substances or	Non-mineral substances or ecosystem properties used for nutritional purposes	*Amount by type*	*The ways the physical environment contribute to our nutritional health*	*Sunlight*	*Vitamin D*

		ecosystem properties used for nutrition, materials or energy	Non-mineral substances used for materials	*Amount by type*	*Gaseous, fluid or non-mineral solid inorganic materials from nature that we can use (excludes water vapour)*	*Ozone; or mineraloids (e.g. Opal)*	*Health benefit; gems*
			Wind energy	*Amount by type*	*Wind power*	*Wind power*	*Renewable energy source*
			Solar energy	*Amount by type*	*Solar power*	*Solar power*	*Renewable energy source*
			Geothermal	*Amount by type*	*Using underground heat*	*Hot springs*	*Renewable energy source*
Regulation & Maintenance (Abiotic)	Transformation of biochemical or physical inputs to ecosystems	Mediation of waste, toxics and other nuisances by non-living processes	Dilution by freshwater and marine ecosystems	*Amount by type*	*Diluting wastes*	*Use of freshwater/marine systems as a pollution sink*	*Reduction of disposal costs, disposal of wastes*
			Dilution by atmosphere	*Amount by type*	*Diluting wastes*	*Use of atmosphere as a pollution sink*	*Reduction of disposal costs, disposal of wastes*
			Mediation by other chemical or physical means (e.g. via Filtration, sequestration, storage or accumulation)	*Amount by type*	*Natural processing of wastes*	*Dissolved silica in runoff*	*Biogeochemical effects of reduced dissolved silica in estuaries causing shifts in phytoplankton species composition*
		Mediation of nuisances of anthropogenic origin	Mediation of nuisances by abiotic structures or processes	*Amount by type*	*Natural protection*	*Screening effect of topography*	*Visual quality*
	Regulation	Regulation of	Mass flows	*Amount by type*	*Physical barriers to landslides*	*Sand bar providing coastal protection*	*Reduction in damage costs*

		baseline flows and extreme events	Liquid flows	*Amount by type*	*Physical barriers to flows*	*Natural levees providing flood protection*	*Reduction in damage costs*
			Gaseous flows	*Amount by type*	*Physical barriers to air movements*	*Topographic control of wind velocity*	*Reduction in damage costs*
		Maintenance of physical, chemical, abiotic conditions	Maintenance and regulation by inorganic natural chemical and physical processes	*Amount by type*	*Regulating living conditions by the physical environment*	*Land/sea breezes*	*Human comfort*
Cultural (Abiotic)	Direct, in-situ and outdoor interactions with natural physical systems that depend on presence in the environmental setting	Physical and experiential interactions with natural abiotic components of the environment	Natural, abiotic characteristics of nature that enable active or passive physical and experiential interactions	*Amount by type*	*Things in the physical environment that we can experience actively or passively*	Caves	*Ecotourism*
		Intellectual and representative interactions with abiotic components of the natural environment	Natural, abiotic characteristics of nature that enable intellectual interactions	*Amount by type*	*Things in the physical environment that we can study or think about*	Rock faces for climbing	*Recreation*

	Indirect, remote, often indoor interactions with physical systems that do not require presence in the environmental setting	Spiritual, symbolic and other interactions with the abiotic components of the natural environment	Natural, abiotic characteristics of nature that enable spiritual, symbolic and other interactions	*Amount by type*	*Things in the physical environment that are important as symbols*	*Iconic mountain peaks*	*Identity*

ONE RIVER
ONE PEOPLE
ONE VISION

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