EXPLORING ECOSYSTEM SERVICES PROVIDED BY THE PANTANAL WETLAND, SOUTH AMERICA

A preliminary review of methods to improve the knowledge on the benefits provided by the wetland

Internship Report

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MSc. Environmental Science – Environmental System Analysis

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PREFACE AND ACKNOWLEDGMENT

Since the year 2016, World Wide Fund for Nature (WWF Netherlands) has been supporting a project in the Pantanal, South America, which aims to "ensure water supply, food security and climate resilience in the transboundary ecoregions of the Pantanal, through effective governance systems and dialogue among civil society actors empowered on the value of natural resources and ecosystem services present in his territory". This initiative is called Pantanal-Chaco, most known as PaCha, and WWF Paraguay and WWF Bolivia are implementing it.

As a result of the communication between project members of WWF Paraguay and the project advisor in WWF Netherlands, the opportunity to carry out an academic internship became possible. Following PaCha's goal, this internship was set to explore the ecosystem services of the Pantanal, how they can be prioritized, and how they can be assessed to focus efforts on their study.

As a Paraguayan master student in the Netherlands, I believed that working on a project, taking place in South America, but in an international organization such as WWF Netherlands was an excellent opportunity. This allowed me to contribute in an on-going project carried out, in part, in Paraguay, but under the supervision of the advisor, Daphne Willems, who is a senior water adviser in the Netherlands. I was able to combine my desire to work in and, somehow contribute to, the PaCha project, with the experience of working in a Dutch organization under the supervision of an experienced professional. There is no doubt that this internship made me face with many personal, professional and academic challenges, nevertheless, they all remain in me as lessons for my future professional career.

I will like to give special thanks to Daphne Willems, my host organization supervisor, who gave me this opportunity, who was always willing to help me and to answer any possible questions I would have, who always had a positive attitude and interest on my work, and from whom I learnt a lot. Thanks to Natascha Zwaal for the introduction to the organization and for showing me how to get started in such a big and interesting organization. Thanks to all employees in WWF Netherlands, and especially in the freshwater unit, who made me feel comfortable the time being there.

In addition, I will like to thank Lucy Aquino and Cristina Morales from WWF Paraguay, who made the contact and communication with Daphne possible. Finally, thanks to my university supervisor, Dolf de Groot, for accepting me as one of the students under his supervision, and encourage me to become interested in ecosystem services.

I hope my contribution is just the beginning of a great future work to understand the benefits and values of the ecosystem services of the Pantanal and I expect it can contribute to the initiative to protect and conserve the Pantanal.

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ACRONYMS AND ABBREVIATIONS

ESs	Ecosystem Services
GDP	Gross Domestic Product
GIS	Geographic Information Systems
ha	Hectares
kg	Kilograms
km	Kilometres
MA	Millennium Ecosystem Assessment
MCA	Multi-Criteria Analysis
NDCs	Nationally Determined Contributions
NPV	Net Present Value
PaCha	Pantanal – Chaco project
SDGs	Sustainable Development Goals
SO	Specific Objective
TEEB	The Economics of Ecosystem and Biodiversity
TEV	Total Economic Value
UNEP	United Nations Environment Programme
UNEP-WCMC	United Nations Environment Programme – World Conservation Monitoring Center
UPRB	Upper Paraguay River Basin
US$	American dollars
yr	Year
WWF	World Wide Fund for Nature

Summary

The Pantanal, located in South America, is the largest freshwater wetland of the world. This wetland houses a unique biodiversity and owns an aesthetic beauty admired globally. Even though it has been recognized as a still pristine ecoregion, during the last decades, it has been facing many anthropogenic threats that are expected to worsen with climate change. Hence, the provision of benefits to people (ecosystem services) of the Pantanal is jeopardized as well. An assessment of the ecosystem services provided by the Pantanal can improve the knowledge on the specific ecological, social and economic benefits provided by the wetland, and can be used as a tool to engage the government and people in its conservation and sustainable development.

This report aims to contribute in the knowledge construction of the direct and indirect benefits that the Pantanal provides to people. There is no integrated assessment of ecosystem services for the Pantanal wetland, and the generation of this information can substantially contribute to the conservation purposes of NGOs working in the area. By means of literature review, it was identified that the Pantanal has the capacity to supply all four ecosystem services categories (provisioning, regulating, cultural and habitat). A description of each of them was included and the pressures threating the Pantanal were related to the ecosystem services of the wetland. Moreover, a prioritization of ecosystem services matrix is presented to focus the study of ecosystem services on those that are more relevant in the area. In addition, methods and tools are suggested to address the ecological, social and economic values of the services provided by this wetland and matrices are applied for the Pantanal based on the literature reviewed carried out for this report.

Some points that are discussed for the future implementation of an ecosystem services assessment is the geographic scale in which the assessment should be carried out (Pantanal vs. Upper Paraguay River Basin), the steps that have to be followed, the use of expert knowledge as a source of information, the available data and the consistency of the results obtained in this report in comparison to other studies. It is hoped that the information provided in this report will provide the basis to initiate the discussion on why it is important to know and understand better the benefits provided by the Pantanal and how this knowledge can contribute to WWF's Global Goals.

1. INTRODUCTION

Wetlands are capable of providing a wide range of services to people and biodiversity, such as water, food, habitat, flood prevention, among others. Nevertheless, wetlands are among the most threatened ecosystems of the world, thereby, the provision of these services it is likely to be affected. Many populations depend on wetlands, and its importance not only arises as a refuge for many species and as a regulator of ecological functions, but also as a source of products and materials that are needed for human well-being. Following this line, the concept of ecosystem services provided by wetlands is gaining importance.

Ecosystem services are the direct and indirect contributions of ecosystems to human well-being (de Groot et al., 2010). Lately, this concept has gained attention as an indicator of human well-being moving beyond the GDP (Costanza et al., 2017) and as an innovative incorporation into conservation assessment in a way that can increase the societal relevance of conservation through the delivery of key ecosystem services that contribute to social well-being (Eastwood et al., 2016; Egoh et al., 2007). Ecosystem services' study has evolved in the last 20 years; however, there are still many ecoregions that have not been assessed under the ecosystem services framework. The Pantanal wetland is one of them.

The Pantanal, located in South America, is the largest freshwater wetland of the world and it is shared by Brazil, Bolivia and Paraguay. It occupies a territory of approximately 160,000 km^2 and it is home for about 4,700 plants and vertebrate animals, including charismatic species such as the jaguar and the giant otter. Many local communities in the Pantanal are highly dependent on the products and ecological functions provided by this wetland, however, populations beyond the Pantanal limits enjoy the benefits.

The assessment of ecosystem services allows identifying, quantifying and valuing the benefits provided by the ecosystem in such a way that the relations between nature and human well-being can be understood. Several methods and models to assess ecosystem services have been developed to this day, but review them takes time and they are usually applicable in certain/specific settings. If an assessment of ecosystem services of the Pantanal is planned to be carried out, it is important to adopt an ecosystem services framework and to get to know the different methods available to implement it.

Following this line, this report aims to contribute in the research of the ecosystem services provided by the Pantanal by generating a preliminary baseline from which future studies can work with and providing some guidance on the steps that can be follow for an assessment and valorization of the ecosystem services of the Pantanal. The methods and tools suggested can be applied in the short term in order to start generating the knowledge required to further study the main ecosystem services of this wetland as well as the services provided by the Upper Paraguay River Basin, in case a broader regional approach is desired.

1.1 Objectives

This internship report had the aim to collaborate with and support the Cerrado-Pantanal Programme and the PaCha initiative, carried out by the offices of WWF in Brazil, Bolivia and Paraguay, by developing a baseline study and suggesting a brief guideline for the assessment of the ecosystem services provided by the Pantanal wetland. Moreover, specific objectives were determined in order to achieve the general objective in a period of four months.

The specific objectives (SO) were:

SO1. Identification and description of the ecosystem services provided by the Pantanal.

SO2. Develop a method for the prioritization of the ecosystem services of the Pantanal.

SO3. Review and recommend ecosystem services assessment methods that can be suitable for the Pantanal context.

1.2 Methodology

The internship period lasted for four months, from April 2018 to August 2018, and took place in the WWF-NL office as well as in Wageningen University. During this period, an extensive literature review (scientific papers, reports and books in Spanish, Portuguese and English) was carried out to collect and review the necessary information for the achievement of the specific objectives and to provide background information on wetlands and ecosystem services.

In order to meet the specific objective 1, documents were reviewed and, since in most cases it was not possible to find documents describing or explicitly mentioning ecosystem services of the Pantanal, ecosystem services were identify by finding words related to them (e.g. fish → food, flood prevention → and mitigation of extreme events) or that are synonyms. Moreover, if ecosystem services such as recreation and tourism in the Pantanal were mentioned in the documents, even though they were not described as ecosystem services per se, these were considered ecosystem services provided by the wetland. Therefore, whenever ecosystem services were mentioned in documents, these were listed in an excel sheet together with the name of the document were it was obtain to facilitate the identification and description of ecosystem services in a later stage of the work. Most literature on the Pantanal that was used for this report can be found in an excel sheet in which the authors, year and study area, name and aim of the document, and the ecosystem services are listed.

For SO2, several scientific papers were reviewed to identify different criteria appropriate for the identification of priority ecosystem services of the Pantanal. Some documents that were used were Hanson et al. (2012), Kettunen et al. (2009), Luck et al. (2012), McInnes & Everard (2017), Peh et al. (2013) and Werner et al. (2014). A simple and qualitative method based on Multi-Criteria Analysis was proposed and further details on the development of the prioritization matrix can be found in chapter 4: “How to prioritize ecosystem services provided by the Pantanal?”.

Finally, for SO3, literature on ecosystem services assessment and valuation were reviewed to recommend a framework suitable for the Pantanal context. The most known and widespread tools and methods were identified and described based on their aim, the ecosystem services they address and their use. Moreover, all concepts and methods presented in this report were related to the available literature on the Pantanal to keep a relation between methods and the study area as well as to highlight the available (and missing) literature of the Pantanal.

Lastly, it is important to point out that all information collected, described and generated in this report was qualitative, and whenever quantitative data was generated, was mainly based on qualitative data.

1.3 Outline of the report

The report is structured in such a way that it follows the order of the specific objectives, since each of the objectives had to be fulfilled before moving on to the next objective. Chapter 2 of the report aims to present the basic concepts that are needed to fully comprehend why this report is relevant for wetlands. Chapter 3 characterizes the Pantanal wetland and describes not only the four categories of ecosystem services it provides, but also the current threats that are jeopardizing the wetland and the provision of ecosystem services. Moreover, chapter 4 presents and depicts the ecosystem services prioritization process and matrix developed specifically for this report, together with an example of the application of the prioritization matrix for the context of the Pantanal.

Chapter 5 reviews and describes more concepts that have to be understood to carry out an ecosystem services assessment and valuation, and presents tools and methods that can be used for such an assessment in the Pantanal. Whenever possible, all the methods were related to the situation in and the available information on the Pantanal in order to give a context to the theoretic topics being addressed. Finally, based on all the reviewed literature, chapter 6 and 7 presents the discussion, recommendations and conclusions of the work, especially focusing on remarkable points and suggestions to the future working team that might implement an assessment of ecosystem services in the Pantanal wetland.

2. Background

2.1 Wetlands and their importance

Wetlands are natural and human-made areas covered by water that provides a variety of inland, coastal, and marine habitats to a wide range of biodiversity. According to Article 1 of the Ramsar Convention on Wetlands, wetlands can be defined as “areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six meters”. Moreover, wetlands can be classified as marine, estuarine, lacustrine, riverine and palustrine (Figure 1) (Ramsar Convention, 2016).

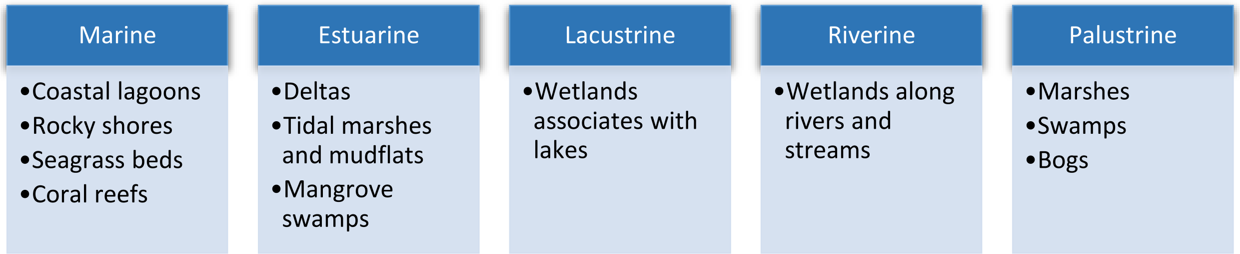

Figure 1. Natural wetlands classification according to the Ramsar Convention.

Wetlands are among the most productive ecosystems of the world occupying an area of approximately 4-6% of the earth land surface. Wetlands are particularly important environments given their influence in the hydrological and biogeochemical cycles, and their capacity to sustain life, not only in terms of biodiversity, but also in relation to the human population that depends on them (Daryadel & Talaei, 2014). Human well-being and the socioeconomic development of human settlements rely upon the benefits provided by wetlands, and conservation of large numbers of mammals, birds, fish, among others, are dependent on the health of wetlands (Ramsar Convention, 2016).

Even though there are well acknowledged reasons to protect and conserve wetlands around the world, there have been a decrease in wetlands surface and quality which has undermined the socio-cultural, ecological and economic benefits that wetlands provide to people (Ramsar Convention, 2016; Ramsar Convention Secretariat, 2015). Globally, natural wetlands decreased by 30% between the year 1970 and 2008 (Dixon et al., 2016). Up to 2009, Europe lost approximately 45% of its wetlands, while wetlands in South America had decreased by 32% (Hu et al., 2017). As for the abundance of species population in freshwater systems, a decline of 81% of population abundance has been calculated between 1970 and 2012, while a reduction of 39% in the abundance of population of wetland-dependent species has been determined for the same period according to the Living Planet Index (WWF International, 2016).

Ecological and hydrological processes and the habitat for diverse fauna and flora species in wetlands have been threatened due to urban developments, dam construction, agricultural intensification and climate change, to mention a few, making more vulnerable the wetlands around the world (Schneider et al., 2017). The destruction of these ecosystems will likely have devastating effects in human populations, with large associated economic loss and numerous negative impacts on biodiversity and human well-being around the world.

The multi-functional character of wetlands together with the range of socio-cultural, environmental and economic values attached by stakeholders with different priorities and interests should be taken into account when adopting management decisions and/or elaborating development plans in wetland areas. This will allow the consideration of the array of impacts, not only on wetlands per se, but on the human populations depending on them (Ramsar Convention, 2016). In this sense, policy makers need information to make the most appropriate decisions that can favorably reinforce the three dimensions of sustainable development (social, environmental and economic), which in the end is in accordance with the concept of wise use of wetlands promoted by the Ramsar Convention.

Following this idea, the concept of ecosystem services provided by wetlands emerges. According to de Groot et al. (2010a), ecosystem services (ESs) are the direct and indirect contributions of ecosystems to human well-being. The integration of the ecosystem services concept in wetland use and management accounts for the relations between wetland management and the ecosystem services (and associated values) that this ecosystem generates. Moreover, highlights the potential of wetlands as multi-functional systems that can be more *"ecologically sustainable, socio-culturally preferable and economically beneficial"* (de Groot et al., 2010b).

2.2 Wetlands and Ecosystem Services

Wetlands are capable of providing goods and services in the form of ecosystem services than can contribute to human well-being (de Groot et al., 2010a). According to The Economics of Ecosystems and Biodiversity (TEEB), ecosystem services can be classified into four categories, namely provisioning, regulating, cultural and habitat services, accounting for 22 ecosystem services (Figure 2).

Figure 2. Typology of ecosystem services used in the TEEB study. Based on de Groot et al. 2010a.

Based on the concept of ecosystem services, a framework that describes the pathway from ecosystem structures or processes, through ecosystem services, to human benefits have been developed by de Groot et al. (2010a), as seen in Figure 3.

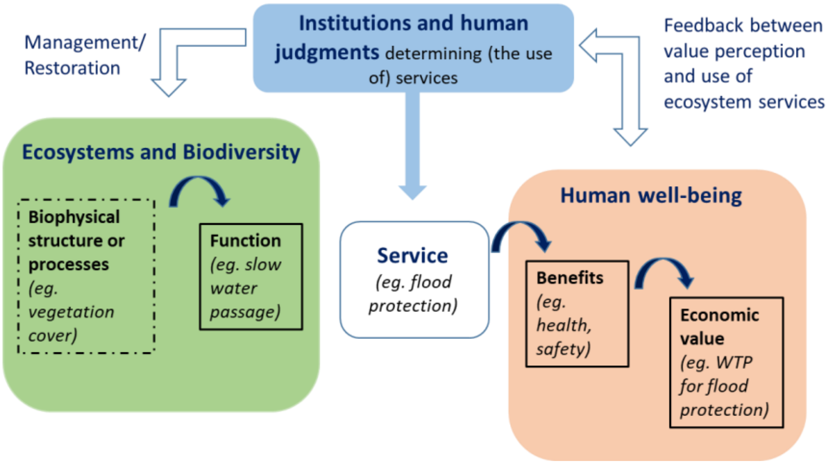

Figure 3. Ecosystem services cascade. Adapted from de Groot et al., 2010a.

The pathway is divided into four main compartments that are interrelated. The ecosystems and biodiversity compartment (green box) includes the biophysical structures and processes as well as ecological functions of the ecosystems. The functions are understood as the capacity of ecosystems to deliver goods and services, which are underpinned by biophysical structure or processes (de Groot et al., 2010b). Moreover, the services compartment (white box) are those “useful things” that ecosystems provide to humans directly (food, water), or indirectly (flood protection, waste treatment). These services contribute to human well-being and can be valued by people (orange box). Finally, institutions and human judgments (blue box) can determine the type of management and use of ecosystem services according to policy contexts or priorities, which in turn have an effect on the ecosystems and their functions (de Groot et al., 2010a).

The value of ecosystem services can be used to enhance and support institutions in the decision-making process regarding actions to manage or restore ecosystems, and can be used to justify and support nature conservation and environmental management (Ghazoul, 2007). Moreover, through the use of the ecosystem services concept and the related cascade model is possible to, somehow, demonstrate in a more comprehensive and complete way the achievement of conservation targets including the ecological processes being protected, the services being provided and the benefits and beneficiaries of those services (Boulton et al., 2016).

It is important to mention that for ecosystem services to become benefits, these services or goods should be used or enjoyed, directly or indirectly, by people, the so-called beneficiaries (Caputo et al., 2016). Therefore, in the identification of ecosystem services provided by wetlands is fundamental to identify who are the people benefiting from the services (users) and who are providing them (providers), given that human intervention can enhance or diminish the provision of ESs.

Commonly, reports and researches on wetlands addresses ecosystem services that are water-related such as water provision, regulation of water flows and flood prevention. However, when analyzed in more detail, it is possible to determine that wetlands are capable of providing a wider range of ecosystem services, in which other provisioning, regulating, cultural and habitat services are identified. In fact, it is believed that there is a disproportionate relation between the area that wetlands occupies worldwide and the biodiversity present on them and the value of ecosystem services provided by this ecosystem (Kingsford et al., 2016) meaning that wetlands provide highly valuable ecosystem services in small portions of territory.

In the Freshwater Ecosystem Services report of the Millennium Ecosystem Assessment (Aylward et al., 2005), water-related ecosystem services are the focus. Services such as water supply and purification and mitigation of extreme events are highlighted, but other relevant ecosystem services mentioned in the report included tourism, recreation, food and medicinal resources. The freshwater report not only addresses the benefits provided by freshwater to human population, but also reveals the high influence that water management decisions have in the trade-offs between provisioning, regulating, cultural and habitat services.

In addition, the TEEB for Water and Wetlands (Russi et al., 2013) highlights the capacity of wetlands to provide multiple ecosystem services but puts emphasis on ecosystem services that can support the water cycle and water security such as water supply, water purification and regulation of water flows. The Millennium Ecosystem Assessment report on Wetlands and Water (MA, 2005) emphasizes benefits provided by wetlands and identifies five ESs that are highly related to human well-being: water supply, food production (fish), water purification, climate regulation (especially for peatlands) and cultural services.

Moreover, wetland ecosystem services can be linked to multilateral agreements such as the Sustainable Development Goals (SDGs) and the Paris agreement through the Nationally Determined Contributions (NDCs). SDGs are a universal call to action to end poverty, protect the planet and ensure that all people enjoy peace and prosperity[1], while the NDCs are the countries-stated efforts to reduce national emissions and to adapt to the impacts of climate change[2]. Wetland restoration and sustainable management contributes not only to reduce emissions while conserving ecosystem services as means of climate change adaption (NDCs), but also becomes a strategy for a sustainable world in which the enhancement of the provision of wetland ecosystem services contributes to the achievement of the SDGs (no poverty, reduced inequalities, good health) (Crumpler et al., 2017). Moreover, in the core of the SDGs is the idea of enhancing the integrity and function of ecosystems so these can still provide benefits to the current and future generations (Wood et al., 2018).

Therefore, NDCs should be considered as means to enhance and restore wetland ecosystem services that in turn contribute to the achievement of the SDGs. In this regard, all ecosystem services provided by wetlands should be taken into account with a holistic approach in the assessment of ecosystem services and wetland management to get a full picture of the benefits that wetlands provide to people (Schindler et al., 2014). In return, there is a substantial contribution for international agreements' targets to be met.

