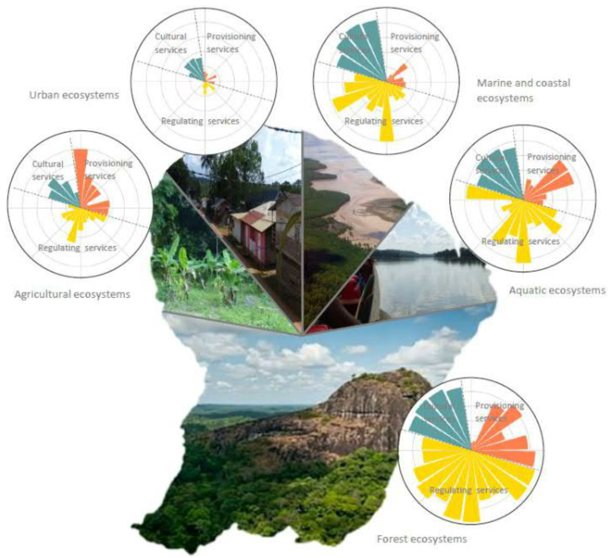
ECOSEO

Mapping and assessment of the capacity of ecosystems in French Guiana to supply ecosystem services



Study and report by Ina M. Sieber, Sylvie C. Campagne & Benjamin Burkhard

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May 2020

Work conducted within the project *"ECOSEO, Ecosystem Services Observatory of the Guiana Shield"*, funded by the Interregional Amazonian Cooperation Program of the European Regional Development Fund, the Office de l'Eau de Guyane and coordinated by the French Guiana office of WWF-France.

ECOSEO

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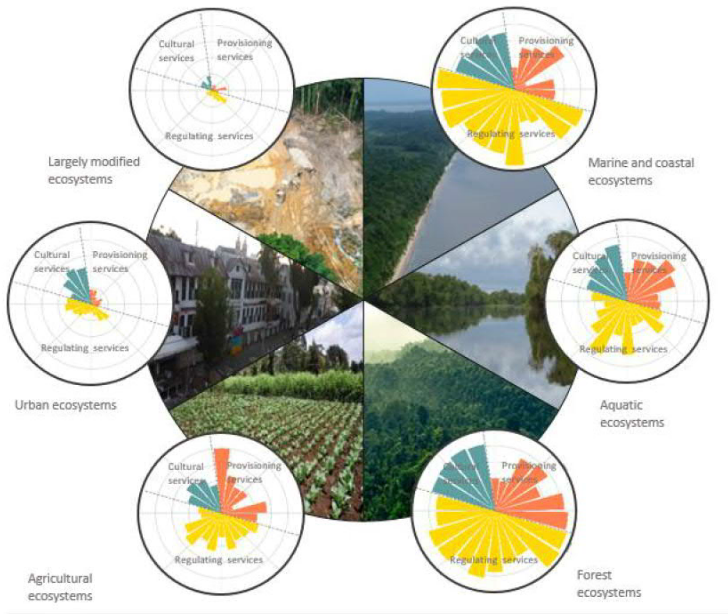

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Work conducted together with WWF Guianas, the Foundation for Forest Management and Production Control (SBB) and within the project *"ECOSEO, Ecosystem Services Observatory of the Guiana Shield"*, funded by the Interregional Amazonian Cooperation Program of the European Regional Development Fund, the Water agency of French Guiana and coordinated by the French Guiana office of WWF-France.

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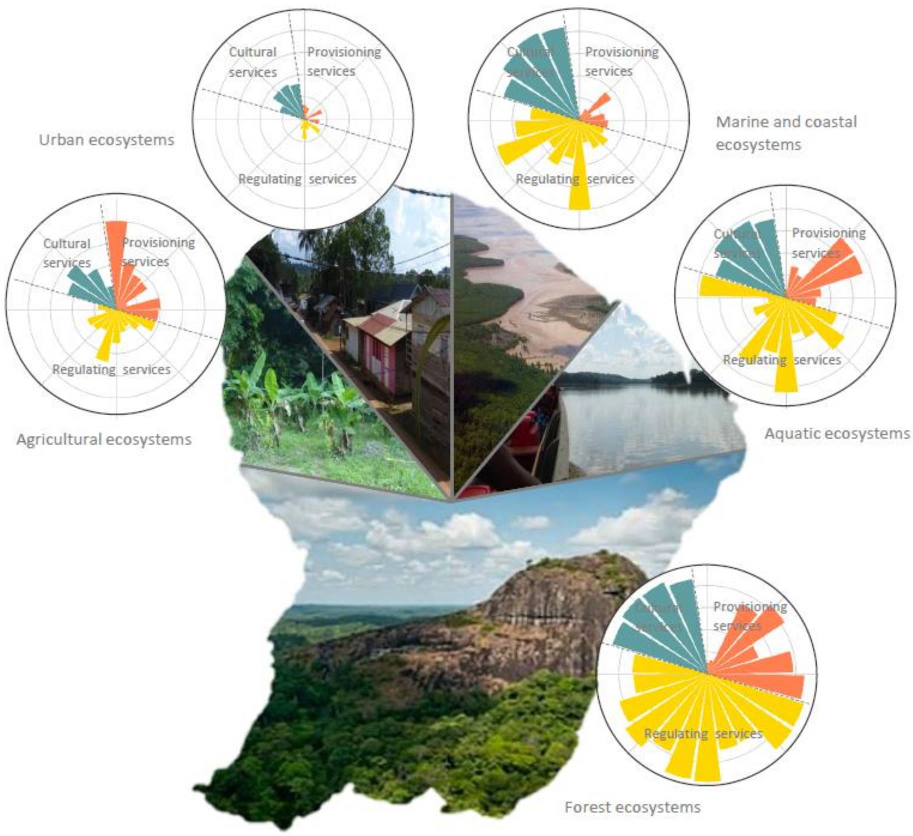

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List of Abbreviations

CBD	Convention on Biological Diversity
CICES	Common International Classification of Ecosystem Services
ECOSEO	Establishing an ecosystem services observatory in the Guianas
ENCA	Ecosystem Natural Capital Accounts
LUH	Gottfried Wilhelm Leibniz Universität Hannover
LULC	Land Use Land Cover
MAES	Mapping and Assessment of Ecosystems and their Services
NBSAPs	national biodiversity strategies and action plans
SBB	Stichting voor Bosbeheer en Bostoezicht
UNDP	United Nations Development Programme
WWF	World Wide Fund For Nature

1. Introduction

The ecosystem services concept has gained global attention, especially in the last two decades (Costanza et al., 2017). It describes the key role of nature and biodiversity in terms of direct and indirect contributions, such as food provision, timber and fuel, medicines derived from plants, clean water, flood control and climate regulative functions. Such ecosystem services are crucial for human well-being – thus humankind is strongly dependent on well-functioning ecosystems and natural capital. This, in turn, forms the basis for a constant flow of ecosystem services from nature to society. With ongoing degradation of the natural environment through land use intensification, deforestation, mining for natural resources or fragmentation of natural habitats, the safeguarding of ecosystem service flows to society is severely endangered – an effect that disproportionally affects poor and underprivileged parts of society (Braun & Gatzweiler, 2014; Kumar & Yashiro, 2014; Schreckenberg et al., 2018).

Ecosystem services have been integrated into many policies and frameworks to protect biodiversity at national and international scales. For example, the Strategic Plan 2011-2020 adopted by the Convention on Biological Diversity (CBD), including the *Aichi targets*, foresees that *"By 2050, biodiversity is valued, conserved, restored and wisely used, maintaining ecosystem services, sustaining a healthy planet and delivering benefits essential for all people"* (CBD 2010[1]). Within their targets, they specifically highlight the importance of protection of "*ecosystems* that provide essential *services*, including *services* related to water […]" (Target 14[2], Strategic Goal D).

In the Guiana Shield, Guyana, Suriname, Brazil as well as the French Overseas Territory, French Guiana have committed to implement the *Aichi targets* in their National Biodiversity Strategies and Action Plans (NBSAPs) (Ministry of Labour & Technical Development and Environment, 2013; Ministry of Natural Resources and the Environment, 2014). First studies on ecosystem services can be found on the local level (Ramirez-Gomez et al., 2016; Ramirez-Gomez et al., 2013). Also, first cross-cutting projects have been set up to jointly work towards better protection of natural resources, e.g. the Guiana Shield Initiative. However, assessing the NBSAPs reveals that there is still potential for the ecosystem services concept. Ecosystem services mapping and assessment are crucial first steps that should be the base for the development of policies and legal frameworks (Prip, 2018).

The implementation of the ecosystem services concept on territorial level requires a flexible framework, taking into account a broad (Burkhard et al., 2009) range of services as well as different spatio-temporal aspects of service supply. Often, qualification and quantification of many different ecosystem services over large geographic regions proves to be difficult. The identification of suitable indicators to measure ecosystem services is complex (Egoh et al., 2012; Müller et al., 2016), and requires a large amount of relevant data at different spatial and temporal scales. As alternative to such approaches, expert-based evaluation has proven to be a robust, reliable semi-quantitative method (Burkhard et al., 2009; Campagne et al., 2017; Jacobs et al., 2015). One method, that can be based on expert estimations of ecosystem services, is the so-called 'ecosystem service matrix approach' (Burkhard et al., 2009). The resulting ecosystem services capacity matrices link geospatial units (such as ecosystem types) and ecosystem service supply in form of lookup tables. Each cell in the matrix is filled with a score from 0 (no service provided) to 5 (overall maximum service provided), reflecting the

1 Key Elements of the Strategic Plan 2011-2020, including Aichi Biodiversity Targets
[2] https://www.cbd.int/sp/targets/

capacity of the respective geospatial unit to supply a certain ecosystem service. To fill the matrix, experts or stakeholders with territorial or national expertise related to ecosystems, their management or usage can be invited. Such a capacity matrix allows an efficient and integrative assessment of whole bundles of ecosystem services, including temporal trends at the landscape scale. The results of such expert-based evaluation of ecosystem services can easily be visualized in maps, when ecosystem service values are combined with spatial data using Geographic Information Systems (GIS). Ecosystem services maps offer possibilities to define ecosystem services hotspots or priority areas for land conservation or certain types of land use. Ecosystem services maps have the potential to become a key concept for sustainable development, land use planning and decision making (Maes et al., 2012).

Objectives of the study

The ECOSEO Project led by the French Guiana office of WWF France aims to promote tools allowing better consideration of ecosystem services and natural capital in decision making and environmental assessments for the Guiana Shield (Guyane, Suriname, French Guiana & Amapá in Brazil). It gathers partners from each territory and is funded by the European Union and the French Guiana water agency. As part of this observatory, the expertise of Leibniz Universität Hannover (LUH) was sought to assess ecosystem services and lead the implementation of a first assessment of ecosystem services in Suriname and French Guiana.

Ultimately, the goal is to provide a method to decision makers and environmental authorities in order to conduct the analysis of these services locally and to get a comprehensive understanding at the Maroni Basin scale in the future. Here we present the method and results of the assessment of ecosystem services provided within French Guiana, on the national and regional scale.

The assessment of the capacity of ecosystems in the Guianas to supply ecosystem services presented in this report was carried out with the approach of ecosystem services capacity matrices. This approach allows to take into account different types of ecosystems and services in a participatory approach integrating the knowledge of the actors of the territory on national level for both Suriname (Sieber et al. 2020, in progress) and French Guiana (this report). The objective hereby was twofold. First, the study aims to take an alternative, non-commodifying approach towards valuing nature. Through looking at ecosystems in a more holistic way, the assessment highlights the multiple goods and services that ecosystems provide, including non-marketable goods and services. Second, this study aims to present the potential of such an ecosystem services approach, including ecosystem services bundles and maps. These can serve as a management tool for policy and decision makers to safeguard sustainable development, **the well-being of local populations** and to provide strong additional arguments for nature conservation efforts.

1.1 Ecosystem services

The term "ecosystem service" was first used in 1981 and has become more and more common in scientific publications in the 1990s. With the publication of the Millennium Ecosystem Assessment (MEA 2005), it has gained momentum globally (Burkhard & Maes, 2017) . Since, it has been developed and adjusted to multiple contexts around the globe (Costanza et al., 2017). It presents a method to assess the state of ecosystems and natural capital, in the context that human well-being depends on the condition, the structure and the functions of ecosystems. Most commonly, ecosystem services are defined as “the benefits people obtain from ecosystems” (MEA, 2005, S. 40). This comprises the direct and indirect contributions of ecosystems to human well-being.

Within the concept of ecosystem services, ecosystem service supply and ecosystem service capacity can be distinguished. By definition, an ecosystem service can only be qualified as such, if there is a benefit to humans (Burkhard & Kroll, 2010). Ecosystem service supply is defined as the “full potential of ecological functions or biophysical elements in an ecosystem to provide a given ecosystem service” (Tallis et al., 2012, S. 977). To define the capacity of ecosystems to supply ecosystem services, we follow the definition by Villamagna et al. as “an ecosystem’s potential to deliver services based on biophysical and social properties and functions” (Villamagna et al., 2013).

To qualify and quantify ecosystem services, it is necessary to estimate the different ecosystems, their condition and the services they provide (Kienast et al., 2009) and their interrelations within complex social-ecological systems (MEA 2005). It is common to divide ecosystem services into three categories: ***Provisioning ecosystem services*** are the material, often “final” products obtained directly from ecosystems (e.g., food, fibres, timber). ***Regulating ecosystem services*** are mostly indirectly obtained, often intangible benefits through the regulation of ecosystem processes (e.g. climate regulation, carbon storage, natural hazard regulation, and water purification, pollination or pest control). ***Cultural ecosystem services*** are the rather intangible benefits of ecosystems, including recreational activities and (eco-)tourism, existence (of nature and species) values, landscape aesthetics or spiritual nature values.

There are different frameworks to assess and model ecosystem services. Figure 1 shows the conceptual framework for assessing ecosystem services developed by the EU Working Group Mapping and Assessment of Ecosystems and their Services (MAES[3]) (Maes et al., 2016). The concept highlights the flow of services from ecosystems to socio-economic systems and the resulting benefits for human well-being. Furthermore, it depicts the socio-economic systems as control system for the change of ecosystems. This framework is partly based on the ecosystem services “Cascade model” (Haines-Young & Potschin, 2018b) and has been customized to estimate ecosystem services of different ecosystems in context of the EU 2020 Biodiversity Strategy (Maes et al., 2016).

MAES is a core component of the EU Biodiversity Strategy to 2020. Within this Strategy to protect biodiversity and halt the loss of species and habitats, Action 5 of the Strategy’s 2nd Target foresees each EU Member State to map and assess the ecosystems and their services in their national territories, creating an EU-wide knowledge base (Burkhard et al., 2018). This is important for the advancement of biodiversity objectives, the creation of informed policies on, for instance, agriculture, water, climate and landscape planning. Furthermore, Action 5 aims at identify areas for ecosystem restoration and a baseline against which the goal of ‘no net loss of BD and ES’ can be evaluated.

[3] https://biodiversity.europa.eu/maes

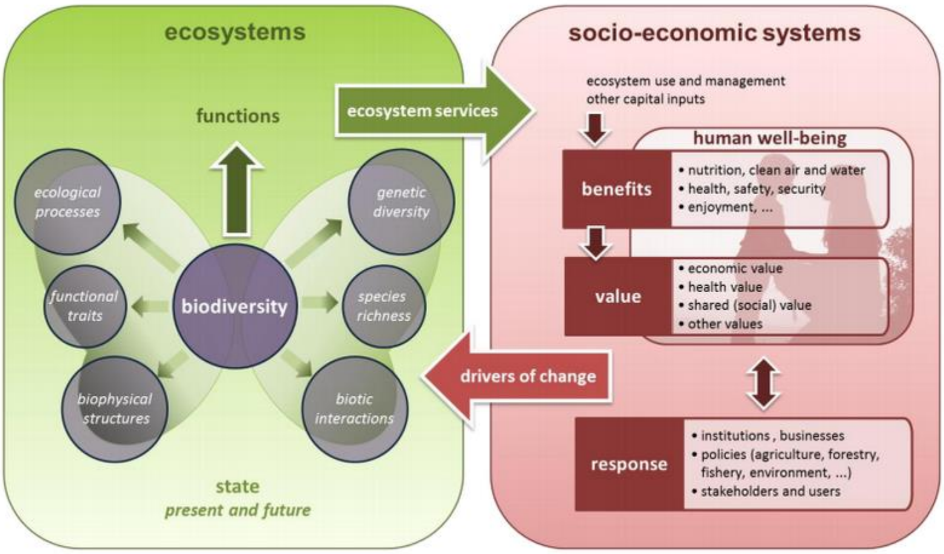


Figure 1: Conceptual framework for assessing ecosystem services (Maes et al. 2016)

1.2 Ecosystem services in the Guianas

The Guiana shield is renowned as one of the last remainders of intact primary forest. The Shield covers 270 million hectares, encompassing Guyana, Suriname, French Guiana, Venezuela and small parts of Colombia and northern Brazil. The UNDP declared it as eco-region of "regional and global significance" and home to a variety of ecosystems and "keystone species of biodiversity" (UNDP 2020[4]).

The Guiana Shield encompasses a coastal plain with half-submerged mangrove landscapes in the north. Littoral forests follow, with patches of savannahs and drowned open swamps. Thereafter, vast rainforest stretches down south, the canopy only broken by large Inselbergs and mountainous formations in the hilly hinterland.

Many of these ecosystems have been altered by human influence, especially in the littoral belt (Odonne et al., 2019). Here, many anthropogenic pressures threaten the condition of ecosystems. Urbanisation, intensification of agriculture and deforestation lead to habitat fragmentation. Resource mining – e.g. for gold depositions in the Greenstone Belt – together with the use of heavy metals, poses severe threats to rivers and aquatic ecosystems throughout the Guiana Shield.

Efforts to understand the links between ecosystems in the Guiana Shield and the services they provide have recently started and are growing. Forest ecosystems have been intensively studied. For example, aspects of forest tree composition and its relation to carbon storage (Guitet et al., 2015; Molto et al., 2014) and the contribution to global and local climate regulation have been assessed (Blanc et al., 2009). Similar tendency holds for mangrove ecosystems. For example, studies on the capacity to store carbon are present (Marchand, 2017). An overview of the importance of Guianese savannahs is given by Stier et al. (2020), touching upon the services they provide. Under the umbrella of the EU BEST programme[5], ecosystem services have been described on national level for French Guiana (Roger et

[4]https://www.gy.undp.org/content/guyana/en/home/operations/projects/environment_and_energy/project_sample2.html

[5] https://ec.europa.eu/environment/nature/biodiversity/best/funding/index_en.htm

al., 2016). To the best of our knowledge, however, there are no studies that take a holistic stance towards ecosystem services, such as mapping or assessing multiple services at the same time.

1.3 The ECOSEO Project

The natural capital of the Guiana Shield is still very rich compared to other parts of the world. However, there is an urgent need to recognize its value at local but also international level in order to guide policies towards sustainable development and prosperity for the next generations. The ECOSEO project "*Ecosystem Services Observatory of the Guiana Shield*" aims to set up a supranational platform with Guyana, Suriname, French Guiana, and the state of Amapá in Brazil for a first assessment of natural capital and ecosystem services in the region. The project is coordinated by WWF France & WWF Guianas and brings together the forestry and environmental state agencies of the region (GFC in Guyana, SBB in Suriname, ONF in French Guiana & SEMA in Amapá) and consultants and experts from ONF-International and Leibniz Universität Hannover. It is funded by the Interreg Amazonian Cooperation of the European Regional Development Fund and the Water Agency of French Guiana. This cooperation is based on the needs of stakeholders and decision-makers in the different territories in line with their commitment to EU and UN Conventions. The main objectives of the ECOSEO project are:

(i) to highlight and promote the need for considering ecosystems values in decision-making; and,

(ii) to build a transnational cooperation network (Figure 2).

The project takes an interdisciplinary stance on ecosystems and nature. Through applying the Ecosystem Natural Capital Accounts (ENCA) method (Weber, 2014) and the ecosystem services framework[6], different methods are employed to showcase the value and importance of ecosystem services.

Figure 2: The ECOSEO INTERREG Project with its main partners

The ECOSEO project foresees a first ecosystem services assessment for French Guiana, as part of the Guianas. This report will outline the outcomes of the expert-based ecosystem services assessment in French Guiana. The aim of this assessment is twofold. First, it will create an overview of relevant ecosystems and a first estimation of capacity of ecosystems to supply ecosystem services within the

[6] https://ec.europa.eu/environment/nature/knowledge/ecosystem_assessment/index_en.htm

territory. Second, ecosystem services mapping and assessment methods developed and applied in mainland Europe within the MAES initiative and related projects will be tested on their suitability for application and adaptation based on the specificities in the Guianas.

2. Methods and materials

In this section, the methods and data for the ecosystem services assessment will be described. The concept of capacity matrices as tool to analyse ecosystem services, the selection of the ecosystem types for this assessment as well as the ecosystem services are described. Further, the section draws upon the participatory stakeholder workshop as core component of this study.

2.1 Capacity matrices as tool to assess ecosystem services

This study applied the ecosystem services capacity matrix method based on the knowledge from a selected expert panel, including specialists of the region and its specific ecosystems. Put simply, a capacity matrix is a comprehensive and flexible method in the form of a lookup table combining ecosystem types and ecosystem services (Burkhard et al., 2009). At the base, appropriate geospatial units, e.g. Land Use/Land Cover (LULC) data can be used to delineate the ecosystem types. These are linked to ecosystem services (Figure 3).

One approach to conduct such a matrix assessment is via expert knowledge. Expert estimations deliver a good overview by integrating all kind of different sources of knowledge and can be a strong capacity building tool at the same time. As all expert-based assessments, the scoring values strongly depend on the experience, knowledge as well as objectivity of the evaluator (Burkhard et al., 2012).

At the intersections in the matrix table, the supply of ecosystem services within the particular geospatial units (e.g. LULC) can be assessed on a scale from 0 (no or very weak capacity) to 5 (very strong/maximum capacity). The normalization to such a relative scale from 0 – 5 allows to compare different ecosystem services (that are usually assessed by different indicators and units). Such an approach is well suited to express values from different domains, including biophysical, socio-cultural non-monetary as well as monetary values of multiple different ecosystem services.

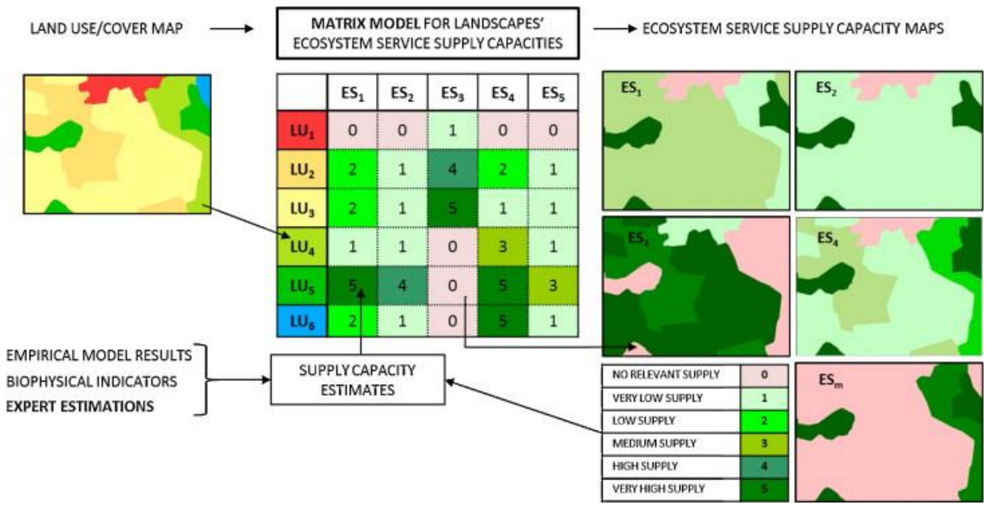


Figure 3: Schematic representation of the Matrix method (after Burkhard et al. 2009, in Jacobs et al. 2015)

This approach has been introduced in 2009 (Burkhard et al., 2009). Since then, numerous studies have applied and developed it (Jacobs et al., 2015). The ecosystem services matrix method found application in various contexts and on different scales. Examples can be found in different countries, e.g. Germany (Burkhard et al., 2012), Bulgaria (Nedkov & Burkhard, 2012), Bangladesh (Sohel et al., 2015) or China (Liu et al., 2012). Also, applications took place on different spatial scales, for example on local and regional scales (Bicking et al., 2018; Campagne & Roche, 2019), on watershed level (Boyanova et al., 2014), but also on supranational level, e.g. across the European Union (Stoll et al., 2015) or in Antarctica (Neumann et al., 2019).

As major limitations of the method, lacking methodological transparency, difficulties to reproduce results and lacking uncertainty (indicators) have been mentioned (Hou et al., 2013). Possibilities to address these limitations are proposed by Campagne et al. (2017).

2.2 The ecosystem services matrix approach

The method used for this ecosystem services assessment follows a framework identified by Campagne and Roche (2018). Their approach towards the ecosystem services matrix method contains 7 steps (Figure 4):

1) *Defining the goal of the assessment, and with key stakeholders, definition of the Ecosystem services and ecosystem type lists for the matrix, the experts' panel and the scoring.* For this study, the goals and lists have been defined with the ECOSEO partners: WWF France, WWF Guianas, SBB and regional experts as presented in Chapter 2.3.

2) *A participatory workshop is organised with all experts to get a common understanding of the study and the scoring process.* The workshop was held on 2nd of October 2019 in Cayenne – detailed in Chapter 2.4.

3) *The initial matrix given to the experts can be pre-filled or empty.*

4) *The fill-in process can be in consensus between the experts or individually.* For this workshop, we decided to start with an empty initial matrix, with individual fill in by each expert. This approach helps to avoid biases based on prefilled scores.

5) *Expert score compilation, analyses and creation of the final matrix.* The analysis of the filled-in matrices, including a description of statistical operations, can be found in Chapter 2.5**.**

6) *Reliability and validation process.* The "draft" final matrix was circulated to all workshop participants for validation and feedback (December 2019), with a month of reviewing time.

7) *Creation of the outputs.* Thereafter, final statistical analyses were run, and the final ecosystem services bundles and ecosystem services maps were created (7) using geographic information systems (ArcMap 10.6). The results are presented in Chapters 3 and 4.