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[1] http://www.undp.org/content/undp/en/home/sustainable-development-goals.html
[2] https://unfccc.int/process-and-meetings/the-paris-agreement/nationally-determined-contributions-ndcs

3. THE PANTANAL: ECOSYSTEM SERVICES AND THREATS

3.1 DESCRIPTION

The Pantanal, in South America, is the largest tropical freshwater wetland of the world, occupying a territory of approximately 160,000 km^2 and mainly located in Brazil (80%), with smaller portions in Bolivia and Paraguay (Figure 4). The climate is characterized by two pronounced patterns: on the one hand a dry season lasting from May to October and, on the other hand, a rainy season with heavy rainfalls during January to March (Junk et al., 2006; Rossotto Ioris et al., 2014).

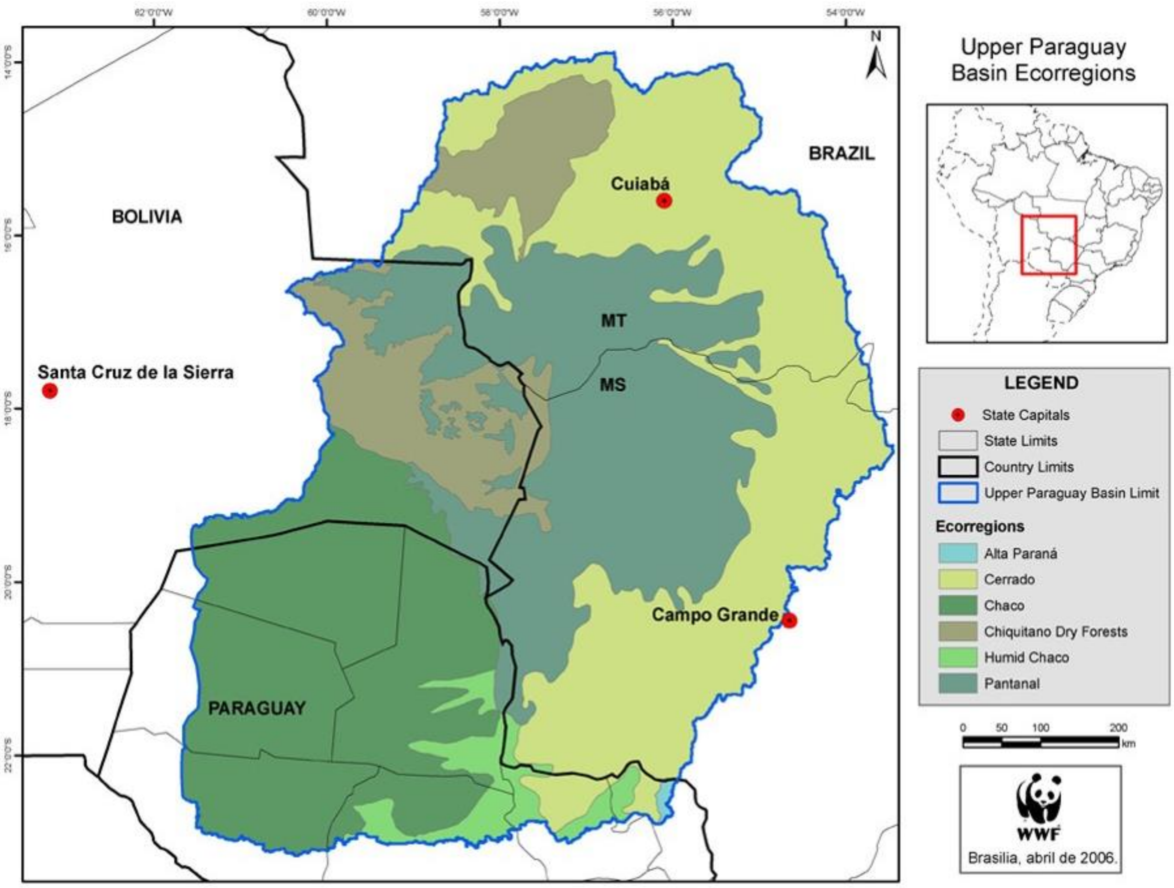

Figure 4. Location of the Upper Paraguay River Basin in South America and the ecoregions included the Pantanal.

The Pantanal (lowlands) is located in the center of the Upper Paraguay River Basin (UPRB) covering 25% of the basin area (Bravo et al., 2012). To the north and east of the Pantanal, the Planalto (highlands or plateaus) region of the basin is located in which most of the runoff in the UPRB is generated, therefore, the water that the wetland receives comes from the basins draining of the Planalto (Bravo et al., 2012). Rivers such as Cuiabá, Taquari, Negro and Aquidauana-Miranda located in the left margin of the Paraguay River feed the Pantanal floodplain, thereby revealing the interaction that the Pantanal has with a larger area that extends beyond the wetland limits (Alho & Silva, 2012).

The ecological structure and processes and high productivity of the Pantanal and its unique biodiversity are the result of what is known as flood pulse (Wantzen et al., 2008). According to Junk et al. (1989), the flood pulse is the driving force for the productivity and biodiversity in floodplain systems which generates aquatic/terrestrial transitions with periods of drought and flooding. The Pantanal floodplain stores water stemming from the plateaus and slowly releases the water to the lower areas of the Paraguay River (Junk & Nunes De Cunha, 2005), preventing the flood season of the Paraná River to coincide with the Paraguay River flood season avoiding possible disasters for the downstream inhabitants (Marengo et al., 2016).

The main land use in the Pantanal is the natural one, which includes forests, shrublands savannas and natural management areas occupying circa 80% of the total territory (WWF-Brazil, Universidade Católica Dom Bosco, & Fundação Tuiuiu, 2017). The remaining territory is occupied by anthropic uses (11%) and water (8%). Pasture areas for cattle ranching is the main anthropic land use class (10.2%), followed by agriculture (0.7%) and urban influence (0.02%). One aspect to highlight is that, by the year 2014, 80% of the Pantanal was still covered by native vegetation (Roque et al., 2016). These land use values reveal the natural condition of the territory and the still reduced human influence in the wetland.

The Pantanal is characterized by a diversity of vegetation and landscapes that depend on seasonal flooding and which have adapted to the flooding regime (Alho & Sabino, 2012; Alho & Sabino, 2011; Harris et al., 2005). The Pantanal provides shelter to a wide variety of fauna, including many endangered species such as the jaguar (*Panthera onca)* and the Brazilian giant otter (*Pteronura brasiliensis*) (Alho & Sabino, 2011). Even though the Pantanal has a large number of species, is not characterized by the presence of endemic species (Junk et al., 2006).

By the year 1998, the Pantanal was already considered a globally outstanding ecoregion in terms of its biological distinctiveness and vulnerable with regards to its conservation status, which called for immediate conservation (Olson et al., 1998). Moreover, the hydrology of this wetland is considered vulnerable to human interventions and to the climate changes expected for the region (Junk et al., 2006).

Finally, it is important to highlight that the Pantanal is interdependent on the health of the UPRB (WWF, 2017). Therefore, the Pantanal should not be isolated from the river basin in which it is embedded, but rather the influences of the UPRB should be considered when studying this wetland, and more specifically when wetland management plans are developed (Schlesinger, 2014).

3.2 Ecosystem Services provided by the Pantanal

The Pantanal's capacity to provide ecosystem services has been acknowledged by many authors (Palacios Nieto, 2016; Schulz et al., 2015; Seidl & Morães, 2000; Viglizzo & Frank, 2006; Wantzen et al., 2008; Watanabe & Ortega, 2014). However, research on the assessment of ecosystem services provided by the Pantanal is still lacking in the literature.

Research has been mostly oriented to study the biodiversity of the Pantanal and the hydrological processes taking place in the wetland. Nevertheless, different ecosystem services are repeatedly mentioned in an indirect way in research, meaning that services are mentioned but not as ecosystem services. Therefore, and as a result of the literature review on wetlands and the Pantanal, it is possible to determine that the Pantanal is capable of providing the four categories of ecosystem services.

3.2.1 Provisioning Services

This ecosystem service category includes the products, goods and materials obtained by people from the wetland. Moreover, these ecosystem services can be directly used or enjoyed by people. The most known provisioning services provided by the Pantanal are food and freshwater. A description of each provisioning service supplied by this wetland is presented below.

Food is a provisioning service that includes all animal and plant species that are consumed by animals or human beings. This group includes not only naturally present sources of food such as fish, wildfood, fruits and nuts, but also cultivated food as is the case of crops and domesticated prey animals such as cattle.

Fish is one of the goods directly extracted from the Pantanal. Fishing is considered a traditional activity in the area which was firstly carried out for subsistence purposes by local communities, but from the 1970's onwards it has become an economic activity through fish commercialization and recreational fishing (Mateus et al., 2011). Riverbank communities that practice subsistence fishing are dependent on fish as a source of protein in their diets (Mateus et al., 2011). Fish species important for these communities includes piavas and piaus (*Schizodon borellii, Leporellus vittatus, L. striatus*). As for professional fishing, commercial fish species with high socioeconomic value that can be found in the Pantanal are "Pacu" (*Piaractus mesopotamicus),* "Pintado" *(Pseudoplatystoma corruscans)* "Dourado" (*Salminus brasiliensis)* and "Curimbatá" (*Prochilodus lineatus)* (Alho & Reis, 2017). In total, 263 fish species have been identified in the Pantanal (Junk et al., 2006).

Due to fishing and environmental pressures in the Pantanal (which are the result of inadequate policies and lack of land use planning), depletion of fish populations has become a problem. This mainly affects local fishers income and creates interest conflicts among stakeholders that use the rivers for different purposes such as leisure, recreation, or even as a place for dilution of sewage specifically in the UPRB (Mateus et al., 2011). In fact, data on fish catch in the Pantanal (Mato Grosso do Sul) suggests that fishery resources have decreased over the last two decades (Alho & Reis, 2017).

Beef meat is one of the products obtained from livestock production in the Pantanal. Originally, livestock production was extensive and made use of the natural pasture and grasslands that were exposed and maintained during low flood levels (Morais Chiaravalloti et al., 2017; Schlesinger, 2014). Most of the cattle ranching activity in the Pantanal is considered to have a low environmental impact given that there is a low stocking density of approximately 0.33 animals/ha (WWF-Brazil, 2015). Even though this activity have increased the capacity to supply food in the area, currently it has been undertaken at expenses of other ecosystem services such as loss of habitat and biodiversity especially in the highlands surrounding the floodplain (Watanabe & Ortega, 2014). According to Seidl et al. (2001), by the year 2000, 80% of the Brazilian-Pantanal land was on cattle ranches and livestock production was considered the main activity in the area.

Wild edible plants, fruits and nuts are also considered provisioning services of the Pantanal. The use of these natural resources is capable of providing food to local communities, contributing to food security in the area and reducing the necessity to deforest for agriculture and cattle ranching (Bortolotto et al., 2017). In areas where there are wildfood and edible plants, local communities are encouraged to make use of these resources in a sustainable way in which biodiversity conservation can be achieved (Bortolotto et al., 2015).

Bortolotto et al. (2015) identified 54 species of edible plants in communities alongside the Paraguay River in the Brazilian Pantanal. Examples of wild edible plants from the Pantanal for human consumption includes "cocotero" (*Acrocomia totai* Mart.), "arroz del Pantanal' (*Oryza glumaepatula, Oryza latifolia*), "urucuri" (*Attalea phalerata*), "Tarumã" (*Vitex cymosa* Bertero ex Spreng.), "cumbaru" (*Dipteryx alata* Vogel), among others, which can be found in Bortolotto et al. (2017) research. These resources are used for own consumption or for commercialization in the form of flour, jam, frozen pulp, rice and nuts. Therefore, their utilization goes beyond being a source of food, but also a source of income for traditional communities. In addition, *Bactris glaucescens,* a fruit present in riparian forests is much known as a source of feed for fishes in the Pantanal (Alho & Reis, 2017).

***Freshwate*r** is provided by the rivers that are part of the Pantanal for domestic, agricultural and industrial uses. The Pantanal is known for having abundant natural resources such as water (Ioris, 2013) and it is a vast plain that has the capacity to retain water from precipitation and coming from the plateaus, storing water that is later available for consumptive and non-consumptive uses. The demand for water in the Pantanal is mostly for watering livestock, and sources of water supply for rural and urban communities are shallow and deep groundwater wells (National Water Agency, Global Environment Facility, United Nations Environment Programme, & Organization of American States, 2005). The north and eastern areas of the Pantanal have the highest water yield capacity while the south and western areas store the lowest quantities, however, the water yield capacity in the Pantanal is strongly influenced by the seasonality, the flood pulse, and the activities impacting the UPRB (Palacios Nieto, 2016).

Raw materials are the products obtained from the fauna and flora present in the Pantanal such as animal skin, fuelwood, timber, biomass, fertilizer, etc. This particular ecosystem service is not frequently mentioned in researches about wetland ecosystem services, however, local communities in the Pantanal, and especially indigenous and traditional communities, have a particular socio-economic and cultural dependence on the natural resources of the area (Reis et al., 2006).

Raw materials in the Pantanal were, and even to date, used as materials in the construction of local people's houses and boats using tree branches, straw and wood which were also used as fuel (Morais Chiaravalloti, 2016). Moreover, the use of natural resources such as timber contributed to the development of the cattle ranching activity by using it in the construction of sheds, fences and corrals (Bergier et al., 2018). Some of the timber species traditionally used for construction in the Pantanal are *Acrocomia aculeata* (Jacq.) Lodd. ex Mart, *Tabebuia* spp., *Curatella americana* L., *Rhamnidium elaeocarpum* Reissek, among others (Carniello et al., 2010). As for animal skins, the jaguar, capybara, tapir and peccary skin were the most demanded by local and international markets until the 1980's, time in which restrictions to poaching and commercialization of animal skin took place, especially in Brazil, favoring the conservation of biodiversity (Kauffman, 2015).

Genetic resources are usually not widely recognized and studied as relevant provisioning services provided by wetlands, even though there is a close relation between genetic diversity and biological diversity in ecosystems. Therefore, since the Pantanal is characterized by being one of the world's most bio-diverse ecosystem (Schwerdtfeger et al., 2014), is expected that the genetic diversity associated to the biodiversity should be as valuable and important as the biodiversity present in the Pantanal. Moreover, Wantzen et al. (2008) considered that a big proportion of the Pantanal should be fully protected to conserve the "genetic heritage" of the area.

As for ***medicinal resources***, this includes all medicinal species that have pharmacological properties. In the Pantanal, it is believed that the traditional knowledge with regards to medicinal species and their use has been preserved and transmitted throughout generations (Teixeira de Sousa Junior, 2011), which also reveals the cultural connotation of this resource. Some of the most recognized medicinal plants includes *Cecropia pachystachya* Trécul, *Genipa americana* L., *Scoparia dulcis*, *Solidago microglossa, Calophyllum brasiliense* and *Lafoensia pacari* (Bortolotto et al., 2015; Costa Bieski et al., 2012; Teixeira de Sousa Junior, 2011). These medicinal resources can be consumed as infusion, syrup or can be externally applied in cases of hypertension, cholesterol, diabetes, pain and inflammation, as a blood cleanser, etc. (Costa Bieski et al., 2012). Given that traditional communities in the Pantanal are still preserving and using their local knowledge on medicinal plants for basic health care, this wetland is considered of interest for ethno-pharmacological studies (Costa Bieski et al., 2012).

Finally, ***ornamental resources*** are the local resources used in artisanal work. In the Pantanal, local people have good abilities to create crafts with raw materials when they have the resources required, however, this activity is not extensively practiced according to Reis et al. (2006). Different parts of the plants, such as the leaves, fibers, stems or branches are used to make basketwork, decorations or bags, for which species such as *Genipa americana* L. and *Attalea speciosa* Mart. Ex Spreng are used (Ministerio de Educación, 2013).

3.2.2 Regulating Services

Regulating services are the benefits people derive from the regulation of ecological functions and processes of the ecosystems (Russi et al., 2013). The ecosystem services provided by wetlands are closely linked to water-related regulating services such as water flow regulation, mitigation of extreme events and water purification. From the list of nine regulating services (Figure 2) described under the TEEB framework, three ESs were not identified in the MA and TEEB reports on water and wetlands (Aylward et al., 2005; Finlayson et al., 2005; Millennium Ecosystem Assessment, 2005; Russi et al., 2013). Air quality regulation, biological control and maintenance of soil fertility were not described as ecosystem services provided by wetlands, and pollination was less mentioned. There is no unique nor definitive explanation of why these ESs are not addressed or taken into consideration, but it is likely that is the result of an under-recording of less visible ecosystem services provided by wetlands (McInnes et al., 2017). As for the remaining five regulating services, all were mentioned in literature, and a description of them for the Pantanal context is presented below.

Climate regulation is a regulating service provided by wetlands since these ecosystems are capable of ***sequestering carbon*** and function as carbon sinks. Given the permanently and seasonally flooded areas in the Pantanal, in addition to the topography and precipitation regimes and the anoxic conditions of wetland soils, carbon storage takes place in the Pantanal, therefore, reducing emissions of CO_2 (Alho, 2011; Lathuillière et al., 2017; Wantzen et al., 2008). Nevertheless, it is important to point out that the conversion of native vegetation into cultivated or intensively grazing grassland areas in the Pantanal reduces the content of organic carbon in the soil; thereby the carbon inputs are less than the carbon outputs (Cardoso et al., 2010). This reveals that the Pantanal has capacity to store carbon, but given the land use changes in the area and more especially in the highlands, there are also carbon emissions.

In addition, the Pantanal has a fundamental role in ***stabilizing the regional and local climate*** (Junk & Nunes De Cunha, 2005). Evapotranspiration together with the presence of vegetation contributes, on the one hand, to the loss of water, and, on the other hand, to the cooling of microclimates (Wong et al., 2017). The evapotranspiration in the Pantanal is higher than precipitation (da Silva et al., 2010), and evapotranspiration contributes to the cooling effect by consuming heat energy, thereby regulating the temperature.

Moderation of extreme events includes ***flood prevention***. Wetlands are buffering zones that have the capacity to retain water and prevent damages from flooding. The Pantanal is a floodplain that becomes flooded, retaining water and contributing to the evapotranspiration of the flood waters, lowering the amount of water transported by the Paraguay River, thereby creating a buffer effect that protects populations downstream against flooding (Wantzen et al., 2008).

Moreover, wetlands contribute to ***drought prevention***. Wetlands store water and slowly release it in dry periods. High levels of precipitation can be observed in the highlands surrounding the Pantanal so, even though in the Pantanal evapotranspiration is higher than precipitation, there is water supply from the highlands that allows the Pantanal to store water in dry seasons, temporarily reducing the socioeconomic impacts of the droughts. In fact, Hamilton (1996), cited in Hamilton (2002), stated that in the most southern area of the floodplain, flooding occurred during the dry season, while Calheiros (2007) highlighted that the Pantanal buffer system maintains a inundated area and navigation conditions during the dry season. Hence, there is a recognition of the role of wetlands in the provision of water during droughts (Ramsar COP12 DR13, 2015).

The ***regulation of water flows*** is another water-related regulating service provided by the Pantanal that can reduce flood risk. This ecosystem service is considered one of the most important in wetlands since it enhances the groundwater recharge, reduces runoff and stream flow, and delays flood events (Kadykalo & Findlay, 2016). The Pantanal is characterized by its hydrological services in which groundwater recharge and discharge buffering are emphasized (Schulz et al., 2015). Alho (2011) highlighted the importance of natural river flows for drainage and river discharge as well as the importance of protecting nature and carry out scientific research in the Pantanal given the relevance of this ecosystem service. In addition, habitat and biodiversity of the Pantanal was identified highly interrelated to the water flows in the area, meaning that alterations in the flows can alter habitat quality and biodiversity present in the Pantanal (Alho & Sabino, 2012).

Waste treatment includes, specifically for the case of wetlands, ***water purification***. The importance of the Pantanal as a valuable area for water purification has already been acknowledge by several authors (Junk & Nunes De Cunha, 2005; Schulz et al., 2015; Wantzen et al., 2008). Wetlands have natural filtration as well as denitrification and detoxification properties (Russi et al., 2013). In the case of the Pantanal, water purification processes are heterogeneous and dependent on spatial and temporal scales (Zeilhofer et al., 2016). According to Wantzen et al. (2008), the Pantanal rivers have an autopurification capacity able to reduce the organic pollution produced in the area. Nevertheless, even though the water quality in the Pantanal is still considered to be good, it has been deteriorating year by year due to the increase of human activities in the area and the lack of appropriate wastewater treatments, which is likely to alter the natural filtering capacity of the wetland in the future (Bergier, 2013; National Water Agency et al., 2005; Schulz et al., 2015).

Erosion control involves sediment retention coming from upland areas reducing the amount of sediments transported by the stream flows. Given the increase of unsustainable agricultural practices in the highlands, higher inputs of sediments are reaching the Pantanal lowlands (Bergier, 2013). During the passage of water from the rivers of the Brazilian highlands through the Pantanal floodplains, sediments are retained in the land, and there is a decrease in the sediments that are then exported downstream of the rivers (Hamilton et al., 1997). Moreover, Alho (2011) pointed out the role of the vegetation in the Pantanal in the prevention of soil erosion and contribution to sediment control. Palacios Nieto (2016) found that even though when there are no land use changes in the Pantanal, the influence of land use changes in the highlands can result in substantial differences in the sediment retention capacity of the floodplain.

For the rest of the report, only these five regulating services are addressed, with the purpose of keeping the report more concise and wetland-related. However, all regulating services can always be included in any ecosystem services assessment.

3.2.3 Cultural Services

This category of ecosystem services represents the non-material benefits that people obtain from wetlands. These ecosystem services have a cultural nature that is linked to the ecosystems properties. In the Pantanal, there are traditional and indigenous communities that are still preserving their own costumes and traditions that were, somehow, shaped through their relationship with the river (Schulz et al., 2017). Besides being a culturally rich area, the Pantanal offers opportunities to the inhabitants of Brazil, Bolivia and Paraguay, as well as for tourist from around the world, to experience a connection with the nature and the people living in the wetland.

The ***aesthetic information*** of the Pantanal has been broadly recognized given its natural and scenic beauty and biological diversity (Alho, 2011; Bergier et al., 2018; Rossotto Ioris et al., 2014; Schulz et al., 2015). The presence of iconic species such as the jaguar and the giant otter, together with the abundant natural resources and the diverse habitats, allows for the creation of different beautiful landscapes giving a high aesthetic and cultural value to the Pantanal wetland (Alho, 2011; Junk & Nunes De Cunha, 2005; Schulz et al., 2015). The aesthetic value of the Pantanal also arises from the aesthetically pleasing feeling derived from nature and the opportunity to escape from urban environments (Alho, 2008). Moreover, local communities and environmental NGO’s have been found to have a strong attachment to the aesthetic value of the Pantanal (Schulz et al., 2017).

Recreation and tourism are among the most known ecosystem services of the Pantanal given the potential of the Pantanal for eco-tourism and well-planned tourism in the wild (Alho & Sabino, 2011). Ecotourism is recurrently mentioned in research on the Pantanal as an economic activity that is gaining ground in the area, even though there is not enough appropriate infrastructure to receive tourists. Sport fishing, bird watching, horseback riding in the fields, hiking, boat rides, canoeing, photographic safari and wildlife-viewing are some activities that take place in the Pantanal within a natural and unique environment that had become the main reason for people to visit the Pantanal (Bergier et al., 2018; Seidl et al., 2001). Among these activities, sport and recreational fishing are one of the main attractions that has contributed to the consolidation of the tourism in the area (Calheiros, 2007; Mateus et al., 2011).

This ecosystem service is also seen as a very convenient alternative to contribute to the conservation of the natural and cultural features of the Pantanal, conveying the heritage of the wetland (Alho & Sabino, 2011). Furthermore, the tourism in the Pantanal can be considered a tool for communicating and consolidating the regional identity inasmuch as it reveals and reinforces the history of the local people (Pereira de Castro Pacheco et al., 2017). Finally, it is believed that the ecological and cultural tourism in the Pantanal can be constructed under the community-based conservation idea, thereby becoming a source of income to the property holders (Kauffman, 2015).

Inspiration for culture, art and design have not been a cultural service highlighted in literature. However, in the Pantanal, through ecotourism, is possible to preserve the cultural heritage and history of the area (Alho & Sabino, 2011). In addition, the mosaic of habitats that creates remarkable landscapes, are sources of inspiration for art and photography (Pereira de Castro Pacheco et al., 2017) and, as stated by Bergier et al. (2018), the rich Pantanal traditions and culture are capable to amuse and inspire visitors of diverse origins. An example is the use of the Pantanal landscape and beauty as the setting of the book “The Testament: A Novel” written by John Grishman, or ”Una camella en el Pantanal” by Lucília Junqueira de Almeida Prado.

Spiritual experience derives from the religious, spiritual or cultural value attached to the elements of the wetlands by local people as well as from people from abroad. The Pantanal can contribute to human well-being and influence personal feelings through the features that makes this wetland so unique and important for the global community. Moreover, there are traditional religious festivities from the communities in the Pantanal, which are considered part of their identity (dos Reis et al., 2006). Some religious festivals includes honoring Christian saints and washing the figure of a saint in a river, as well as evangelical cults (Reis et al., 2006; Schulz et al., 2017; Wantzen et al., 2008).

In the Pantanal, there are communities that hold and conserve in their memories and histories myths and legends of the region. Those myths, legends and beliefs are used to overcome situations or difficulties that might be present in the everyday life, and are also considered one of the main motivations for tourist trips (Fittipaldi Gonçalves et al., 2011). These beliefs are also considered to shape the behavior towards nature that local people has.

Information for cognitive development is about the contribution that the Pantanal wetland makes to the development of scientific research and environmental education (Alho, 2011). Given the Pantanal still pristine condition in some areas, it has become of increasingly interest for the scientific community and organizations around the world who aim to protect this wetland by using local knowledge and generating new relevant information contributing to the understanding of this ecosystem. The local knowledge on natural phenomena in the wetland has already been considered relevant and applicable in natural scientific research and, given that traditional knowledge in the Pantanal is still preserved and to protect this information, there are initiatives, especially in Brazil, to document this highly valuable knowledge (Calheiros, 2007; Teixeira de Sousa Junior, 2011).

Most of the current traditional knowledge held by local communities are considered to be passed from parents to sons, for example the techniques of the traditional artisanal work in the Pantanal (Pereira de Castro Pacheco et al., 2017). Bortolotto et al. (2015) found that riverine communities in the Pantanal had very valuable knowledge on the native wild edible plants being the elderly the ones holding more knowledge. In addition, the presence of medicinal plants being used by the local people made the Pantanal an important field for ethnopharmacological and ethnobotanical research (Costa Bieski et al., 2012).

University extension programs are also carried out in the Brazilian Pantanal to exchange knowledge among students, rural communities and NGO's with the aim of valorizing their biodiversity and local culture (Bortolotto et al., 2017). These activities includes culinary workshops, postharvest techniques and different courses for training that involve discussions and sharing experiences among the participants. Moreover, environmental education learning activities have been carried out in schools located in the Pantanal, such as the education program of WWF Bolivia, based on conservation and biodiversity and highlighting the related positive values of the environment (Porfirio et al., 2014).

3.2.4 Habitat Services

Habitat services highlights the importance of ecosystems to provide refuge and a space for reproduction to different species and for the maintenance of biodiversity (de Groot et al., 2010a). The maintenance of biodiversity, one of the most known features of the Pantanal, is strictly related to the habitat quality of the ecosystem, allowing for the identification of "hot spots" for conservation. The isolation of the Pantanal due to the difficulty of access and poor communication infrastructures contributed to maintain this wetland quite pristine, but also hampered, in the past, the generation of scientific knowledge with regards to species present in the Pantanal (Junk et al., 2006). Nevertheless, the biodiversity in the Pantanal is probably the most studied ecosystem service of the wetland.

Species diversity and landscape units are dependent on the annual flooding in the Pantanal, capable to adapt to dry and wet conditions, and favoring the growth of aquatic macrophytes, and the presence of a high number of terrestrial grasses and herbs (Junk et al., 2006). The mosaic of habitats in the Pantanal are the result of the different soil types, flooding regimes and seasonality that creates a suitable refuge for transient and generalist species (Harris et al., 2005).

Even though the Pantanal is not characterized by the presence of endemic species, the high biological diversity and density of species makes this wetland a home for several charismatic species such as the jaguar, giant otter, giant anteater, Jabiru stork and Hyacinth Macaw. "Healthy population of endangered species" can be found in the Pantanal, reason why this wetland provides many opportunities for wildlife management (Alho & Sabino, 2011; Junk & Nunes De Cunha, 2005). As a matter of fact, the Pantanal is considered one of the most important refuge for species that are endangered or in decline in other biomes (Bergier et al., 2018).

Large wetlands such as the Pantanal, do not only harbor wetland-dependent species, but also many other large populations from the surrounding ecosystems that depend on permanently terrestrial habitats of the Pantanal (Junk et al., 2006). According to Pott et al. (2011), there are around 2,000 flora species in the Pantanal that have a wide distribution and are shared with other ecoregions such as the Cerrado, the Chaco, Amazonia and Atlantic Forest. In addition, the authors identified the presence of grasslands, riparian forests, savannas, dry forests and pioneer woodlands as part of the floodplain vegetation.

As for fauna species, there are more than 260 fish species described for the Pantanal, many of which are highly valuable in terms of livelihood (Alho & Reis, 2017). In the Pantanal, there are 390 bird species that have been recorded and confirmed, but no endemic species have been found (Junk et al., 2006). Circa 40 migratory bird species are found in the Pantanal, coming mainly from the northern hemisphere (Alho & Silva, 2012). Some migratory bird species includes the Black-necked Stilt (*Himantopus mexicanus*), the Neotropical Cormorant (*Phalacrocorax brasilianus*), the Southern Lapwing (*Vanellus chilensis*) and the Anhinga (*Anhinga anhinga*) (Morrison et al., 2008).

According to Tomas et al. (2010), there are 152 mammals species recorded in the Pantanal, none of them endemic, from which 45 belong to the medium to large size mammals and 73 to bats. From the total number of mammals, 18 species are considered endangered according to the International Union for Nature Conservation (IUCN). The pygmy short-tailed opossum (*Monodelphis kunsi*), giant otter (*Pteronura brasiliensis*), giant armadillo (*Priodontes maximus*), bush dog (*Speothos venaticus*) and marsh deer (*Blastocerus dichotomus*) are among the endangered species present in the Pantanal. Information on aquatic invertebrates, terrestrial arthropods, reptiles and amphibians can be found in Junk et al. (2006).

3.3 Threats

In the last decades, the Pantanal have been facing several threats as the result of the increasing socioeconomic development of the area and surroundings, especially in the highlands or catchment areas of the UPRB where the biggest and more populated cities are located. Moreover, the ecosystem services of the Pantanal (particularly regulating services) are considered public goods, which tends to generate more degradation on the services than the societies' interest on preserve it.

Even though many areas of the Pantanal still remain pristine, given the "functional and ecological interdependency between lowlands and Cerrado uplands" (Roque et al., 2016), several pressures originated in the uplands, have been threating the Pantanal's condition, affecting the provision of ecosystem services (Table 1). In fact, the Pantanal is considered very vulnerable to the impacts generated in the highlands of the UPRB.

Table 1. Threats and related ecosystem services at risk in the Pantanal

Threats to the Pantanal*	Main ecosystem services at risk in the Pantanal
Deforestation	Habitat and biodiversity, Carbon sequestration, Regulation of water flows
Agriculture and cattle ranching	Habitat and biodiversity, Erosion control
Dams and reservoirs	Food (fish population), Regulation of water flows
Urban development and un-controlled tourism	Habitat and biodiversity, Water purification
Construction of waterways	Mitigation of extreme events, Habitat and biodiversity
Overexploitation of rivers and aquifers	Water supply, Regulation of water flows, Habitat and biodiversity
Mining	Water quality, Habitat and biodiversity, Aesthetic value
Climate change	Habitat and biodiversity, Mitigation of extreme events

*Threats are mainly originated in the highlands of the UPRB, affecting not only the ecosystems in the highlands, but also the Pantanal wetland.

One of the most important characteristic of these threats is that they are likely to cause alterations in the flood pulse of the Pantanal, thereby affecting a fundamental function of the wetland which governs the economic, social and cultural aspects of the Pantanal population (WWF, 2017).

Deforestation has become one of the main threats to the Pantanal. The conversion of forest and native vegetation in the highlands of the UPRB to clear land for ***agricultural*** purposes (soy) or to replace it with exotic pastures for ***cattle ranching*** (meat) can negatively affect the ecosystem services in the lowlands (de Souza et al., 2018; Harris et al., 2005; Junk & Nunes De Cunha, 2005; Rossotto Ioris et al., 2014). Both activities mainly takes place in the highlands, outside the borders of the wetland (Palacios Nieto, 2016), however, cattle ranching is also carried out in the Pantanal wetland but is more extensive and creates less pressure in the ecosystem than in the uplands (WWF-Brazil et al., 2017). Moreover, unsustainable agricultural practices in the area have been established as the result of poorly informed producers, lack of planning at the farmer level and the non-existent or not implemented land management plans (WWF, 2017).

Deforestation, together with the expansion of soy production and cattle ranching, have jeopardized the habitat for species where only small fragments of habitat remain, affecting birds' population (Silva et al., 2011). Any land use change which removes or decreases natural native vegetation in the Pantanal can alter the hydrological and carbon cycles, water infiltration and surface runoff, modify the flood and drought cycles and increase erosion and sedimentation problems (Silva et al., 2011; Watanabe & Ortega, 2014; WWF-Brazil & The Nature Conservancy, 2012).

Unsustainable agricultural practices leading to intensive production in the Cerrado highlands have increased the natural erosive processes in the area which end up generating the siltation of the highlands-water courses, most probably affecting the rivers in the Pantanal (Azevedo & Monteiro, 2003). In addition, Bergier (2013) stated that higher nutrient and sediment inputs to the Pantanal caused by unsustainable agroecosystems in the highlands reduces the provision of ecosystem services and resilience of the wetland.

Hydroelectric dams and reservoirs have also been identified as a major threat to the Pantanal (Alho & Reis, 2017; Harris et al., 2005; Junk & Nunes De Cunha, 2005; WWF, 2017). These human-made infrastructures, needed for electricity generation, have been considered detrimental for fish population, and is expected to alter ecological processes related to the hydrological cycle (Harris et al., 2005). According to Alho and Reis (2017), many small hydroelectric plants are planned to be constructed in the northern section of the highlands surrounding the Pantanal, in the rivers that directly feed the wetland. The authors' state that this will not only disrupt the transport of sediments downstream but will also interrupt the movement of long-distance migratory fishes affecting the commercial fisheries by creating a physical barrier (dams). Moreover, the construction of dykes and dams can affect the most important attribute of the Pantanal: the flood pulse, by altering the seasonal stages of the hydrological cycle (Wantzen et al., 2008).

Urban development and un-controlled tourism have introduced concerns in the Pantanal with regards to the environmental and socioeconomic impacts of these developments, given the lack of regulation in the area (Junk et al., 2006). According to Alho and Reis (2017), the sewage generated in the cities and villages in the Pantanal drain directly into the rivers polluting the water and altering the waste treatment property of the rivers and wetland. In addition, the lack of urban planning (including tourism) developed into environmental degradation including water pollution, increase in waste generation, and destruction of habitats and fish populations (Alho & Sabino, 2011; Calheiros, 2007; de Souza et al., 2018; Junk et al., 2006). Even though these impacts have been already identified, there is a lack of more in depth analysis of the long-term environmental risks of urban growth and the related socioeconomic activities (Ioris, 2013).

Construction of waterways such as the Paraguay-Paraná waterway can have negative environmental impacts in the Pantanal, more specifically affecting the flood pulse and the downstream passage of flood peaks. The Paraguay-Paraná waterway stretches 3,442 km and aims at connecting the Paraguay and Paraná rivers from Brazil (city of Cáceres) to Uruguay (city of Nueva Palmira) (Schulz et al., 2017). Through dredging, regularization of riverbanks and modification of the natural canal of the Paraguay river, the transport of agricultural products by large vessels is facilitated in the waterway (Schlesinger, 2014). This can have negative effects on the flood prevention capacity of the wetland by reducing water storage in the floodplain; the different habitats and biodiversity present in the Pantanal can be disturbed; and the ecological processes can be disrupted (Harris et al., 2005). In general, the construction of this waterway is likely to have adverse effects in the hydrology, ecology and biodiversity of the Pantanal, thereby affecting the livelihood of local communities and their traditional culture (Schulz et al., 2017).

Overexploitation of rivers and aquifers are considered the result of inadequate practices that includes unsustainable agricultural practices (WWF, 2017). This threat can alter the aquatic habitat, jeopardize the water quality, affect groundwater levels and reduce water supply in the Pantanal area. The indiscriminate use of the river springs that form the Pantanal can alter the water supply by the damming of the water sources or other infrastructures that reduce the water flow in these areas (Azevedo & Monteiro, 2003). Moreover, the lack of the integration of water resource management into land planning and agricultural practices is favoring the continuance of this threat (WWF, 2017).

Mining is another anthropic activity that threatens the Pantanal. The demand for limestone, iron and minerals are the main drivers for mining in the Pantanal and the Cerrado ecoregion surrounding the Pantanal (Figure 4) (WWF, 2017). The mining activity consumes large amounts of water and pollutes water, and its development specifically in the Bolivian Pantanal, can increase the pressure in the wetland by the establishment of urban settlements (Crespo & Patiño, 2010). Moreover, air pollution due to dust, smoke and suspended particles are expected not only to affect the environment but people's health (Ribera Arismendi, 2008). Mining in the Brazilian Pantanal have degraded habitats and the landscape and have imposed physical and chemical alterations to the water streams that were used for mineral extraction together with an increase in the sediment load (Callil & Junk, 2011).

Climate change is also a threat mentioned in literature but not fully researched in the area. Rises in temperature and varying precipitation patterns, together with an increase in extreme inter-annual events such as droughts and floods, and high evaporation rates are likely to happen in the Pantanal wetland, resulting in drier conditions (Alho & Silva, 2012; Rossotto Ioris et al., 2014; WWF, 2016). The largest changes are predicted to occur in the north/north-western part of the Cerrado-Pantanal region and in the Pantanal (WWF, 2016). Climate change is expected to further affect the access and use of natural resources in the area generating serious impacts and altering the delivery of ecosystem services of the Pantanal (Marengo et al., 2016; Rossotto Ioris, 2014). Furthermore, given the precipitation and evapotranspiration changes due to climate change, the river flow regime, the floodplain inundation dynamics and water supply can be altered (Bravo et al., 2014). McGlue et al. (2016) concluded that there is a need to generate new knowledge to put some light on the sensitivity of the Pantanal to climate change impacts mainly because the valuable ecosystem services provided by this wetland are likely to be threatened.

To conclude, anthropic activities in the areas of high contribution and headwaters of the Upper Paraguay River Basin (highlands) threatens the Pantanal functioning, and thus, main conservation and restoration measures have to be implemented in those areas (WWF-Brazil, 2013). It is important to highlight that what happens in the highlands have an effect in the lowlands and many of the threats faced by the Pantanal are common across the different ecoregions part of the UPRB. Even though all these pressures have been affecting the Pantanal, they are still not as threating as they are in other freshwater ecosystems, but this should not be a reason to delay the management and conservation of this wetland (Alho & Reis, 2017).

4. How to prioritize ecosystem services provided by the Pantanal?

According to the TEEB, there are 22 ecosystem services. This number represents the broad range of benefits people derive from wetlands, but also represents the multiple disciplines that are required to study wetland ecosystem services and the large amount of resources needed for addressing the total bundle of ESs. In this sense, ecosystem services prioritization allows to identify the highest priority wetland services for study, monitoring and management (Werner et al., 2014).

The Pantanal is a complex system that, for its study, needs the collection of original data that is usually time and resource consuming. The prioritization of ecosystem services becomes an interesting option to select which wetland services should be first addressed to produce a greater impact with the generated information. Therefore, in the first stage of the assessment of the ecosystem services of the Pantanal, the most relevant ecosystem services can be identified and research and data collection can be focused on them.

Many research papers present methodologies for the spatial prioritization of areas for conservation or with highly valuable ecosystem services (Casalegno et al., 2014; Luck et al., 2012); however, methodologies for prioritizing ecosystem services in a specific area are rather limited to identify the importance of ESs for stakeholders. The approach developed for this report to prioritize ESs supplied by the Pantanal is based on Multi-Criteria Analysis (MCA). MCA is usually used to evaluate the performance of different alternatives based on multiple indicators and, in environmental studies, it helps to address complex situations in a structured way by using qualitative information collected from, for instance, experts (Koschke et al., 2012). Experts are defined as people with experience, skills, knowledge and professional interest on the topics being addressed (Bezák & Bezáková, 2014).

The criteria included in the prioritization process were selected from different studies that aimed to identify the most important ecosystem services at a specific site (Hanson et al., 2012; Kettunen et al., 2009; Luck et al., 2012; McInnes & Everard, 2017; Peh et al., 2013; Werner et al., 2014). After the selection of the criteria, these were grouped in three dimensions, namely ecological, social and economic (Table 2). It is likely that some criterion have some overlap between two dimensions, but to keep it simple, the criterion was assigned to the dimension that is more related to.

Table 2. Criteria for the prioritization of ecosystem services provided by the Pantanal

Dimension	Criteria	Interpretation
1. Ecological	**1.1** Pressure/ Threats	Ecosystem services are affected by anthropic pressures/threats such as deforestation, agriculture, cattle ranching, dam construction, urbanization and unsustainable tourism.
	1.2 Importance of site	Importance of the wetland in providing the ecosystem service based on its capacity to supply it.
2. Social	**2.1** Social well-being	Contribution of the ecosystem service to social well-being (security, health, good social relations, material for good life, freedom).
	2.2 Beneficiaries	Considers the number and diversity of beneficiaries and the scale at which the benefits accrue (local, regional, national and global).
3. Economic	**3.1** Dependence	Local people (and from surrounding areas) dependence on the provision of ecosystem services in terms of livelihood.
	3.2 Economy	Impact of the provision of ecosystem services on the local, regional and international economy.

Once the criteria are defined, these can be weighted to reflect the relative importance of each criterion in the selection of the prioritized ecosystem services. Once the criteria and the weights are determined, scores against the performance of the criteria for each ecosystem service are assigned. The scores are qualitative and a Likert scale (0 to 5) is used to standardize the scores for all criteria (Table 3). The scores follow the same sense of direction, meaning that higher scores reveal the ecosystem service is of high relevance, while lower scores are traduced in less relevance.