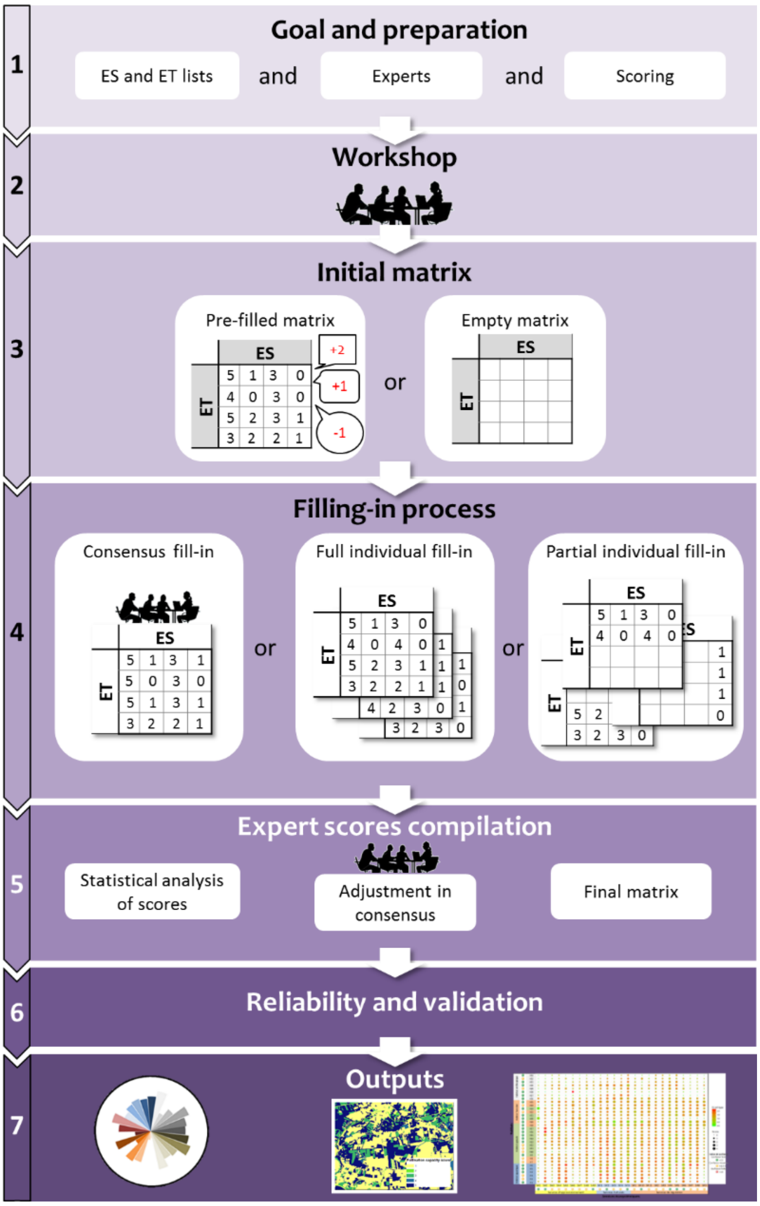


Figure 4: Schematic representation of the ecosystem services assessment following the matrix method (Campagne and Roche 2018)

2.3 Compilation of the initial matrix

The composition of the initial matrix consists out of two major steps: the identification of ecosystem types and the selection of relevant ecosystem services for the two territories, Suriname and French Guiana. The selection processes will be explained in the following.

2.3.1 Selection of ecosystem types

To map ecosystem services requires spatial information on the extent and location of ecosystems. For French Guiana, spatial data on LULC has been obtained from the Geoguyane Portal[7], the regional geographic database. For the littoral belt, CORINE LULC[8] data was present for the year 2018. CORINE

[7] https://www.geoguyane.fr/accueil

[8] https://land.copernicus.eu/pan-european/corine-land-cover/clc2018

land cover data has been developed for the European region, but is now available for 39 countries. This LULC dataset is based on Sentinel-2 and Landsat-8 imagery for gap filling on a scale of 1:100 000 and consists out of 44 land cover classes. Minimum Mapping Unit (MMU) is 25ha for areal phenomena and 100m minimum width for linear phenomena[9]. This was harmonized with the works of WWF, ONF and PAG, who also provide data on national scale. Their geospatial dataset "Synthèse occupation du sol 2015[10]" consists out of coastal information from 2015 (ONF), Land use data for the National Park Area from 2015 (PAG) and information on impacts of gold mining activities 2015 (WWF) on a scale of 1:5000.

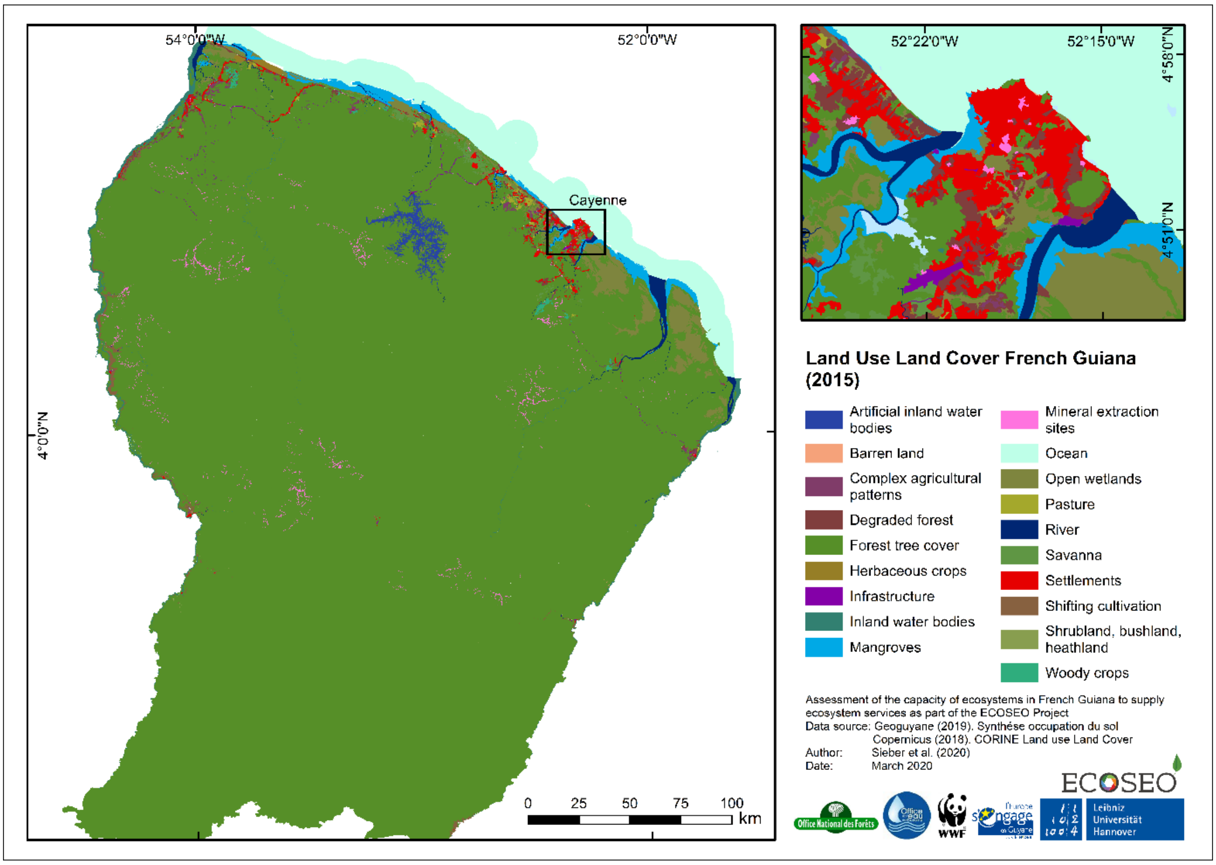


Figure 5: Map of Land use Land cover in French Guiana based on year 2015 (adjusted from Joubert, 2017)

As can be seen in Figure 5, the majority (96,8%) of French Guianas surface is covered by forest tree cover, of which 91.6% is primary forest (FAO 2015), with large protected areas in the hinterland, e.g. the Parc Amazonien de Guyane[11]. In the littoral belt, beaches, mangroves, swamps, littoral forest and savannahs are located. Here, settlements and big cities have formed, including agricultural lands. The capital of Cayenne is the largest settlement (cut-out Figure 5), with more than 60.000 inhabitants. Whilst the densely forested areas are mainly deserted, the border regions with Suriname, the Maroni River basin in the West, and the border region with Brazil, the Oyapock River in the East are also inhabited. The city of St-Georges-de-l'Oyapock and the highway to Cayenne are visible. In many of the

[9] https://land.copernicus.eu/pan-european/corine-land-cover
[10] https://www.geoguyane.fr/geonetwork/srv/fre/catalog.search#/metadata/3d681d4f-b8bd-48b2-80d2-04a215a8a099
[11] http://www.parc-amazonien-guyane.fr/fr

inhabited, remote forested regions, rivers represent the only transportation option connecting the coast with the forested hinterland.

Artificial planted forests have been cultivated in the territory, e.g. for paper production. Even though these forest are still listed to have a size of 700-1000 ha, these forest are not actively managed anymore (FAO, 2010). Nonetheless, we decided to include them in this evaluation, as this kind of forest is clearly distinguishable from natural forests, and therefore, expected to differ in their capacities to provide ecosystem services.

The LULC for French Guiana as described above and a similar LULC for Suriname (Sieber et al., 2020) have been harmonized as basis for the delineation of ecosystems throughout the Guianas (Annex 2). As there is a vast amount of sub-ecosystems, but limited information on their specific locations, we grouped and clustered this information based on major ecosystem clusters and ecosystem types (Table 1). Ecosystem cluster in this assessment refers to the broader groups of ecosystem communities resembling each other. These ecosystem communities are included as ecosystem types.

Table 1: Ecosystem clusters and ecosystem types assessed for French Guiana

Ecosystem cluster	Code	Ecosystem type
Marine and littoral ecosystems	H1	Ocean
	H2	Beaches and dunes
	H3	Mangroves
Aquatic ecosystems	H4	Rivers and creeks
	H5.1	Lakes
	H5.2	Inland water bodies - semi natural
	H6	Open swamp
Forest ecosystems	H7	Open savannah
	H8	Inselbergs
	H9.1	Littoral forest
	H9.2	Continental forest
	H9.3	Inundated forest
	H10	Planted forest
Agricultural ecosystems	H11	Small scale agriculture
	H12	Large scale agriculture
	H13	Grasslands
	H14	Shifting cultivation (*Abattis*)
Urban ecosystems	H15	Bare soil
	H16.1	Urban area
	H16.2	Industrial areas
	H17	Infrastructure
Largely modified ecosystems	H18.1	Mineral extraction sites – official
	H18.2	Mineral extraction sites -- inofficial

Such generalisation inevitably reduces the complexity of the natural mosaic landscape in the Guiana Shield to major ecosystem types. However, this reduced complexity and the resulting manageable number of geospatial units (ecosystem types) for the matrix allowed to start with collection of data for first ecosystem services maps. Based on the available data, the list of ecosystem clusters in the matrix has been compiled (see Table 1).

Within this list of ecosystem types for the assessment, the different ecosystem types have been coded (H1 – H18). Some codes refer to subtypes, e.g. H5.1 and 5.2 – lakes and semi natural water bodies. This is based on the fact that the geodata does not distinguish these LULC classes. The selected ecosystem types are shown in Table 1. This list includes Marine and littoral ecosystems (Ocean, Beaches, Mangroves), Aquatic ecosystems (Rivers and creeks, Lakes, Inland water bodies –semi natural, and Open swamp). In the category of Forest ecosystems, we clustered Open savannah, Inselbergs, Forest tree cover and Planted forest. In terms of Agricultural ecosystems, Small and Large scale agriculture can be distinguished as well as Grasslands used as pasture and Shifting cultivation (*Abattis*). Urban ecosystems comprise Bare soil, Urban areas, Infrastructure and Mineral extraction sites. Based on this data, the ecosystem classes have been defined (Table 1).

2.3.2 Selection of ecosystem services

The list of ecosystem services has been compiled together with WWF, Office de L'Eau and regional experts from both French Guiana and Suriname (Table 2, more detailed in Annex 3). A initial list was proposed by LUH based on an intensive literature review (Sieber et al., 2018) and inspired by the work conducted by DREAL in French mainland (Campagne & Roche, 2019). The selection of ecosystem services for this list was complied with the Common International Classification of Ecosystem Services (CICES 4.3). Ecosystem services from different CICES sections, thus the three main categories of provisioning, regulating and cultural services were selected. Within each section, the services can be clustered into Divisions and Groups, with increasing level of detail (Haines-Young & Potschin, 2013). In accordance to the updated CICES 5.1 classification (Haines-Young & Potschin-Young, 2018), this assessment only considered biotic ecosystem services, hence services that depend on living systems. Even though many physical processes (e.g. salt, crude oil, minerals) of natural system are of importance to people, this assessment aims to highlight the existential contribution of ecosystems and biodiversity to human well-being.

To adapt the ecosystem services to the Guiana Shield ecosystems, several meetings with Office de L'Eau and a five day field mission to the Maroni River Basin took place between June and October 2019 with WWF Guyane (Figure 6 & 7). During this week, interviews with different stakeholders in the area of Maripasoula and Papaichton took place.

Figure 6: Example for SA6 "Materials and fibres", wood provided by forest ecosystems in the lower Maroni river basin used for traditional, cultural ornamental purposes (© IM Sieber 2019)

Figure 7: Example of SA4 "Wild animals and their outputs" for as biomass for nutrition, as well as cultural notions of traditional fishing activities on the upper Maroni River (© IM Sieber 2019)

Overall, 22 ecosystem services have been assessed (Table 2): the workshop assessed seven provisioning services, including biomass for food consumption (SA1, SA2), biomass for multiple purposes, including wild foods (SA3, SA4), water for drinking purposes (SA5) and raw materials (SA6, SA7). Regulating services comprise 11 services that can be divided into services maintaining biological, physical and chemical conditions (SR1- SR8) and services related to mediating mass flows, contributing to risk reduction (SR9 – SR11). The four cultural services for this assessment consist out of three representational services, (SC1-SC3), that have a highly subjective notion and include aspects of cultural identity. The forth cultural service in this assessment is rather objective, and refers to the actual use of landscapes for recreational activities including (eco-) tourism (SC4). A full delineation including definitions can be found in the Annex 3.

Table 2: List of ecosystem services assessed in French Guiana

Sec-tion	Division	Group	Code	Sec-tion
Provisioning Services	Nutrition	Biomass for food consumption	Cultivated crops / food	SA1
			Reared animals and their outputs	SA2
		Biomass	Wild plants, algae and their outputs	SA3
			Wild animals and their outputs	SA4
		Water	Freshwater supply for drinking purposes	SA5
	Materials	Raw materials	Materials and fibres	SA6
			Plants and resources for medical use	SA7
Regulating Services	Maintaining biological, physical and chemical conditions		Carbon Sequestration	SR1
			Global and local climate regulation	SR2
			Disease control	SR3
			Pest control	SR4
		Maintaining nursery populations and habitats	Maintaining nursery populations and habitats	SR5
			Pollination and seed dispersal	SR6
			Hydrological cycle and water quality and flow maintenance	SR7
			Maintaining soil quality	SR8
	Mediation of mass flows - risk reduction		Mass stabilisation and control of erosion rates	SR9
			Storm protection	SR10
			Flood protection	SR11
Cultural Services	REPRESENTA-TIONS-subjective		Emblematic or symbolic	SC1
			Heritage (past and future) and existence	SC2
			Aesthetic	SC3
	USE-objective		Recreational activities including (eco-) tourism	SC4

2.3.3 The ecosystem services matrix for French Guiana

The ecosystem services matrix consisted out of 22 ecosystem services and 23 ecosystem types, as previously described, resulting in 506 scores in total. The same ecosystem codes (H1- H18.2) and ecosystem services abbreviations (SA, SR, SC) have been used in this report and in the study in Suriname (Sieber et al. 2020) for comparative purposes.

For each cell in the matrix, the score ranged between 0 (no to very weak capacity) and 5 (very strong/maximum capacity). In addition, a confidence index allowed the experts to indicate their individual level of comfort with the given scores from 1 (weak confidence) to 3 (strong confidence). This score applied to ecosystems as well as ecosystem services. The overall confidence scores per ecosystem and per services where then calculated using an arithmetic mean confidence index of all experts.

2.4 Data collection

Data collection for this study was based on a participatory expert-based assessment in October 2019. In addition, a field trip to the Maroni River Basin took place.

2.4.1 Field trip to the Maroni

During the preparation phase of the ecosystem services assessment, a 5 day field trip to the Maroni River basin took place in September 2019.

The Maroni (or Marowijne) river marks the natural border between Suriname and French Guiana (Figure 8). It has a length of 610 kilometres and a River Basin area of 65.000 km². 95 % of the watershed are covered by tropical rainforest. Human settlements can be found on both sides of the river (Figure 8), with official borders largely ignored. For most of these settlements, the Maroni River is the only way of transportation, connecting the coast and the forested inland. The vast majority of inhabitants strongly rely on the ecosystems and the services they provide.

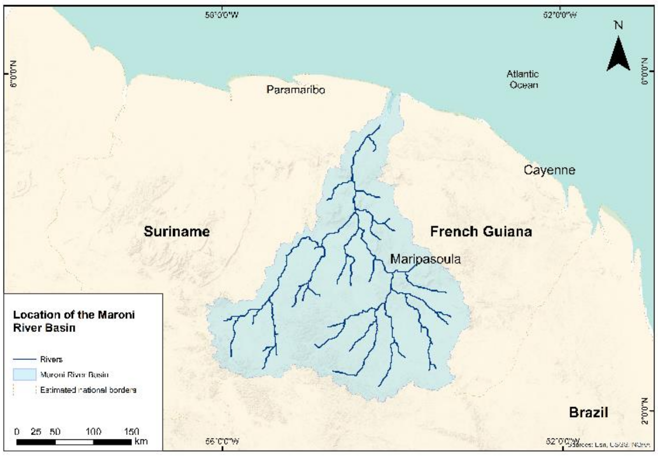


Figure 8: Location of the Maroni River Basin between Suriname and French Guiana.

The objective of this 5 day field trip was to learn about the indigenous population and their relation to ecosystems and hence, the ecosystem services that are provided and actively used within the Maroni River Basin. Special attention was put on potential changes in ecosystem service supply due to land use changes and intensification. During this period, 18 people were interviewed in 13 interviews in the area between Maripasoula and Papaichton/Abattis Cottica. Three transect walks took place in the abbatis, as well as informal transects through the villages (Figure 9).

Figure 9: traditional Aluku housing in the upper Maroni River Basin (© C. Villien, 2019)

The interviews took between 45 minutes and 1.5 hours. Interviewees spoke French, English and Aluku. For the latter, a translator was present. Topics discussed during the fieldtrip where related to the increase in droughts in the river and navigation problems with the pirogue. Also, interviewees mentioned the effects of drought on their *abattis* and resulting problems to cultivate crops and food. A deteriorating quality of river water was mentioned, and hence reduced supply of wild animals from the river. Elaborating the findings of the work would go beyond of the scope of this report, but will follow shortly (Sieber, Villien et al., in progress).

2.4.2 Expert workshop in October 2019

The participatory expert workshop took place on October 2nd 2019 at the premises of Guyane Development Innovation (GDI, Campus Universitaire Guyanais de Troubiran, Cayenne, French Guiana). Dr. Sylvie Campagne, Ina Sieber from LUH and Clement Villlien from WWF Guyane moderated and guided through the day (Figure 10).

Figure 10: Impressions from the expert workshop in Cayenne on October 2nd 2019 (© IM Sieber)

The workshop was scheduled from 9:30 a.m. to 13 a.m. The first part was devoted to presentations on the ecosystem services concept and related work of ECOSEO and WWF in the Guiana Shield. Impressions from other related EU projects where shared, such as EU MOVE project[12] (Mapping and assessing the state of ecosystems and their services in the Outermost Regions and Overseas Countries and Territories: Establishing links and pooling resources). The introduction of the principles of expert based assessments followed, including the list of ecosystems and the list of ecosystem services. The agenda can be found in Box 1. During the second part of the workshop, the experts had to fill in their

[12] https://moveproject.eu/

ecosystem services matrices individually, discuss questions, problems and remarks on the applicability of the method (Figure 10).
Discussion took place for instance on the anthropocentric notion of the ecosystem services concept. The ecosystem services concept with its "strong Eurocentric notion" (participant's quotation) concept was criticised as being ill-equipped to capture local and indigenous perceptions towards ecosystems and their importance for everyday life in French Guiana. Also, participants highlighted the importance of local and indigenous knowledge in the assessment of ecosystem services. The use of symbols to visualise the ecosystem services in the presentation was criticised: here, experts pointed out the necessity to use adequate symbology for the territory rather that standard symbols, as used for instance in the WWF Reports (Barrett et al., 2018). These comments will be addressed in Chapter 4.2.

Workshop Agenda

9h30 **Introduction et contexte**
Le projet ECOSEO, Clément Villien, WWF Guyane
Le projet MOVE-UE, Aurélie Dourdain, CIRAD
Les habitats forestiers de Guyane – Olivier Brunaux, ONF

10h00 **Méthode d'évaluation des services écosystémiques (Sylvie Campagne et Ina Sieber, LUH)**
La matrice des capacités
La classification des habitats pour cette étude – Clément Villien, WWF
Les services écosystémiques

10h30 **Pause-café**

10h45 – 13h **Remplissage de la matrice, évaluation et discussion**

The original workshop invitation in French is available in Annex 1.

Box 1: Workshop agenda and speakers

2.4.3 The expert panel

During the workshop, 17 experts from different fields, public as well as private sector and academia joined the assessment. In addition, individual interviews were offered for those experts that could not physically attend the workshop, following the same procedures.

It has been proven in a regional scale case study in France that an expert panel with a minimum of 15 people is sufficient to reach stabilized mean scores and a stable plateau for the ecosystem services matrix. After that, the scoring deviation becomes negligible (Campagne et al., 2017). Hence, with 17 participants, our expert panel had a sufficient size to obtain an ecosystem services capacity matrix with robust scores.

The assessment also included questions on the experts' profiles. Less than half of the participants were female – with 40% female participation, gender equality is fairly decent represented. Most of the participants in the expert panel came from fields of research and public authorities (Figure 11). The work of the experts was diverse: 6% of the experts worked on the supranational scale, 65% stated their expertise to be on the national scale, 30% worked on the regional scale. Experts working entirely on the local scale were not present. Not surprisingly, the work of most of the experts was related to forests and their management or conservation.

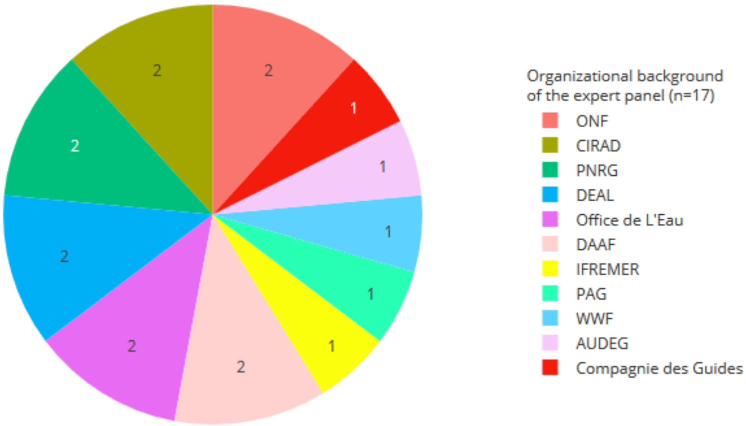


Figure 11: Organizational background of the expert panel in French Guiana

2.5. Analysis

The individually-filled ecosystem services matrices were analysed using the following statistical methods and equations:

- The mean score of all experts' valuations, including confidence indices, were computed with arithmetic mean. Bootstrap mean or other more complex calculation are not needed due to the sufficient size of the expert panel (Campagne et al. 2017).The arithmetic mean is the sum of all values for a cell in the matrix divided by the number of entries (n=17), as shown in Equation 1.

Equation 1: the arithmetic mean ($\overline{x}$)

$$\overline{x} = \frac{1}{n}\left(\sum_{i=1}^{n} x_i\right) = \frac{x_1 + x_2 + \cdots + x_n}{n}$$

where {x1, x2, … xn} are the observed values of the sample items, $\overline{x}$ is the mean value of these observations, and n is the number of observations in the sample (n=17).

- The standard deviation was used to estimate the variability between the expert scores and hence to identify variability in scoring agreement between experts. This score analyses the amount of variation or dispersion of a set of values. A low standard deviation indicates that the values tend to be close to the mean (also called the expected value) of the set, whilst a high standard deviation indicates that the values are spread out over a wider range (Equation 2).

Equation 2: the standard deviation (s)

$$s = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}(x_i - \overline{x})^2}$$

where x are the observed values of the sample items, $\overline{x}$ is the arithmetic mean of these observations, and *n* is the number of observations in the sample (*n*=17).

- Weighted means are used of the graphic representations of the bundles of ecosystem services. For the bundles, a weighted mean has been calculated based on surface area for each ecosystem cluster. For this, the surface area for each ecosystem type has been determined. The expert estimations for each ecosystem type were then multiplied by the percentage of land cover within the ecosystem types (Table 2). This ensured that ecosystem types with small surface area do not lead to overestimated ecosystem service capacity values within each cluster. However, the weighted mean only comes into consideration for the ecosystem services bundles per ecosystem cluster (Equation 3).

Equation 3: Weighted means

$$\bar{x} = \frac{\sum_{i=1}^{n} w_i x_i}{\sum_{i=1}^{n} w_i}$$

where $\overline{x}$ represents the weighted arithmetic mean, x represents the variable of each data value for the observations, w is the weight which is the number of items with the same value of x, and n is the number of observations in the sample (n=17).

- Pearson's Correlation

The Pearson's Correlation is used to analyse the expert matrix on similarities and correlations between the different ecosystem capacities to supply services. Equivalent to the bundle analysis as visual tool, the Pearson's correlation allows to calculate ecosystem service synergies and trade-offs statistically. Such statistical analysis helps to identify the degree of statistical dependency between two variables such as Pearson's correlation coefficient or Spearman's rank correlation coefficient. The Pearson's correlation coefficient indicates the linear strength of correlation between two elements. The following Equation 4 expresses the correlation coefficient r, where n is the number of observations and x and y represent the different variables (Equation 4).

Equation 4: Pearson's correlation coefficient (r)

$$r = \frac{n(\sum xy) - (\sum x)(\sum y)}{\sqrt{[n\sum x^2 - (\sum x)^2][n\sum y^2 - (\sum y)^2]}}$$

Positive r values indicate a positive correlation or synergy while negative values indicate a negative correlation or trade-off. The correlation coefficient (*r*) can range in value from −1 to +1. The larger the absolute value of the coefficient, the stronger the relationship between the variables.

For the Pearson correlation, an absolute value of 1 indicates a perfect linear relationship. A coefficient of 0.5 indicates a moderate linear relationship. A correlation close to 0 indicates no linear relationship between the variables. Negative values indicate negative relationships between the different variables.