Table 3. Scores for the criteria

Scores	Interpretation
0	None/Not important
1	Very low
2	Low
3	Medium/Moderate
4	High
5	Very high

The overall score that allows obtaining the final ranking of ecosystem services in order of priority is calculated by multiplying the criterion weight times the score of the criterion of a specific ecosystem service and finally summing up the values for all criteria. These values are then organized in descendent order (from higher to lower values) to identify the ecosystem services that should be prioritized. For this purpose, a ranking is made to organize the ecosystem services according to their priority. Therefore, number 1 in the ranking represents the highest priority. In this sense, the ecosystem services that are the most affected by anthropogenic pressures and threats; that contributes the most to social well-being; that benefit a wider range of beneficiaries; that people highly depend on; and that influence the most the local, regional and international economy, are the ecosystem services considered a priority for their study and management.

The prioritization matrix (Table 4, Appendix A) provides a practical and simple method to identify and prioritize ecosystem services from the Pantanal, where data is scarce. Experts can initially complete the prioritization matrix by means of expert elicitation, but the inclusion of local people can also contribute to account for more perspectives. Is possible to add more complexity to this method by introducing quantitative data, which can be done in later stages of the ecosystem services assessment.

Prioritization is expected to be objective, nevertheless, subjectivity usually takes place when ecosystem services are ranked according to their importance in a given region (Casalegno et al., 2014). To reduce the subjectivity in the process of selecting priority ecosystem services for the Pantanal, a set of defined criteria was identified and adapted from literature. Instead of asking experts and local people which ESs they consider most important, a list of criteria that can evaluate the performance and contribution of the ESs is provided and more considerations than just importance are taken into account. In addition, it is important to highlight the subjective nature that ecosystem services have for themselves given that the value of the ESs "arises only when humans appreciate or benefit from it" (Aretano et al., 2013).

Application of the Prioritization matrix for the Pantanal

For the purpose of exemplify the use of the ecosystem services prioritization process, the matrix was applied and all answers (weights and scores) were based on the literature reviewed for this report. This allows getting a first picture of the possible prioritized ecosystem services of the Pantanal. Table 4 shows the results for the first ten prioritized ecosystem services of the Pantanal (see also Figure 5).

Table 4. Ecosystem services prioritization matrix

Dimension	Criteria	Weight	Food	Water	Raw materials	Flood prevention	Regulation of water flows	Water purification	Erosion prevention	Aesthetic information	Recreation and tourism	Maintenance of biodiversity
1. Ecological	1.1 Pressure/Threats	15	3	3	2	4	4	3	3	2	2	5
	1.2 Importance of site	20	4	5	3	5	5	5	4	5	4	5
2. Social	2.1 Social well-being	25	5	5	4	5	5	4	3	5	4	4
	2.2 Beneficiaries	15	4	4	3	5	5	4	3	5	3	5
3. Economic	3.1 Dependence	20	5	5	5	5	5	5	4	4	4	4
	3.2 Economy	5	4	4	1	5	5	4	3	3	4	4
		Overall score ∑ (Weight*Score)	430	450	340	485	485	425	340	425	355	450
		Ranking	**5**	**3**	**9**	**1**	**1**	**6**	**9**	**6**	**8**	**3**

The values in the table are based on the author's own perception (based on the literature of the reference list studied) and are not binding. Only the top 10 priority ecosystem services are included. For the complete table with all ecosystem services provided by the Pantanal and the related overall scores please see Appendix A.

The highest weight was assigned to the social dimension given the strong dependency that local communities have on the natural resources of the Pantanal as means to have a better life. Some of these communities are distant from urban centers, which makes the access to other resources more challenging. The ecological dimension was considered the second most important dimension because of the very valuable services that the Pantanal provides for people and different species. Finally, the economic dimension received the lowest relative score from the three dimensions.

As it is likely to expect, water-related ecosystem services were assigned a highest priority for the Pantanal. According to these results, flood prevention and regulation of water flows received the same score, thereby occupying the first place in the priority ranking. These two ecosystem services are the most threatened by the anthropic pressures, are very important services provided exclusively by the Pantanal, contribute to human well-being reaching to a broad range of beneficiaries and have an impact on the household and regional economy.

The next high priority ecosystem services of the Pantanal were water supply, maintenance of biodiversity and food. Most of the top five priority ESs of the Pantanal according to this result are water-related (flood prevention, regulation of water flows and water supply), have already been acknowledged by the global community (biodiversity) and local people is highly dependent on them as a source of nutrition (food). Moreover, these prioritized ecosystem services are in line with the main wetland ecosystem services identified and described by the TEBB and MA (see page 7). It is important to highlight that the identified priority-ecosystem services are much related to the dynamics of the Pantanal (flood pulse) and benefit a range of beneficiaries that are outside the borders of the wetland.

Ideally, these ecosystem services should be paid more attention when carrying out an ecosystem services assessment in the Pantanal. Nevertheless, other ecosystem services such as inspiration for culture, art and design, information for cognitive development and genetic resources, which were found to have the lowest priority for the Pantanal, can also be addressed depending on the resources available or the type of analysis used to address them. The fact that some ecosystem services are not ranked in the top places of priority does not mean that they are not important, but rather that some ecosystem services should be first addressed given their relevance under ecological, social and economic criteria.

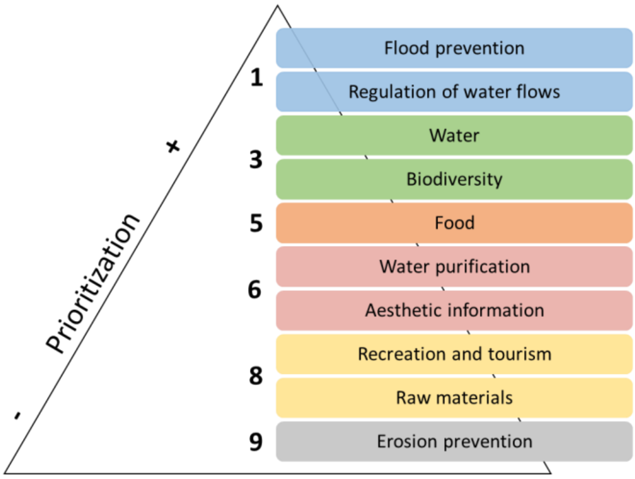

Figure 5. Top ten prioritized ecosystem services of the Pantanal based on the application of the prioritization matrix.

5. Ecosystem Services Assessment

An integrated assessment of ecosystem services requires identifying the benefits, beneficiaries and values attached to ecosystem services. In general, the framework for ESs assessment and valuation, indicators and methods presented in this report are oriented to address the Pantanal's situation. Therefore, all recommendations are based on the consideration of possible limitations that can be found in the area. Nevertheless, the most used and known tools and methods in ESs assessment are presented so the range of options is not restricted by the limitations encountered for the Pantanal.

5.1 Framework to capture the benefits and values of ecosystem services

Figure 3 depicts the links between ecosystem functions and processes and the ecosystem services values, however, the analyses to assess the ecosystem services cascade are not included. In this sense, the framework that is being developed by de Groot et al. (2018)[3] provides a simple and straightforward representation of the steps that have to be implemented to capture the benefits and values of ecosystem services (Figure 6). This framework was initially developed for restoration projects in degraded landscapes (Commonland's 4 returns' project), but all steps can be used in the context of other projects or assessments. In this report, it will be considered under the Pantanal wetland context for creating a baseline assessment.

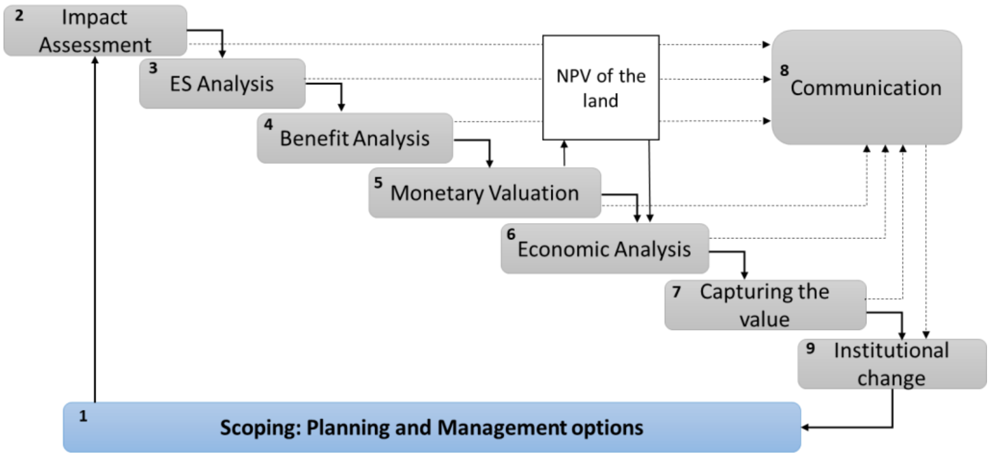

Figure 6. Framework to capture the benefits and values of ecosystem services. Adapted from de Groot et al., 2018.

The first step is to define the scope and purpose of the assessment in consultation with relevant stakeholders to account for the main interests. Moreover, in step 1, management or restoration practices planned for the area should be clearly defined. Land management can influence (positively or negatively) the properties and functions of ecosystems, which can be assessed by an impact assessment (Step 2). In the context of the Pantanal, the impact assessment can be done considering the current and expected threats on the wetland and, together with an ecosystem services analysis (Step 3), the effects of the threats on the actual and potential use of ecosystem services can be identified. The same can be applied considering possible conservation or management practices.

[3] Final version will be available in https://www.fsd.nl/ and https://www.commonland.com/en

Changes in ecosystem services have implications in the benefits people receive from wetlands. Benefit analysis (Step 4) allows identifying the positive and/or negative effects of wetland ecosystem services on human well-being. Moreover, people can attach monetary values to the benefits derived from ecosystems by means of the calculation of the monetary valuation (Step 5). The monetary valuation quantifies the monetary effects of the threats (or conservation/management practices) on the total economic value (TEV) of the bundle of ecosystem services.

In step 6, the economic analysis contributes to determine the impact of the threats or management initiatives in terms of economic indicators (employment, profits). From the combination of information generated in steps 5 and 6, financial incentives (payment for ecosystem services, tradable rights) can be developed to capture the value of ecosystem services and include them in decision-making (Step 7). Finally, steps 8 and 9 aim at communicating and involving people in the implementation of the outcomes to ensure long-term applicability and acceptance of the outcomes of the assessment.

As de Groot et al. (2018) stated, this assessment can be done in a few months or several years depending on the level of detail required and the purpose of the assessment. The steps of this framework can be selected according to the type of assessment, the available data, the data and information that wants to be generated, and the place where is going to be carried out. Moreover, following the purpose of this report and as a suggestion for the process of developing an ecosystem services baseline for the Pantanal, the steps of ecosystem services analysis, benefit analysis and monetary valuation are further described.

5.2 Ecosystem Services Values

The valuation of ecosystem services tries to put a value on the benefits provided by ecosystems. Generally, values are associated to economic or monetary values; however, this can be expanded to socio-cultural and ecological values. Wetlands' ecosystem services valuation should be carry out to reveal the full importance or value that the goods and services of this ecosystem has for human well-being (de Groot et al., 2006). According to de Groot et al. (2012), given the degradation of habitats and loss of biodiversity, ecosystem services should not be treated anymore as “free services”, but rather values should be attached to them to properly address the costs of environmental degradation and encourage conservation initiatives.

Ecosystem services provided by wetlands are usually undervalued in decision making, as the bundle of ecosystem services are not considered as a whole and the less tangible ESs are neglected (such as regulating or cultural services). In addition, the assessment of trade-offs of future developments or uses of wetlands might provide misleading information when only a few ecosystem services are taken into account, benefiting land use scenarios in which, for instance, unsustainable practices are carried out substantially increasing the value of provisioning services, at expenses of other ESs, as it was observed in Palacios Nieto (2016) research. Therefore, to have a complete picture of the total value or importance of ecosystem services is fundamental to address the ecological, social and economic value of all ecosystem services (Figure 7).

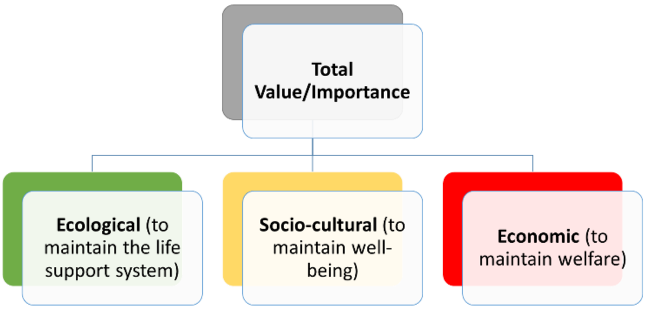

Figure 7. Total value/importance of ecosystem services. Source: de Groot (2017).

- **Ecological values** reveal the importance of ecosystems and biodiversity in the maintenance of life support processes and can be addressed through the collection of **biophysical data** (Farber et al., 2002). This type of value is frequently associated with ecosystem functions and processes that allows the delivery of benefits from nature and can relate to the health of an ecosystem (i.e diversity, integrity) (de Groot et al., 2010b). Moreover, the relevance of this value lies in the importance of ecosystems as ecological systems capable of providing a wide range of direct benefits to people (food, water), and as supporters of other several ecosystem services than contribute more indirectly to human well-being (Gómez-Baggethun et al., 2014).

There is a lack of ecological data of the ecosystem services provided by the Pantanal (especially in the Paraguayan and Bolivian Pantanal) and available biophysical data are outdated and dispersed in individual publications making the access to ecological information difficult (Junk et al., 2006). Most available information relates to hydrological processes taking place in the Pantanal and the biodiversity present; however, information regarding other ecological processes (e.g. sediment retention, water purification) is also needed to have a comprehensive picture of the ecological functioning of the Pantanal and the level or capacity to provide ecosystem services that this wetland has.

- **Socio-cultural values** or importance highlights the role of ecosystems as sources of non-material well-being and can be obtained by means of **stakeholders' perceptions and preferences**. The value people attach to ecosystem services can be seen as socio-cultural values since different levels of preferences can be associated with the ESs. The range of values attributed to ecosystem services by stakeholders can vary depending on aspects such as the knowledge or expertise of people and their relation with nature and the area under study, the intrinsic value of the nature and the contribution of ESs to people's well-being (Iniesta-Arandia et al., 2014).

For instance, it is likely that indigenous and local communities in the Pantanal feel more attached to the territory given the cultural identity they have developed throughout the years living in the Pantanal. Among the indigenous communities from different linguistic ethnicities living in the Pantanal is possible to find the family of Zamuco Ayoreo, Chamacoco Ybytoso, Chamacoco Tomárána, Chamacoco Yshiro, Guató and Chiquitano Pantanal indigenous community. Moreover, the local people in the Pantanal, especially in Brazil, call themselves "*pantaneiro*" when they live inside the territory and *"ribeirinho"* when they live in any of both margins of the rivers that run through the Pantanal (Morales de Luiz, 2018).

All these communities probably place higher social values to the ecosystem services provided by the Pantanal than people living far from the area, especially in relation to the natural resources they depend on, which cannot be dissociated from their everyday life (Almeida & Da Silva, 2011). In fact, Schulz et al. (2017) found that local communities place cultural values rather than economic values to the water resources in the area.

- The **economic value** reveals the importance of ecosystems as sources of income or welfare and it is usually expressed as money (Farber et al., 2002). In order to capture the monetary value of all ecosystem services, the **Total Economic Value (TEV)** must be calculated. The TEV is a concept that groups the use (direct and indirect use) and non-use values (related to people's feelings towards nature) of ecosystem services (de Groot et al., 2010a).

There are only a few studies on the total economic value of the total set of ecosystem services provided by the Pantanal (Morães et al., 2009; Seidl & Morães, 2000), even though this is a method capable of measuring and comparing the benefits and costs of wetlands conservation and the costs of wetlands degradation (Chaikumbung et al., 2016). Independent valuations of ecosystem services in specific areas of the Pantanal are found in literature; however, some of these economic valuations were not made under the ecosystem services concept but they do capture the monetary value of the benefits provided by the Pantanal. Examples include the economic valuation of tourism carried out by Rivarola Gaona & Amarilla Rodríguez (2015), of recreational fishing by Shrestha et al. (2002), of water and carbon services by Watanabe & Ortega (2014), and of sediment retention, water yield and food (soy and meat) by Palacios Nieto (2016).

5.3 Ecosystem Services Indicators

Indicators are measurement units used to quantify the economic, socio-cultural and ecological importance of wetland ecosystem services (de Groot et al., 2006), and are specially needed in steps 3, 4 and 5 of the ecosystem services assessment (see Figure 6). Indicators facilitate data collection by providing specific measurement units able to inform the state and trends in the provision of wetland ecosystem services and the values associated to them (Russi et al., 2013). In general, ecosystem services indicators are relevant for planning and monitoring, decision-making and reporting, conveying in a concise way useful information for a wide range of stakeholders at local and national scales (UNEP-WCMC, 2011).

Data on the capacity of a wetland to supply ecosystem services or the current use of wetland services can be obtained through **biophysical indicators**. **Socio-cultural or benefit indicators** allows the identification of socio-cultural features that are valuable for people, the proportion of people benefiting from ecosystem services and which benefits they receive; while **economic and monetary indicators** can reveal the economic relevance of ecosystem services in human welfare and their monetary value.

Data scarcity in the Pantanal and the difficult access to the territory hampers the data collection of the functions and services that this wetland provides. Moreover, sometimes, information is not easily accessible through the organizations responsible of generating it. Most probably, original data on the Pantanal ecosystem services would have to be generated for the assessment of ecosystem services.

Therefore, the selection of the most appropriate indicators to measure ecosystem services is a fundamental step that can save time and economic resources (Werner et al., 2014).

A brief list of indicators is provided in Table 5 (for a more extended list please see Appendix B). This list was made based on the selection of simple and straightforward indicators that can be applicable for the Pantanal. The most appropriate and informative indicators are suggested regardless data restrictions so that the identification of optimal indicators is not influenced by data availability (Maes et al., 2016). Some indicators may provide information on the supply, demand, or state of ESs but all of them are good indicators of the provision and situation of ecosystem services in a certain point in time.

Table 5. Ecosystem services indicators

ES	Biophysical, State indicator	Benefit indicator	Monetary indicator
Provisioning services	Caught fish and animal production (ton/ha/yr); crop yield (kg/ha/yr); water amount (m^3/ha/yr); harvested biomass (kg/ha/yr); species with useful genetic material, medicinal properties and used for artisan work (names and number)	Employment (number of employees); Livelihood (number of people and extent (% of their income) to which they depend on ES); Health (number of people that rely on medicinal resources, access to water)	Market price (€ or $/kg or ton/yr)
Regulating services	Carbon storage (tonCO_2/ha); floodplain area (ha); water quality (sediments, nutrients); soil erosion rate (kg/ha/yr); floodplain water storage capacity (mm/m)	Security (number of vulnerable people living in potential flooding areas); Livelihood (loss of livelihoods associated to changing climate); Health (number or % of people with access to clean water)	Market price (€ or $/ton of sequestered carbon); Replacement cost (cost of water treatment, cost of concrete wall surrounding vulnerable areas); Avoided cost (health costs avoided, reduction in annual fluvial flood expenditure)
Cultural services	Protected areas (ha); recreational activities (number/yr); overnight accommodations (number/yr); cultural and spiritual sites (names, number and visitors/yr); scientific studies and environmental education events (number/yr)	Employment (number of employees); Education (number of participants in voluntary conservation and citizen science actions); Visitors at parks (number/yr); Spirituality (number of people that attach spiritual and religious significance)	Market price of tourist attraction and activities; Contingent valuation (Willingness-to-pay for conserving, maintaining or willingness-to-accept loss of landscape); Research budgets destined to the wetland/yr
Habitat services	Number of transient, endangered and endemic species; habitat quality index	Livelihood (number of communities or people that rely on hunting and gathering for sustenance or cultural continuity)	Contingent valuation (Willingness-to-pay for a public programme for preservation of the ecosystem); Investment cost (investment made in protection, conservation/yr)

Source: Hattam et al., 2015; Maes et al., 2016; Russi et al., 2013; UNEP-WCMC, 2011; Value of Nature to Canadians Study Taskforce, 2017; de Groot et al., 2018.

Seidl and Morães (2000) highlighted the importance of the season (dry and wet) in the provision and value of ecosystem services. Different ecosystem services in varying quantities and quality are provided under distinct seasons of the year, especially in territories where the seasons strongly differ such as in the Pantanal. Therefore, is probably necessary to account for the dry and wet seasons of the Pantanal to evaluate the provision of ecosystem services when detailed assessments are required. Moreover, when selecting the most appropriate indicators is also important to consider the different habitats that the Pantanal comprises, given that each habitat can provide different ESs to a varying extent according to their characteristics (Werner et al., 2014).

5.4 Ecosystem Services Analysis

Ecosystem services analysis is used to explore the relationship between ecosystem functions and properties and their transition to goods and services (de Groot et al., 2010a). Through this analysis, it is possible to identify the ecosystem services in a specific area, as well as to quantify in biophysical terms, or with qualitative approaches, the changes in the provision of ecosystem services.

Ideally, primary data should be generated with the use of indicators during fieldwork since this enhances data accuracy (especially if it is quantitative data). The data generated with the use of the indicators can be later applied into more complex biophysical models or mapping software such as InVEST, SolVES, ARIES, WaterWorld or Co$ting Nature (Table 6).

Table 6. Methods and tools available for the assessment of ecosystem services

Method/Tool	Aim	Ecosystem services addressed
InVEST – Integrated Valuation of Ecosystem Services and Tradeoffs	Spatial-explicit model that assess quantified tradeoffs associated with alternative management choices and identify areas where investment in natural capital can enhance human development and conservation. Returns results in either biophysical or economic terms.	Crop pollination, fisheries, habitat quality, recreation, water yield, scenic quality, sediment retention, water purification.
SolVES - Social Values for Ecosystem Services	GIS application to assess, map, and quantify the perceived social values of ecosystem services.	Biodiversity, recreation, aesthetics, spiritual experience, information for cognitive development.
ARIES - Artificial Intelligence for Ecosystem Services	Networked software technology to mapping natural capital, natural processes, human beneficiaries, and service flows to society.	Carbon sequestration and storage, flood regulation, aesthetics, water supply, sediment regulation, subsistence fisheries, recreation.
WaterWorld	Spatial hydrological policy support system to examine baseline hydrology and the impacts of scenarios for change or management interventions. It is a detailed process-based modelling of water quantity, quality and some regulation ecosystem services.	Water-related ecosystem services.
Co$ting Nature	Web-based tool for natural capital accounting and analyzing and identifying ecosystem services and beneficiaries.	Water purification, water supply, carbon, hazard mitigation, nature-based tourism, biodiversity.
GRACE - Guidance for the Rapid Assessment of Cultural Ecosystem Services	Rapid guidance suitable for non-experts for assessing cultural ecosystem services and communicating their non-monetary benefits.	Cultural ecosystem services: aesthetic value, recreation and tourism, spiritual and religious, etc.
TESSA - Toolkit for Ecosystem Service Site-Based Assessment	Toolkit that guides in the selection of accessible methods for identifying ecosystem services relevant at a site, and for evaluating the magnitude of benefits that people obtain from them currently and under alternative uses.	Carbon storage, water supply, flood protection, water purification, raw materials, food, nature-based recreation.
RAWES - Rapid Assessment of Wetland Ecosystem Services	Method to carry out a comprehensive assessment of the plurality of benefits and beneficiaries of wetland ecosystem services. Rapid and cost-effective.	All ecosystem services.

InVEST is a model that has local and global applications, with moderate to high data requirements (quantity and quality) but does not need high technical skills to be applied. SolVES, on the other hand, has a local application and a lower data requirement but based on field surveys, and intermediate GIS knowledge is required for its use. As for ARIES model, it has a local, regional and global application, with high spatial data requirements and does need high technical skills for its use. WaterWorld and Co$ting Nature are both web-based tools that have regional to global applications, have already a readily available database and require a low level of technical skills for their use. For more details on the inputs and outputs of these models, please see Appendix C.

All these tools are spatially explicit and their selection is highly dependent on the purpose of the assessment and level of detail required, the study area, the available data, and the economic and human resources. Whenever is not possible to generate biophysical data or models cannot be implemented, qualitative methods can be applied.

By means of preference assessment surveys, questionnaires, workshops, participatory mapping, etc. relevant data can be collected based on experts and local peoples' knowledge and perception. In this sense, the Toolkit for Ecosystem Service Site-Based Assessment (TESSA)[4] becomes particularly useful and convenient for the selection of accessible methods to gather data, which includes the collection of real field, locally relevant data through surveys (provided by the toolkit). In addition, matrices or spreadsheet methods can be implemented. These methods can provide an overview of the ecosystem services in the study area and relate them with land uses, such as with the land use capacity matrix (see Table 7), or can be used to represent biophysical and sociocultural values (Barton et al., 2017; Burkhard et al., 2012). Finally, in case of time and resource constraints, secondary data from other wetlands or locations with similar characteristics can be adapted and used. Since the Pantanal is a tropical wetland, information from other tropical wetlands such as the Llanos of the Orinoco and the Amazonian floodplains can be more or less comparable.

Moreover, spatial data is also required for the analysis of ecosystem services, therefore, updated and detailed land use and land cover maps should be available for the Pantanal. WWF Brazil generates land use maps every two years (latest version 2016) of the UPRB, including the Pantanal area, and since the 2000s, they have monitored the vegetation in the Brazilian portion of the UPRB. Land use maps allows identifying the spatial distribution of ecosystem services, and eventually contributes to assess the effects of land use change in the provision of ecosystem services (Zhang et al., 2015). Collaborative and participatory mapping also constitutes an additional method for mapping ecosystem services (García-Nieto et al., 2015).

Up to date, not many ecosystem services analysis has been carried out in the Pantanal wetland. One of the latest ecosystem services analysis was done by Palacios Nieto (2016), who addressed differences in biophysical and monetary values of three ecosystem services under different management scenarios in the Pantanal using the InVEST model.

[44] http://tessa.tools/

Application of the Land Use Capacity matrix for the Pantanal

The land use capacity matrix was developed by Burkhard et al. (2009) and aims to analyse the existing landscape data to evaluate, by means of expert judgement, the capacities to provide ecosystem services in a spatial manner (Burkhard et al., 2009). Thereby, this matrix allows to identify which land uses are capable of providing more ecosystem services, or how ecosystem services provision differs among the land uses.

The land use classes of the Pantanal were obtained from the "Monitoring of Vegetation Coverage and Land use in the Upper Paraguay River Basin – 2016" report (WWF-Brazil et al., 2017). All the land use classes were later related to their capacity to supply provisioning, regulating, cultural and habitat services based on a scale ranging from 0 (no capacity to supply the ecosystem service) to 5 (very high relevant capacity to supply the ecosystem service) (Table 7).

Table 7. Capacity matrix illustrating the capacity of different land uses of the Pantanal to supply ecosystem services

Land use class	**Provisioning Services ∑**	Food	Water	Raw materials...	**Regulating Services ∑**	Flood prevention	Regulation of water flows	Water purification	Erosion prevention...	**Cultural Services ∑**	Aesthetic information	Recreation and tourism...	**Habitat Services ∑**	Maintenance of biodiversity
Shrubland Savannah	**11**	2	0	3	**12**	3	2	1	3	**14**	4	3	**4**	4
River Influenced Vegetation	**13**	3	0	3	**17**	4	3	3	4	**13**	4	3	**4**	4
Natural Management Area	**13**	5	0	3	**7**	1	1	1	2	**13**	3	3	**3**	3
Forest Formation	**21**	4	0	5	**19**	3	3	3	5	**19**	5	4	**5**	5
Agriculture	**7**	5	0	1	**1**	0	0	0	0	**5**	1	1	**1**	1
Pasture Areas	**10**	5	0	1	**7**	1	1	1	2	**7**	2	2	**3**	3
Mining Influence	**6**	0	0	5	**0**	0	0	0	0	**5**	0	2	**0**	0
Urban Influence	**1**	1	0	0	**0**	0	0	0	0	**7**	1	3	**0**	0
Reforestation	**8**	1	0	4	**11**	2	2	2	2	**8**	3	2	**3**	3
Water	**17**	5	5	2	**15**	3	3	4	0	**23**	5	5	**5**	5

The values in the table are based on the author's own perception (based on the literature of the reference list studied) and are not binding. Blue columns represents the value of the sum of all ecosystem services under a specific ecosystem service, it is not the sum of the few ecosystem services on the table. For the complete table with all the ecosystem services please see Appendix D.

Table 7 reveals which land uses are capable to provide more of each ecosystem service category (see also Figure 8). According to the results, forest formation has the highest capacity to supply provisioning and regulating services in the Pantanal. Since the forest formation land use class in the Pantanal includes 23 plant typologies and presents densely arranged trees together with shrubs and herbaceous vegetation, there are more resources that can be found and exploited by local people and is able to perform better the regulating processes (Sohel et al., 2015). Water has the highest capacity to supply cultural services in the wetland. This is in accordance with what was previously explained regarding how the culture and traditions in the Pantanal are shaped through the relationship between local people and the river. As for habitat services, forest formation and water have the highest capacity to supply this service in the Pantanal, given the suitable conditions to function as refuge for different species. The high capacity of both land uses to supply ecosystem services can be explained by their fundamental role in the provision of a range of critically important ecosystem services (Brockerhoff et al., 2017).

Mining and urban influence are the land uses in the Pantanal with the lowest capacity to supply ecosystem services. This is strictly related with the anthropogenic use given to the land and the impacts that these can generate in the ecosystem. Moreover, when more detail is required to identify which land use is capable to provide more (or less) of an individual ecosystem service, different land uses gain more importance. For instance, agriculture is among the land uses with the lowest capacity to supply ecosystem services; however, it has a very high capacity to supply food in the area. The same happens with pasture areas.

Finally, based on the results of Table 7, the natural land uses and water in the Pantanal have the highest capacities to supply all four categories of ecosystem services in comparison to the anthropic land uses. In fact, land use changes from natural ecosystems to urban or industrial areas are believed to have a negative impact in the value of ecosystem services (Zhang et al., 2015). These somehow relates with the fact that the sustainable use of wetlands has been shown to be economically more beneficial than its use for other alternative and anthropic developments when most ecosystem services are assessed (de Groot et al., 2012).

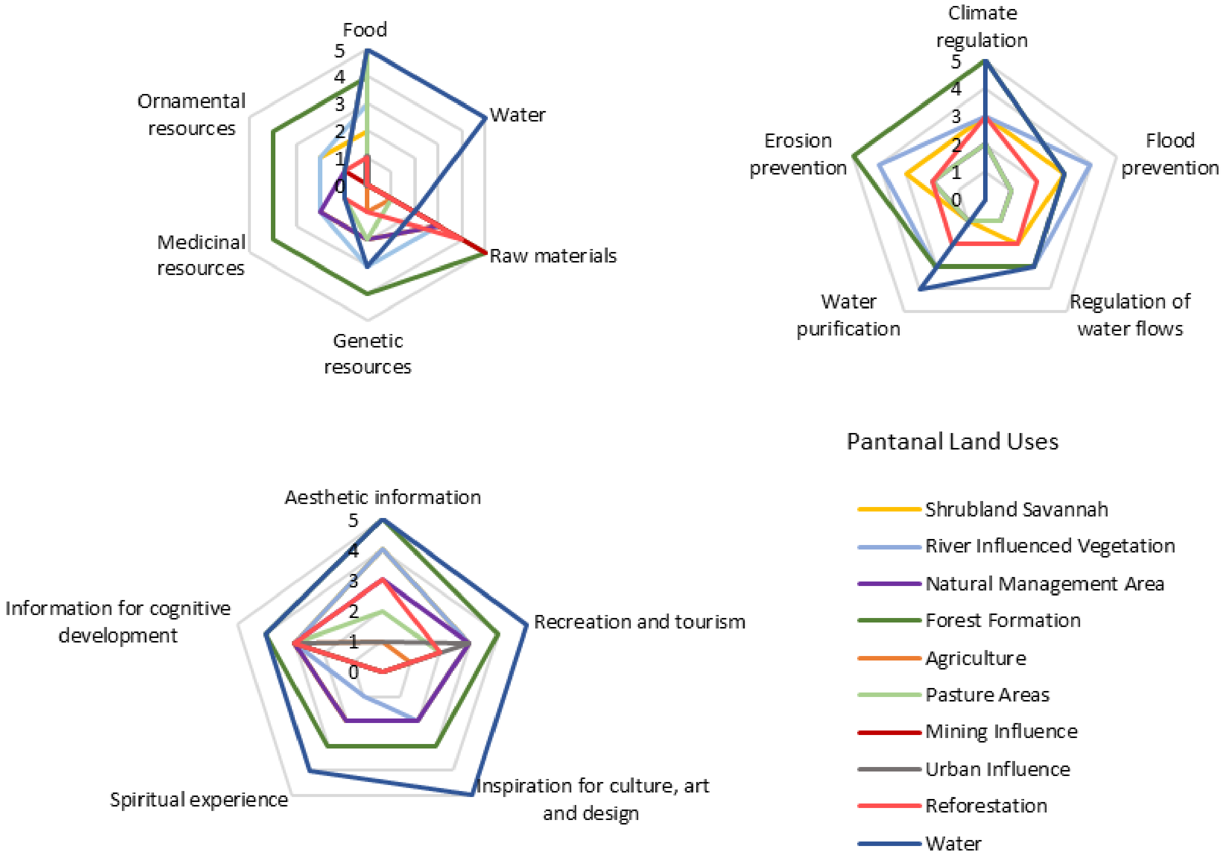

Figure 8. Spider diagrams of the capacity of the Pantanal land uses to supply ecosystem services. 0= no capacity; 5= highest capacity.

5.5 Benefit Analysis: Benefits and Beneficiaries

Ecosystem services have an effect on social benefits people derive from nature, and these can be assessed through peoples' well-being. Human well-being have multiple components such as basic material for a good life (livelihood, shelter), health (mental and physical), social relations (social cohesion, respect), security (personal safety, security against disasters) and freedom of choice and action (MA, 2005). Therefore, ecosystem services can be studied from a social perspective addressing the varying effect of ecosystem services provision on the different components of human well-being.

Ecosystems goods and services can only be considered benefits once a user or beneficiary make use of them directly or indirectly (Caputo et al., 2016). A large number of ecosystem services' stakeholders can affect or be affected by the provision of ESs, but for them to become beneficiaries, they must benefit from the consumption or the appreciation of the goods and/or services provided by ecosystems (Suwarno et al., 2016). Moreover, the stakeholders and beneficiaries can be divided into different categories according to institutional scales: municipal, provincial, national and global (Hein et al., 2006); bio-economic processes: private, public and household (Suwarno et al., 2016); and/or by answering questions regarding interactions, responsibilities and benefits derived from ecosystem services (Aziz et al., 2016).

The identification of stakeholders and beneficiaries is relevant since it improves the understanding of the provision of ecosystem services in specific land use types and facilitates decision-making processes because it considers the range of interest of people involved or affected by management practices (Aziz et al., 2016; Hein et al., 2006). Methods such as surveys, interviews, informal conversations with local people, use of indicators and statistical data can be applied to identify ecosystem services beneficiaries. Moreover, stakeholder analysis can help to, systematically, identify beneficiaries, users, and suppliers of ecosystem services and their related influence and interests in more detail with relation to each ecosystem service.

According to WWF-Brazil and WWF Freshwater Practice (2017), the Pantanal is home to 1.2 million people and there are more than 8 million beneficiaries of the ecosystem services it provides. A preliminary list of the Pantanal ecosystem services' beneficiaries has been identified and presented in Table 8. Appendix E provides a list of questions that can help identify a preliminary list of ecosystem services' beneficiaries.

Table 8. Potential beneficiaries of ecosystem services provided by the Pantanal (based on Kettunen et al., 2009)

Ecosystem Service Category	Ecosystem Services	Spatial extent	Beneficiaries*
Provisioning	Food (fish, cattle, crops)	Local, regional and national	Fishermen, cattle ranchers, farmers, local communities, consumers, tourists
	Freshwater	Local, regional	Local communities, fishermen, cattle ranchers, farmers, industries
	Raw materials	Local	Local communities
	Genetic resources	Local, regional and global	Local communities, farmers, researchers
	Medicinal resources	Local	Local communities, consumers and sellers
	Ornamental resources	Local	Local communities

Continuation of Table 8.

Ecosystem Service Category	Ecosystem Services	Spatial extent	Beneficiaries*
Regulating	Climate regulation (carbon sequestration and microclimate)	Local, regional and global	Local communities, global population
	Moderation of extreme events	Local and regional	Local communities, communities downstream, farmers and cattle ranchers
	Regulation of water flows	Local and regional	Local communities, communities downstream, fishermen
	Waste treatment	Local and regional	Local communities, fishermen
	Erosion control	Local	Farmers and cattle ranchers, local communities
Cultural	Aesthetic value	Local, regional and global	Local communities, tourists, global community who appreciates the wetland
	Tourism and recreation	Local	Owners and managers of touristic attractions, tourists
	Inspiration for culture, art and design	Local, regional and global	Local communities, artists
	Spiritual experience	Local and regional	Local communities and people who feel connected to the area
	Information for cognitive development	Local, regional and global	Local communities, researchers, non-governmental organizations
Habitat	Maintenance of biodiversity	Local, regional and global	Local communities, tourists, inhabitants of the countries sharing the Pantanal, global communities interested in biodiversity

*This table provides a preliminary list of beneficiaries. The intensity of the dependency on ESs and the amount of beneficiaries in each spatial scale varies according to the importance that beneficiaries attach to the ecosystem services.

In the Pantanal, local communities have a strong dependency on the natural resources and natural processes within the wetland and most of the human and economic activities in the Pantanal rely on the ecosystem services being provided (i.e. cattle ranching, recreational and commercial fishing, contemplative tourism) (Bergier et al., 2018; Bortolotto et al., 2017). This dependency makes them not only beneficiaries of ecosystem services, but most probably, their well-being is linked to this ecosystem. For instance, their reliance on the sources of food available in the wetland is closely related to their health and their access to basic material for a good life; while their cultural traditions can be strongly linked to their social relations.

As for benefits, The Guidance for the Rapid Assessment of Cultural Ecosystem Services (GRACE) tool[5], even though it was initially developed for cultural services and social benefits, can be implemented as a guide to identify benefits of all ecosystem services categories following the same methodological approach. This tool suggests the use of methods such as attitude statements with Likert scales and ranking exercises to reveal the social benefits of ecosystem services.

In addition, matrices can be developed to link ecosystem services to the social benefits they provide. These can be qualitatively assessed by giving scores revealing the perception of the contribution of the ecosystem service to the benefit (+, ++, -, --, ?) (Table 9). Other matrices can be developed to relate ecosystem services to beneficiaries (Table 8), or to relate the beneficiaries to the social benefits perceived.

[5]https://live-fauna-flora-international.pantheonsite.io/wp-content/uploads/old-images/grace_report_final.pdf

These type of matrices also help to distinguish between winners and losers of specific developments or management decisions. For example, Schulz et al. (2017) found that the Paraguay-Paraná waterway project might have more beneficial and positive impacts for the agribusiness sector, the state government and navigation and logistics companies; while environmental NGO's, the fishing sector, and academics tend to oppose to this development given the negative impacts on the hydrology, ecology and biodiversity of the Pantanal. They stated the need to implement the waterway in such a way local communities would still be able to maintain their traditional culture and livelihoods, while the agribusiness operates and contributes to the local economy by, e.g. taxation. The authors clearly explained a situation in which major decisions affecting ESs in the Pantanal can benefit some (winners), while disadvantaging others (losers).

Application of the Benefit matrix for the Pantanal

The benefit matrix aims to relate the social benefits people receive and perceive with the ESs provided by the Pantanal. By means of stakeholders and beneficiaries' perception, this matrix allows to identify the effect of ecosystem services provision on the different components of human well-being, since the relationship of these components with ecosystem services varies in intensity.

For the purpose of this report, a qualitative assessment of the benefits derived from the ecosystem services of the Pantanal was carried out based on the literature reviewed (Table 9). The qualitative assessment can be replaced for statistics and values when a quantitative assessment is required. For instance, health can include health statistics and employment can be valued through the number of jobs involved.

Table 9. Contribution of ecosystem services to the social benefits. Based on de Groot et al. (2018) and McInnes & Everard, 2017

Ecosystem Service		Benefits				
		Health	Security	Livelihood	Social relations	Employment
Provisioning services	Food	++	++	++	+	++
	Water	++	++	++	+	?
	Raw materials	+	+	+	+	+
	Genetic resources	+	+	?	-	-
	Medicinal resources	++	+	+	-	+
	Ornamental resources	+	-	++	++	+
Regulating services	Climate regulation	+	++	?	-	?
	Flood prevention	+	++	+	+	+
	Regulation of water flows	+	++	+	+	+
	Water purification	++	+	+	+	+
	Erosion prevention	-	+	+	?	+
Cultural services	Aesthetic information	++	-	+	+	+
	Recreation and tourism	+	?	++	++	++
	Inspiration for culture, art and design	+	-	+	+	+
	Spiritual experience	+	+	?	++	?
	Information for cognitive development	-	+	+	?	++
Habitat	Maintenance of biodiversity	+	+	++	+	++

++ Highly contributes; + Contributes; - Does not contributes; --Negative contribution; ? I do not know. Answers in the table are based on the author's own perception and are not binding.

From the results obtained is possible to identify that food, recreation and tourism, and the maintenance of biodiversity in the Pantanal are likely to have the highest contribution to the different constituents of human well-being, followed by water supply, flood prevention, regulation of water flows and water purification. Therefore, most probably, these ecosystem services can deliver a wider range of social benefits to local people than other ecosystem services. Nevertheless, if each of the constituents of human well-being are analyzed independently, health and security are perceived to be the social benefits most connected to the ecosystem services.

In this respect, Calheiros (2007) pointed out that local people depend on the quality and quantity of the environmental services in the Pantanal, which in turn contributes to social benefits such as good quality of life, health and well-being. Moreover, Morais Chiaravalloti et al. (2017) in their research about land tenure in the Pantanal stated that the right to use traditional territories is a mean for local communities to secure their livelihood and maintain the social cohesion, both social benefits provided by the ecosystem services in the wetland.

The Pantanal's ecosystem services do not only contribute to individual and social well-being, but they can also be linked to broader goals such as the SDGs. Therefore, it is possible to link each ecosystem service to the benefits they provide, and these benefits can be in turn correlated to the SDGs. As it is shown in Table 9, some ecosystem services contribute with different levels of intensity to the social benefits, thereby, the level of contribution of the Pantanal's ecosystem services to the achievement of the SDGs varies as well. Figure 9 illustrates the ecosystem services that have a high contribution to the social benefits addressed in Table 9, and the related SDGs.