In the literature, it is recommended to define a threshold that distinguishes a "no-effect" relationships from relevant relationships. Lee and Lauterbach (2016) found that there is no clear threshold definition in the ecosystem services literature. Whilst applied statistics textbooks recommend to define a Pearson's correlation coefficient under 0.3 as negligible or weak relationship, ecosystem services literature works with a Pearson's correlation coefficient of 0.2 as a meaningful correlation (Jopke et al., 2015). Therefore, Lee and Lauterbach (2016) recommend a correlation coefficient between -0.25 and 0.25 as a "no-effect" label to relationships between ecosystem services.

3. Results

The main result of the workshop is the completed ecosystem services capacity matrix for French Guiana as presented in Table 3 with the mean scores of all 17 experts and their respective mean confidence scores. Another representation of the capacity matrix and its scores is presented in Table 4 with the median scores (size of the points), the standard deviation (and colour of the points in Table 4) and the average of the confidence indices for each ecosystem and each service (green, yellow or red smileys in Table 4). The results in form of the matrix sheet used during the workshops can be found in Annex 4.

How to interpret the results of the matrix comprehensively?
When interpreting the matrix, there are several aspects to consider: **scores**, **standard deviation** and **confidence index**.
- The scores represent the capacity of an ecosystem to supply the respective ecosystem service; these are the values in Table 3 and the size of the bullets in Table 4. The scores are the main results. The other values are additional data to the scores that should be considered when analyzing and interpreting the results

- The standard deviation of a score illustrates the variability of the scores between the different participants, namely the divergence in the representation of the capacity. It is illustrated by the colour of the dots in Table 4.

- The confidence index represents the ease of the participant in their score (1= no confidence, 3 = strong confidence) and is presented for each ecosystem and each service by green, yellow or red smileys in Table 4.

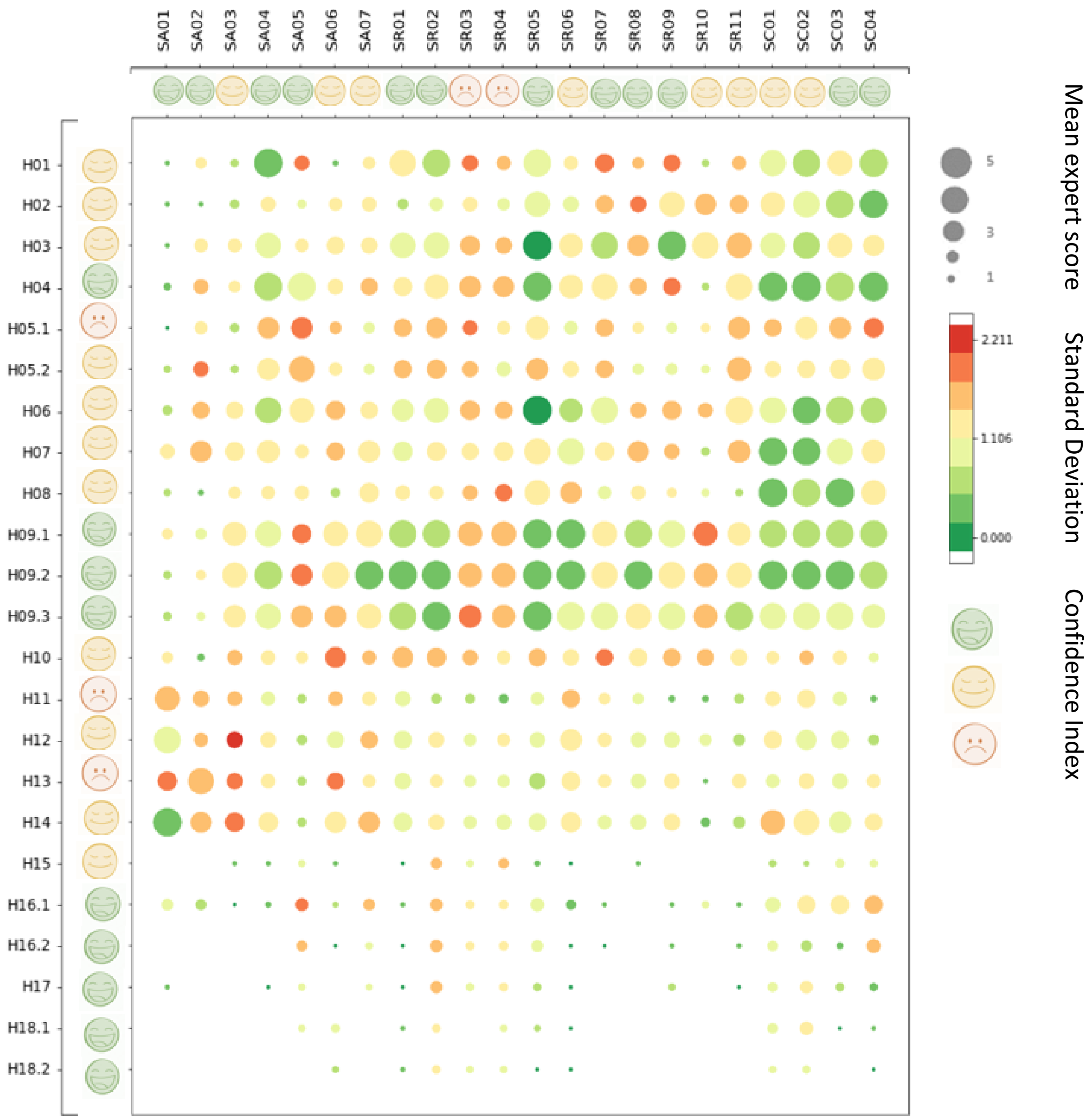
The results for French Guiana show an average score of all ecosystems for all services of 1.77 (on a scale of 0 to 5), an average standard deviation of 1.09, and an average confidence index at 2.03 ("rather comfortable") for ecosystem services and of 2.02 for ecosystem types. Standard deviations vary greatly between ecosystem types and between the different ecosystem services. The expert panel showed highest deviation, thus most different valuation estimations amongst all experts, in Aquatic ecosystems (mean standard deviation of 1.18), and lowest deviation, thus high consensus amongst experts, in Urban ecosystems (mean standard deviation of 0.07) and for mining sites (mean standard deviation of 0.37).

The confidence indices are heterogeneous between the types of ecosystems. Experts indicated high confidence in Forest ecosystems (H9.1, H9.2, 2.52 confidence index), whilst confidence in Grasslands, thus Savannahs, scored lowest (H13, 1.29). For the ecosystem services, the confidence indices are heterogeneous as well. Highest confidence existed on the scores on “Maintaining nursery populations and habitats” (SR5; 2.35), followed by “Hydrological cycle and water quality and flow maintenance” (SR7, 2.29). Experts were least confident with their scoring on ecosystem services “Disease control” (SR3, 1.41) and “Pest control” (SR4, 1.35)

Table 3: Representation of the final ecosystem services capacity matrix of 2019, based on expert evaluation (n=17). Confidence index is included (C), colour-coding corresponds to the final matrix score for each cell (white =no to weak capacity, green =very strong capacity)

Final ecosystem service capacity matrix at national scale for French Guiana				Provisioning Services							Regulating Services											Cultural Services			
				Biomass for nutrition				Water	Materials		Maintaining biological, physical and chemical conditions								Mediation of mass flows - risk reduction			REPRESENTATIONS- subjective			objec- tive
				Cultivated crops/Food	Reared animals and their outputs	Wild plants, algae and their outputs	Wild animals and their outputs	Freshwater supply for drinking purposes	Materials and fibres	Plants and resources for medical use	Carbon Sequestration	Global and local climate regulation	Disease control	Pest control	Maintaining nursery populations and habitats	Pollination and seed dispersal	Hydrological cycle and water quality and flow	Maintaining soil quality	Mass stabilisation and control of erosion rates	Storm protection	Flood protection	Emblemic or symbolic	Heritage (past and future) and existence	Aesthetic	Recreational activities including (eco-) tourism
Ecosystems		Code	C	SA1	SA2	SA3	SA4	SA5	SA6	SA7	SR1	SR2	SR3	SR4	SR5	SR6	SR7	SR8	SR9	SR10	SR11	SC1	SC2	SC3	SC4
Marine and littoral ecosys-tems	Ocean	H1	2.06	0.12	0.71	0.35	4.82	1.29	0.18	0.88	4.06	4.41	1.47	1.18	4.53	1.12	2.00	0.76	1.71	0.29	1.12	4.06	4.41	3.65	4.59
	Beaches, rocks and sand	H2	2.00	0.12	0.12	0.47	1.29	0.47	1.00	1.24	0.65	1.06	1.24	0.88	3.82	1.41	1.82	1.47	3.71	2.65	1.88	3.53	4.12	4.53	4.59
	Mangroves	H3	2.06	0.12	1.06	1.06	3.76	1.00	1.82	1.53	3.76	3.94	2.24	1.59	4.94	3.29	4.24	2.65	4.76	4.12	3.76	3.71	4.18	3.47	2.59
Aquatic ecosys-tems	Rivers and creeks	H4	2.18	0.29	1.29	0.76	4.59	4.59	1.41	1.71	2.06	3.53	2.71	2.53	4.76	3.35	3.94	1.65	1.76	0.29	4.12	4.71	4.88	4.71	4.82
	Lakes	H5.1	1.41	0.06	0.94	0.47	2.71	2.71	0.82	0.71	1.88	2.47	1.24	1.00	3.12	1.00	1.82	0.71	0.65	0.47	2.82	1.76	2.88	2.71	2.24
	Inland water bodies - semi natural	H5.2	1.82	0.29	1.35	0.35	2.88	3.88	1.00	0.65	1.88	2.18	1.47	1.24	2.82	1.41	1.76	0.71	0.76	0.41	3.41	1.47	1.82	2.35	3.06
	Open swamp	H6	1.94	0.53	1.71	1.76	4.00	3.65	2.12	1.76	2.88	3.65	2.24	1.82	5.00	3.24	4.29	1.47	2.12	1.24	4.41	4.12	4.59	4.47	3.94
Forest ecosys-tems	Open Savanna	H7	1.82	1.24	2.71	2.12	3.06	1.06	1.88	2.82	2.29	2.12	1.65	2.18	4.00	4.12	2.06	2.53	1.35	0.41	3.00	4.53	4.53	3.94	3.29
	Inselbergs	H8	1.94	0.29	0.18	0.82	1.06	1.18	0.47	2.24	1.24	1.12	1.29	1.71	3.76	2.71	1.00	1.18	0.53	0.35	0.29	4.76	4.65	4.82	3.65
	Littoral forest	H9.1	2.53	0.65	0.71	3.41	3.94	2.18	3.65	4.12	4.41	4.41	3.47	3.59	4.88	4.82	3.76	4.35	4.24	3.41	3.18	4.29	4.47	4.47	4.29
	Continental forest	H9.2	2.53	0.35	0.53	3.65	4.53	2.71	4.18	4.71	4.76	4.88	3.35	3.35	4.88	4.82	4.12	4.65	4.12	3.29	3.71	4.76	4.88	4.76	4.41
	Inundated forest	H9.3	2.29	0.41	0.41	2.94	3.76	2.82	2.82	3.65	4.35	4.71	3.00	3.12	4.88	4.53	4.29	3.88	4.29	3.35	4.53	4.06	4.24	4.35	3.29
	Planted forest	H10	2.00	0.71	0.29	1.29	1.18	0.82	2.53	1.12	2.59	2.18	1.35	1.06	1.82	1.53	1.65	1.88	1.82	1.65	1.59	0.94	1.12	1.12	0.53
Agricul-tural ecosys-tems	Small scale agriculture	H11	1.53	3.59	1.53	1.24	1.12	0.47	1.24	1.12	1.35	0.59	0.53	0.47	0.94	1.88	0.76	0.71	0.24	0.24	0.53	1.29	1.94	1.12	0.24
	Large scale agriculture	H12	1.76	4.24	1.12	1.53	1.41	0.59	1.65	1.76	1.94	1.41	0.88	0.94	1.35	2.76	1.12	1.29	1.47	0.82	0.76	1.88	2.41	1.82	0.65
	Grasslands	H13	1.29	2.18	4.00	1.53	1.18	0.47	1.71	0.94	1.59	0.94	0.82	0.88	1.53	2.06	1.00	1.24	1.35	0.12	1.18	1.06	1.41	1.41	1.06
	Shifting cultivation	H14	1.82	4.71	2.53	2.18	2.29	0.47	2.65	2.65	2.06	1.41	1.00	1.35	1.82	2.35	1.12	1.41	1.65	0.47	0.82	3.53	3.76	2.76	1.71
Urban and largely modified ecosys-tems	Barren lands	H15	2.00	0.00	0.00	0.12	0.12	0.29	0.12	0.00	0.06	0.71	0.29	0.59	0.18	0.06	0.00	0.12	0.00	0.00	0.00	0.29	0.18	0.47	0.35
	Urban Areas	H16.1	2.18	0.76	0.65	0.06	0.18	0.94	0.18	0.76	0.12	0.88	0.41	0.47	1.00	0.53	0.12	0.00	0.12	0.29	0.12	1.29	1.88	2.00	1.88
	Industrial and comercial zones	H16.2	2.29	0.00	0.00	0.00	0.00	0.65	0.06	0.29	0.06	0.88	0.41	0.47	0.76	0.06	0.06	0.00	0.12	0.00	0.12	0.59	0.65	0.24	1.12
	Infrastructure	H17	2.24	0.12	0.00	0.00	0.06	0.29	0.00	0.24	0.06	0.82	0.35	0.41	0.35	0.06	0.00	0.00	0.29	0.00	0.06	0.53	0.88	0.41	0.35
	Mineral extraction sites - legal	H18.1	2.35	0.00	0.00	0.00	0.00	0.29	0.41	0.00	0.12	0.41	0.00	0.29	0.24	0.06	0.00	0.00	0.00	0.00	0.00	0.59	1.00	0.06	0.12
	Mineral extraction sites - illegal	H18.2	2.35	0.00	0.00	0.00	0.00	0.00	0.24	0.00	0.12	0.41	0.29	0.29	0.06	0.06	0.00	0.00	0.00	0.00	0.00	0.29	0.35	0.00	0.06
1: weak confidence to 3: strong confidence		Confidence		2.25	2.25	2.00	2.13	2.13	1.88	1.50	2.13	2.13	1.25	1.25	2.38	1.75	2.13	2.00	1.88	1.75	1.63	1.50	1.38	2.13	1.75

Table 4: Confidence index (1-3) of all 22 experts (outer bullets: red bullet <1.6, yellow bullet <2.3, green bullet >2.3), Scores and standard deviation of expert scores (colours)



In the following, the scores will be interpreted, showing examples on how to read the matrix.

3.1 Ecosystem services across ecosystem types in French Guiana

In this section, mean capacity score, the standard deviation and confidence index are taken into consideration for the interpretation of the matrix. The matrix included altogether 506 scores. Explaining all ecosystem services would go beyond the scope of this report. Therefore, the 10 ecosystem services that are of greatest interest for WWF and Office de L'Eau will be discussed in detail.

The provisioning service **"Wild plants and their outputs"** for consumption **(SA3)** was estimated to be supplied with overall weak capacity (mean 1.14). Experts scored their confidence in this score at 1.94, thus moderate confidence. The standard deviation for this service was 1.09. Especially Forest and Agricultural ecosystems contributed to the supply: Forested ecosystems (H9.1 – H9.3) and Shifting cultivation (H14) contributed significantly (between 2.94 and 3.65, and 2.18). Also, Savannah (H7) reached a mean of 2.12 to provide wild plants and their outputs. Urban ecosystems showed no to weak capacity to provide this service, however a standard deviation of 0.86 for Urban areas (H16) indicates the differing opinion of experts on this score. This probably relates to the fact that experts disagreed on the contribution of home gardens to supply this service. Nonetheless, this highlights the dependence of the local population on such natural ecosystems for wild food and alimentation.

The service **"Wild animals and their outputs" (SA4)** included the capacity of ecosystems to provide wild foods, such as game meat and wild fish for consumption. Experts estimated a mean provision of all ecosystems of 2.08, thus a moderate capacity, with standard deviation of 0.92. Especially Marine and littoral and Forest ecosystems were important for the supply of this service. The Ocean (H1), Mangroves (H3), and Rivers and creeks (H4) provided a strong to very strong capacity (4.82, 3.76 and 4.59 respectively). Continental forest also significantly contributed to the supply of game meat with a mean of 4.53. Infrastructure (H17) and Mineral extraction sites (H18.1 and 18.2) showed the lowest capacity to supply this service (0.00). For this service, experts indicated a mean confidence of 2.24, thus a moderate confidence.

The service **"Plants and resources for medical use" (SA7)** entailed the capacity of ecosystems to provide plants used for medical and health purposes, etc. On average, ecosystems showed a weak capacity to provide this service (mean of 1.76). This capacity varied between ecosystems with a standard deviation of 1.17. The highest capacity to provide this service came from Forest ecosystems (H9.1-H9.3, 4.35 – 4.71). Savannah (H7) had the third highest capacity to supply this service (2.82). Shifting cultivation (H14) followed with a mean score of 2.65. The mean confidence index for this service was 1.76, a moderate to strong confidence of experts in their evaluation. Nonetheless, it can be assumed that a similar exercise with indigenous population would probably result in a much higher value for this service in *Abbatis,* as each cultivated plant in the *Abbatis* has a medical purpose in traditional knowledge (Abbatis visit with Aluku, personal communication 26.09.2019).

The regulating service **"Carbon sequestration" (SR1)** is of utmost importance when it comes to climate change mitigation. Whilst ecosystems in the territory were assessed with an overall moderate capacity to sequester carbon (mean of 2.18, standard deviation of 0.94), few ecosystems were highlighted with strong tendencies to supply this service. Forest (H9.1-H9.3), Ocean (H1) and Mangrove ecosystems (H3) showed the highest capacity to supply this service (4.50, 4.06 and 3.76 respectively), followed by Shifting cultivation (H9). The confidence index for this services averaged 2.16.

The service **"Maintaining nursery populations and habitats" (SR5)** refers to the capacity of ecosystems to provide habitats for species and biodiversity, as well as providing nesting sites and reproduction capacity. Average value for all French Guianese ecosystems was 2.67, the highest overall capacity amongst all 22 services, with a deviation of 0.87. Open wetlands (H6) scored highest in the provision of this service (5), the highest capacity within the whole matrix. Rivers and creeks (H3), Open swamp (H4) and Forests (H9.1 – H9.3) followed, all with strong capacities to provide habitats and nursery populations. The lowest value for supplying this regulating service was reached by Urban and largely modified ecosystems, followed by Agricultural ecosystems. Here, experts indicated their confidence to be moderate (CI 2.00 – 2.35).

The regulating service **"Hydrological cycle and water quality and flow maintenance" (SR7)** was asessed with a mean of 1.47 by all ecosystems, with standard deviation of 1.04. Especially Forest (H9.1 – H9.3, 4.35 – 4.88), Mangroves (H3, 2.65), and Savannah (H7, 2.53) were assessed to contribute to an intact hydrological cycle. Urban ecosystems and mineral extraction sites contributed least to water quality and flow. Experts stated an overall high confidence index for this service- with CI of 2.18.

In terms of cultural services**, "Heritage (past, present and future) and existence" (SC2)** and **"recreational activities including (eco-) tourism" (SC4)** will be highlighted. Ecosystems throughout French Guiana showed a heritage value with an average of 2.84, the highest mean score for all habitats to supply a service. Here, Marine and littoral habitats, Aquatic habitats and Forest habitats showed the strongest capacity to supply this service (between 1.82 for semi-natural lakes (H5.2) and 4.88 for Continental forest tree cover (H9) and Rivers and creeks (H4)). Inselbergs (H8) contributed significantly to the sense of heritage (4.65), one of the highest capacities for ecosystem service supplied by Inselbergs. The least heritage value was attached to Industrial sites, with a mean of 0.88. Similarly low scores were shown by inofficial mineral extraction sites (0.35). The CI for this service reached 1.82.
As it comes to the capacity of ecosystems to supply recreational activities (SC4), a mean capacity of 2.30 was reached, with standard deviation of 1.07. Based on expert estimation, Rivers and lakes (H4) bore highest capacity for this service (4.82), followed by Ocean and Beaches (H2). Continental forest followed with a score of 4.41, with strong capacities for recreational activities. Agricultural and urban ecosystems supplied this service to a weak degree, only Urban areas, thus settlements, reach a weak to almost good capacity (1.88) – which might be due to urban green, parks and nature creation in the vicinity of settlements. However, experts strongly disagreed amongst each other on the values for recreational capacity in Urban areas, individual scores range from of 0 to 5. The average expert confidence in this service reached 2.18

3.2 Ecosystem services supplied per ecosystem type

After discussing the individual ecosystem services, the scores will be presented per ecosystem cluster. Calculating an overall mean for provisioning, regulating and cultural services is possible, however, computing such an unweighted mean over the various different ecosystems and services is problematic and presents a skewed picture as it combines many different services. Especially the anthropogenic impacted ecosystems, such as Urban ecosystems, lower this mean significantly. Rather, we suggest to have a look at the ecosystem types individually. Natural forest ecosystems have the strongest capacity to supply ecosystem services (mean of 3.09), whilst Urban areas show low scores (mean of 0.35). Mining sites score lowest on average (mean of 0.13). A representation of the final matrix with colour coding is presented in Table 3 for simplification.

Marine and littoral ecosystems, comprising Ocean (H1), Beaches, rocks and sand (H2) and Mangroves (H3), showed an overall moderate capacity to supply ecosystem services (mean of 2.32). Marine and littoral ecosystems showed the highest capacity to supply cultural services: experts ranked these to have moderate and strong capacities (3.65 for SC3 to 4.59 for SC3). For the Ocean (H2), provisioning service SA4 was ranked highest at 4.82. The strongest regulating service was "maintaining nursery populations and habitats” (SR5) with a mean score of 4.53, followed by “Global and local climate regulation” (SR2), scored at 4.41. Beaches (H2) were rated to contribute little provisioning services. In terms of regulating ecosystem services, “Maintaining nursery populations and habitats” scored 3.82, a good capacity. This ecosystem service is of special relevance for the various turtle populations, including the Leatherback Sea Turtle. Mangrove ecosystems (H3) showed an overall good capacity to supply ecosystem services. Regulating ecosystem services were ranked with strongest capacities – SR5 at 4.94, SR9 at 4.76 and SR7 at 4.24. Among the provisioning services, mangroves showed the highest capacity to supply “Wild animals and their outputs” (SA4), with 3.76. The capacity of mangroves to supply “Cultivated crops/food” (SA1) scored least, with a mean score of 0.12, indicating no or very weak capacity. Cultural services received average values between 3.59 (SC4) and 4.18 (SC2).This indicated that mangroves bear the least capacity for “Recreational activities including (eco-) tourism” amongst the Marine ecosystem types.

Aquatic ecosystems, including Rivers and creeks (H4), Lakes and semi-natural inland water bodies (H5.1, H5.2) and Open Swamp (H6) showed an overall moderate capacity for ecosystem services (mean of 2.29).

Rivers and lakes (H4) were scored to have a strong to very strong capacity to supply cultural ecosystem services (between 4.71 (SC1, SC3) and 4.88 (SC2). Out of all assessed ecosystems, Rivers contributed most to SA4, “Wild animals and their outputs” (4.59). Their regulating functions, especially SR5 (4.76) and SR7 (3.94) should be highlighted. Experts estimated the capacity to control erosion rates and the capacity for storm protection (SR8 and SR9) to be weak (1.65, 1.76 respectively).

Lakes and semi-natural water bodies (H5.1, H5.2) showed a strong correlation in their capacities to supply ecosystem services, with overall mean of 1.60 and 1.69. Biggest difference can be found in their capacity to provide “Freshwater for drinking purposes” (2.71 versus 3.88). However, natural lakes received a greater valuation for “Heritage” (SC2, 2.88, versus 1.82, see Table 3).

Open Swamps (H6) reached a mean capacity to supply ecosystem services of 2.95, a moderate to good capacity thus. **All experts agreed that swamps showed the highest capacity to “Maintain nursery populations and habitats” (SR5**) with a mean of 5 and standard deviation between experts of 0. This is the highest value obtained in this assessment. In terms of regulating functions, swamps also scored high in their capacities to maintain the hydrological cycle (SR7) and “flood protection” SR11 (4.29, 4.41 respectively). Cultural services ranked between 3.94 (SC4) and 4.59 (SC3).

Forest ecosystems, including Open Savannah (H7), Inselbergs (H8), Forest tree cover (H9.1 – H9.3) and Planted forest (H10) showed an overall good capacity to supply ecosystem services (3.09). This is the highest value for all ecosystem types.

Open Savannah (H7) reached a mean of 2.59 on overall ecosystem service supply. This ecosystem type showed a strong capacity for the supply of cultural ecosystem services – especially with its emblematic or existence value (SC1, SC2) stood out. Savannahs showed a strong capacity to “maintain nursery populations and habitats” (SR5, 4.0) as well as for “Pollination and seed dispersal” (SR6, 4.12). Also, this ecosystem showed good capacity to supply “Wild animals and their outputs” (SA4, 3.06) and “plants and resources for medical use” (SA7, 2.82).

Amongst the forested ecosystems, Inselbergs (H8) showed an overall weak capacity for ecosystem services (1.79). Provisioning services supplied by Inselbergs were ranked with no to weak capacities by the experts. “Plants for medical use” (SA7) obtained the highest value with 2.24. In the category of regulating services, “Maintaining nursery populations” (SR5) and “Pollination and seed dispersal” (SR6)

received values of 3.7 and 2.7. Inselbergs contributed little to control of erosion rates, flood and storm protection (SR9 - SR11 < 0.53), which can be explained by limited surface cover. Nonetheless, their cultural appreciation was very strong (SC1- SC4).
Forest tree cover showed similar mean scores amongst the three ecosystem types (littoral, continental and inundated forest) with 3.67, 3.88 and 3.53 an overall good capacity to supply ecosystem services. For example, all three forest types contributed little to “Cultivated crops/food”, but littoral forests showed a higher capacity than continental forests. Here, the spatial segregation becomes visible: whilst littoral forests are easily accessible, continental forest is often dense and difficult to access, due to its location in the hinterland. **All forest types contributed equally to “Maintaining nursery populations and habitats” (SR5). With a value of 4.88, this is the strongest capacity, followed by “Pollination and seed dispersal” (SR6**). Cultural values of forest ecosystems were ranked between 3.29 (capacity for “Recreational activities including (eco-) tourism in inundated forest) to 4.88 (“Heritage and existence” in continental forests). Experts indicated their confidence in inundated forest to be highest (mean of 0.84), however, standard deviation for this forest type was highest as well, indicating diverging opinions within the expert panel.
The ecosystem services supply capacity of Planted forest (H10) was highly debated amongst experts, as this ecosystem type is currently not actively managed in French Guiana. This ecosystem type showed an overall weak capacity to supply ecosystem services (1.4), was marked by little to no capacity for provisioning services except “Materials and fibres” (SA6, 2.53). Also the capacity for the supply of regulating ecosystem services was estimated to be weak to moderate, with highest scores for “Carbon sequestration” (SR1) and “Global and local climate regulation” (SR2, 2.18). Planted forest was estimated to have little capacity to “Maintaining nursery population and habitats” as well as “Pollination and seed dispersal” (SR5, SR6, 1.82, 1.53 respectively) Also, cultural valuation of these ecosystems was weak. Notably, experts indicated a moderate confidence in their scores, with high deviation of scores.