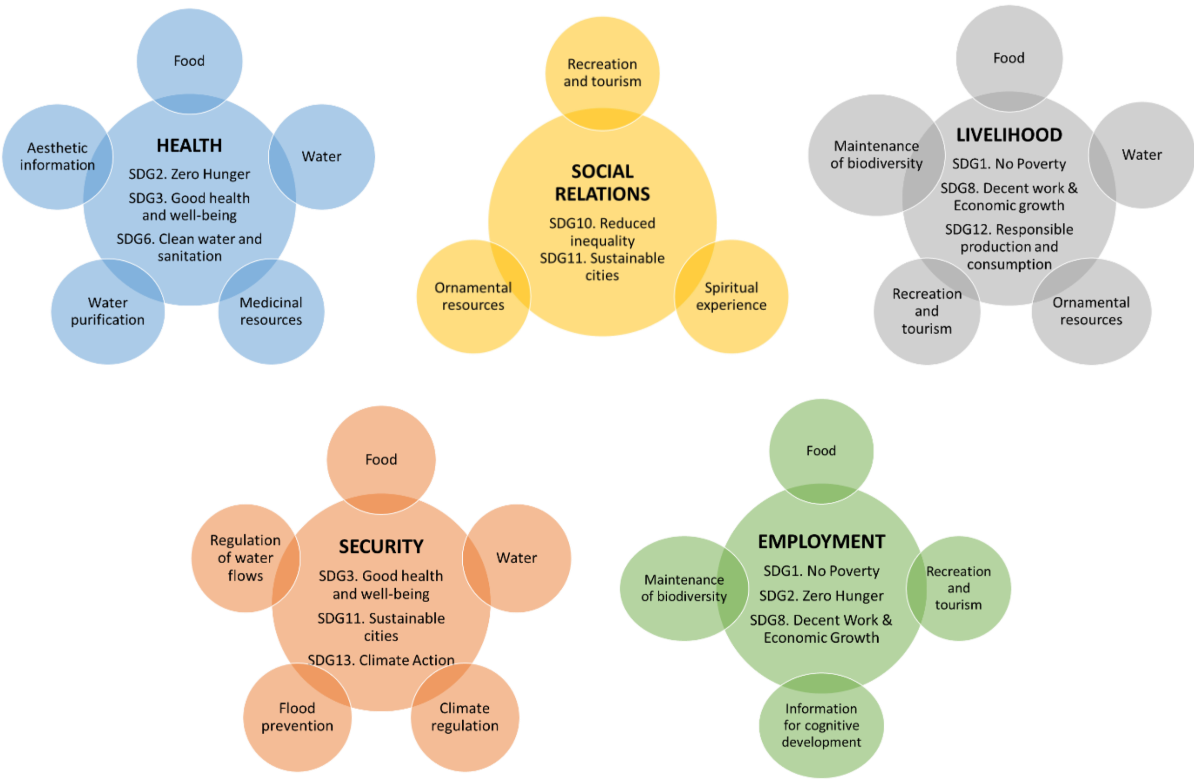

Figure 9. Relation between ecosystem services, social benefits according to MA (2005) and the SDGs (only ecosystem services with high contribution to social benefits are included).

5.6 MONETARY VALUATION

Monetary valuation is a method used to reveal the economic importance and welfare implications of ecosystems, and it attaches a value to ecosystem services that can be measured through monetary units (de Groot, 2006). The Total Economic Value (TEV) is a framework widely used for the calculation of the monetary value of wetland ecosystems. Figure 10 provides an illustration of the TEV framework with the related valuation methods and ecosystem services.

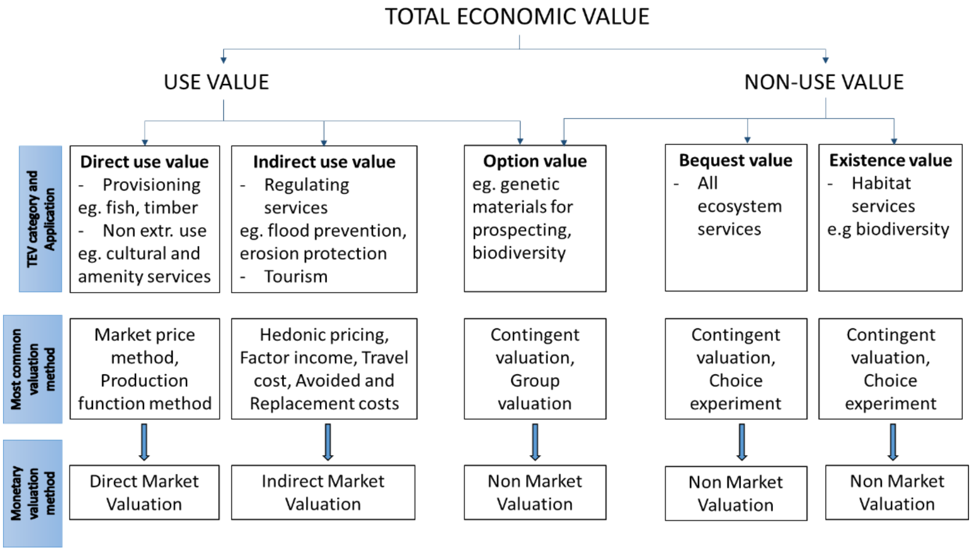

Figure 10. TEV Framework. Adapted from de Groot et al., 2006 and Ding et al., 2017.

Direct use value derives from goods or services (food, water, recreation) that can be consumed or enjoyed directly from nature (de Groot et al., 2006). Generally, the valuation methods are straightforward, e.g. market price, since provisioning (food, timber) and some cultural services (recreation and tourism) can be traded on the market.

Indirect use value is also known as functional value, and derives from the services that support the delivery of ecosystem services directly used by humans (Ding et al., 2017). Regulating services usually fall into this category and valuation methods are used to estimate the revealed willingness to pay (WTP) for the availability of the services, or the willingness to accept a compensation for the loss of ecosystem services (de Groot et al., 2006). Methods such as avoided cost are used to estimate the costs that would occur if any ecosystem service is absent (e.g. damage from flooding), or replacement cost to calculate the costs of replacing ecosystem services (e.g. wastewater treatment plant). Moreover, many other revealed preferences methods can be applied to calculate the monetary value of regulating services, which includes restoration and mitigation costs, hedonic pricing and travel cost[6].

Option value reveals the value of having the option to enjoy any ecosystem service at a later date, by themselves or by future generation. Bequest value relates to the individual satisfaction of letting future generations enjoy nature; and existence value is the value attached to nature for the simple

[6] For explanation see https://www.ramsar.org/sites/default/files/documents/pdf/lib/lib_rtr03.pdf pages 24-25

fact that it exists and is mainly related to habitat services. For these three types of values, stated preference valuation methods are used, which measures the stated preference (WTP) for the availability of any ecosystem service (Pascual et al., 2010). For this purpose, contingent valuation, group valuation and choice experiment are used by means of surveys, questionnaires and discussions.

Data on the monetary value of the different ESs can be obtained by means of primary or secondary data. Fieldworks might be necessary, but in general, the values are calculated with the use of secondary data that is collected through literature review or by requesting the data to the entities responsible of its generation. Whenever data for the calculation of any ecosystem service is not available, surveys and group discussions become an alternative to reveal the economic value of the services by means of WTP. In any case, it is very important to state and explain the calculations made and the base year in which the values are being estimated, together with the assumptions made and the uncertainties (Stelk & Christie, 2014).

The choice of the most appropriate valuation method is dependent on the purpose of the study and the socioeconomic and environmental data available for the study area (de Groot et al., 2012). Ideally, new empirical data should be generated for the calculation of monetary values; however, benefit transfer is an alternative when data cannot be generated. Benefit transfer estimates the value of a certain ecosystem service based on previous results of valuations in other similar study sites (Rodríguez Ortega et al., 2014). For the case of the Pantanal, other tropical wetlands can be considered for benefit transfer such as "Los Llanos", the Amazon, or the "Iberá" wetland. The "Guidance manual on value transfer methods for ecosystem services" elaborated by Brander (2013) provides a very concise explanation of how to apply benefit transfer together with applied examples for wetlands. Moreover, monetary values of ESs of different biomes and ecosystems around the world are available and accessible online in the TEEB Valuation Database[7] and in the GecoServ Ecosystem Services Valuation Database[8].

For the case of the Pantanal, there are only two studies in which the TEV of the ecosystem services was estimated. Seidl & Morães (2000) calculated for the first time the total economic value of the Pantanal. The authors re-estimated the values from Costanza et al. (1997) research using locally derived data in application to the Nhecolândia Pantanal (Brazil). Results estimated an annual value of ecosystem services of (1994) US$ 5,840/ha. Moreover, in 2009, Morães et al. published a new estimation of the TEV of the Pantanal. Considering the use and non-use values of ecosystem services, the authors calculated the TEV based on previous studies carried out in the Pantanal, and in some cases, benefit transfer was implemented (timber products). Results estimated an annual (minimum and maximum) value of ecosystem services of (2007) US$ 8,120/ha to US$ 17,477/ha.

If the values of both ecosystem services valuation were updated to the current value of the US$ (2018)[9], the monetary value of the ecosystem services provided by the Pantanal will be around US$ 10,050/ha and US$ 21,723/ha. Hence, considering the total area of the Pantanal, the ecosystem services have a monetary value that ranges from US$ 160,800,000,000 – US$ 347,568,000,000.

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[7] http://www.teebweb.org/publication/tthe-economics-of-ecosystems-and-biodiversity-valuation-database-manual/
[8] http://www.GecoServ.org.
[9] https://www.bls.gov/data/inflation_calculator.htm

6. DISCUSSION AND RECOMMENDATIONS

Strengths and weaknesses of ecosystem services concept and assessment

The term of ecosystem services first appeared in the 1980's, and since then, many related ideas, concepts and frameworks have been developed in the academic literature that fostered the research and policy interest in ecosystem services (Costanza et al., 2017). Ecosystem services assessment is a rapidly developing interdisciplinary field with many challenges to overcome in relation on how to properly evaluate the relations between natural capital and benefits to people (Häyhä & Franzese, 2014).

According to Bull et al. (2016), knowledge gaps, disparities and inconsistencies with existing tools, datasets and frameworks, the "commodification" of ecosystem services and the ambiguous and incomplete scientific basis have challenged the implementation of the ESs concept. Moreover, given that the "connection between ecosystem processes, functions and benefits to humans are complex, non-linear and dynamic" (Costanza et al., 2017), it is likely that relations will be characterized by oversimplification and that estimations of values of nature to people will probably be underestimated.

Ecosystem services valuation, as part of the ecosystem services assessment, has a wide range of uses in raising awareness and interest, in urban and regional land use planning, in specific policy analysis and in payment for ecosystem services; however, there is always the challenge of dealing with "imperfect information" that can influence the value that people attach to ESs (Costanza et al., 2017).

Regardless of the weaknesses in the previous paragraphs, decision makers have increasingly included ESs in environmental policies and natural resource management strategies. In addition, Bull et al. (2016) identified several strengths of ecosystem services assessment. This includes the interdisciplinary and holistic approach able to account for the different values (ecological, social and economic) of ecosystem services, the relevance of the ESs concept as a communication and advocacy tool, the increased societal engagement capable of reconnecting people to nature, and the opportunities to align ecosystem services to existing policies and international agreements such as the Convention on Biological Diversity or the SDGs.

Even though there are issues that remain unsolved in the integration of ecosystem services into everyday planning, there are many projects and initiatives that keep on working in the incorporation of the ecosystem services concept in environmental planning and decision-making (de Groot et al., 2010).

Pantanal vs. Upper Paraguay River Basin

One of the first aspects to take into consideration when implementing an ecosystem services assessment is the geographic scale of the study. Following this line, it is very important to make a distinction between the Pantanal wetland and the Upper Paraguay River Basin (see Figure 4). The UPRB has an area of 600,000 km^2 and encompasses different ecoregions: the Cerrado, Chaco, Chiquitano Dry Forests, Humid Chaco and, of course, the Pantanal wetland. Given the presence of different but interrelated ecoregions, ideally, ecosystem services analysis should be carried out independently in each ecoregion, since the quantity and quality of ESs in different ecoregions are spatially heterogeneous (Xie et al., 2017). The heterogeneity here refers to “the degree of spatial variation within the spatial distribution of ESs” and varies per ecosystem service and per study area (Schröter et al., 2015; Zulian et al., 2018).

Even though it is possible to carry out an ESs assessment at the UPRB scale, information on the services provided by each of the ecoregions that are part of the basin is generalized and, given the different spatial-temporal data sources that are commonly used (e.g. Palacios Nieto research), there can be potential information loss after resampling (Mercado-Garcia et al., 2018). Nevertheless, in data scarce situations, most of the spatial models of ESs are implemented at a regional scale (UPRB) since local information is not available. In fact, Pandeya et al. (2016) considered that mapping and modelling tools may be more convenient for a regional/watershed scale, since at local scale a mixed approach of quantitative and qualitative methods can better account for the diversity of natural capital and ESs relevant for policy making. As a first approach, the alternative of considering the UPRB for the use of models is more convenient (in terms of reduced costs and labour intensity) because it can accurately reflect broad patterns of information and is also possible to zoom in on the study area (e.g. Pantanal) although thematic and spatial uncertainties might increase (Petz et al., 2016).

If the aim is to convince the governments to protect the Pantanal, based on all literature reviewed, a recommendation is to study this wetland independently of the other ecoregions to properly assess the benefits that the Pantanal provides to people and integrate them into decision-making. That said, given that ecosystem services provision are often governed by processes occurring outside the study area (Boulton et al., 2016), the study of the trade-offs and the influence that the neighbor’s ecoregions in the UPRB have on the wetland (Ibanez Martins, 2010) should not be overlooked.

The economic activities and unsustainable developments in the highlands of the UPRB (Cerrado, Chaco and Chiquitano Dry Forest) are currently threatening the Pantanal’s condition and capacity to supply ecosystem services (WWF, 2017). Moreover, evapotranspiration is higher than precipitation in the Pantanal, which makes this wetland dependent on the runoffs or water contribution from the highlands. In conclusion, the highlands in the UPRB determines the hydrological character of the basin (UNEP & OAS, 1998). Therefore, policies to conserve the Pantanal must also include the maintenance and protection actions on the areas of high water contribution, i.e. water towers, and on the surrounding ecoregions that have effects on the wetland (WWF-Brazil, 2018).

Implementation of an ecosystem services assessment of the Pantanal wetland

An assessment of ecosystem services provided by the Pantanal can certainly be a step towards the valorization and conservation of the wetland. Knowing this, it is important to ask: “how to start the implementation of such an assessment?”. Concepts and methods have already been explained in the previous chapters; nevertheless, some hints on how to start the assessment and which steps to follow can make the work easier (Figure 11).

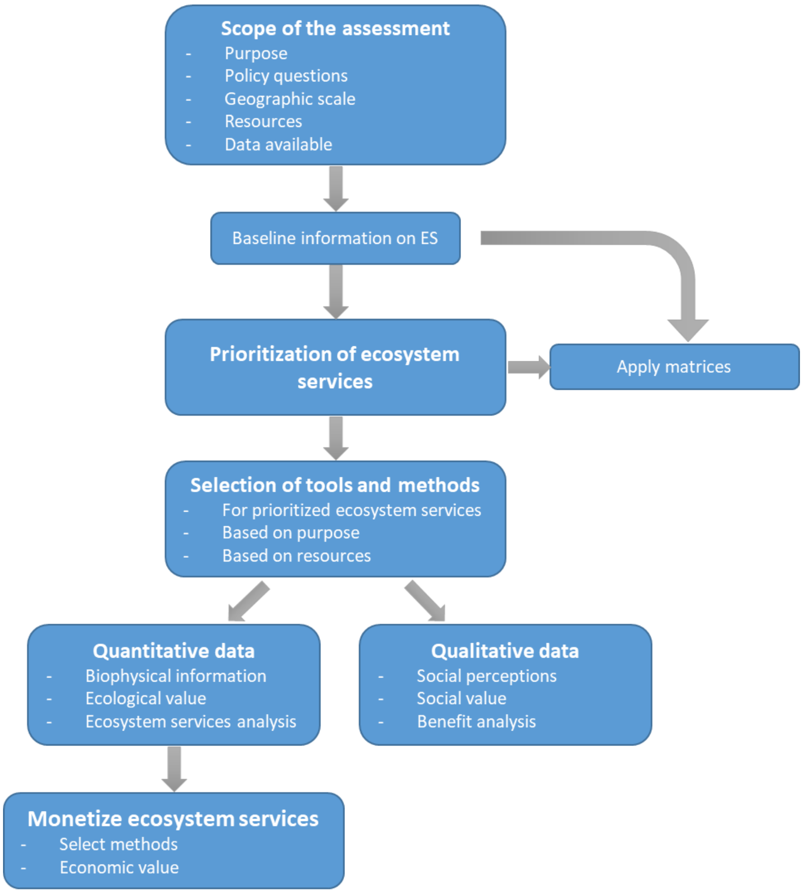

Figure 11. Steps in the implementation of the ecosystem services assessment of the Pantanal.

First of all, it is fundamental to clearly define the purpose of the assessment, the policy questions to be answered, the geographic scale, who is going to participate and the available data and resources (human, economic, time) (Bullock & Ding, 2018). Starting with clear goals and with a common understanding on why the assessment is necessary and how it would help to achieve the objectives of the broader project, will facilitate the implementation of the ESs assessment.

Given the wide range of benefits that the Pantanal provides to people, and the possible work limitations, the prioritization of ESs should be carried out at the first stage of the assessment to reduce the number of ecosystem services that will be further studied in a sensible and argument-based way. This step should only be implemented when baseline information on the ecosystem services of the Pantanal has already been reviewed, to reduce the subjectivity in the answers.

Commonly, prioritization is carried out by experts who identify which ecosystem services are the most important for monitoring and management in a specific area. In Russell et al. (2011), Werner et al. (2014), Luck et al. (2012) and Maynard et al. (2010) researches, the list of experts included technical, scientific and social experts, representative decision and policy-makers, resource managers and academic experts with knowledge on the study area. Nevertheless, if the matrix is going to be distributed to and applied by local people, it should be adapted to account for the different background (usually not scientific) of the habitants of the Pantanal.

Once the priority ecosystem services have been identified, tools and methods to quantify the ESs and identify benefits and beneficiaries of the selected ESs have to be chosen. The selection of methods, tools or indicators for which data should be collected and/or generated will be dependent on the purpose of the assessment, the timeframe of the project and the available resources. Moreover, the selection of methods is subject to the type (qualitative or quantitative) of data expected to obtain. For this stage, is also relevant to identify which are the institutions or organizations responsible of the generation of data for the Pantanal in each country (Brazil, Bolivia and Paraguay) in order to create, if possible, a database that centralizes the information of the area given that, currently, information is dispersed (Junk et al., 2006).

In this report, some simple and straightforward matrices based on experts' perception (see Table 7, Table 8 and Table 9) are suggested in order to start the assessment of ecosystem services of the Pantanal. Given the ease in completing the matrices, all ecosystem services are included; therefore, is not necessary to carry out the prioritization of ESs to apply these matrices. The information generated with the use of the matrices (pages 32, 34, 36) can provide the baseline information or first picture of the present ecosystem services of the Pantanal, the related benefits and beneficiaries and the capacities of the land uses of the Pantanal to supply ESs.

It is important to point out that the matrices suggested in this report do not provide a definitive answer, but rather contribute to the generation of data in a data scarce context based on stakeholders' perceptions. Initially the matrices are developed for experts in order to get an immediate answer, but it can always be extended to local people. Following this line, the expert-based and community-based participatory approaches should be considered. On the one hand, expert-based information is recognized as an essential data source in areas of limited data availability. On the other hand, the community-based approach provides detailed local knowledge and enables the ESs assessment to be user-inspired, user-useful and user-friendly (Cowling et al., 2008). Moreover, since perceptions and attached values may vary among stakeholders, an inclusive participation of stakeholders (farmers, ranchers, local people, public servants, etc.) in ESs assessment is vital given their influence in the outcome (Iniesta-Arandia et al., 2014).

After the selection and application of the tools, and once quantitative or biophysical information is generated (usually by means of survey, indicators or models), and benefits and beneficiaries have been identified, the monetary valuation of ecosystem services can be implemented. Valuation methods will have to be selected and most probably, the collaboration of local people will be essential to collect data on the value of non-material ecosystem services (regulating, cultural services).

Lastly, experts can start the assessment and become one of the main sources of information together with any quantitative data available, but as the assessment progresses, the involvement of local people is essential to reflect the social and cultural values of the ESs of the Pantanal in order to include what matters to the people in ESs assessment and make it more policy-oriented (Pandeya et al., 2016).

Results of the implementation of the matrices

Given the time limitations of the internship, and the scope of this report, only matrices (not models) were implemented with the aim to show preliminary results and how to complete the matrices. In total, three matrices were applied: the prioritization of ESs matrix, the land use capacity matrix and the benefit matrix.

The first matrix implemented was **the prioritization of ecosystem services matrix**. As explained, this was developed specifically for this report, so it has not been implemented before. Moreover, the results are presented based on one specific distribution of weightings for each criterion and no sensitivity analysis was carried out since the purpose was to complete the prioritization tool, not to present definitive results.

This matrix is based on a Multi-Criteria Analysis (MCA). Most commonly, effects on ecosystem services and ecosystem processes and services are used as the evaluated criteria (rows in the table) on MCA (Langemeyer et al., 2016). However, in this report, the criteria selected for the prioritization of ESs of the Pantanal are chosen in a way that they can cover all three dimensions of sustainable development (ecological, social, economic), so the ecosystem services are located in the columns of the table rather than in the rows. Furthermore, the innovation of this tool relies on the fact that it does not ask stakeholders to choose the main ecosystem services, but rather that the scoring of different criteria will reveal which ecosystem services should be prioritized in the Pantanal. Nevertheless, ideally, this tool should be tested and applied by a wider audience, and since it is considered an easily applicable and flexible tool, it should be adapted if any proper suggestions are made.

In this report, with the use of the proposed prioritization matrix, flood prevention, regulation of water flows, water supply, maintenance of biodiversity and food were identified as ecosystem services with the highest priority in the Pantanal. Russell et al. (2011) speculated that the high ranked services are most probably the ESs that are more visible to people. In a study carried out in the Moeyungyi Wetland Wildlife Sanctuary (Merriman & Murata, 2016), in Myanmar, through two scoping workshops, the authors identified global climate change mitigation in terms of carbon storage, nature-based recreation, flood protection, provisioning of water and provisioning of wild goods as the main ESs provided by the wetland. Even though some main ecosystem services are the same in this report and in Merriman and Murata (2016) research, there are differences that might arise from the different prioritization methods used (use of criteria for selecting ESs, group discussion). Similar to what Werner et al. (2014) stated, the prioritization approach developed in this internship report is part of the pool of methods that aims to simplify the implementation of ESs assessment, and cannot be considered better or worse than other methods.

Ideally, more participants should take part of the process of prioritization of ecosystem services to account for different perspectives that might bring to light ecosystem services that are important for different groups of people (even the less tangible ESs). In addition, the results from the prioritization can be further validated by stakeholders and workshop participants (if workshops are carried out) to check consistencies (or inconsistencies) between the results (Russell et al., 2011).

The second matrix completed was the **land use capacity matrix**. This matrix was developed by Burkhard et al. (2009) and has been applied in several researches. In the Pantanal, forest formation was the land use and land cover (LULC) class with the highest capacity to supply *provisioning* and *regulating* services. This result is in line with the results obtained by Tao et al. (2018), in which the forestland of the Yangtze River Delta Region in China had the highest capacity to supply ecosystem services. As for *cultural* services in the Pantanal, water and forest formations are the LULC classes with the highest capacity to supply these services. Periotto and Tundisi (2018) found, for two watersheds in São Paulo State in Brazil, that water bodies and native vegetation (Cerrado) had the highest capacity to supply cultural services, which is in accordance with the result obtained for the Pantanal. Lastly, forest formation and water were the LULC classes of the Pantanal with the highest capacity to supply *habitat* services, and Periotto & Tundisi (2018) obtained the same results in their research.

Moreover, if ecosystem services are reviewed individually and not under a broader group, such as the ESs category, different land uses are observed to have high capacity to supply different ecosystem services (see Appendix D). For each of the prioritized ESs of the Pantanal, different land uses had a high capacity to supply them: the LULC water had the highest capacity to supply water and regulation of water flows; forest LULC to supply biodiversity; agriculture to supply food. The same variation of land uses and capacities to supply ecosystem services has been observed in Tao et al. (2018) and Periotto and Tundisi (2018). This reveals that all land uses in the Pantanal have a stake in ecosystem services provision; nevertheless, water and forest formations have even a more relevant role since both have the highest capacities to supply all ecosystem services. Strict conservation and/or restoration of these two natural land uses was suggested by Tao et al. (2018) and decision-making of land management to improve and secure all four categories of ecosystem services (considering trade-off and reinforcing synergies) to generate win-win situations was pointed out by Periotto and Tundisi (2018).

Therefore, and as a result of the preliminary application of the land use capacity matrix for the Pantanal, it is appropriate to say that there is consistency in the results obtained in this report, with the results obtained in other study areas using the same matrix. The results also reflect that same or similar land uses have comparable capacities to supply the same ecosystem services categories. Nevertheless, it is important to mention that there can be uncertainty sources in experts' perceptions when inferring the capacity to provide ES by different land uses (Campagne et al., 2017). These sources of uncertainty derive from the diversity of expertise among experts and the confidence in assigning a capacity score to the land uses. Despite these sources of uncertainty, expert evaluation helps to obtain a picture of the provision of ecosystem services in diverse land uses and it is considered a tool to initiate ecosystem services assessments (Burkhard et al., 2012). Moreover, these assessments can be further enhanced with the integration of original data from fieldwork.

The last matrix completed for the Pantanal wetland was the **benefit matrix**. This matrix aims to relate ecosystem services with the social benefits it provides. The results indicate that the ecosystem services that provide most benefits in the Pantanal are food, water, recreation and maintenance of biodiversity. Following this line, Schmidt et al. (2016) pointed out that recreation and tourism contribute to health, while Kumar et al. (2011) identified that food such as fish was strictly linked with livelihoods of the communities in Lake Chilika, India, benefiting around 200,000 fishermen. In addition, from the benefit matrix it was identified that the ecosystem services of the Pantanal provide more benefits in terms of health, livelihood and security. In fact, wetlands are seen as settings where people live and where their health and livelihood are strongly and directly connected to that ecosystem (Horwitz & Finlayson, 2011).

Even though the matrices were completed taking into consideration only one point of view or perception, the results are in accordance with other researches that applied the same methods on other settings. This reveals that even with one person's perception, good insights are obtained. However, most probably, these results can become even more robust and legitimate if more participants with greater knowledge on the Pantanal participate on the assessment.

Gaps of knowledge

In the year 2012, Junk et al. stated that the Pantanal is reasonably well known. This statement is not clear enough to determine if there is proper and updated information of the Pantanal suitable for ESs assessment. In addition, Kauffman (2015) stated that there is much known about the Pantanal functions but not about the human communities that live in there. Moreover, in the beginning of the 20th century, most expeditions took place in the Brazilian Pantanal and the generation of knowledge was oriented to scientific research on the flora and fauna of this wetland, which might explain why there is a vast knowledge on the biodiversity of the Pantanal (Kauffman, 2015). As for the knowledge of the Brazilian, Bolivian and Paraguayan portions of the Pantanal, Hamilton (2002) indicated that the Bolivian and Paraguayan areas are much less studied than the Brazilian one, statement that was confirmed during the elaboration of this internship report since the lack of studies on the Bolivian and Paraguayan Pantanal was striking.

Draw from the authors' statements, it is possible to determine that there is available information about the Pantanal but from the literature review conducted for this report, more specific data on the functions and benefits (ecological, social, economic) of the wetland is missing. Zeilhofer et al. (2016) identified that in the Pantanal "datasets are sporadic and discontinuous", Junk et al. (2006) pointed out that "ecological information is dispersed in individual publications", and Alho (2008) indicated that there is a lack of scientific knowledge on the value of biodiversity that might affect the potential benefits of the Pantanal's biodiversity. Most commonly, studies and researches generate data on only one specific area of the Pantanal at one specific point in time, so it is difficult to find long-term and spatially extensive data (Costa-Pereira et al., 2017; Morais Chiaravalloti, 2017). Therefore, it is expected that data on the indicators provided on Appendix B might not be easily available for the Pantanal wetland and, as recommended by Hagedoorn et al. (2016), recent primary data and research should be carried out.

Furthermore, in 2014, Schwerdtfeger et al. stated that hydrological studies in the Pantanal are rarely found. However, this was not a finding from the literature reviewed done for this report. In fact, in page 27 the availability of hydrological studies was highlighted in comparison to other types of studies in the Pantanal. Hydrological research in the Pantanal includes the work by Bravo et al., 2014; Girard, 2011; Gonçalves et al., 2011; Schwerdtfeger et al., 2016; and Fantin-Cruz et al., 2015.

As for the estimated monetary value of the ecosystem services provided by the Pantanal (Morães et al., 2009; Seidl & Morães, 2000), these values are based on outdated data, mainly from the 1990s and early 2000s. Given that the threats to the wetland have increased in the past decades, an update of these data and the generation of new original data can highly contribute to a better understanding of the current value of the largest wetland in the world, since the degradation of wetlands affects the well-being of local communities who will place a higher value to the ESs they depend on (de Groot et al., 2012). It is very important to make the existing information easily accessible and available for students, researches, experts, etc. interested in researching and working in the area, if possible under a common platform. In this sense, the sharing of information is highly relevant to avoid repeated efforts on generating existing data and to identify which data is missing to expand the current knowledge on the Pantanal.

A very valuable alternative to bridge the gap of knowledge in the Pantanal is to collect, retrieve, and most importantly, to record the traditional ecological knowledge before it disappears (Bortolotto et al., 2017). In fact, Calheiros (2007) highlighted the "high quality of local knowledge of locally observable natural phenomena" and system functioning in the Pantanal. In addition, to fill in the knowledge gaps, an alternative is to provide university students thesis opportunities in which they can contribute to the generation of knowledge about the Pantanal.

Lastly, it is understood that the knowledge gap on some aspects of the Pantanal was also a motive for the "Trinational declaration for the conservation and social, economic, and sustainable development of the Pantanal", which was signed by Brazil, Bolivia and Paraguay at the 8th World Water Forum (March 2018) and that included the expansion of the scientific knowledge on the Pantanal as one of the aims of the declaration.

Limitations of the report

The internship period lasted for four months and took place in the Netherlands. The distance to the Pantanal and the restricted duration of the internship represented limitations to the elaboration of the report that were reduced by making an efficient use of the available time and by an extensive literature review that allowed collecting as much information as possible of the Pantanal.

For filling in the matrices, only one point of view (the author's) was considered, which makes the results more sensible. However, the answers are based on all the literature that was reviewed (approximately 80 documents for the Pantanal-UPRB) during the months that the internship lasted. In any case, the results should not be considered definitive, but rather preliminary. Moreover, results can be modified and become more robust and legitimate if more respondents are included (Hauck et al., 2016).

It is important to highlight that the main objective of this report (see page 1) was to suggest an ecosystem services prioritization method as well as to recommend methods for the assessment of ecosystem services of the Pantanal that can be later applied in the study area. The purpose of the application of certain matrices was to demonstrate how matrices should be completed and what type of results can generate based on the perception of a person that is not working in the Pantanal project.

As far as the data availability concerns, the reduced (or even the lack of) information on the Bolivian and Paraguayan side of the Pantanal remained as the main limitation. Therefore, most of the information used for this report is from the Brazilian Pantanal. Nevertheless, since the ecoregions is shared among the three countries, it is a not too risky assumption to say that the information is applicable for the entire Pantanal. In addition, it is likely that, given the dispersed information (and probably only locally available), some reports or data have been missed in the literature review.

7. Conclusion

The Cerrado-Pantanal is among the 35 WWF global priority places “scientifically recognized as either being home to irreplaceable and threatened biodiversity, or representing an opportunity to conserve the largest and most intact representative of their ecosystem” (WWF International, 2008). Hence, its conservation has a global relevance, but the local and regional relevance is even greater given the potential impact of the Pantanal’s ecosystem services in the well-being of people that depend on them.

The literature review carried out for this report indicated that the Pantanal is capable of providing all four categories of ecosystem services (provisioning, regulating, cultural and habitat services). Nevertheless, additional efforts are needed to focus the construction of knowledge on the ecological, social and economic benefits that the Pantanal provides, moving beyond the most known benefits like biodiversity and aesthetic information. This type of key information can be used as a hook to attract the attention and commitment of policy makers, to give a social context to conservation initiatives, to provide data on the economic loses that the degradation of this wetland can generate (cost of policy inaction) and to justify conservation. The ecosystem services assessment will not only support the communication of the complexities in the relationships between nature and human beings (Bull et al., 2016), but also increase the environmental awareness and respect to nature of lay people and will bring to the table valuable information to engage people and governments in the protection and sustainable development of the Pantanal.

Finally, it is important to highlight that even though there are limitations for the elaboration of an integrated ESs assessment in the Pantanal, specifically in terms of available data, this should not represent an excuse to postpone its implementation. Limitations should be overcome by selecting appropriate methodologies that are already available in the literature, or methods can be adjusted to implement them in the Pantanal context. In this report, emphasis was placed on the use of experts’ knowledge in data scarce situations and it was recommended to complement all data collected with traditional and local knowledge since it increases the social relevance of the assessment.

At last, it is hoped that the information provided in this report will provide the basis to initiate the discussion on why it is important to know and understand better the benefits provided by the Pantanal and how this knowledge can contribute to WWF’s Global Goals and other multilateral agreements such as the Sustainable Development Goals.

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APPENDIX

Appendix A. Ecosystem services prioritization matrix

The author of this report assigned the scores and weights. It aims to visualize and provide a first overview of the prioritization process and the identified prioritized ecosystem services from the Pantanal.

Dimension	Criteria	Weight	Food	Water	Raw materials	Genetic resources	Medicinal resources	Ornamental resources	Climate regulation	Flood prevention	Regulation of water flows	Water purification	Erosion prevention	Aesthetic information	Recreation and tourism	Inspiration for culture, art and design	Spiritual experience	Information for cognitive development	Maintenance of biodiversity
1. Ecological	1.1 Pressure/Threats	15	45	45	30	30	30	30	30	60	60	45	45	30	30	15	15	0	75
	1.2 Importance of site	20	80	100	60	80	60	60	80	100	100	100	80	100	80	60	60	80	100
2. Social	2.1 Social well-being	25	125	125	100	50	100	75	75	125	125	100	75	125	100	75	75	50	100
	2.2 Beneficiaries	15	60	60	45	30	30	45	60	75	75	60	45	75	45	30	30	45	75
3. Economic	3.1 Dependence	20	100	100	100	40	80	80	40	100	100	100	80	80	80	60	80	60	80
	3.2 Economy	5	20	20	5	10	5	5	15	25	25	20	15	15	20	5	5	10	20
Total (overall score)			430	450	340	240	305	295	300	485	485	425	340	425	355	245	265	245	450
Ranking*			**5**	**3**	**9**	**17**	**11**	**13**	**12**	**1**	**1**	**6**	**9**	**6**	**8**	**15**	**14**	**15**	**3**

*Number 1 in the ranking represents the first position (the highest priority), 2 the second position, 3 the third position, and so on.

Ecosystem service	Rank - Top 5
Flood prevention	1
Regulation of water flows	1
Water	3
Maintenance of biodiversity	3
Food	5

Appendix B. List of indicators

- Biophysical indicators

Category	Ecosystem service	Indicator	Measure
Provisioning	P1. Fish	P1.1 Fish production P1.2 Caught fish P1.3 N° species of commercial use	Catch in tones ton/ha N° of species
	P2. Livestock	P2.1 Animal production P2.2 Density of grazing livestock P2.3 Total area of grasslands suitable for grazers	kg/ha N° of animals/ha ha
	P3. Crops	P3.1 Yield P3.2 Area under cultivation	ton/ha/yr ha
	P4. Freshwater	P4.1 Total amount of water P4.2 Water extracted P4.3 Total freshwater resources	m3/ha m3/ha/yr million m3
	P5. Timber or fuelwood	P5.1 Total biomass P5.2 Area for harvesting fodder P5.3 Harvested biomass P5.4 Timber tree species	kg/ha ha kg-m3/ha/yr Names
	P6. Genetic resources	P6.1 Total number of species P6.2 Species with useful genetic material	N° of species Names and/or N°
	P7. Medicinal resources	P7.1 Distribution of plant species with medicinal properties P7.2 Total biomass P7.3 Name and N° of species	ha kg/ha N°
	P.8 Ornamental resources	P8.1 Species used for artisan work, etc. P8.2 Available amount of items collected	Names kg/ha
Regulating	R1. Climate regulation	R1.1 Carbon storage in trees and soils R1.2 Forest area	kg/ha or tonCO2/ha ha
	R2. Flood prevention/mitigation	R2.1 Floodplain area R2.2 Reduction in flow/runoff R2.3 Delay of flood peaks R2.4 Area of natural barriers (vegetation) R2.5 Area of avoided flood damage	ha days ha ha
	R3. Regulation of water flows	R3.1 Infiltration capacity/rate R3.2 Water storage capacity R3.3 Floodplain water storage capacity	amount of water/ha m3/ha mm/m
	R4. Water purification	R4.1 Water quality R4.2 Potential water purification R4.3 Denitrification R4.4 Total dissolved solids	sediment, turbidity, phosphorus, nutrients kg/ha kg N/ha/yr mg/l
	R5. Erosion control	R5.1 Soil erosion rate R5.2 Potential erosion prevention R5.3 Vegetation cover R5.4 Soil erodibility	kg/yr or kg/ha/yr kg/ha % slope, characteristics, texture, organic matter content
Cultural	C1. Aesthetic value	C1.1 Landscape features with stated appreciation C1.2 Protected area	N° and/or ha N° and/or ha
	C2. Recreation and tourism	C2.1 Known bird watching sites C2.2 Fishing licenses C2.3 Recreational activities C2.4 Overnight accommodations C2.5 Visitors to site	Names and/or n° N° N° N° N° visitors/yr

Category	Ecosystem service	Indicator	Measure
Cultural	C3. Inspiration for culture, art and design	C3.1 Cultural sites	N°, names, visitors/yr
		C3.2 Art	N° of painting/ illustrations, songs, products, portraying the landscape/
	C4. Spiritual experience	C4.1 Presence of landscape features or species with spiritual value	N°, names, visitors/yr
		C4.2 Sacred or religious sites	N°, names, visitors/yr
		C4.3 People who attach spiritual or religious significance to the wetland	N° of people
	C5. Information for cognitive development	C5.1 Scientific studies	N° of scientific studies
		C5.2 Environmental education events	N°/yr
Habitat		H1.1 Number of transient species	N°
		H1.2 Number on endangered species	N°
		H1.3 Number of endemic species	N°
		H1.4 Habitat quality index	normalization index (0-1)

Sources: de Groot et al., 2018; Maes et al., 2016; McCarthy & Morling, 2014; Russi et al., 2013; UNEP-WCMC, 2011; Value of Nature to Canadians Study Taskforce, 2017.

- Benefit indicators

Category	Ecosystem service	Social Benefit	Indicator - Measure
Provisioning	P1. P2. P3. Food	Nutrition	gr protein/yr/person or /household
		Employment	N° of employees/jobs
		Livelihood	Amount of fish landed commercially by locals
		Livelihood	N° of people and extent to which they depend on ES
	P4. Freshwater	Health	N° of people with access to clean water
	P5. Timber or fuelwood	Livelihood	N° of people and extent to which they depend on ES
		Safety	N° of houses made with local resources
	P6. Genetic resources	Employment	N° of people working with local genetic
		Science	N° of people interested in research
	P7. Medicinal resources	Health	N° of people that rely on local medicinal resources
		Health - Livelihood	N°/quantity of native species being developed and distributed to broader population in natural form
		Employment	N° of employees/jobs
		Science - Health	N°/quantity of native species contributing to pharmaceutical development
	P.8 Ornamental resources	Employment	N° of employees/jobs
Regulating	R1. Climate regulation	Security - livelihoods	Risk of loss of food sources
		Livelihoods	Loss of livelihoods associated to changing climate
	R2. Flood prevention/mitigation	Security - Risk reduction	N° of vulnerable people living in potential flooding areas, downstream
		Security	Sense of security (expressed) related to risk of natural hazards
	R3. Regulation of water flows	Security - Risk reduction	Incidence or risk of flooding
		Security - Risk reduction	N° of vulnerable people living in potential flooding areas, downstream
	R4. Water purification	Health	Incidence of water-borne disease
		Health	N° of people with access to clean water
		Safety	N° of people with ready access to the swim sites
	R5. Erosion control	Security - Risk reduction	Incidence, risk of harm and damage to persons and property from flooding (e.g., due to wetland loss)

Category	Ecosystem service	Social Benefit	Indicator - Measure
Cultural	C1. Aesthetic value	Appreciation	N° of tourist photos taken Participation in nature appreciation (e.g., birding, wildlife viewing) N° of visits to a site
	C2. Recreation and tourism	Social relations Employment	Participation rates (n° of people or days) in nature festivals, nature tourism, nature-based recreation N° of events, or places to recreate or participate in ecotourism Visitors at parks and natural areas N° of employees/jobs
	C3. Inspiration for culture, art and design	Livelihood	N° of people which income depends on these activities
	C4. Spiritual experience	Spirituality Freedom	N° of people that attach spiritual and religious significance Expressed sense of peace from being in nature
	C5. Information for cognitive development	Employment Education	N° of employees/jobs (research, projects) N° of participants and extent in voluntary conservation and citizen science actions
Habitat		Livelihoods	Resilience of communities that rely on hunting and gathering for sustenance or cultural continuity

Sources: Hattam et al., 2015; Olander et al., 2018; Value of Nature to Canadians Study Taskforce, 2017.