Agricultural ecosystems contained Small - and Large scale agriculture (H11, H12), Grasslands (H13) and Shifting cultivation (H14). These (agro-) ecosystems obtained an average of 1.49. **Overall, the values for these agricultural ecosystems showed similarities: they all showed a strong capacity for food provisioning services (SA1, SA2 for Grasslands**). All agricultural ecosystems scored lowest in their capacity to provide “Freshwater for drinking purposes”, SA5 (<0.50), reflecting no or very weak capacity for the supply of this service. Regulating and cultural services scored overall weak to moderate, with SR3, SR4, SR7 and SR11 between 0.40 and 1.35. Shifting cultivation (H14) scored slightly higher in overall provision of services (average of 2.03 compared to 1.05-1.54 H11, H12, H13). Cultural services related to Shifting cultivation were estimated to be high compared to small and large scale agriculture, i.e. the aspect of “Heritage” received a mean capacity of 3.76, and a symbolic value of 3.53. However, the capacity for “Recreational activities” in Shifting cultivation scored low (mean of 1.71).

Urban ecosystems comprised Bare soil (H15), Urban areas (H16.1), Industrial areas (H16.2) Infrastructure (H17) and Mineral extraction sites (official sites H18.1 and inofficial sites H18.2). Ecosystems in this cluster are strongly impacted and altered by humanity. Their **overall capacity to supply ecosystem services was estimated to be weak,** at 0.35 for Urban areas and 0.13 for Mineral extraction sites. Provisioning and regulating services scored overall low – with no to weak capacity.

Bare soil (H15) scored >= 0.00 in all services. Therefore, **Bare soil was scored to have the second least ecosystem services capacity in comparison to all other ecosystems, only Mineral extraction sites (H18) scored lower values.**
Urban areas (H16.1) and industrial areas (H16.2) resembled each other in their values, with overall mean of 0.67 and 0.36. Overall service supply showed no to weak capacity, however, Urban areas stood out with provisioning services of slightly higher capacities to supply “Cultivated food/crops”, “Reared animals and their outputs”, ”Freshwater for drinking purposes” and “Plants for medical use”. This can be reasoned by the impact of homestead gardens. In terms of regulating services, both H16.1 and H16.2 show low capacities. Only in terms of cultural services, a difference became visible – urban areas were rated with weak to moderate capacity for SC1 (1.29), SC2 (1.88), SC3 (2.00) and SC4 at 1.88 – the highest supply capacity in Urban ecosystems.

Largely modified ecosystems, comprising Mineral extraction sites (H18.1 and H18.2) was, from the human-modified ecosystem types, the one that scored lowest in overall ecosystem service provision. With a mean of 0.13, no to weak services were supplied. Highest capacity of official mineral extraction sites was obtained for its “Heritage” value (SC2), which was estimated at weak capacity (1.00). For inofficial mineral extraction sites, experts ranked highest the capacity for “Global and local climate regulation” (SR2) with 0.41, a value that indicates no to weak capacity.
Experts indicated their confidence in Urban ecosystems to be between moderate and comfortable, whilst standard deviations for Urban and Mineral extraction sites is lower than 0.39 – indicating consensus between experts on the given scores.

3.3 Ecosystem service bundles in French Guiana

The concept of ecosystem services bundles allows to discover the relationships and trade-offs between different ecosystem services, also across various ecosystems and landscapes (Raudsepp-Hearne et al. , 2010). Whilst a correlation analysis (Chapter 3.4) might be difficult to read, a bundle analysis presents ecosystem services in an easily understandable, visual form. This allows to show patterns of the supply of ecosystem services derived from the different ecosystems, as well as the possibility to map and assess multiple ecosystem service capacities for geospatial units such as ecosystem types or LULC classes.

Prioritizing or increasing the provision of those services that are favourable for societies, e.g. food production and timber, has often led to the decline and even depletion of other ecosystem services, for example regulation of water balances, maintaining soil quality or the amelioration of infectious diseases (Bennett & Balvanera, 2007; Foley et al., 2007). At the same time, positive relationships can be possible, so called synergies between different services responding to same drivers, e.g. through reforesting barren land, vegetation increases, leading to increased carbon storage capacity. At the same time, this increase in vegetation can lead to enhanced nursery population maintenance services, biodiversity and species richness (Strassburg et al., 2010), which can for instance result in increased pollination services etc.

Applying the expert-based matrix approach has its advantages: it allows to assess and compare different ecosystem services supply capacities in by different ecosystem types on a relative scale from 0 to 5. This allows to compare service supply between the different ecosystem clusters and ecosystem types assessed.

3.3.1 Ecosystem bundles per ecosystem type in French Guiana

A graphic representation of ecosystem services bundles, like we propose in Figure 12, allows an overview of all ecosystem services supplied by one or several ecosystem types. Figures of ecosystem services bundles can be compiled for each ecosystem type, depicting one row in the final capacity matrix (Table 3).

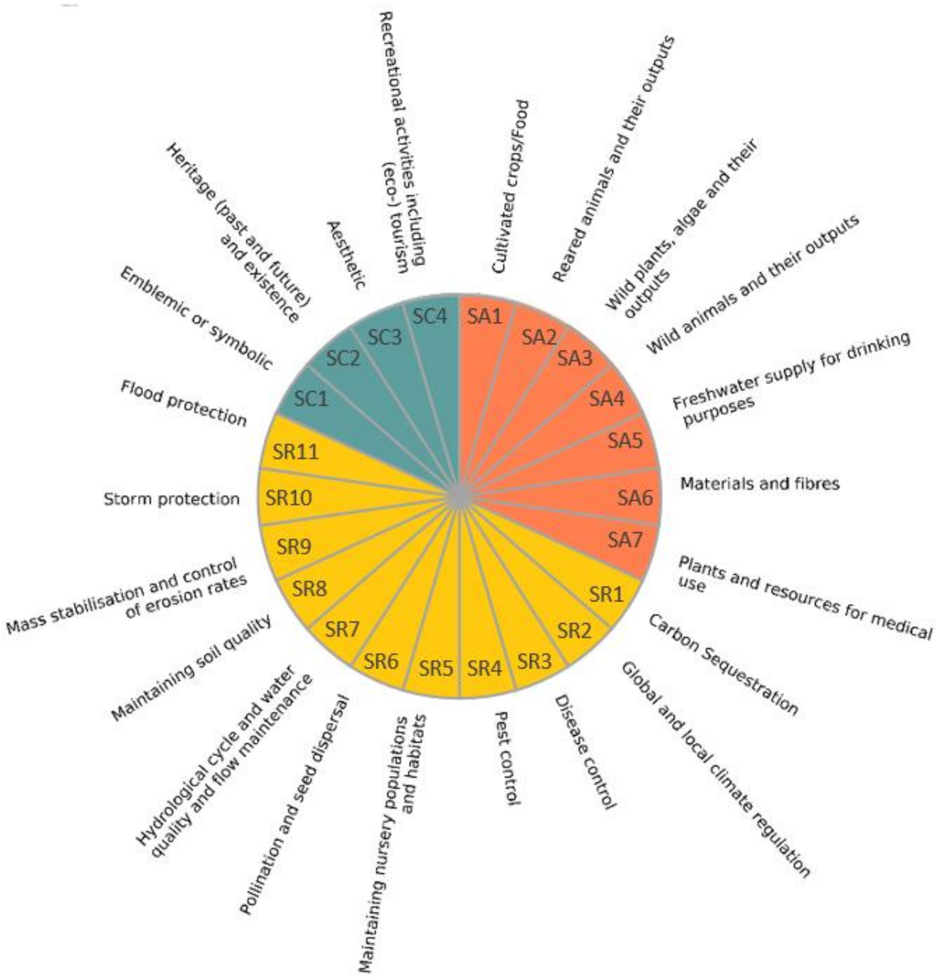


Figure 12: reading instruction for the 22 assessed ecosystem services in French Guiana in bundled form

How to interpret bundles of ecosystem services?

In each bundle of ecosystem services, each share (differentiated by colours) refers to a different section of ecosystem service (provisioning in yellow, regulating in orange, cultural services in blue. The codes are referring to the different services in the matrix). The correspondence between the colours and the services is presented in Figure 12. The length of the bars indicates the capacity score, i.e. the score of the matrix on a scale from 0 (centre of the bundle, no to very weak capacity to supply a certain ecosystem service) to 5 (outer circle of the bundle), thus a very strong capacity to supply a certain individual service.

For the compilation of the ecosystem service bundles, the mean score of each ecosystem type within an ecosystem cluster was calculated, weighted by the surface area of each ecosystem type (see details in Methods Chapter 2.4). Such a weighted factor was used to account for the fact, that some ecosystems only cover small areas. For example, Inselbergs (H8) only have a very limited surface area within the forested ecosystem types, of less than 1% of the territory. Inselbergs showed a very weak to weak capacity to supply provisioning and regulating ecosystem services, e.g. “Materials and fibres” (SA6, value of 0.47) or “Storm-” and “Flood protection” (SR10 and SR11, values of 0.35 and 0.29 respectively). Without such a weighting factor, the impact of ecosystem types such as Inselbergs in the bundles would be overestimated, reflecting a skewed picture of the actual supply of services for Forest ecosystems. Figure 13 shows the weighted ecosystem service provision for the six different ecosystem clusters. In the radar plots, the different categories of provisioning, regulating and cultural ecosystem services are displayed.

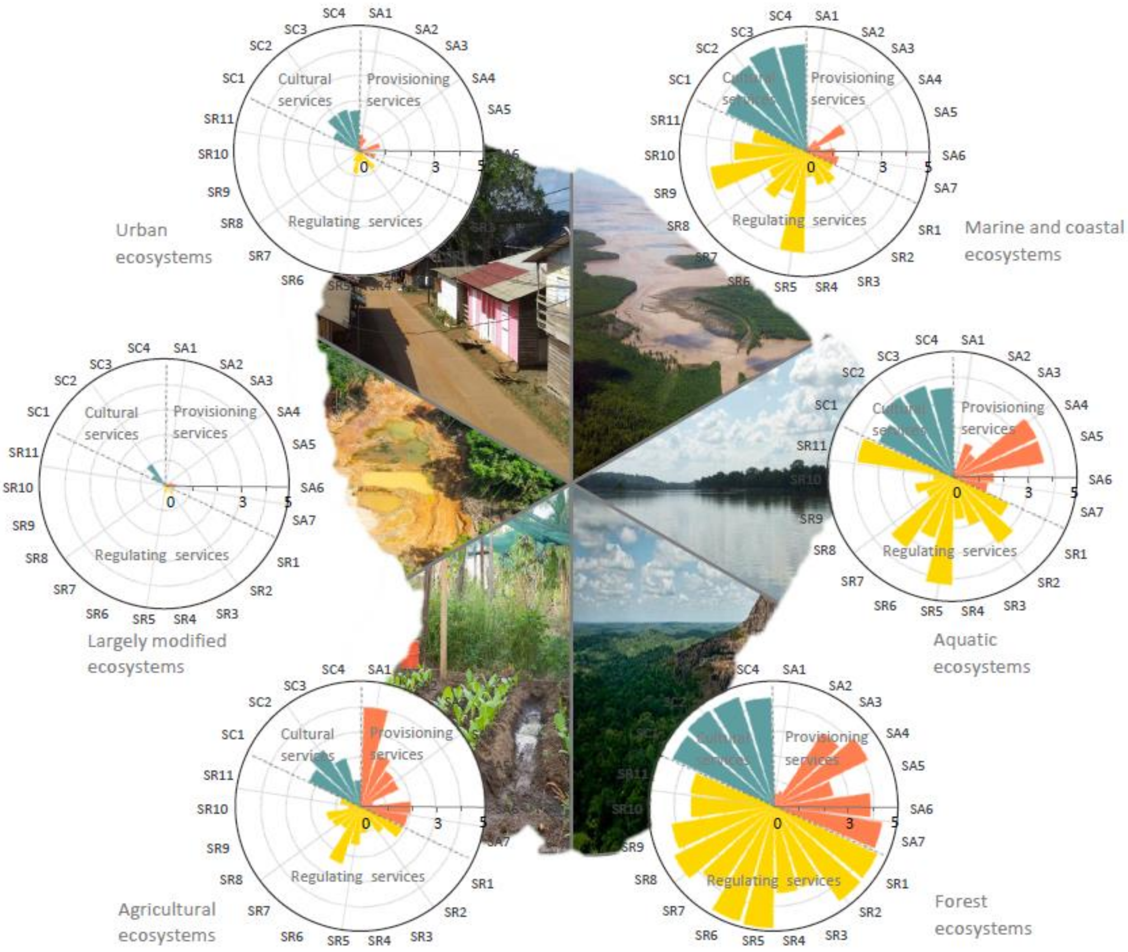


Figure 13: Ecosystem services bundles for the 22 assessed ecosystem services and the major ecosystem clusters in French Guiana

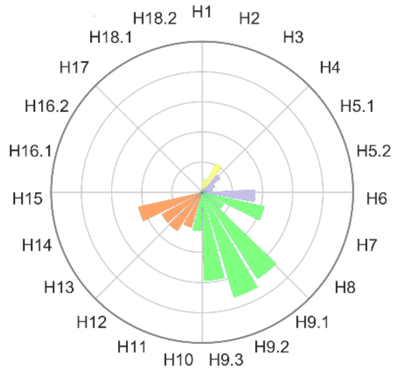
More visual than the matrix, the bundles allow to analyse the differences between the ecosystem service capacities. A quick comparison of ecosystem clusters strongly altered by mankind and natural ecosystems shows the variation within the ecosystem services bundles. Marine and littoral, Aquatic and Forest ecosystems showed an overall varied, moderate to strong capacity to supply ecosystem services. They were assessed with high supply capacities for cultural services, aesthetics as well as recreational activities (blue bars in Figure 13 depicting cultural ecosystem services). These bundles highlight synergies and trade-offs between ecosystem services. Forest ecosystem services have the overall highest capacity to supply ecosystem services. Almost all petals of the bundle showed strong to very strong capacities, except SA1, SA2 and SA5. Agricultural ecosystems, for example, indicate a high capacity for "Cultivated food" (SA1), and a moderate capacity to provide "Reared animals and their outputs" (SA2). On the contrary, their capacities to contribute to regulating services (SR1-SR11) were perceived weak. The exception was SR6, "Pollination and seed dispersal" which was supplied with moderate capacity. Cultural ecosystem services related to agricultural landscapes are supplied with weak to moderate capacity (SC1-SC4). Urban ecosystems showed a weak capacity to supply ecosystem services according to the expert estimation. Largely modified ecosystems, thus Mineral extraction sites reflected even less capacities to supply ecosystem services.

3.3.2 Ecosystem type bundles per ecosystem service

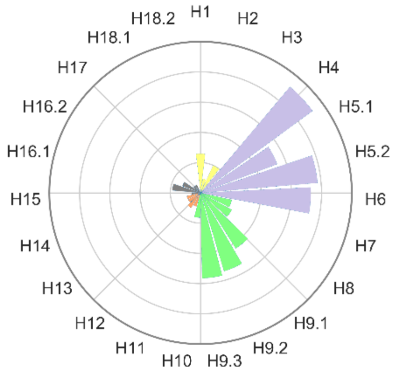
The same type of bundle representation can be inversed and depict the distribution of individual services across ecosystem types. In the pie charts below (Figure 14), the following ecosystem services are highlighted: "Wild plants and their outputs" (SA3), "Freshwater supply for drinking purposes" (SA5), "Carbon sequestration" (SR1), "Maintaining soil quality" (SR8) and "Heritage (future and past) and existence" (SC2).

"**Wild plants and their outputs**" (SA3), upper left chart, are dominantly supplied by Forest ecosystems (green petals). Agricultural ecosystems, especially Shifting cultivation (H4) contributed to the supply of wild plants. Amongst the Aquatic ecosystems, Open swamp showed weak capacity to supply this service. Urban ecosystems and Mining sites contributed least to the supply of this service.

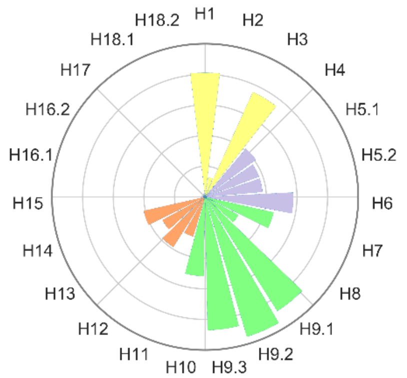
"**Carbon sequestration**" (SR1), middle left chart, is mainly supplied by Forest ecosystems. This is not surprising, as biomass accumulation in these ecosystem types, especially in Littoral, Continental and Inundated forests is high. Similarly, Marine and littoral ecosystems, namely Ocean (H1) and Mangroves (H3) show similar tendencies. Aquatic ecosystems showed a weak to moderate capacity to store and sequester carbon. Here, Open swamps should be highlighted as they showed the highest capacity according to the expert estimation.



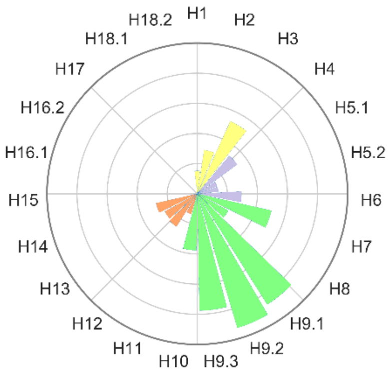
Capacity to supply „Wild foods and their outputs“ (SA3)



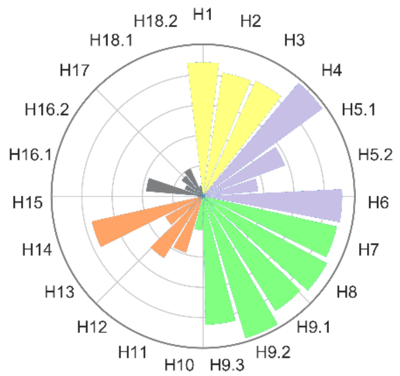
Capacity to supply „Freshwater for drinking purposes” (SA5)



Capacity to supply “Carbon sequestration” (SR1)



Capacity to supply “Maintaining soil quality” (SR8)



Capacity to supply “Heritage (past, present and future) and existence” (SC2)

Code	Ecosystem
H1	Ocean
H2	Beaches
H3	Mangroves
H4	Rivers and creeks
H5.1	Lakes
H5.2	Inland water bodies - semi natural
H6	Open swamp
H7	Open savanna
H8	Inselbergs
H9.1	Littoral forest
H9.2	Continental forest
H9.3	Inundated forest
H10	Planted forest
H11	Small scale agriculture
H12	Large scale agriculture
H13	Grasslands
H14	Shifting cultivation
H15	Bare soil
H16.1	Urban areas
H16.2	Industrial areas
H17	Infrastructure
H18.1	Mineral extraction sites – official
H18.2	Mineral extraction sites - inofficial

Figure 14: Ecosystem services supplied per ecosystem type, based on the expert valuation, the bundles show the capacity of ecosystems in French Guiana to supply SA3”Wild plants and their outputs”, SA5 “Freshwater for drinking purposes”, SR1 “Carbon sequestration”, SR8 “Maintaining soil quality” and SC2 “Heritage (past, present and future) and existence”

3.4 Correlation between ecosystem services in French Guiana

As the results show, one ecosystem often has capacities to supply multiple ecosystem services simultaneously. Understanding the multi-functionality of landscapes, including the relations between different ecosystem services, can help to enhance the understanding of synergies, and attenuate undesired trade-offs. Especially for decision makers and land use planners, a proper understanding of the complexity of ecosystems can improve the ability to sustainably manage landscapes and their capacity to supply multiple ecosystem services (Bennett et al., 2009). Through calculating the Pearson coefficient, it is possible to unravel these synergies and trade-offs statistically (Jopke et al., 2015; Lee & Lautenbach, 2016).

How to interpret the correlation between ecosystem services?

The Pearson correlation coefficient indicates the linear strength of correlation between two elements. Positive values indicate a positive linear correlation or synergy while negative values indicate a negative correlation or trade-off. A positive correlation implies that when one ecosystem service increases, the correlated ecosystem service will also increase – and on the other hand, a negative correlation indicates that with the increase of a certain service, the correlated ecosystem service will decrease.

The correlation coefficient (r) can range in value from −1 to +1. The larger the absolute value of the coefficient, the stronger the relationship between the variables. For the Pearson correlation, an absolute value of 1 indicates a perfect linear relationship, i.e. the two ecosystem services are strongly and positively correlated. A coefficient of 0.5 indicates a moderate linear relationship, i.e. the two ecosystem services are moderately and positively correlated. A correlation close to 0 indicates no linear relationship between the variables. Negative values indicate negative relationships between the different variables.

The results of the analysis of the Pearson correlations between the services of the ecosystem matrix are presented in Figure 15. Blue cells indicate positive correlations, while red cells indicate negative correlations.

Figure 15 presents the statistical relationships between the different ecosystem services in French Guiana. The highest value of correlation can be seen in the diagonal from top left to bottom right – each service has a strong positive linear correlation with itself. Other than this, i.e. the provisioning service “Cultivated crops/food” SA1 does not have a strong positive linear relation to any other services. Thus, based on statistical analysis, there are no strong synergies. Rather, there is no linear relationship (pale cells, e.g. SA4, A8 etc.). With some other services there is a slight negative linear relationship, for example with “Freshwater supply for drinking purposes” (SA5) and regulating service “Global and local climate regulation” (SR2) and “Recreational activities including (eco-) tourism” (SC4), thus a trade-off exists. Hence, where land is used for agricultural purposes, it basically supplies cultivated food, but is not suitable for supplying other ecosystem services such as recreational activities at the same time.

For other services, e.g. “Freshwater production for drinking purposes” (SA2), a moderate correlation with “Cultivated food (SA2) exists (second row of Figure 13). All other services are show no linear relationships with this particular service, while "Storm protection" (SR10) shows a slight negative value (r = -0.13).

Synergies can be found among SA3 and SA5 and SA6, SR3 and SR4. Bundles between SR54, SR5, SR6 and SR8 occur, as well as a resemblance between SR5 and all cultural ecosystem services (SC1-4). SR9 and SR10 seem to positively correlate as well as all the cultural services with each other (r between 0.88 and 0.97, cluster in the bottom right of the heat map in Figure 15).

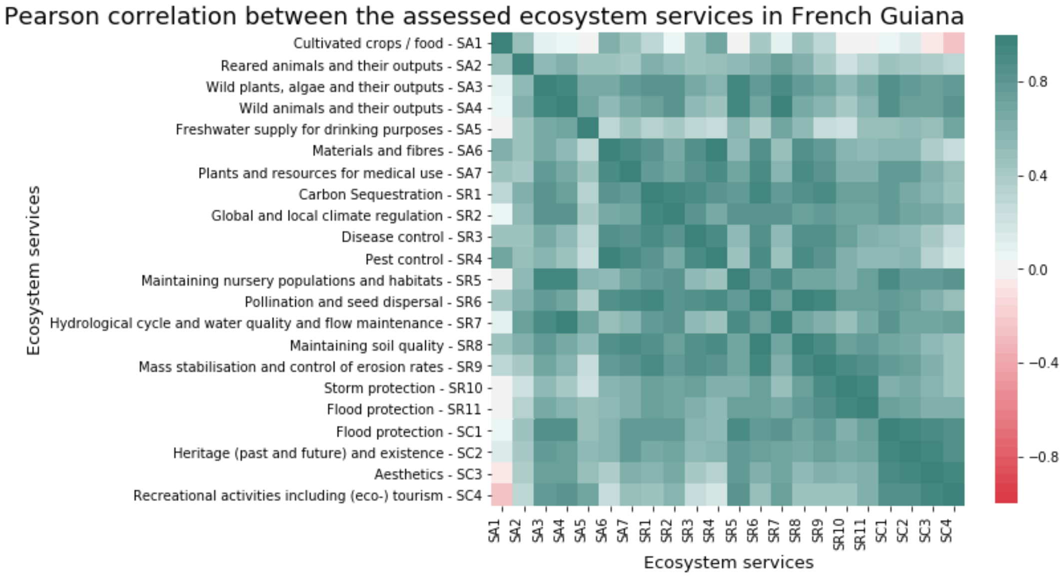


Figure 15: Correlation between the 22 different ecosystem services supplied by ecosystems in French Guiana, based on the Pearson correlation (r), where 1 = strong positive correlation, and therefore strong synergy, and -1=strong negative correlation, and therefore, a trade-off.

3.5 Ecosystem services maps

Maps are powerful tools to communicate spatially complex information. This also works for the ecosystem services concept: maps depict the spatially-explicit provision of ecosystem services. If designed well, ecosystem services maps can be excellent intuitive and comparably simple methods to convey information to stakeholders, citizens, practitioners, policy and decision makers (Burkhard et al., 2013).

Mapping ecosystem services based on the ecosystem services matrix approach is rather straightforward through linking the geospatial units (LULC classes or ecosystem types) with ecosystem services. This way, all 22 ecosystem services assessed in this report can be visualized in form of maps for each individual ecosystem service. In Figure 16, examples of regional level ecosystem services maps are presented for the municipalities of Macouria, Matoury, Montsinéry-Tonnégrande and Rémire-Montjoly. Figure 16 A shows the capacity of ecosystems to provide "Freshwater for drinking purposes" (SA5). Overall, the map shows a weak to moderate capacity for ecosystems in this region to supply freshwater. This service is supplied predominantly by rivers, e.g. by the Mahury and Cayenne and Montsinéry River depicted in the dark green colour. The olive green areas present open wetlands and submersed landscapes in the vicinity of the rivers. Urban areas contribute with no to very weak capacity, as the light rose colour indicates.

The “Capacity of ecosystems to sequester carbon” (SR1) is shown in Figure 16 B. A balanced mix of all colour classes is visible, Urban and Agricultural areas show weak capacity. A strong capacity for this service can be found amongst forested ecosystems as seen in dark green colours.

Figure 16 C presents the capacity of ecosystems to supply “Sense of heritage and existence” (SC2). Especially around the city of Cayenne, located on a former island in the Cayenne River, the Colline de Montabo (North), Salines de Montjoly (North) and Mont Mahury including lac Rorota (East) are visible as dark green spots. The similarities between SR1 and SC2 seem to be strong, as the regional overview shows. Indeed, the statistical analysis shows a strong correlation between these services (Figure 15) – areas with high vegetation density and therefore a strong capacity to sequester carbon seem to be linked to a strong sense of heritage in French Guiana.

How to read and interpret the ecosystem service maps?

For a comprehensive interpretation and understanding of the maps it is important to consider the following aspects:

- The ecosystem type mapping scale: the compilation of the ecosystem services maps is based on a cartographic layer drawing on land use classes. The spatial resolution of this map layer determines the finest scale. For the territory of French Guiana, the ecosystem types used in this assessment are based on a synthesis of land use land cover (Joubert 2017). The maps were originally obtained at a scale of 1:50.000.

- The scale of ecosystem services: as ecosystem services are provided by different ecological functions, the spatial scale on which they are provided also varies. Some services are important on local scale, other become relevant on a regional, national to a global level. For example, “Carbon sequestration” (SR1) provides benefits on the global scale, while the service “Freshwater supply for drinking purposes” (SA52) is highly relevant at the watershed level. On contrary, the service “Maintaining soil quality” (SR8) is provided from a watershed level to a highly local scale (Raudsepp-Hearne and Peterson 2016). Therefore, mapping SR8 would be recommended at a local scale. An overview of suitable scales to map individual ecosystem services can be found in literature (e.g. Campagne and Roche 2019).

One main assumption of this method is that LULC or ecosystem types are the main factors influencing the supply of ecosystem services. However, in reality ecologic systems must be understood as heterogeneous mosaics of different ecosystem types of shifting steady states (Chapin et al., 2002), rather than uniform land use classes with sharp boundaries. Also land use does not account for temporal dynamics, such as the unable and continuously changing coastline and mangrove ecosystems (Fromard et al., 2004), unless time series are considered. This means that the point in time and the spatial resolution of the LULC dictate the degree of detail of the ecosystem maps. Therefore, this degree of reduced complexity should be kept in mind when analysing the maps.

Whilst the Regional Overview maps in Figure 16 show a limited degree of detail, local maps can help to illustrate the ecosystem service supply more in detail (Figure 17). Here, the structure of smaller settlements, agriculture and infrastructure becomes visible, which disappears on a national overview as seen in Figure 16. For such local maps, however, the spatial resolution of the input data, in this case the national LULC dataset, is decisive. The higher the resolution, the greater is usually the detail, hence the more accurate should the depiction of the ecosystem services be.

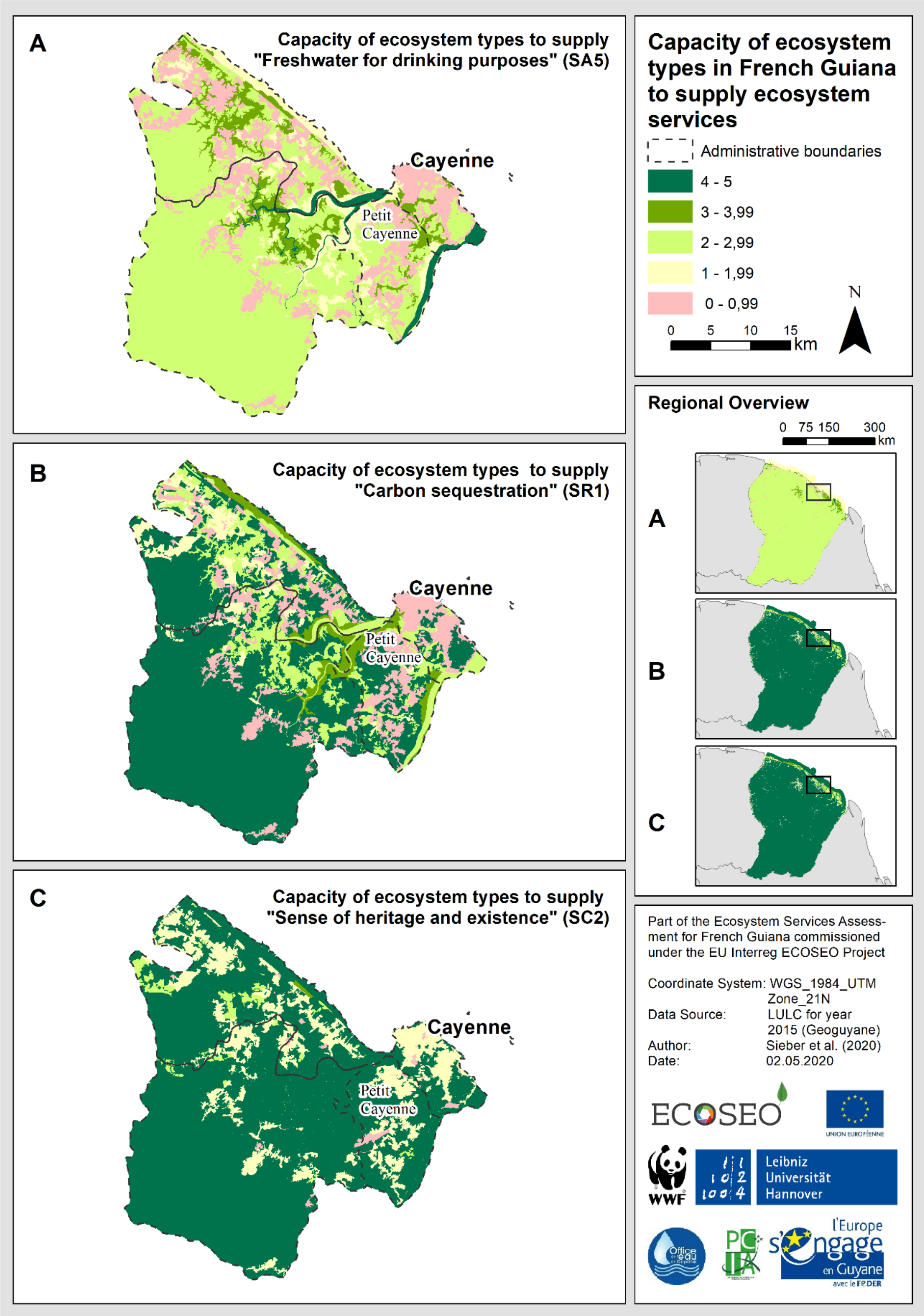


Figure 16: Ecosystem services supplied in different ecosystem types in the municipalities of Cayenne. Macouria, Matoury, Montsinéry-Tonnégrande and Rémire-Montjoly, and on territorial level for French Guiana, on a scale of 0 (no to very weak capacity) to 5 (very strong capacity), based on the participatory expert workshop (n=17, October 2019)

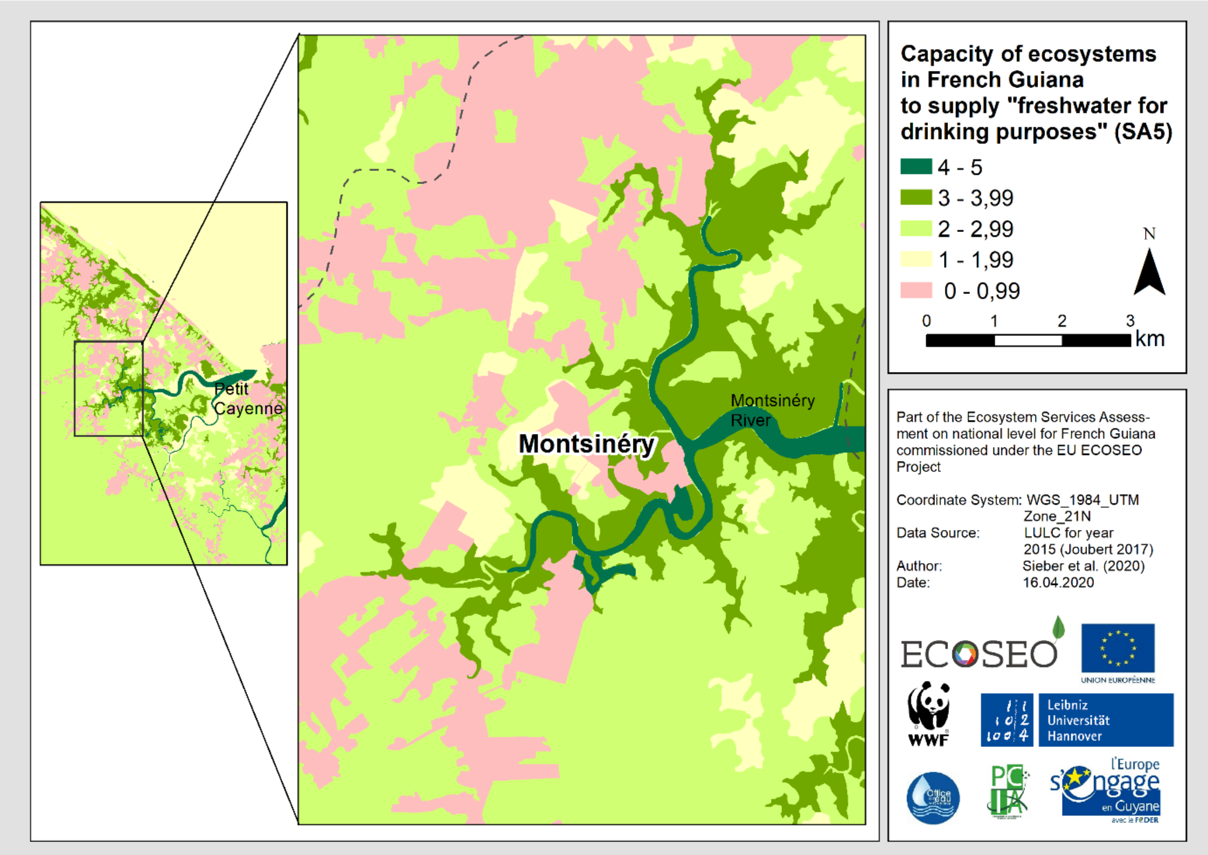


Figure 17: Capacity of ecosystems to supply freshwater for drinking purposes at municipal scale in Montsinéry, French Guiana, on a scale of 0 (no to very weak capacity) to 5 (very strong capacity), based on the participatory expert workshop (n=17, October 2019)

However, cartographic representation of single ecosystem services leads to reduced complexity – ideally, one should always look at landscape multifunctionality (e.g. through ecosystem services bundles), as depicted in Figures 12 and 13. In addition, one could combine such ecosystem service maps with other indicators, such as biodiversity and/or socio-economic data, to get further information in interactions in human-environmental systems. This way, ecosystem services maps can become a purposeful decision aid, whilst taking into account the complexity of ecosystems and their management.

4. Discussion

4.1 Feedback on the results

The results, in form of the final capacity matrix, are based on an expert evaluation by 17 participants of an ecosystem services assessment workshop held in Cayenne, French Guiana on October 2nd 2019. This workshop obtained 17 individually filled matrices. This number should be sufficient to get scientifically sound results, as studies by Campagne et al. show (2017). Based on these 17 matrices, the final ecosystem services matrix (Table 3) has been compiled.

The ecosystem services supplied per ecosystem type differ. According to the expert evaluation, forests have the strongest capacity to store and sequester carbon (SR1), contribute to “Pollination and seed dispersal” (SR6) and provide “Materials and fibres” (SA6) for building, carpentry, ornamental purposes etc. (Figure 18). Shifting cultivation (“*Abattis*” in French) showed the highest capacity to supply “Cultivated crops and food” (SA1). Similarly, Rivers and ocean contribute to food security through supply of “Wild animals”, e.g. through the supply of fish for consumption. In terms of cultural ecosystem services, “Beaches and Forests” are important for recreational activities. Notably, “Urban areas”, settlements and mining sites contribute with no to weak capacities to supply ecosystem services.

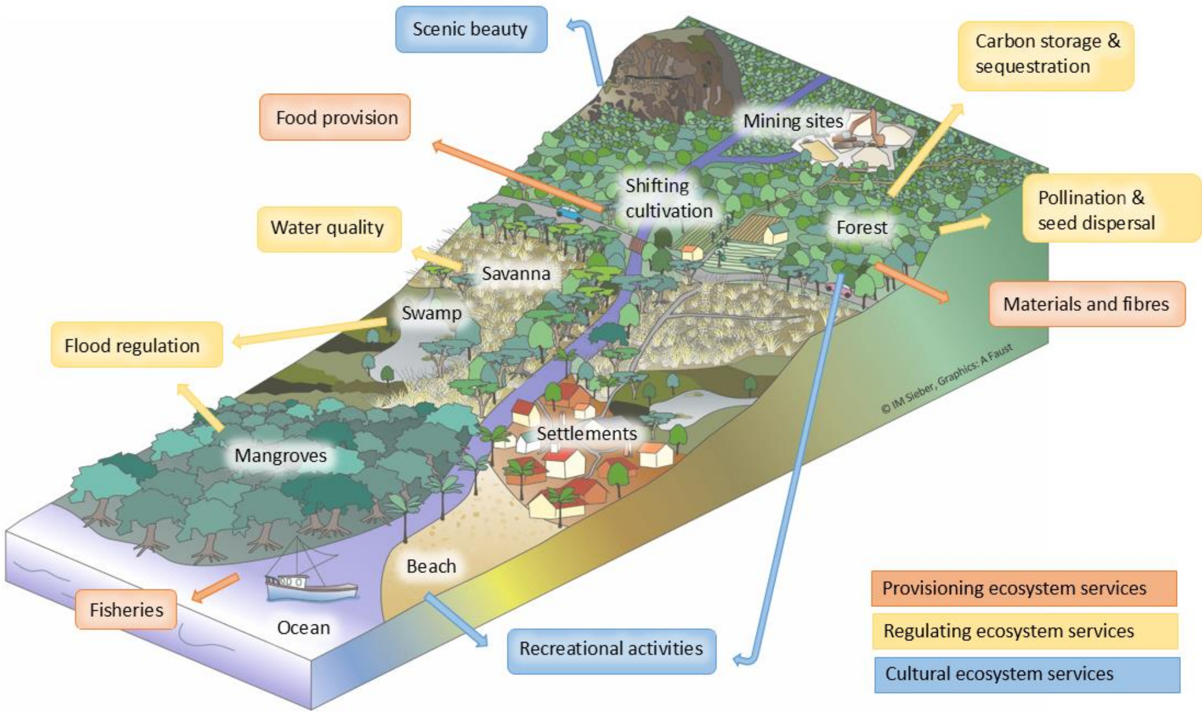


Figure 18: Schematic representation of major ecosystem types and their services in the Guiana Shield (©IM Sieber, Graphics: A. Faust, design related to Campagne and Roche 2019)

It has to be noted that there was a variation in expert scores for some cells of the matrix. Highest deviation was found for the capacity of ”Large scale agriculture” (H12) to provide “Wild plants, algae and their outputs” (SA3), with standard deviation of 2.21. Also, experts disagreed on the capacity of “Rivers and creeks” (H4) to supply “Mass stabilisation and control of erosion rates” (SR9), with a deviation of 2.14. Such a high standard deviation expresses the divergence of expert opinions and can have multiple reasons: disciplinary biases within the expert panel, gaps in knowledge, diverging interpretations of ecosystems and/or their services or a lack of relevant experts (Campagne & Roche, 2018). Also, the heterogeneity of the expert panel and the multiple backgrounds of the evaluators can lead to such disparities for each of the ecosystems and services.

The results show disparity in terms of confidence of expert scores for the different ecosystems as well as between ecosystem services (Table 3). The experts that participated in this assessment were most confident in their estimation of Littoral and Continental forests (H9.1 and H9.2), followed by mineral extraction sites (H18.1 and H18.2). Least confidence was indicated in Grasslands for agricultural use (H13) and natural lakes (H5.1).

In terms of ecosystem services, the expert confidence was highest in scores of ecosystem capacity to "Maintaining nursery populations and habitats" (2.35), followed by landscape "Aesthetics" (SC3), "Hydrological cycle and water quality and flow maintenance" (SR7) and "Freshwater for drinking purposes" (SA5), with confidence index of 2.29. All other services were indicated with moderate confidence, except "Pest control" and "Disease control" (SR3, SR4), which reached a mean confidence index of 1.35, 1.43 respectively.

For French Guiana, the ecosystem services bundles visualize the variation in the set of the 22 assessed services across the ecosystem clusters. Such bundle analysis allows to identify how different ecosystem services interact in different ecosystems. Forest ecosystems tend to have the strongest overall capacity to supply multiple services simultaneously, whilst Urban areas and Mining sites show the least capacity to contribute to human well-being through the supply of ecosystem services (Figure 10). This reflects the need for multi-functional landscape planning where the supply of multiple ecosystem services is desirable.

A statistical analysis of the expert-based scores unravels the correlation between the different services. Such a correlation becomes important when assessing management options to optimize individual ecosystem services (e.g. in agro-ecosystems). In this case, positive or negative correlations can occur to other associated services. The analysis of such correlations can be conducted using the Pearson coefficient, assessing linear relations between the different services, the synergies and trade-offs (Figure 12). For French Guiana, synergies can be found amongst others between the services "Wild animals and their outputs" (SA3) and "Wild plants and their outputs" (SA4), suggesting that there is a linear relationship between these two services. Similar relations can be found between SR3 and SR4, SR5 and SR7, SR10 and SR11. A strong linear correlation also exists for all cultural services (SC1-4).

Major trade-off can be found between "Cultivated crops/food" (SA1) and "Freshwater supply for drinking purposes" (SA5), "Maintaining nursery populations and habitats" (SR5) and "Recreational activities including (eco-) tourism (SC4).

These results can be caused by different factors. For example, the relationship between individual regulating services can be explained by similar underlying physical ecosystem processes (Bennett et al., 2009; Lee & Lautenbach, 2016). The strong interrelationship between cultural services observed can be explained by the fact that the assessed ecosystem services are closely interwoven - landscapes providing "Aesthetics" (SC3) or "Heritage and existence" (SC2) can bear great capacities for "Recreational activities" (SC4) and vice versa, as many scholars argue (Daniel et al., 2012). Another possibility to explain such correlations can be the subjective scoring of the expert panel. Here, the possibility exists that experts evaluated certain ecosystems more favourable to provide a set of ecosystem services than others, based for instance on expertise, preferences or knowledge deficits. To assess the robustness of the correlations, further research would be needed to validate the results with additional biophysical and socioeconomic data resulting for example from direct measurements, statistics, modelling or in-depth interviews.

Ecosystem services maps and ecosystem service bundles can be used to communicate the results of this study to decision makers and the broader public. They represent a good tool for decision support (Campagne & Roche, 2018). Together with the use of the ecosystem service bundles, the correlations can be shown in an easily understandable manner. However, ecosystem services maps need to be well designed for the purpose and their limitations and input factors should to be clearly communicated, when used (Burkhard & Maes, 2017).

4.2 Ecosystem services and indigenous worldviews

During the workshop, some of the participants criticised the ecosystem services concept as being predominantly influenced and based upon western world views and biases. This criticism is not new to the environmental domain, including the ecosystem services concept. Many scholars have argued that the ecosystem services concept indeed has its limitations to incorporate multiple knowledge systems, people and nature relations, cultural and indigenous beliefs (Díaz et al., 2018), sparking a subsequent scientific debate (Kadykalo et al., 2019). This claim, however, is contradicting with the initial idea of the ecosystem services concept as inclusive approach in terms of worldviews and multiple values, also including cultural values and indigenous knowledge (Maes et al., 2018). Especially the inclusion of social sciences and the development of methods and approaches to capture socio-cultural notions of benefits and services of ecosystems shows this (Santos-Martín et al., 2018; Scholte et al., 2015). In addition, the growing body of ecosystem services literature on indigenous values towards ecosystems and their services contradicts this claim, as examples from Columbia (Angarita-Baéz et al., 2017), Suriname (Ramirez-Gomez et al., 2016; Ramirez-Gomez et al., 2013) or Népal (Dorji et al., 2019) show.

Such western world biases are in line with the critique by Turnhout et al. (2013), who argue that *"the ecosystem services discourse contributes to the commodification of biodiversity*" (Turnhout et al., 2013, S. 156). This critique especially addresses socio-economic approaches and monetary assessments of ecosystems and their services (O'Neill et al., 2008). Through explicitly drawing upon the expert-based ecosystem services capacity matrix, a method that restrains from economic valuation in monetary terms and eventually commodification, we aimed to avoid this. Rather the expert-based ecosystem service capacity matrix approach is well suited to express values from different domains, including biophysical, socio-cultural non-monetary values, but also monetary values where appropriate, of multiple different services.

4.3 Limitations

In this section, the limitations considering the method, the ecosystem services approach, the interpretation of the maps as well as limits related to such an expert-based evaluation will be discussed.

Methodological limitations

Limitations of the ecosystem services capacity matrix method have been evaluated in several studies, such as Jacobs et al. (2014), who underlined the comparably low methodological transparency and the lack of appropriate consideration of methodological uncertainties. Hou et al. (2012) systemically listed the uncertainties associated with landscape and ecosystem services assessments. In two studies, Campagne et al. (2018) investigated how to take into account uncertainties in the expert scores, how to calculate the final scores and the minimum size of expert panels for a robust ecosystem service matrix assessment. In addition, they have identified various advantages and limitations inherent in the matrix approach (Campagne et al., 2017; Campagne & Roche, 2018).

Limitations related to expert-based assessments

- **Subjectivity**

For all participants, there is a variability related to their subjectivity, confidence in knowledge and understanding of the concepts and study itself. The validity of expert-based assessments is highly dependent on the experience, knowledge, education and opinion of the participants (Hou et al., 2013). In order to take into account the participants' confidence, the participants expressed their uncertainties in the form of a confidence score.

- **Participants profiles**

In a participatory ecosystem services assessment, the profiles of the participants should be considered. A balanced expert panel is important for a sound ecosystem services assessment. This includes a balance in variability between experts in terms of fields of expertise (professional or personal knowledge depending on their fields of work; Hou et al., 2012) and a balanced representation of age, gender and education level. In our study, we considered that the profile must be linked to the type of evaluation made. This means, expertise on territorial level as well as on local level is needed, covering as many ecosystems and ecosystem services as possible. However, no participants from autochtonous communities were present.

Studies have shown significant differences in appreciation between a rural and/or elderly audience - who prefer provisioning services - and an urban and young audience - who are more interested in regulating services. Other differences in individual assessments were related to the level of education of the experts (often, the lower the level of education, the higher the preference for provisioning services). Gender of respondents was also relevant: while men show a tendency to prefer provisioning services, women tend to value regulating services higher (Prévot & Geijzendorffer, 2016).In the context of this study, we did not observe these rating biases associated with the profiles of the experts. At least the gender ratio was nearly equal and age distribution was balanced.

- **Limitations related to understanding and interpretation**

The definitions of services and ecosystems are not simple and can lead to different interpretations. For instance, experts expressed difficulties to grasp the difference between various cultural services or the way to assess the ecosystem services for anthropogenic ecosystems, which seem highly modified from natural ecosystems at first sight (e.g. Urban areas (H16.1). In addition, there are several concepts in the evaluation of ecosystem services: supply, capacity, use/flow demand, and others. In order to reduce uncertainties related to conceptual misunderstandings, time was taken to explain and review with the participants all the definitions related to the study during the workshop.

- **Limitations linked to the ecosystem typology**

The selection of ecosystem types used for the creation of the capacity matrix impacts the ecosystem services assessed by experts. For some ecosystem services, a typology based on ecosystem types suffices, for example, for an assessment of the carbon sequestration service. For other ecosystem services, an assessment based on such ecosystem types is insufficient. For example, for the distinction between the supply of timber (Materials and fibres services) and the supply of wood for energy purposes, it would be necessary to distinguish forest ecosystems based on species composition. Likewise, a selection of ecosystem types, e.g. agro-ecosystems (H11, H12) does not allow to distinguish between different types of cultivated crops and different management methods. However, the impact of such decisions on ecosystem services supply that these land use units produce can be high. Lastly, it proved difficult to include urban ecosystems in this assessment, as many of the defined subtypes (e.g. Bare soil, Mineral extraction sites) present ecosystem structure and functions. Here, a framing of topology based on LULC could have led to better understanding among the experts. Nonetheless, it is crucial to include such humanly modified areas into the assessment to highlight the differences in ecosystem services supply, and hence the loss of ecosystem services that occurs when transforming natural areas into agricultural or urban space.

- Temporal notion

If applied in the way as in this study, the ecosystem services matrix gives average annual values of the ecosystem services supply. Thus, several ecosystem services matrices would be needed to take into account the annual and multiannual variabilities. The matrix might give the impression that provisioning, regulating and cultural services can be provided at the same time. However, in most cases it is impossible to manage ecosystems so that all services are provided at the same time with a maximum level of supply, thus trade-offs occur (see Chapter 3.4).

- Spatial heterogeneity

The matrix, as applied in this study, gives an average score per ecosystem type. Thus, two distant locations with the same ecosystem type will have the same scores without taking into account their specificity (Jacobs et al., 2015). The protection status, the condition of the ecosystems, topographic or topological particularities, and other relevant factors are usually not taken into account. Of course, they could be taken into account with integration of additional data and further analysis. In order to take spatial heterogeneity into account an option would be to integrate the source of heterogeneities in the ecosystem types list of the matrix, i.e. Protected forest and Unprotected forest.

5. Outlook

This study will be continued by an integration of the ecosystem services assessments in Suriname and French Guiana. Comparing both matrices across national borders might highlight the different values people attach to ecosystems and their services as well as regional peculiarities. Also, such a transnational comparison will help to validate the correlations between the ecosystem services supplied in different areas of the Guiana Shield.

As a next step, the ECOSEO project will conduct a holistic, comparative assessment of ecosystem services. A closer look at the Maroni River basin will allow to deepen the insights from the two national assessments. For this, the comparative setup of the workshops, the selection of similar ecosystem types in both countries and the crosswalk between ecosystems and their services are advantages. In addition, an important contribution will be made by the results of a field trip to the Maroni region (report in progress), including an assessment of local perceptions towards the condition of ecosystems and their services and the expertise of the ECOSEO partners in this part of the Guiana Shield. This comparative assessment will be a first step towards MAES implementation in the EU Outermost Region French Guiana.