- **Monetary indicators**

Category	Ecosystem service	Method	Indicator/Measure
Provisioning	P1. P2. P3. Food	Market price	€ or USD per kg or ton or ha
	P4. Freshwater	Market price	€ or USD per m3
	P5. Timber or fuelwood	Market price	€ or USD per kg or ton or ha or m3
	P6. Genetic resources	Contingent valuation (breeds and varieties) Revenues	Willingness-to-pay (WTP) for (protecting, conserving, maintaining) or willingness-to-accept (WTA) loss of genetic resources € or USD
	P7. Medicinal resources	Market price	€ or USD per kg or ton or ha
	P.8 Ornamental resources	Market price	€ or USD per unit
Regulating	R1. Climate regulation	Market price - carbon credit	€ or USD per ton of sequestered carbon
	R2. Flood prevention/mitigation	Avoided damage cost Replacement cost	Prevented damage from storm-floods by natural ecosystems Conventional concrete wall surrounding vulnerable areas
	R3. Regulation of water flows	Avoided cost	Reduction in annual fluvial flood expenditure
	R4. Water purification	Avoided cost Replacement cost Replacement cost	Health costs avoided: hospital admissions Cost of a water treatment plant Costs of primary vs tertiary sewage treatment;
	R5. Erosion control	Restoration cost Mitigation cost Replacement cost	Afforestation cost Cost of mitigating sediment effects (e.g. cost of dredging) Costs of Hard vs soft defense against erosion, erosion fences
Cultural	C1. Aesthetic value	Contingent valuation	WTP for (conserving, maintaining) or WTA loss of landscape beauty
	C2. Recreation and tourism	Market price Travel cost	Revenues from tourism Price of access to a park, forest, etc.
	C5. Cognitive development		Research budgets destined to the ecosystem
Habitat		Investment cost Contingent valuation	Investment made in protection, conservation WTP for a public programme for preservation of the ecosystem

Source: Hattam et al., 2015; Pascual et al., 2010; de Groot, 2017.

Appendix C. Inputs and Outputs of InVEST, SolVES, ARIES, WaterWorld and Co$ting Nature

Model	Ecosystem service	Data Inputs	Outputs
InVEST - Integrated Valuation of Ecosystem Services and Tradeoffs For more details see: http://data.naturalcapitalproject.org/nightly-build/invest-users-guide/html/	**Crop Production**	1. Land Use and Land Cover map 2. Land cover to Crop table: able that maps a landcover ID to a crop name 3. Fertilization rate per crop: CSV table that contains crop names, and application rates for nitrogen, phosphate, and potassiun	Result table (CSV) with all the crops modeled in the run, the area covered, percentile or modeled production, observed production, and nutrient information for each model, Crop production rasters.
	Fisheries	1. Population parameters CSV file: age/stage names of the species in chronological order, subregions names, each unique pair of age/stage and subregion should contain a survival rate from natural mortality, exploitation fraction, larval dispersal, relative vulnerability to harvest for each class, maturity, duration, weight, fecundity 2. Recruitment parameters: initial number of recruits, recruitment function type, spawners by individuals or weight, alpha, beta, recurring number of recruits. 3. Migration parameters: migration matrix CSV Files: for each age/stage where migration occurs, there should be a single CSV within the migration director 4. Valuation parameters: fraction of harvest kept after processing, unit price	Population breakdown (number of individuals within each class in each subregion, for every time step), final harvest after equilibration, and the cumulative harvest across the entire area of interest per time step up to the equilibrated time step. 'Final Harvest by Subregion After XX Time Steps', shows the final harvest (by individuals or weight, depending on inputs) for each subregion, valuation of each subregion harvest (in the input currency). 'Time Step Breakdown', shows the cumulative harvest across all subregions for each time step before the model equilibrates and this will also include a column for valuation of the subregion harvest using the input currency.
	Seasonal Water Yield Model	1. Land Use and Land Cover map 2. Maps of monthly precipitation (mm) 3. Maps of monthly reference evapotranspiration (mm) 4. Digital elevation model 5. Shapefile delineating the boundary of the area(s) of interest, or watershed to be modeled 6. Table comprising for each LULC type: runoff Curve Number for each soil type, Monthly Kc values 7. Map of SCS soil hydrologic groups (A, B, C, or D), used in combination of the LULC map to compute the Curve Number map 8. Table with 12 values of rain events per month. A rain event is defined as >0.1mm 9. Threshold flow accumulation	Map of runoff Curve Numbers values, Map of quickflow QF values [mm], Map of local recharge L values [mm], Map of available local recharge , i.e. only positive L values [mm], Map of baseflow BB values [mm], the contribution of a pixel to slow release flow, Map of cumulative baseflow Bsumvalues [mm], the flow through a pixel, contributed by all upslope pixels, that is not evapotranspirated before it reaches the stream, Map of cumulative local recharge values [mm], the flow through a pixel, contributed by all upslope pixels, that is available for evapotranspiration to downslope pixels, Map of cumulative available local recharge values [mm], the available water to a pixel, contributed by all upslope pixels, that is available for evapotranspiration by this pixel, Annual average baseflow [mm], Map of the values of recharge (contribution, positive or negative, to the total recharge
	Climate Regulation (Carbon Storage and Sequestration)	1. Current Land Use and Land Cover map 2. Carbon pools for each LULC (Mg/ha) (carbon density in aboveground mass, in belowground mass, in soil and in dead mass) 3. Future land cover (optional) 4. Economic data (value of sequestered carbon, market discount rate, annual rate of change in the price of carbon)	Current carbon storage, carbon storage difference between current and future scenarios, economic value of sequestered carbon between current and future scenarios
	Nutrient Delivery Ratio model	1. Land Use and Land Cover map 2. Digital Elevation Model 3. Nutrient runoff proxy (representing the spatial variability in runoff potential, i.e. the capacity to transport nutrient downstream) 4. Biophysical table (a .csv table of land use/land cover (LULC) classes, containing data on water quality coefficients: nutrient loading for each land use, nutrient retention capacity, the distance after which it is assumed that a patch of LULC retains nutrient at its maximum capacity, proportion of dissolved nutrients over the total amount of nutrients) 5. Subsurface retention efficiency (maximum nutrient retention efficiency that can be reached through subsurface flow) 6. The distance (traveled subsurface and downslope) after which it is assumed that soil retains nutrient at its maximum capacity 7. Threshold flow accumulation value (integer value defining the number of upstream pixels that must flow into a pixel before it's considered part of a stream) 9. Borselli k parameter	kg.yr−1kg.yr−1: total nutrient loads (sources) in the watershed, i.e. the sum of the nutrient contribution from all LULC without filtering from the landscape per watershed, kg.yr−1: total nutrient export from the watershed
	Sediment Delivery Ratio model	1. Land Use and Land Cover map 2. Digital Elevation Model 3. Rainfall erosivity index 4. Soil erodibility 5. Watersheds 6. Biophysical table (for each land use type assign cover management factor and support practice factor) 7. Threshold flow accumulation 8. Maximum theoretical Sediment Delivery Ratio	Total potential soil loss per pixel +A2:D37in the original land cover, Total potential soil loss per pixel in the original land cover, Total potential soil loss per pixel in the original land cover calculated from the USLE equation, Map of sediment retention with reference to a bare watershed, ndex of sediment retention, used to identified areas contributing more to retention with reference to a bare watershed, Table containing total amount of sediment exported to the stream per watershed, Total amount of potential soil loss in each watershed calculated by the USLE equation and Difference in the amount of sediment delivered by the current watershed and a hypothetical watershed where all land use types have been cleared to bare soil.

InVEST - Integrated Valuation of Ecosystem Services and Tradeoffs For more details see: http://data.naturalcapitalproject.org/nightly-build/invest-users-guide/html/	**Crop Pollination**	1. Land Use and Land Cover map 2. Table of pollinator species or guilds: species, nesting suitability index, foraging activity, average distance each species or guild travels to forage on flowers, relative abundance 3. Table of biophysical land cover attributes: LULC code, nesting availability index, floral resources index 4. Farm polygon: with a table including crop type, half saturation coefficient, season, floral resources available at the farm in specific season, nesting substrate suitability, proportion of crop dependent on pollinators, proportion of pollination required on the farm provided by managed pollinators	Wild pollinator yield index, total pollinator yield index, pollinator abundance per species per season, average pollinator abundance on the farm for the active season, total yield index, including wild and managed pollinators and pollinator independent yield per farm, index of potential pollination dependent yield attributable to wild pollinators and index of the total yield attributable to wild pollinators.
	Unobstructed Views:Scenic Quality Provision	1. Polygon of the Area of interest 2. Point feature layer impacting the scenic quality 3. Digital elevation model 4. Refractivity coefficient 5. Population raster	Raster layerthat classifies the visual quality within the Area of Interest, polygon feature layer contains a field called "AreaVShed" which expresses the percentage of area within each polygon where at least one point contributing to negative scenic quality is visible as compared to the total area of that polygon, table and indicates the approximate number of people within the AOI that are 1) unaffected (no sites contributing to negative scenic quality are visible) and 2) affected (one or more sites visible).
	Visitation: Recreation and Tourism	1. Area of Interest 2. Start year and end year	Average photo-user-days per year, the average photo-user-days for each month,table contains the total photo-user-days counted in each cell for each month of the chosen date range.
	Habitat Quality	1. Current Land Use and Land Cover map 2. Future LULC map (optional) 3. Threats data (CSV table with name of the specific threat, maximum distance over which each threat affects habitat quality (measured in km), impact of each threat on habitat quality, relative to other threats, type of decay over space for the threat.) 4. Sources of threat (raster file of the distribution and intensity of each individual threat) 5. Habitat types and relative sensitivity of habitat types to each threat (according to LULC) 6. Half-saturation constant	Relative level of habitat degradation on the current landscape, Habitat quality on the current landscape.
SolVES - Social Values for Ecosystem Services For more details see: https://pubs.usgs.gov/of/2015/1008/pdf/ofr2015-1008.pdf	**Biodiversity, recreation, aesthetics, spiritual experience, information for cognitive development**	1. Environmental data (raster): LULC, slope, elevation, distance to roads, distance to water, physical characteristics. 2. Survey data*: specifically formatted value and preference survey response data including survey ID, use_attitude, attitude_types, value_allocation, survey_points. *based on Public Values and Preferences regarding Forest Uses and Management on the Pike and San Isabel National Forests, Colorado (Survey sections 2, 4A, 4B). 3. Other spatial data: Polygon of the Study Area	Value Index Map and Landscape Metrics, Predicted Value Index Map and Landscape Metrics
ARIES - Artificial Intelligence for Ecosystem Services (all data are spatial) For more details see: https://unstats.un.org/unsd/envaccounting/seeaRev/meeting2013/EG13-BG-7.pdf	**Carbon sequestration and storage**	1. Carbon source models: average annual actual evapotranspiraiton, carbon sequestration, forest successional stage, LULC, mean annual precipation, percent tree canopy cover, soil C:N ratio, vegetation type 2. Carbon sink models (potential stored carbon release): average annual actual evapotranspiration, deforestation risk, fire frequency, forest successional stage, LULC, mean annual precipitation, percent tree canopy cover, population density, slope, soil C:N ratio, soil carbon storage, soil oxygen conditions, soil pH, vegetation carbon storage, vegetation type, hardwood:softwood ratio 3. Carbon use models (anthropogenic carbon emissions): GHG emissions, per capita emissions, population density	ton C absorbed/yr tonnes stored carbon release/yr anthropogenic greenhouse gas emissions (tonnes C/yr)
	Aesthetic viewsheds and proximity	1. Aesthetic proximity source models: area, beach, urban areas, desert scrub, emergent wetland, farmland, fire threat, forests, grassland, lakefront, park, riparian and wetland quality, riverfront, woody wetland, water quality. All spatial data. 2. Aesthetic proximity sink models: highways 3. Aesthetic proximity use models: housing values, presence of housing, urban proximity (population density) 4. Aesthetic viewshed source models: lake, mountain, ocean, scenic vegetation. All spatial data. 5. Aesthetic viweshed sink models: clearcuts, comercial industrial transportation, developed land, highways, mines, transmission lines 6. Aesthetic viewshed models: housing values, presence of housing, scenic highways, view use	Map of sources of high quality open space or visually desirable views Maps of sinks that degrade high quality open space or visually desirable views Maps of users of open space or viewsheds (relative rankings)
	Flood regulation	1. Flood regulation source model: annual precipitaiton 2. Flood regulation sink models: average annual actual evapotranspiration, average annual runoff, average annual soil infiltration, detention basins, dam storage, hydrologic soils group, impervious surface cover, mean days of precipitation per year, slope, successional stage, tree canopy cover, vegetation height, vegetation type 3. Flood regulation use model: farmland, floodplain extents, highways, railways 4. Flood flow models: dams, elevation, floodplain extents, hydrography (stream network), levees	Maps of cources of precipitation (that can cause flood) (mm/yr) Maps of sinks that absorb, detain, or promote infiltration of floodwater (mm/yr) Maps of beneficiaries locations that may receive flood mitigation services
	Subsistence fisheries (marine and costal fisheries)	1. Subsistence fishery source models: fish species relative abundance 2. Subsistence fishery use models: distance to coas, population density, poverty 3. Subsistence fishery flow models: paths	Map of the quantity of fish supplied or demanded (relative abundance maps, kg of fish biomass) Maps of the demand for fish from subsistence users Maps of the move of a given quantity of fish (in kg) from the ocean to areas of demand along roads or paths

ARIES - Artificial Intelligence for Ecosystem Services (all data are spatial) For more details see: https://unstats.un.org/unsd/envaccounting/seeaRev/meeting2013/EG13-BG-7.pdf	**Sediment Regulation**	1. Sediment source models: average annual precipitation, average annual runoff, avverage annual soil loss (RUSLE), hygrologic soils group, RUSLE factors, slope, slope stability, soil texture, successional stage, tree canopy cover, tropical storm probability, vegetation type 2. Sediment regulation sink models: floodplain tree canopy cover, floodplain width, reservoirs, stream gradient 3. Sediment regulation use models: Farmland, floodplains, reservoirs 4. Sediment flow models: dams, elevation, floodplain extents, hygrography (stream networks), levees	Maps of sources of waterborne sediments (tons) Maps of sink regions where sediment deposition occurs (annual sedimetn sink, tons of sedimets/yr) Maps of user who either value or are harmed by the delivery of sediment or the presence of excessively turbid waterways (map the locations of reservoirs, drinking water intakes, and navigation infrastructure (where high turbidity or excess sedimentation are undesirable), floodplain farmers (where sedimentation may be beneficial or undesirable, using a simple overlay of floodplains and farmland), or erosion-prone farmers
	Water Supply	1. Water supply source models: precipitation, snowmelt, soil infiltration, springs 2. Water supply sink models: actual evapotranspiration, annual maximun temperature, hydrologic soils group, hydrography, impervious surface cover, mountainfront recharge zones, runoff, slope, soil infiltration, springs, tree canopy cover, vegetation type 3. Water supply use models: surface diversions, water extraction amounts and user types, well capacity, well depth, well locations, well user type 4. Water supply flow models: elevation, hydrography (stream networks)	Total annual surface water source (mm3/yr) Total surface water sink (mm3/yr): annual quantity of water transitioning between surface and groundwater, and vice versa. Annual quantity of water used by beneficiaries in each location (mm3/yr) Map surface water flow directions
	Recreation	1. Recreation source models: amphibian, bird, mammal, pertile species richness; elevation. Habitat for game species, hidrography, lakes and ponds, public lands, rare and charismatic bird habitat presence, riparian condition class, springs 2. Recreation sink models: developed land, energy infrastructure, transportation infrastructure 3. Recreation use models: scenic viewpoints, population density 4. Recreation flow models: road speed limits and travel capacity, trails	Map sources of recreational value (areas capable of providing the natural setting needed for a particular activity) (abstract units 0-100) Map sinks of recreational value (landscape features that reduce those source values, if applicable) (abstract units 0-100) Map the users of a particular recreation area for a given activity
WaterWorld For more details see: http://www.policysupport.org/waterworld	**Water-related ecosystem services**	All data required for the functioning of the model is already avaiable (provided globally). Nevertherless, own data bases can also be used.	**Spatial Resoultion: 1ha ó 1km2** **Annual:** Total annual actual evapo-transpiration (mm/yr), Per capita water availability (Mm^3/person), Annual total water balance (mm/yr), Annual total soil deposition (mm/yr), Total fog deposition (mm/yr,) Annual total gross soil erosion (mm/yr), Fog inputs as a percentage of water balance (%), Fog inputs as a percentage of total precipitation, Total annual fog runoff (m^3), Total annual fog runoff (mm/yr), Total fog inputs (mm/yr), Annual total gross hillslope soil erosion (mm/yr), Annual total hillslope net soil erosion (mm/yr), Total annual hillslope runoff (m^3), Total fog impaction (mm/yr), Mean percentage of water may be polluted (%), Annual total net soil erosion (mm/yr), Annual % of runoff generated by fog (%), Runoff ratio by subcatchment (fraction), Total annual runoff (m^3/s), Total annual runoff (m^3), Total annual runoff (mm), Total annual potential evapo-transpiration (mm/yr), Total wind-corrected rainfall (mm/yr), Annual total soil transportation (mm/yr), Water storage capacity (mm), Mean annual terrain corrected wind speed (m/s), Difference between rainfall and wind driven rainfall (mm/yr), Freq. of potentially condensing conditions (%), River network (dimensionless), Total annual rainfall (not wind corrected) (mm/yr), Mean annual wind exposure (topex scale). **Monthly:** Terrain-corrected wind direction (degrees from N), Actual evapo-transpiration (mm/hr), Water balance (mm/hr), Water storage (mm), River flow generated from fog inputs (mm/hr), Hillslope Runoff (mm/hr), Percentage of runoff derived from fog (%), Percent of water that may be polluted (%), Wind-corrected rainfall (mm/hr), Runoff (mm/hr), Snow Pack Water Equivalent (mm), Fog inputs as a % of total precipitation (%), Meltwater production (mm/hr), Mean terrain-corrected wind speed (m/s).
Co$ting Nature For more details see: http://www.policysupport.org/costingnature	**Biodiversity**	All data required for the functioning of the model is already avaiable (provided globally). Nevertherless, own data bases can also be used.	Relative biodiversity index of red-list species, Relative conservation priority index, Endemism richness of red-list species, Relative pressure index, Relative threat index, Species richness of red-list species
	Water purification		Clean water provided (Mm3/year), Per capita clean water provided (Mm3/person)
	Water supply		Relative untapped water provisioning services, Relative potential water provisioning services, Relative realised water provisioning services index
	Carbon		Net carbon sequestration (dry matter NPP t C/km^2/yr), Carbon stock (t C/km^2), Relative potential carbon value index
	Hazard mitigation		Relative socio-economic exposure to ES relevant hazards, Relative potential for ES relevant hazards, Relative potential hazard mitigation, Relative ES relevant risk (exposure x vulnerabilty), Relative socio-economic vulnerability to hazards, Relative realised hazard mitigation ecosystem services
	Nature-based tourism		Realised tourism magnitude (index), Relative untapped recreational value, Relative potential recreational value, Potential recreational magnitude (index)

Appendix D. Capacity Matrix

Experts should fill in this matrix.

Land use class	**Provisioning Services ∑**	Food	Water	Raw materials	Genetic resources	Medicinal resources	Ornamental resources	**Regulating Services ∑**	Climate regulation	Flood prevention	Regulation of water flows	Water purification	Erosion prevention	**Cultural Services ∑**	Aesthetic information	Recreation and tourism	Inspiration for culture, art and design	Spiritual experience	Information for cognitive development	**Habitat Services ∑**	Maintenance of biodiversity
Shrubland Savannah	**11**	2	0	3	2	2	2	**12**	3	3	2	1	3	**14**	4	3	2	2	3	**4**	4
River Influenced Vegetation	**13**	3	0	3	3	2	2	**17**	3	4	3	3	4	**13**	4	3	2	1	3	**4**	4
Natural Management Area	**13**	5	0	3	2	2	1	**7**	2	1	1	1	2	**13**	3	3	2	2	3	**3**	3
Forest Formation	**21**	4	0	5	4	4	4	**19**	5	3	3	3	5	**19**	5	4	3	3	4	**5**	5
Agriculture	**7**	5	0	1	1	0	0	**1**	1	0	0	0	0	**5**	1	1	0	0	3	**1**	1
Pasture Areas	**10**	5	0	1	2	1	1	**7**	2	1	1	1	2	**7**	2	2	0	0	3	**3**	3
Mining Influence	**6**	0	0	5	0	0	1	**0**	0	0	0	0	0	**5**	0	2	0	0	3	**0**	0
Urban Influence	**1**	1	0	0	0	0	0	**0**	0	0	0	0	0	**7**	1	3	0	0	3	**0**	0
Reforestation	**8**	1	0	4	1	1	1	**11**	3	2	2	2	2	**8**	3	2	0	0	3	**3**	3
Water	**17**	5	5	2	3	1	1	**15**	5	3	3	4	0	**23**	5	5	5	4	4	**5**	5

*All answers are based on the author's perception of the capacity of the Pantanal land uses to provide ecosystem services.

Scale for assessing capacities	
0	No relevant capacity
1	Low relevant capacity
2	Relevant capacity
3	Medium relevant capacity
4	High relevant capacity
5	Very high relevant capacity

Appendix E. List of questions to identify beneficiaries of ecosystem services.

- Who are the people who uses or enjoy ecosystem services?
- Which ecosystem services do they benefit from?
- Who is most dependent on the resources at stake? Is this a matter of livelihood or economic advantage?
- At what spatial scale are the beneficiaries present?
- Can different beneficiary groups be identified to take into account power imbalances or competing priorities?
- Who are the people or groups most knowledgeable about, and capable of dealing with, the resources at stake?
- Who are the people that could be negatively (or positively) impacted by changes in the provision of ecosystem services?
- Who holds positions of responsibility in relation to the management and use of the natural resources?

Taken and adapted from Golder, WWF-US, & Gawler, 2005; Schneider, 2014; Value of Nature to Canadians Study Taskforce, 2017.