For the future, French Guiana will be part of the MOVE-ON EU project[13] (running from May 2020 – 2023). Within this project, the participating EU Outermost Regions and Overseas Countries and Territories will be encouraged to implement the ecosystem services concept, fine-tuning and developing the MAES methodologies to be adapted to the natural and human realities of the specific regions. Within this process, French Guiana will be one of the selected MOVE-ON Anchor regions. The ultimate goal hereby is to produce regional and thematic strategies, good practice guidance and policy recommendations on for the implementation of MAES, the protection of valuable ecosystems, biodiversity and a safeguarding of the services they supply as crucial contribution to human well-being.

[13] Under the Programme Implementation of the PILOT PROJECT — MAPPING AND ASSESSING THE STATE OF ECOSYSTEMS AND THEIR SERVICES IN THE OUTERMOST REGIONS AND OVERSEAS COUNTRIES AND TERRITORIES: ESTABLISHING LINKS AND POOLING RESOURCES,
Grant Agreement Nº: 07.027735/2019/SI2.808239/SUB/ENV.D2

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Annex 1: Official Invitation to the workshop

ECOSEO Observatoire des services écosystémiques du plateau des Guyanes

Atelier d'évaluation des services écosystémiques en Guyane

Invitation à un atelier de travail le Mardi 1er Octobre 2019, de 9h30 à 12h30, à Guyane Développement Innovation à Cayenne, Campus Troubiran

Dans le cadre du projet de recherche **ECOSEO** (Observatoire des services écosystémiques du plateau des Guyanes), nous vous invitons à participer à l'évaluation des services écosystémiques en Guyane.

Le projet de coopération régional ECOSEO, mené par le WWF, vise à évaluer, cartographier, valoriser et in fine mieux préserver les services écosystémiques à l'échelle du plateau des Guyanes. Un travail spécifique à la Guyane est mené en collaboration avec l'Université de Hanovre et l'Office de l'eau pour évaluer les services écosystémiques, en particulier dans la zone transfrontalière du Maroni. Il fait suite aux travaux menés dans le cadre du projet Best UE qui a constitué le premier pas vers une évaluation des écosystèmes. Le projet MOVE UE a également repris ce travail pour les territoires ultra-marins de l'UE, testant et adaptant des méthodes pour qualifier et quantifier les services écosystémiques. Cette évaluation s'appuiera sur et prolongera ces travaux.

Quoi ?

Les services écosystémiques (SE) sont les contributions que les écosystèmes apportent au bien-être humain.
3 catégories de services écosystémiques sont généralement reconnues (Figure 1):

Services d'approvisionnement : les services à l'origine des « produits finis » que l'on peut extraire des écosystèmes, tels que la nourriture, les différents matériaux et fibres naturels, etc.

Services de régulation : les services non matériels contribuant plus indirectement au bien-être de l'homme à travers les fonctions de régulation des écosystèmes, telles que la régulation du climat ou des incendies.

Services culturels : représentent les différentes valeurs immatérielles que l'on peut attribuer aux écosystèmes, une valeur esthétique, symbolique (comme les valeurs emblématiques) et récréative, telles que les activités de pleine nature (chasse, pêche, randonnée, etc.).

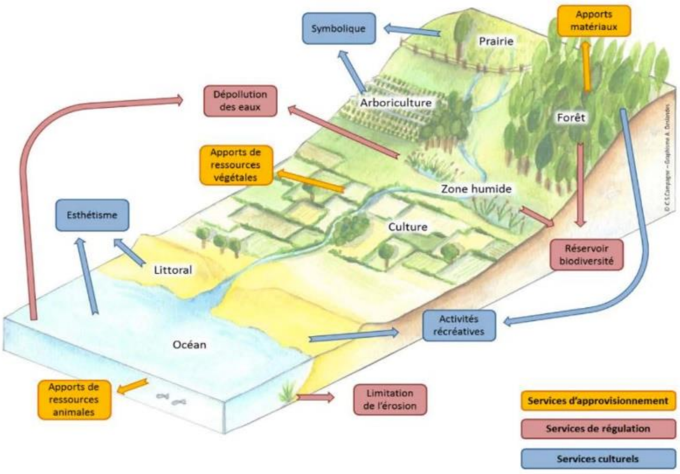


Figure 1 : Exemple des services écosystémiques ©C.S. Campagne- Graphisme A. Deslandes

Comment ?

Parmi les nombreuses méthodes d'évaluation des SE, nous souhaitons utiliser **la méthode des matrices des capacités** qui consiste à évaluer l'ensemble des services produits par les différents écosystèmes au travers d'une série de scores. Une matrice des capacités est un tableau qui relie les types d'écosystèmes ; et/ou les modes d'occupation et/ou d'usage du sol ; avec aux services écosystémiques (Figure 2).

Chaque score est établi à dire d'experts et représente la capacité d'un écosystème à fournir un service.

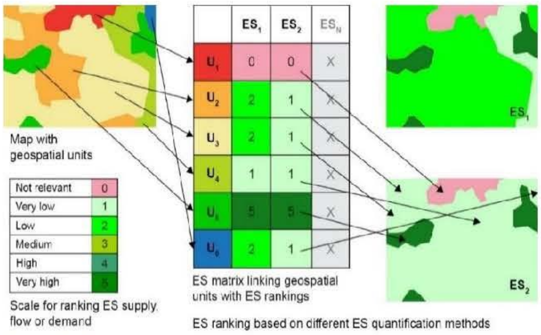


Figure 2: Construction d'une matrice à partir de l'occupation du sol et création de cartes de services produits par les types d'occupation du sol (Burkhard & Maes, 2017).

Depuis 2009, cette méthode est de plus en plus utilisée internationalement et surtout utilisée depuis 2014 en France métropolitaine dans de nombreux PNR en France (Baronnies Provençales en 2014, Scarpe-Escaut en 2015, 2016 et 2017, des Alpilles en 2018, et d'autres). Récemment, à l'échelle de la Région Hauts-de-France la première évaluation de l'ensemble des SE a été faite avec cette approche par l'IRSTEA et la DREAL (plus d'informations sur le site de la DREAL).

Pour faire **la matrice des capacités de la Guyane**, nous sommes en train de faire les listes :

- des écosystèmes présents sur le territoire de la Guyane ;
- des services écosystémiques rendus par ces écosystèmes.

Quelle est votre contribution?

Pour faire cette évaluation, nous avons besoin de prendre en compte chaque expertise présente en Guyane Française : **votre contribution est importante !** Durant un atelier de travail, nous souhaiterions vous demander de remplir la matrice avec votre expertise via un score de 0 à 5 (0 pas de capacité à rendre ce service – 5 : une très forte capacité à rendre ce service). Cette capacité est la capacité maximale annuelle des écosystèmes à produire des services écosystémiques.

Quand ?

Le Mardi 1er Octobre 2019 de 9h30 à 12h30, à Cayenne, dans les locaux de Guyane Développement Innovation (GDI), sur le Campus Troubiran (Université de Guyane).

Pour mieux appréhender la région du Maroni, un atelier similaire sera également organisé au Surinam.

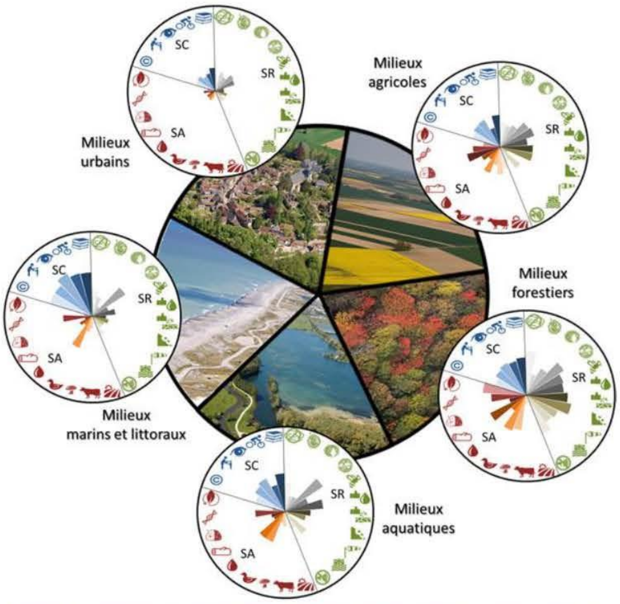


Figure 3: Bouquets des services rendus par les 5 grands types d'écosystèmes de la Région Hauts-de-France C.S. Campagne 2019 lien

Quels résultats ?

Tout d'abord, à partir des scores de la matrice de nombreux **résultats et interprétations directes** peuvent être faits.

Ensuite, la matrice étant faite à partir de données spatiales, nous pouvons faire **des cartes sur les services** produits á l'échelle de l'ensemble de la Guyane Française (à partir du moment où nous avons une occupation du sol) ou à des échelles plus fines.

Finalement, il est possible de faire **des bouquets de services** produits comme le montre la Figure 3 avec ceux des principaux types d'écosystèmes de la Région Hauts-de-France (plus le pétale est grand, plus le service est produits).

Pour plus d'information : Ina Sieber, Université de Hanovre (sieber@phygeo.uni-hannover.de)
Clément Villien, WWF Guyane (cvillien@wwf.fr)

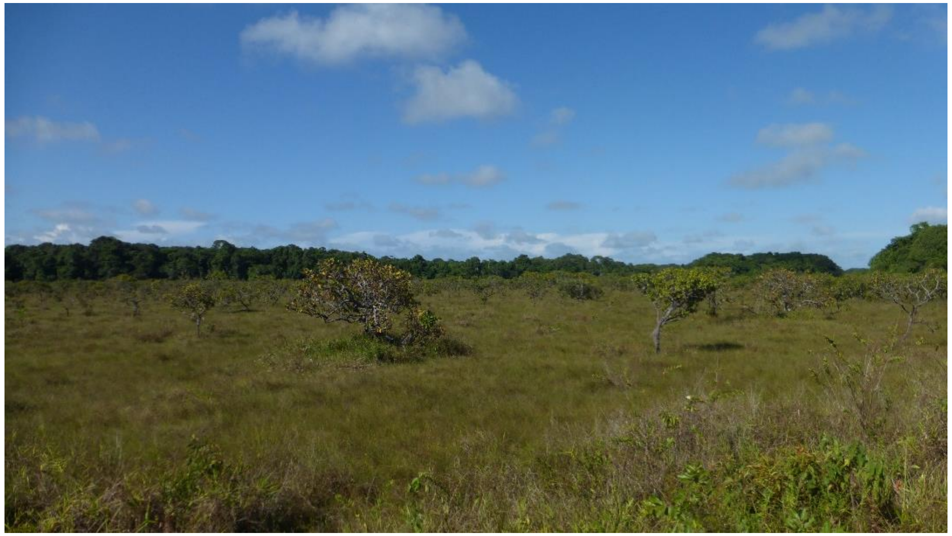
Merci de confirmer votre participation en vous inscrivant via le formulaire en ligne

Annex 2: Overview of assessed ecosystems and ecosystem types in this assessment

	Code	Suriname	Definition	Grouping for this assessment	French Guiana
Marine and littoral	H1	Ocean	Ocean	Ocean	Océan
	H3	Mangroves	Mangroves, almost perennial, subject to the swaying tides and regularly flooded during high tide.	Mangroves	Mangroves
Aquatic ecosystems	H4	Rivers and creeks	Network of rivers, streams, and waterways greater than 5m wide. May be subject to ocean tide rising 30 to 50 km inland	Rivers	Fleuves et criques
	H5.1	Lakes	Natural ponds and lakes	Inland water bodies	Eaux stagnantes
	H5.2	Inland water bodies - semi natural	Artifical ponds and lakes, including water bassins, pisciculture and artifical canals.		Zones aquatiques artificielles
	H6	Open swamp	Inland swamps and wooded swamps, often bordering mangrove swamp. Mostly located in flat, poorly drained coastal areas, on clay soils (old consolidated marine silts). riparian swamps maritime wetlands	Wetlands	Zones humides, marais
Forest ecosystems	H7	Open savanna	Broad range of lands with dominant shrubby and bushy vegetation, including dry and humid savannes.	Shrubland, bushland, heathland	Savanes
	H8	Inselbergs	Inselbergs, Savanna-rock	Inselbergs	Inselbergs
	H9	Forest tree cover	All types of natural forest, including disturbed forests	Forest tree cover	Forêts littorales
					Forêts continentales
					Forêts inondées ou marécageuses
	H10	Planted forest	Forest plantations solemnly used for timber extraction, with little biodiversity.	Woody crops	Plantations forestières
Agricultural ecosystems	H11	Small scale agriculture	Arable land with possibility for irrigation Cultivation of rice, cereals etc.	Herbaceous crops	Terres arables
	H12	Large scale agriculture	Intensive agricultural patterns, permanent plantations	Agriculture	Cultures permanentes
	H13	Grasslands	Pasture used for animal husbandry	Pasture	Prairies
	H14	Shifting cultivation	Complex agricultural patterns and parcel systems (Abattis) Territories mainly occupied by agriculture with presence of vegetation	Shifting cultivation	Zones agricoles hétérogènes - abattis
Urban ecosystems	H15	Bare soil	Bare soil due to anthropogenic interference	Barren lands	Sol nu
	H16	Urban areas	Continuous and discontinuous urban fabric, isolated building, heterogeneous settlements with limited green areas	Urban areas	Zones urbanisées
	H17	Infrastructure	Industrial or commercial zones		Zones industrielles ou commerciales
			Road networks, communication networks and associated spaces Ports, airports	Infrastructure	Infrastructures routiéres
	H18	Mineral extraction sites	Gold mining sites, legal extraction activities	Mineral extraction sites	Activitées minières légales
			Gold mining sites, unauthorized extraction activities		Activitées minières illégales

Examples of ecosystem types: top left: the Plage de Montjoly as example for ecosystem type Beaches (B2); top right: the Salines de Montjoly as example of Mangrove ecosystems (H3); the Comte River in Cacao as example of Rivers and Creeks (H4); bottom right: the Pripri de Yiyi in Sinnamary as example of Open swamps (H6); (© Sieber, October 2019)

Top left: Savanne des Peres close to Kourou as example of Open Savannah (H7), top right: example of ancient, currently uncultivated planted forest (H10) with Pinus in Sinnamary province, small scale agriculture (H11) in Maripasoula, Bare soil (H15) along the Route de l'Est (© IM Sieber, October 2019), next page: example of a gold mining site (H18) in the forest (© C. Villien)




Annex 3: Overview of assessed ecosystem services in this assessment

	Ecosystem Services			*Code*	*Definitions*	*Potential Indicators - examples*
Provisioning Services	**Nutrition**	**Biomass for food consumption**	**Cultivated crops / food**	**SA1**	Potential capacity of a habitat to **provide nutrition for human consumption in form of agricultural produce and cultivated crops**	Sort, qualtity and quantity of food derived from plant species cultivated through agricultural practices. *Corn, rice, cassava (tapioca), sugar, cocoa, vegetables, bananas etc.*
			Reared animals and their outputs	**SA2**	Potential capacity of an ecosystem to **provide nutrition for human consumption in form of reared animals and their outputs**	Type and quantity of food derived from species raised on farms or in aquaculture. *Pork, chicken, cows, etc.*
		Biomass	**Wild plants, algae and their outputs**	**SA3**	Potential capacity of an ecosystem to **provide nutrition for human consumption in form of wild plants, vegetables and/or mushrooms.**	Type and quantity of food for human consumption derived from ecosystems: *wild plant and fungal species gathered, e.g. Acaii, wild vegetables and fruit.*
			Wild animals and their outputs	**SA4**	Potential capacity of an ecosystem to **provide nutrition in form of wild animals and their outputs**	Type and quantity of food from hunted animals for human consumption. *Meat from hunting, fish and seafood from fishing*
		Water	**Freshwater supply for drinking purposes**	**SA5**	Potential capacity of an ecosystem to **provide water (surface water, groundwater recharge) for human consumption** (not including water retention and storage)	Quantity of water withdrawable for *irrigation, domestic consumption and / or industrial / energy use*
	Materials	**Raw materials**	**Materials and fibres**	**SA6**	Potential capacity of an ecosystem to **provide fibres and other materials from plants, algae and animals for direct use or processing; Materials from plants, algae and animals for agricultural use**; and/or **biomass-based energy sources**	Quantity of wild or cultivated natural materials used for non-food purposes such as *lumber, fibers for stationery, textile fibers, decorative bouquets of flowers, etc .* Quantity of material used for forage and fertilization purposes. *Hay, alfalfa, pastures, green manures, nectar for bees, etc.* *Also, materials used for energy purposes, such as fuelwood, cereals or beetroot for ethanol production, etc.*
			Plants and resources for medical use	**SA7**	Potential capacity of an ecosystem to **provide natural resources and materials for medical purposes, and/or to unique pool of genetic resources** used for scientific, industrial, agricultural or agri-food purposes.	Quantity of species used for pharmaceutical, aromatic, and other medicinal purposes, e.g.

	Ecosystem Services			Code	Definitions	Potential Indicators - examples
Regulating Services	Maintaining biological, physical and chemical conditions		**Carbon Sequestration**	**SR1**	Potential capacity of an ecosystem to **sequester and store carbon dioxide out of the atmosphere in the long term**	Storage of carbon in *plant biomass above and belowground*
			Global and local climate regulation	**SR2**	Potential capacity of an ecosystem to **influence the local and global climate**	Contribution to climate variability *(influence on temperature, humidity, regulation of wind and local climate by hedges or other vegetation ... etc.).*
			Disease control	**SR3**	Potential capacity of an ecosystem to **regulate and limit the spread of harmful animal vectors transmitting diseases for humans**	Some environments are less favorable than others for the spread of animals acting as vectors for harmful diseases to humans such as *mosquitoes, ticks, etc.*
			Pest control	**SR4**	Potential capacity of an ecosystem to **regulate pests affecting agricultural production**	Presence of species regulating pest species such as the presence of *ant eating animals, presence of parasitic wasps, etc.*
		Maintaining nursery populations and habitats	**Maintaining nursery populations and habitats**	**SR5**	Potential capacity of an ecosystem to **provide suitable habitats for different wildlife as nesting, breeding sites or refuges.**	Habitat used as *nesting, breeding, refuge, foraging, etc.*
			Pollination and seed dispersal	**SR6**	Potential capacity of an ecosystem to **provide habitats for pollinating or seed dispersing species**	*Presence of pollinators and species dispersing seeds such as birds, mammals and insect* s. Note: This service focuses primarily on pollinator abundance.
			Hydrological cycle and water quality and flow maintenance	**SR7**	Potential capacity of an ecosystem to **maintain and preserve a good chemical status of fresh and saline water by filtration and self-purification functions**	Ecosystems, ecosystem features or organisms that contribute to *water filtration or purification.*
			Maintaining soil quality	**SR8**	Potential capacity of an ecosystem to **maintain a naturally productive soil contributing to soil fertility**	Ecosystem activities related to *nutrient storage, maintenance of good biogeochemical soil conditions and soil biological activity*
	Mediation of mass flows - risk reduction		**Mass stabilisation and control of erosion rates**	**SR9**	Potential capacity of an ecosystem to **stabilize and mitigate mass flows, store sediments and/or provide vegetation cover that limits erosion**	Combination of two functions: erosion control and sediment storage. *Presence of vegetative cover, root systems and other elements limiting all forms of erosion*
			Storm protection	**SR10**	Potential capacity of an ecosystem to **protect against and limit the impact of storms**	Presence of natural elements that regulate and prevent the impact and damage caused by storms such as *hedgerows, tree lines, etc.*
			Flood protection	**SR11**	Potential capacity of an ecosystem to **maintain water flows and regulate floods and inundations**	Presence of natural elements regulating floods and inundations such as *buffer zones, riparian forests, natural retention basins, etc.*

			Ecosystem Services	Code	Definitions	Potential Indicators - examples
Cultural Services	**REPRESENTATIONS- subjective :** spiritual, symbolic, religous & historic interactions	evaluation of the actual value based on collective and societal notions	**Emblemic or symbolic**	**SC1**	Refers to ecosystems themselves or the species they entail which have a emblematic or symbolic notion for certain social or institutional groups in the present time	Places of natural heritage or ecosystems housing an emblematic or symbolic species for the territory. Examples: *mangroves, forests, coastal environments etc.*
		evaluation of the values based on long term perspectives - subjective	**Heritage (past and future) and existence**	**SC2**	Ecosystems and their elements that create inspiring pleasure by their pure existence and create a willingness to preserve them for us and future generations	Example valuation methods: *societal costs to preserve a habitat or one of its elements; socio-cultural preferences expressed, value of attachment, etc.*
		evaluation of the actual value based on personal notions of aesthetics - subjective	**Aesthetic**	**SC3**	Ecosystems and elements of ecosystems that are considered aesthetic, direct or indirect notion	Example evaluate method: *Number of photos taken from an ecosystem or one of its elements*
	USE- objective : physical and intellectual interactions with ecosystems and landscapes	evaluation of the actual value based on collective/societal notions	**Recreational activities including (eco-) tourism**	**SC4**	Physical interactions with ecosystems for tourism, art and recreational activities such as outdoor sports, hunting, recreational fishing etc.	Inspiration of natural or cultural landscapes for culture, art and design (*books, films, paintings, folklore, national symbols, architecture, advertising, etc.) Ecotourism, leisure activity as outdoor sports, hunting, recreational fishing, etc.*
	Characteristics		*Ecosystem Services*	*Code*	*Definitions*	*Potential indicators - examples*

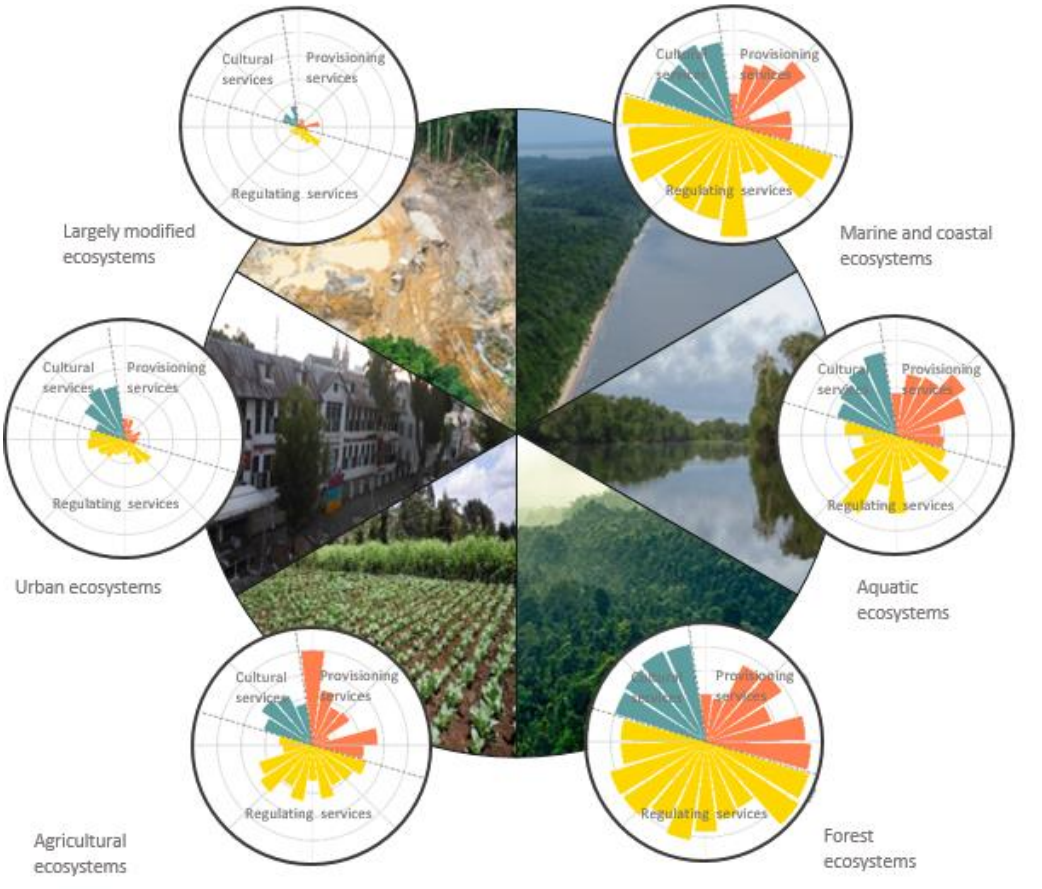
Annex 4: Original French matrix from the participatory, expert based ecosystem services capacity assessment in French Guiana (October 2019), showing the mean scores per ecosystem type and ecosystem services (n=17)

Résultats de l'évaluation des services écosystémiques de la Guyane Francaise - Atelier a Cayenne le 2 Octobre 2019

Capacité potentielle des habitats naturels à fournir un service écosystémique.						
	5	Très fort potentiel	3	Potentiel moyen	1	Faible potentiel
	4	Fort potentiel	2	Potentiel modéré	0	Pas ou très faible de potentiel

				Services d'approvisionnement							Services de régulation et d'entretien											Services culturels			
				Biomasse				Eau douce	Matériaux		Maintien des conditions biologiques, physiques, chimiques								Régulation des risques			REPRESENTATIONS			USAGES
			Services écosystémiques	Production végétale alimentaire cultivée	Production animale alimentaire élevée	Ressource végétale et fongique alimentaire sauvage	Ressource animale alimentaire sauvage	Eau douce	Matéri-aux et fibres	Ressources médicinales	Séquestration du carbone	Régulation du climat local	Régulation des animaux vecteurs de maladies	Régulation des ravageurs	Offre d'habitat, de refuge et de nursery	Pollini-sation et disper-sion des graines	Maintien de la qualité des eaux	Maintien de la qualité du sol	Contrôle de l'érosion	Protection contre les tempêtes	Régulation des inondations et des crues	Emblème ou symbole	Héritage (passé et futur) et existence	Esthé-tique	Activités récréatives
	Code	HABITAT	Confiance	SA1	SA2	SA3	SA4	SA5	SA6	SA7	SR1	SR2	SR3	SR4	SR5	SR6	SR7	SR8	SR9	SR10	SR11	SC1	SC2	SC3	SC4
Habitats marins et littoraux	H1	Océan	2.06	0.12	0.71	0.35	4.82	1.29	0.18	0.88	4.06	4.41	1.47	1.18	4.53	1.12	2.00	0.76	1.71	0.29	1.12	4.06	4.41	3.65	4.59
	H2	Plages, dunes et sables	2.00	0.12	0.12	0.47	1.29	0.47	1.00	1.24	0.65	1.06	1.24	0.88	3.82	1.41	1.82	1.47	3.71	2.65	1.88	3.53	4.12	4.53	4.59
	H3	Mangroves	2.06	0.12	1.06	1.06	3.76	1.00	1.82	1.53	3.76	3.94	2.24	1.59	4.94	3.29	4.24	2.65	4.76	4.12	3.76	3.71	4.18	3.47	2.59
Habitats aquatiques	H4	Fleuves et criques	2.18	0.29	1.29	0.76	4.59	4.59	1.41	1.71	2.06	3.53	2.71	2.53	4.76	3.35	3.94	1.65	1.76	0.29	4.12	4.71	4.88	4.71	4.82
	H5.1	Eaux stagnantes	1.41	0.06	0.94	0.47	2.71	2.71	0.82	0.71	1.88	2.47	1.24	1.00	3.12	1.00	1.82	0.71	0.65	0.47	2.82	1.76	2.88	2.71	2.24
	H5.2	Zones aquatiques artificielles	1.82	0.29	1.35	0.35	2.88	3.88	1.00	0.65	1.88	2.18	1.47	1.24	2.82	1.41	1.76	0.71	0.76	0.41	3.41	1.47	1.82	2.35	3.06
	H6	Zones humides, marais	1.94	0.53	1.71	1.76	4.00	3.65	2.12	1.76	2.88	3.65	2.24	1.82	5.00	3.24	4.29	1.47	2.12	1.24	4.41	4.12	4.59	4.47	3.94
Habitats forestiers	H7	Savanes	1.82	1.24	2.71	2.12	3.06	1.06	1.88	2.82	2.29	2.12	1.65	2.18	4.00	4.12	2.06	2.53	1.35	0.41	3.00	4.53	4.53	3.94	3.29
	H8	Inselbergs	1.94	0.29	0.18	0.82	1.06	1.18	0.47	2.24	1.24	1.12	1.29	1.71	3.76	2.71	1.00	1.18	0.53	0.35	0.29	4.76	4.65	4.82	3.65
	H9.1	Forêts littorales	2.53	0.65	0.71	3.41	3.94	2.18	3.65	4.12	4.41	4.41	3.47	3.59	4.88	4.82	3.76	4.35	4.24	3.41	3.18	4.29	4.47	4.47	4.29
	H9.2	Forêts continentales	2.53	0.35	0.53	3.65	4.53	2.71	4.18	4.71	4.76	4.88	3.35	3.35	4.88	4.82	4.12	4.65	4.12	3.29	3.71	4.76	4.88	4.76	4.41
	H9.3	Forêts inondées ou marécageuses	2.29	0.41	0.41	2.94	3.76	2.82	2.82	3.65	4.35	4.71	3.00	3.12	4.88	4.53	4.29	3.88	4.29	3.35	4.53	4.06	4.24	4.35	3.29
	H10	Plantations forestières	2.00	0.71	0.29	1.29	1.18	0.82	2.53	1.12	2.59	2.18	1.35	1.06	1.82	1.53	1.65	1.88	1.82	1.65	1.59	0.94	1.12	1.12	0.53
Habitats agricoles	H11	Terres arables	1.53	3.59	1.53	1.24	1.12	0.47	1.24	1.12	1.35	0.59	0.53	0.47	0.94	1.88	0.76	0.71	0.24	0.24	0.53	1.29	1.94	1.12	0.24
	H12	Cultures permanentes - arbres fruitiers	1.76	4.24	1.12	1.53	1.41	0.59	1.65	1.76	1.94	1.41	0.88	0.94	1.35	2.76	1.12	1.29	1.47	0.82	0.76	1.88	2.41	1.82	0.65
	H13	Prairies	1.29	2.18	4.00	1.53	1.18	0.47	1.71	0.94	1.59	0.94	0.82	0.88	1.53	2.06	1.00	1.24	1.35	0.12	1.18	1.06	1.41	1.41	1.06
	H14	Zones agricoles hétérogènes - abattis	1.82	4.71	2.53	2.18	2.29	0.47	2.65	2.65	2.06	1.41	1.00	1.35	1.82	2.35	1.12	1.41	1.65	0.47	0.82	3.53	3.76	2.76	1.71
Habitats urbains	H15	Sol nu	2.00	0.00	0.00	0.12	0.12	0.29	0.12	0.00	0.06	0.71	0.29	0.59	0.18	0.06	0.00	0.12	0.00	0.00	0.00	0.29	0.18	0.47	0.35
	H16.1	Zones urbanisées	2.18	0.76	0.65	0.06	0.18	0.94	0.18	0.76	0.12	0.88	0.41	0.47	1.00	0.53	0.12	0.00	0.12	0.29	0.12	1.29	1.88	2.00	1.88
	H16.2	Zones industrielles ou commerciales	2.29	0.00	0.00	0.00	0.00	0.65	0.06	0.29	0.06	0.88	0.41	0.47	0.76	0.06	0.06	0.00	0.12	0.00	0.12	0.59	0.65	0.24	1.12
	H17	Infrastructures routiéres	2.24	0.12	0.00	0.00	0.06	0.29	0.00	0.24	0.06	0.82	0.35	0.41	0.35	0.06	0.00	0.00	0.29	0.00	0.06	0.53	0.88	0.41	0.35
	H18.1	Activitées miniéres légales	2.35	0.00	0.00	0.00	0.00	0.29	0.41	0.00	0.12	0.41	0.00	0.29	0.24	0.06	0.00	0.00	0.00	0.00	0.00	0.59	1.00	0.06	0.12
	H18.2	Activitées miniéres illégales	2.35	0.00	0.00	0.00	0.00	0.00	0.24	0.00	0.12	0.41	0.29	0.29	0.06	0.06	0.00	0.00	0.00	0.00	0.00	0.29	0.35	0.00	0.06
		1: confiance faible á 3: forte confiance	Confiance	2.25	2.25	2.00	2.13	2.13	1.88	1.50	2.13	2.13	1.25	1.25	2.38	1.75	2.13	2.00	1.88	1.75	1.63	1.50	1.38	2.13	1.75

Mapping and assessment of the capacity of ecosystems in Suriname to supply ecosystem services



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Work conducted together with WWF Guianas, the Foundation for Forest Management and Production Control (SBB) and within the project *"ECOSEO, Ecosystem Services Observatory of the Guiana Shield"*, funded by the Interregional Amazonian Cooperation Program of the European Regional Development Fund, the Water agency of French Guiana and coordinated by the French Guiana office of WWF-France.

May 2020

Ecosystem Services Observatory of the Guiana Shield

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Table of Contents

List of Abbreviations

CBD	Convention on Biological Diversity
CICES	Common International Classification of Ecosystem Services
ECOSEO	Establishing an ecosystem services observatory in the Guianas
ES	Ecosystem Services
ENCA	Ecosystem Natural Capital Accounts
LUH	Gottfried Wilhelm Leibniz Universität Hannover
LULC	Land Use Land Cover
MAES	Mapping and Assessment of Ecosystems and their Services
NBSAP	National Biodiversity Strategies and Action Plans
NIMOS	National Institute for Environment and Development in Suriname (Nationaal Instituut voor Milieu en Ontwikkeling in Suriname)
SBB	Foundation for Forest Management and Production Control (Stichting voor Bosbeheer en Bostoezicht)
UNDP	United Nations Development Programme
WWF	World Wide Fund For Nature

1. Introduction

The Ecosystem Services (ES) concept has gained global attention, especially in the last two decades (Costanza et al. 2017). It describes the key role of nature and biodiversity in terms of direct and indirect contributions, such as food provision, timber and fuel, medicines derived from plants, clean water, flood control and climate regulation functions. Such ES are crucial for human well-being – thus mankind is strongly dependent on well-functioning ecosystems and natural capital (MEA 2005). This, in turn, forms the basis for a constant flow of ES from nature to society. However, with ongoing degradation of the natural environment, the safeguarding of ecosystem service flows to society is severely endangered – an effect that disproportionately affects poor and underprivileged parts of society (Braun and Gatzweiler 2014; Kumar and Yashiro 2014; Schreckenberg et al. 2018).

Many policies and frameworks to protect biodiversity at national and international scales have adopted the ES concept. For example, the Strategic Plan 2011-2020 adopted by the Convention on Biological Diversity (CBD), including the 'Aichi targets', foresees that *"By 2050, biodiversity is valued, conserved, restored and wisely used, maintaining ecosystem services, sustaining a healthy planet and delivering benefits essential for all people"* (Convention on Biological Diversity 2011)[1]. Within their targets, the CBD specifically highlights the importance of protection of "*ecosystems* that provide essential *services*, including *services* related to water […]" (Target 14[2], Strategic Goal D).

The Guiana Shield, namely Guyana, Suriname, Brazil as well as the French Overseas Territory French Guiana have committed to implement the Aichi targets in their National Biodiversity Strategies and Action Plans (NBSAPs) (Ministry of Labour and Technical Development and Environment 2013; Ministry of Natural Resources and the Environment 2014). Application of the ES concept and conservation management can be found on the local level (Ramirez-Gomez et al. 2013; Ramirez-Gomez et al. 2016). On the regional level, the link between Chenier morphodynamics and beach ecosystem services has been established (Anthony et al. 2019). Also, first cross-border initiatives have been set up to jointly work towards better protection of natural resources, e.g. the Guiana Shield Initiative or the RENFORESAP Project, strengthening the network of protected areas in the Guianas[3]. However, assessing the NBSAPs reveals that there is still potential for the ES concept. Identification of relevant ES, their mapping and assessment are crucial first steps that should be the base for the development of policies and legal frameworks (Prip 2018).

The implementation of the ES concept on national level requires a flexible framework. Such a framework needs to takes into account a broad range of services as well as different spatio-temporal aspects of ES supply. Often, qualification and quantification of many different ES over large geographic regions proves to be difficult. The identification of suitable indicators to measure ES is complex (Egoh et al. 2012; Müller et al. 2016), and requires a large amount of relevant data at different spatial and temporal scales. As alternative to such approaches, the so-called 'ecosystem services matrix approach' can be applied (Burkhard et al. 2009). The ES capacity matrix method, including an expert-based ES evaluation has proven to be a robust, reliable semi-quantitative method (Burkhard et al. 2009; Jacobs et al. 2015; Campagne et al. 2017). The resulting capacity matrices link geospatial units (such as ecosystem types) and ES supply in form of a lookup table. Each cell in the matrix (ES per geospatial

1 Key Elements of the Strategic Plan 2011-2020, including Aichi Biodiversity Targets
[2] https://www.cbd.int/sp/targets/
[3] https://doe.gov.gy/published-content-details/Guyana-signs-Protected-Area-Cooperation-Agreement-with-Suriname-and-French-Guiana/5bbfe9cd48f2780d37a923e9

unit) is filled with a score from 0 (no service supplied) to 5 (overall maximum service supplied), reflecting the capacity of the respective geospatial unit to supply a certain ES. To fill the matrix, stakeholders with territorial or national expertise related to ecosystems, their management or usage can be invited to fill the ES matrix, a so called expert-based evaluation. Such an ES capacity matrix allows an efficient and integrative assessment of whole bundles of ES, including temporal trends at landscape scale. The results of such expert-based evaluation of ES can easily be visualized in maps, when ES values are combined with spatial data. Hence, they offer the possibility to define ES hotspots or priority areas for land conservation or land use. As a result, the ES maps have become a key concept for sustainable development, land use planning and decision making (Maes et al. 2012).

The assessment of the capacity of ecosystems in the Guianas to supply ES presented in this report was carried out with the approach of capacity matrices. This approach allows to take into account all the different types of ecosystems and services in a participatory approach integrating the knowledge of the stakeholders of the territory on national level for both French Guiana (this report) and Suriname (Sieber et al. 2020). The objective hereby was twofold. First, the study aims to take an alternative, non-commodifying approach towards valuing nature. Through looking at ecosystems in a holistic way, the assessment highlights the multiple goods and services that ecosystems supply, including non-marketable goods and services. Second, this study aims to present the potential of such an ES approach, including ES bundles and maps. These can serve as a management tool for policy and decision makers to safeguard sustainable development and to provide strong additional arguments for nature conservation efforts.

Objectives of this study

The ECOSEO Project led by WWF aims to promote tools allowing better consideration of ecosystem services and natural capital in decision making and environmental assessments. The expertise of Leibniz Universität Hannover (LUH) was asked to assess ecosystem services and lead to the development of a framework document on ecosystem services in Suriname and French Guiana.

Ultimately, the goal is to provide a method to decision makers and environmental authorities in order to conduct the analysis of these services locally. Here we present the method and results of the assessment of ecosystem services supplied within Suriname, on national and regional scale.

1.1 Ecosystem Services

The term ”ecosystem service” was first used in 1981 and has become more and more common in scientific publications in the 1990s. With the publication of the Millennium Ecosystem Assessment (MEA 2005) it has gained momentum globally (Burkhard and Maes 2017) . Since, it has been developed and adjusted to multiple contexts around the globe (Costanza et al. 2017). It presents a method to assess the state of ecosystems and natural capital, in the context that human well-being depends on the condition, the structure and the functions of ecosystems. Most commonly, ES are defined as “the benefits people obtain from ecosystems” (MEA 2005, p. 40). This comprises the direct and indirect contributions of ecosystems to human well-being.

Within the concept of ES, ecosystem service supply and ecosystem service capacity can be distinguished. By definition, an ES can only be qualified as such, if there is a benefit to humans (Burkhard and Kroll 2010). Ecosystem service supply is defined as the “full potential of ecological functions or biophysical elements in an ecosystem to provide a given ecosystem service" (Tallis et al. 2012, p. 977). To define the capacity of ecosystems to supply ES, we follow the definition by Villamagna et al. as "an ecosystem's potential to deliver services based on biophysical and social properties and functions" (Villamagna et al. 2013, p. 116).

To qualify and quantify ES, it is necessary to estimate the different ecosystems, their condition and the services they supply (Kienast et al. 2009) and their interrelations within complex social-ecological systems (MEA 2005). It is common to divide ES into three categories: ***Provisioning ES*** are the material, often "final" products obtained directly from ecosystems (e.g. food, fibres, timber). ***Regulating ES*** are mostly indirectly obtained, often intangible benefits through the regulation of ecosystem processes (e.g. climate regulation, carbon storage, natural hazard regulation, water purification, pollination or pest control). ***Cultural ES*** are the rather intangible benefits of ecosystems, including recreational activities and (eco-) tourism, existence (of nature and species) values, landscape aesthetic or spiritual nature values.

There are different frameworks to assess and model ES. Figure 1 shows a conceptual framework for assessing ES developed by the EU Working Group Mapping and Assessment of Ecosystems and their Services MAES (Maes et al. 2016). The concept highlights the flow of services from ecosystems to socio-economic systems and resulting benefits for human well-being. Furthermore, it shows the socio-economic systems as a control system for the change of ecosystems. This framework is partly based on the ES "Cascade model" (Haines-Young & Potschin, 2018b) and has been customized to assess a broad variety of ES within various different ecosystems in context of the EU 2020 Biodiversity Strategy (Maes et al. 2016).

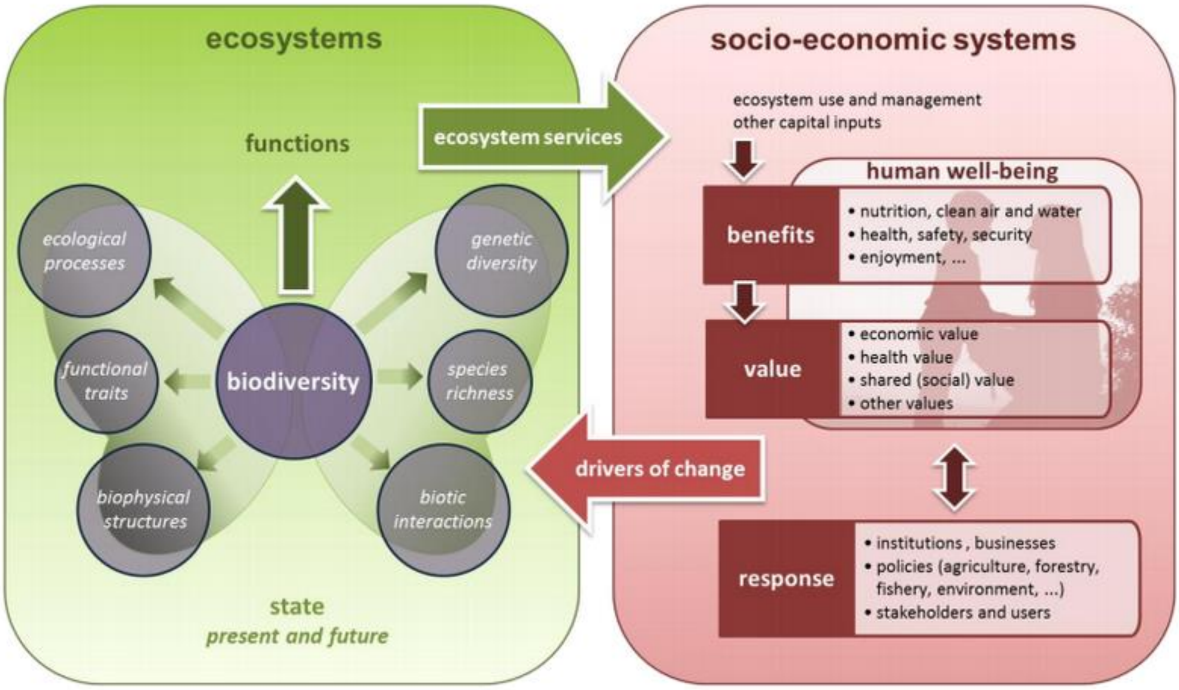


Figure 1: Conceptual framework for assessing ecosystem services[4]

[4] https://biodiversity.europa.eu/maes

Within the EU Biodiversity (BD) Strategy to protect biodiversity and halt the loss of species, MAES is a core component. Action 5 of the Strategy's 2nd Target foresees each EU Member State to map and assess the ecosystems and their services in their national territories, creating an EU-wide knowledge base (Burkhard et al. 2018). This is important for the advancement of biodiversity objectives, the creation of informed policies on, for instance agriculture, water, climate and landscape planning. Furthermore, Action 5 aims at identifying areas for ecosystem restoration and a baseline against which the goal of 'no net loss of BD and ES' can be evaluated.

1.2 Ecosystem services in the Guianas

The Guiana shield is renowned as one of the last remainders of intact primary forest. The Shield covers 270 million hectares, encompassing Guyana, Suriname, French Guiana, Venezuela and small parts of Colombia and Amapá, northern Brazil. The UNDP declared it as eco-region of "regional and global significance, "and home to a variety of ecosystems and "keystone species of biodiversity" (UNDP, 2020[5]).

The Guiana Shield encompasses a coastal plain with half-submerged mangrove landscapes in the north. Littoral forest follows, with patches of savannas and drowned open swamps. Thereafter, vast rainforest stretches down south, the canopy only broken by large Inselbergs and mountainous formations in the hilly hinterland. Comprehensive overviews of ecosystems in Suriname are presented by Dijn (2018).

Many of these ecosystems have been altered by human influence, especially in the coastal zone (Odonne et al. 2019). Here, anthropogenic pressures threaten the condition of ecosystems. Urbanisation, intensification of agriculture and deforestation lead to habitat fragmentation. Resource mining – e.g. for gold depositions in the Greenstone Belt – together with the use of heavy metals, poses severe threats to rivers and aquatic ecosystems throughout the Guiana Shield.

Efforts to understand the links between ecosystems in the Guiana Shield and the services they supply have recently started and are growing. Forest ecosystems have been intensively studied. For example, aspects of forest tree composition and its relation to carbon storage (Molto et al. 2014; Guitet et al. 2015) and the contribution to global and local climate regulation have been assessed (Blanc et al. 2009). Similar tendency holds for mangrove ecosystems. For mangroves, studies on the capacity to store carbon are present (Marchand 2017). First studies in Suriname apply participatory approaches to capture the cultural ES provided by ecosystems to indigenous communities (Ramirez-Gomez et al. 2013; Ramirez-Gomez et al. 2016). However, to the best of our knowledge, there still is a knowledge gap on holistic mapping and assessment of ecosystem services

Mapping and assessment of ecosystem services could be a first step to inventory where which ES are provided. This could, in turn, feed into solutions to address the degradation of biodiversity, ecosystems and their services. In a second step, such knowledge could inform conservation efforts, which should not be restricted to national territories, but should be sought in transboundary collaboration (McPherson and Boyer 2015).

[5]https://www.gy.undp.org/content/guyana/en/home/operations/projects/environment_and_energy/project_sample2.html

1.3 The ECOSEO Project

The natural capital of the Guiana Shield is still very rich compared to other parts of the world. However, there is an urgent need to recognize its value at local but also international level in order to guide policies towards sustainable development and prosperity for the next generations. The ECOSEO project “Ecosystem Services Observatory of the Guiana Shield” aims to set up a supranational platform with Guyana, Suriname, French Guiana and Amapá, Brazil for a first assessment of natural capital and ES in the region. This cooperation is based on the needs of users and decision-makers in the different territories in line with their commitment to EU and UN Conventions. The main objectives of the ECOSEO project are:

(i) To highlight and promote the need for considering ecosystems values in decision-making; and,

(ii) To build a transnational cooperation network (Figure 2).

The project takes an interdisciplinary stance on ecosystems and nature. Through applying the Ecosystem Natural Capital Accounts (ENCA) method (Weber 2014) and the ES framework[6], two different methods are employed to showcase the value and importance of ES.

Figure 2: the ECOSEO INTERREG Project with its main partners

The ECOSEO project foresees an application of ES mapping and assessment methodologies in the Guianas. This report will outline the outcomes of the expert-based ES assessment in Suriname. The aim of this assessment is twofold: First, it will create an overview of relevant ecosystems and a first estimation of ES potentially supplied within the territory. Second, the methods developed and applied in mainland Europe will be tested on their suitability for application and adaptation based on the specificities in the Guianas.

[6] https://ec.europa.eu/environment/nature/knowledge/ecosystem_assessment/index_en.htm

2. Methods and materials

In this section, the methods and data drawn upon for this ES assessment will be presented. The concept of ES capacity matrices as tool to analyse ES, the selection of the ecosystem types for this assessment as well as the selected ES are described. Further, the section draws upon the participatory stakeholder workshop as core component of this study.

2.1 Capacity matrices to assess ecosystem services

This study applied the ES capacity matrix method based on the knowledge from an expert panel, including specialists of the region and its specific ecosystems. Put simply, a capacity matrix is a comprehensive and flexible method in the form of a look-up table combining ecosystem types and ES (Burkhard et al. 2009). At the base, appropriate geospatial units, e.g. Land Use/ Land Cover (LULC) data can be used to delineate the ecosystem types. These are then linked to ES that are relevant in the study region (Figure 3). At the intersections in the matrix table, the supply of ES within the particular geospatial units (e.g. LULC types) can be assessed on a scale from 0 (no or very weak capacity) to 5 (very strong/maximum capacity). The normalisation to such a relative scale from 0 – 5 allows to compare different ES (that are usually assessed by different indicators and units). Such an approach is well-suited to express values from different domains, including biophysical, socio-cultural, non-monetary as well as monetary values of multiple ES.

One approach to conduct such a matrix assessment is via expert knowledge. Expert estimations deliver a good overview by integrating all kind of different sources of knowledge and can be a strong capacity building tool at the same time. As all expert-based assessments, the scoring values strongly depend on the experience, knowledge as well as objectivity of the evaluators (Burkhard et al. 2012).

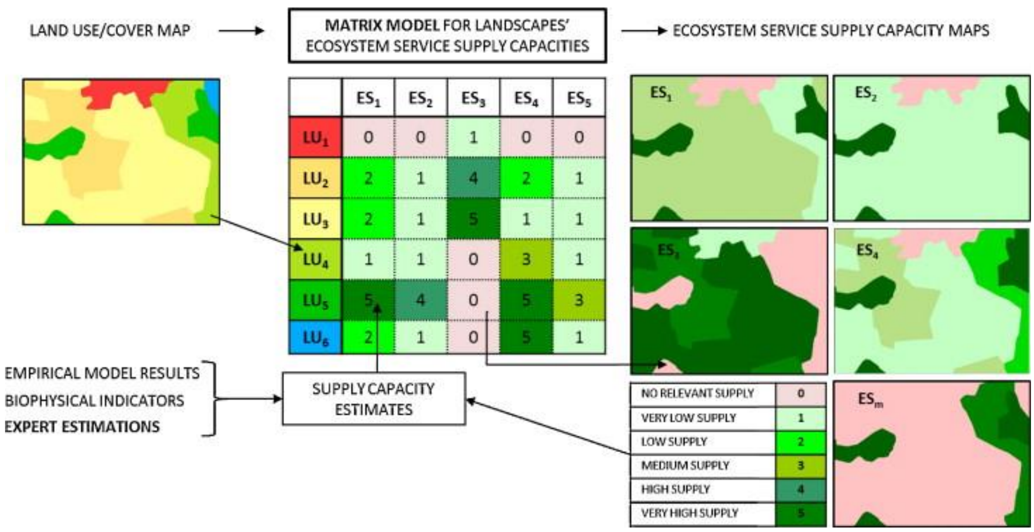


Figure 3: Schematic representation of the ecosystem services Matrix method (after Burkhard et al. 2009, in Jacobs et al. 2015)

The ES matric approach has been introduced in 2009 (Burkhard et al. 2009). Since then, numerous studies applied and developed the approach (Jacobs et al. 2015). The ES matrix method found applications in various contexts and on different scales. Examples can be found in different countries, e.g. Germany (Burkhard et al. 2012), Bulgaria (Nedkov and Burkhard 2012), Bangladesh (Sohel et al.

2015) or China (Liu et al. 2012). Also, applications took place on different spatial scales, for example on the local and regional scales (Bicking et al. 2018; Campagne and Roche 2019), on the watershed level (Boyanova et al. 2014), but also on the supranational level, e.g. across the European Union (Stoll et al. 2015) or in Antarctica (Neumann et al. 2019).

As major limitations of the method, lacking methodological transparency, difficulties to reproduce results and lacking uncertainty (indicators) have been mentioned (Hou et al. 2013). Possibilities to address these limitations were proposed by Campagne et al. (2017).

2.2 The expert-based ES Matrix approach

The method used for this ES assessment follows a framework identified by Campagne and Roche (2018). Their approach towards the ES matrix method (Figure 4) contains 7 steps:

1) *Defining the goal of the assessment, and with key stakeholders, definition of the ecosystem services and ecosystem types' lists for the matrix, the experts' panel and the scoring.* For this study, the lists of ES and ecosystems for the matrix, the experts' panel and the scoring have been defined with the ECOSEO partners: WWF France, WWF Guianas, SBB and regional experts as presented in Chapter 2.3.

2) *Organising* a *participatory workshop with all experts to get a common understanding of the study and the scoring process.* The workshop was held on 8th of October 2019 in Suriname – detailed in Chapter 2.4.

3) *Filling the initial matrix by experts, either a pre-filled or empty matrix by individual or by consensus between experts during the workshop (4).* For this workshop, we decided to start with an empty initial matrix, with individual matrices filled in by each expert. This approach helps to avoid biases based on prefilled scores.

5) Expert score compilation, analyses and creation of the final matrix. The analysis of the filled-in matrixes, including a description of statistical operations, can be found in Chapter 2.5.

6) Reliability and validation process. The "draft" final matrix was circulated to all workshop participants for validation and feedback (December 2019), with a month of reviewing time.

7) Creation of the outputs. Thereafter, final statistical analyses were run, and the final ES bundles and ES maps were created (7) using a Geographic Information System (ArcGIS). The results are presented in the Chapters 3 and 4.

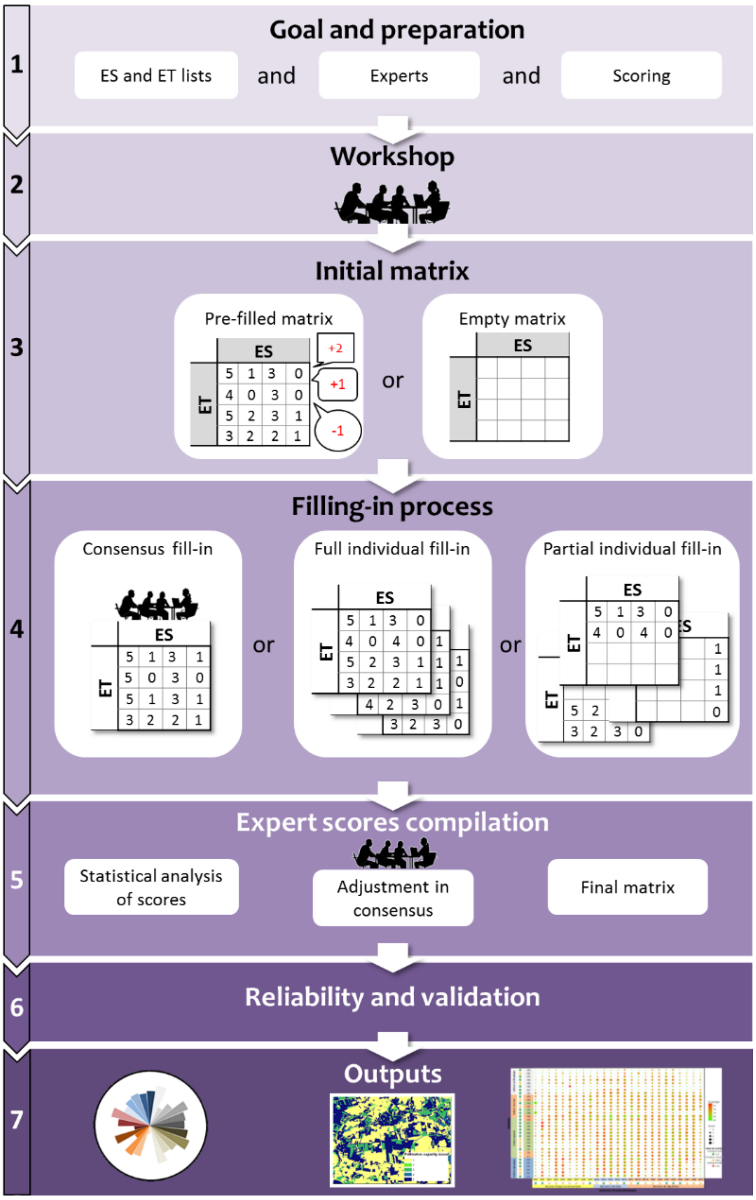


Figure 4: Schematic representation of the ecosystem services assessment following the matrix method (Campagne and Roche 2018)

2.3 Compilation of the initial matrix

The initial matrix was compiled in two major steps: the identification of ecosystem clusters and the selection of relevant ES for the national level of Suriname. For a comparative future assessment, a comparative approach has been taken in both Suriname and French Guiana, where a similar assessment took place (Sieber et al. 2020). The identification and selection processes will be explained in the following.

2.3.1 Selection of ecosystem types

Mapping of ES requires spatial information on the location and extent of abundant ecosystems. In both Suriname and French Guiana, such information is available in online Geodatabases. As there is a vast amount of specific and highly localized ecosystems, but limited spatial information on their specific locations, we grouped and clustered them into major ecosystem clusters and ecosystem types based on the available geodata of the two territories. Ecosystem cluster in this assessment refers to the broader groups of ecosystem communities resembling each other. These ecosystem communities are included as ecosystem types. This inevitably reduced the complexity of the natural mosaic landscape in the Guiana Shield to major ecosystem types. However, this reduced complexity and the resulting manageable number of geospatial units (ecosystem types) for the matrix allowed to start with collection of data for first ES maps. Based on the available data, the list of ecosystem clusters in the matrix has been compiled (see Table 1).

Table 1: Ecosystem types and ecosystems assessed for Suriname

Ecosystem cluster	Code	Ecosystem type
Marine and littoral ecosystems	H1	Ocean
	H3	Mangroves
Aquatic ecosystems	H4	Rivers and creeks
	H5.1	Lakes
	H5.2	Inland water bodies - semi-natural
	H6	Open swamp
Forest ecosystems	H7	Open savannah
	H8	Inselbergs
	H9	Forest tree cover
	H10	Planted forest
Agricultural ecosystems	H11	Small scale agriculture
	H12	Large scale agriculture
	H13	Grasslands
	H14	Shifting cultivation
Urban (and largely modified) ecosystems	H15	Bare soil
	H16.1	Built area
	H17	Infrastructure
	H18.2	Mineral extraction sites

For the Surinamese assessment we worked with the "Land Use Land Cover 2015" GIS Shapefile available on the Gonini geoportal[7], produced within the National Forest Monitoring System of Suriname. The LULC data combined Landsat 8 satellite images of 2000-2015; Sentinel 2A images of 2015; Google Satellite and Bing Satellite imagery (SBB 2018). In addition, ancillary data, participatory workshops and ground truthing had been added used to maximize the accuracy of the LULC data (SBB 2017). The data had been compiled by SBB in close collaboration with the National Institute for Environment and Development in Suriname (NIMOS) and other national stakeholders and REDD+ Suriname under the framework of the Cross Cutting Capacity Development (CCCD) project.

[7] https://www.gonini.org/

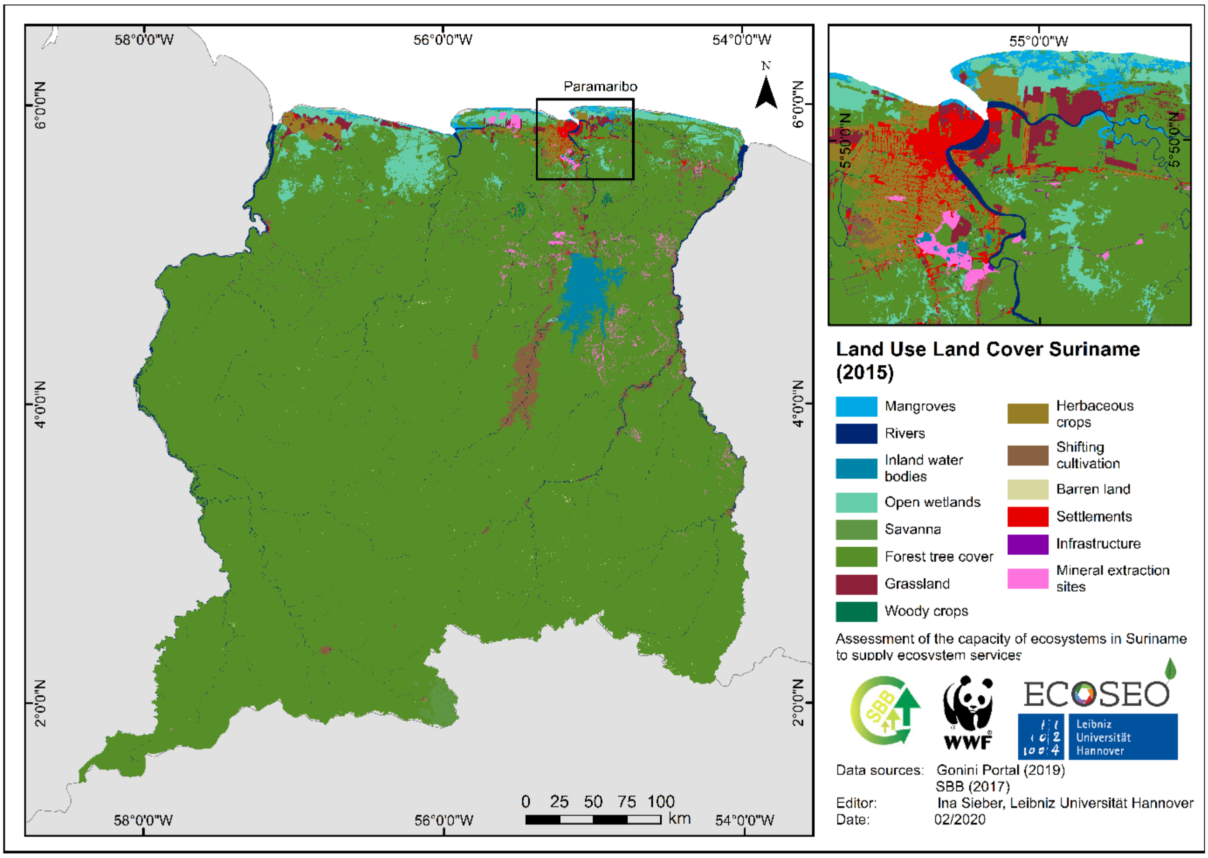


Figure 5: Land use land cover map of Suriname based on the year 2015 (source: SBB (2018). Land Use Land Cover 2015. www.gonini.org)*).*

On first sight, the vast amount of forest becomes visible in the LULC map (Figure 5). The major land cover of Suriname is indeed forest. The Brokopondo water-reservoir in the centre of Suriname is a clearly distinguishable feature. Major settlements can be found along the ocean in the coastal plains, but also alongside the rivers, e.g. the Marowijne in the east, corresponds to red spots on the map. Agricultural areas can be found in the immediate proximity of settlements, for example in the vicinity of Paramaribo city (Figure 5, regional map in the upper right). In the plains, herbaceous crops are cultivated, including intensive agriculture, whilst in the forested areas, shifting cultivation is the dominant agricultural practice. Shifting cultivation is a method of small-scale farming that includes clearing and burning the land, planting and harvesting crops, and then abandoning the land before moving to a new area (Lininger, 2011). Especially alongside the Suriname River, large patches of shifting cultivation can be found. These are mainly executed by the people from the villages. Woody crops, namely planted forest, can be found in the northeast of the country.

Based on the geospatial data, the LULC data sets for Suriname and French Guiana were harmonized. The individual feature classes were regrouped and renamed for comparative purposes, where needed (Annex 3). Some codes refer to subtypes, e.g. H5.1 and 5.2 – lakes and semi natural water bodies. This is based on the fact that the geodata do not distinguish these LULC classes. The selected ecosystem types are shown in Table 1. This list includes marine and littoral ecosystems (oceans, mangrove ecosystems), aquatic ecosystems (rivers and creeks, lakes, inland water bodies –semi natural, and open swamp). In the category of forest ecosystems, we clustered open savanna, inselbergs, forest tree cover and planted forest. In terms of agricultural ecosystems, small and large scale agriculture can be distinguished as well as grasslands used as pasture and shifting cultivation. Urban ecosystems comprise bare soil, built area, infrastructure and mineral extraction sites.

The LULC data for Suriname focus solely on terrestrial land uses. The data do not contain information on marine and benthic ecosystems. Therefore, this study focuses on terrestrial forests and non-forest ecosystems.

2.3.2 Selected ecosystem services

The list of ES has been compiled together with WWF, Office de L'Eau and regional experts from both French Guiana and Suriname (Table 2, more detailed in Annex 3). An initial list was proposed by LUH based on an intensive literature review (Sieber et al. 2018) and inspired by the work conducted by DREAL in French mainland (Campagne and Roche 2019). The selection of ES complies with the ES classes of the Common International Classification of ES (CICES 4.3). ES can be grouped in Sections, thus the three main categories of provisioning, regulating and cultural services. Within each Section, the services can be clustered into Division and Groups, with increasing level of detail (Haines-Young and Potschin 2013). In accordance to the updated CICES 5.1 classification (Haines-Young and Potschin-Young 2018), this assessment only considered biotic ES, thus services that depend on living systems. Even though many physical processes (e.g. salt, crude oil, minerals) of natural system are of high importance to people, this assessment aims to highlight the existential contribution of ES and biodiversity to human well-being.

To adapt the ES list to the Guiana Shield ecosystems, several meetings and a five day field mission to the Maroni River Basin took place between June and October 2019 with WWF Guyane, WWF Guianas and SBB Suriname.

Overall, 22 ES were selected (Table 2): the workshop assessed 7 provisioning services, including biomass for food consumption (SA1, SA2), biomass for multiple purposes, including wild foods (SA3, SA4), water for drinking purposes (SA5) and raw materials (SA6, SA7). Regulating services comprise 11 services that can be divided into services maintaining biological, physical and chemical conditions (SR1-SR8) and services related to mediation of mass flows, contributing to risk reduction (SR9 – SR11). The 4 cultural services for this assessment consist of three representational services, (SC1-SC3) that are highly subjective and include aspects of cultural identity. The fourth cultural service in this assessment is rather objective, and refers to the actual use of landscapes for recreational activities including (eco-) tourism (SC4). A full delineation including definitions can be found in Annex 3.

Table 2: List of ecosystem services assessed in Suriname based on CICES 4.3. Section refers to the three groups of provisioning, regulating and cultural services, Divison and Group entail specific information on the different ES assessed.

Sec-tion	Division		Group	Code
Provisioning Services	Nutrition	Biomass for food consumption	Cultivated crops / food	SA1
			Reared animals and their outputs	SA2
		Biomass	Wild plants, algae and their outputs	SA3
			Wild animals and their outputs	SA4
		Water	Freshwater supply for drinking purposes	SA5
	Materials	Raw materials	Materials and fibres	SA6
			Plants and resources for medical use	SA7
Regulating Services	Maintaining biological, physical and chemical conditions		Carbon sequestration	SR1
			Global and local climate regulation	SR2
			Disease control	SR3
			Pest control	SR4
		Maintaining nursery populations and habitats	Maintaining nursery populations and habitats	SR5
			Pollination and seed dispersal	SR6
			Hydrological cycle and water quality and flow maintenance	SR7
			Maintaining soil quality	SR8
	Mediation of mass flows - risk reduction		Mass stabilisation and control of erosion rates	SR9
			Storm protection	SR10
			Flood protection	SR11
Cultural Services	REPRESENTA-TIONS-subjective		Emblematic or symbolic	SC1
			Heritage (past and future) and existence	SC2
			Aesthetic	SC3
	USE-objective		Recreational activities including (eco-) tourism	SC4

2.3.3 The ecosystem services matrix of Suriname

The ecosystem services matrix consisted of 22 ES and 18 ecosystem types, as previously described, i.e. 396 scores in total. For comparative purposes, the same ecosystem codes (H1- H18.2) and ES abbreviations (SA, SR, SC) were used in this report and in the study on French Guiana (Sieber et al. 2020).

For each cell in the matrix, the score ranged between 0 (no to very weak capacity) and 5 (very strong/maximum capacity). In addition, a confidence index allowed the correspondents to indicate their individual level of comfort with the given scores from 1 (weak confidence) to 3 (strong confidence). This score applied to ecosystems as well as to ES. The overall confidence scores per ecosystem and per service were then calculated using an arithmetic mean confidence index of all experts.

2.4 Data collection: Expert workshop in October 2019

The participatory expert workshop took place on October 8th 2019 on the premises of SBB (Ds. Martin Luther Kingweg perc. no. 283, Paramaribo, Suriname). Ina Sieber from LUH and Jerrel Pinas from WWF Guianas moderated and guided through the workshop (Figure 6).

Figure 6: Impressions from the expert workshop in Paramaribo on October 8th, 2019

The workshop was scheduled from 8:30a.m. to 1p.m. The first part was devoted to presentations on the concept of ES, the work of ECOSEO and WWF in the Guiana Shield, the principles of expert based assessments including the list of ecosystem types and the list of ES. During the second part of the workshop, the experts filled in the empty capacity matrix individually, discuss questions, problems and remarks on the applicability of the method.

Discussions on the importance of local and indigenous knowledge in the assessment of ES were held. A mission to the Marowijne basin took place in the week of October 23rd in order to learn more about local perceptions of ecosystems and the benefits they provide. This information will be used to validate the matrix with local knowledge as final step.

Box 1: Agenda of the Participatory expert based workshop on 8.10.2019

Workshop Agenda

8h30 Introduction and context
Welcome words - Sarah Crabbe, SBB
The ECOSEO Project - Clément Villien, WWF Guyane

9h15 Assessing ecosystem services
The capacity matrix
Classification of Land Use classes for this assessment – Valentien Moe Soe Let, SBB
The ecosystem services

10h15 Coffee break

10h30 Filling the matrix and discussion

13h End of the Workshop

The original workshop invitation is available in Annex 1.

2.4.1 The expert panel

During the workshop, 22 experts from different fields, from the public and private sector and academia gathered. For those experts who could not personally attend the workshop, individual interviews were offered, following the same procedure as during the workshop.

This number of participants suffices to obtain scientifically sound results. It has been proven in the regional scale case study in France that an expert panel with a minimum of 15 people is sufficient to reach stabilized mean scores and a stable plateau for the matrix. With each additional participant, the scoring deviation becomes negligible (Campagne et al. 2017). Hence, with 22 experts, the size of our expert panel was sufficient to obtain a capacity matrix with robust scores.

The assessment also included information on the experts' profiles. 40% of the experts were female, leading to a decent representation of gender equality. Most of the experts came from fields of research and public authorities. The panel of experts showed a high diversity of profiles with seven decision makers, seven (programme) managers, eight environmentalists and researchers participated. 68% of the experts stated their expertise to be on the national scale, 22% worked on the regional scale and 10% had expertise on the local scale. Most of the experts' work was related to forest and its management or conservation.

2.5. Analysis

The individually-filled ES matrices were analysed using the following statistical methods and equations:

- The mean score of all expert scores, including confidence indices, were computed with arithmetic mean. Bootstrap mean or other more complex calculations were not needed due to the sufficient size of the expert panel (Campagne et al. 2017).
  The arithmetic mean is the sum of all values for a cell in the matrix divided by the number of entries.

  Equation 1: the mean (x)

$$\overline{x} = \frac{1}{n}\left(\sum_{i=1}^{n} x_i\right) = \frac{x_1 + x_2 + \cdots + x_n}{n}$$

  where {x1, x2, … xn} are the observed values of the sample items, $\overline{x}$ is the mean value of these observations, and n is the number of observations in the sample (n=22).

- The standard deviation was used to estimate the variability between the expert scores and hence to identify variabilities in scoring agreement between experts. This score analyses the amount of variation or dispersion of a set of values. A low standard deviation indicates that the values tend to be close to the mean (also called the expected value) of the set, whilst a high standard deviation indicates that the values are spread out over a wider range.

  Equation 2: Standard deviation (s)

$$s = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}(x_i - \overline{x})^2}$$

- Weighted means were used as the graphic representations of the ES bundles. For the bundles, a weighted mean was calculated based on surface area. For this, the surface area for each ecosystem type has been determined. The expert estimations for each ecosystem type were then multiplied by the percentage of land cover within the broader ecosystem types (Table 2). This ensured that ecosystem types with small surface area did not lead to overestimated ES supply values. However, the weighted mean only came into consideration for the ES bundles per ecosystem cluster.

Equation 3: Weighted means

$$\bar{x} = \frac{\sum_{i=1}^{n} w_i \, x_i}{\sum_{i=1}^{n} w_i}$$

where $\bar{x}$ represents the weighted arithmetic mean, x represents the variable of each data value for the observations, w is the weight which is the number of items with the same value of x, and n is the number of observations in the sample (n=22).

- Pearson's Correlation

  The Pearson's Correlation is used to analyse the expert matrix on similarities and correlations between the different ecosystem capacities to supply ES. Equivalent to the bundle analysis as visual tool, the Pearson's correlation allows to calculate the synergies and trade-offs statistically. Such statistical analysis helps to identify the degree of statistical dependency between two variables such as Pearson's correlation coefficient or Spearman's rank correlation coefficient. The Pearson's correlation coefficient indicates the linear strength of correlation between two elements. The following equation expresses the correlation coefficient r, where n is the number of observations and x and y represent the different variables.

Equation 4: Pearson's correlation coefficient (r)

$$r = \frac{n(\sum xy) - (\sum x)(\sum y)}{\sqrt{[n\sum x^2 - (\sum x)^2][n\sum y^2 - (\sum y)^2]}}$$

Positive r values indicate a positive correlation or synergy while negative values indicate a negative correlation or trade-off. The correlation coefficient (r) can range in value from −1 to +1. The larger the absolute value of the coefficient, the stronger the relationship between the variables.

For the Pearson correlation, an absolute value of 1 indicates a perfect linear relationship. A coefficient of 0.5 indicates a moderate linear relationship. A correlation close to 0 indicates no linear relationship between the variables. Negative values indicate negative relationships between the different variables.

In the literature, it is recommended to define a threshold that is distinguishing "no-effect" relationships from relevant relationships. Lee and Lauterbach (2016) found that there is no clear threshold definition in the ES literature. Whilst applied statistics textbooks recommend to define a Pearson's correlation coefficient under 0.0 as negligible or weak relationship, ES literature works with a Pearson's correlation coefficient of 0.2 as meaningful correlation (Jopke et al. 2015). Therefore, Lee and Lauterbach (2016) recommend a correlation coefficient between -0.25 and 0.25 as "no-effect" label to relationships between ES.

3. Results

The main result of the workshop is the completed ecosystem service capacity matrix for Suriname presented in Table 3 with the mean scores of all 22 experts and the respective confidence scores. Another representation of the capacity matrix and it scores is presented in Table 4 with the mean scores (size of the points), the standard deviation (colour of the points in Table 4) and the average of the confidence indices for each ecosystem and each service (green, yellow or red smileys in Table 4).

How to read and interpret the results of the matrix?
When interpreting the matrix, there are several aspects to consider: **scores, standard deviation and confidence index.**
- The scores represent the capacity of a certain ecosystem type to supply the respective ecosystem service; these are the values in Table 3 and the size of the points in Table 4. The scores are the main results. The other values are additional data to the scores that should be considered when analysing and interpreting the results.
- The standard deviation of a score illustrates the variability of the scores between the different participants, namely the divergence in the representation of the capacity. It is illustrated by the color of the dots in Table 4.
- The confidence index is the ease of the participants in their score (1= no confidence, 3 = strong confidence) and is presented for each ecosystem type and each ecosystem service by green, yellow or red circles in Table 4.

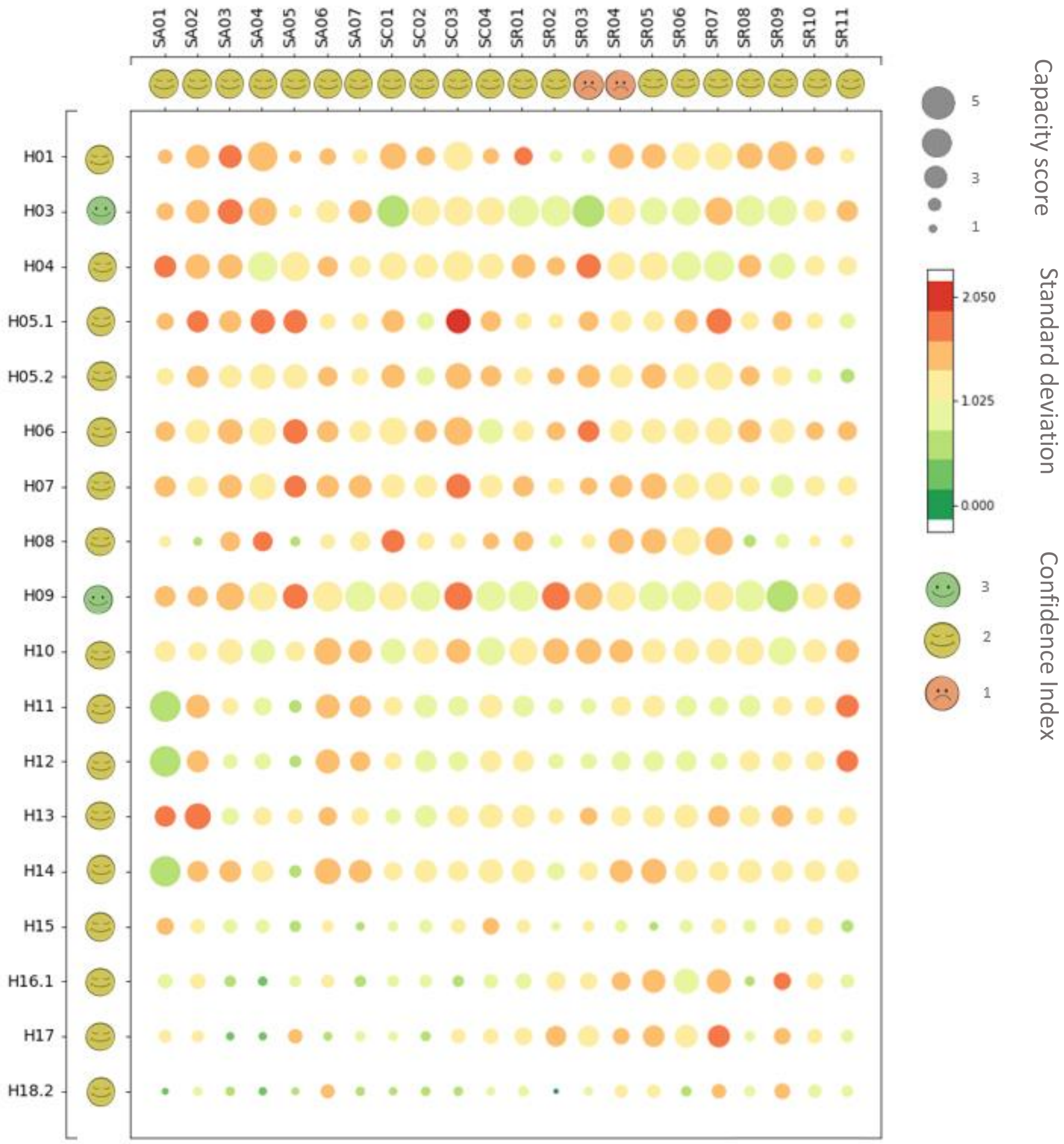
The results for Suriname show an average score of all ecosystems for all services of 2.04 (on the scale of 0 to 5), an average standard deviation of 1.12, and an average confidence index at 2.03 ("rather comfortable") for ES and 2.07 for ecosystem types. Standard deviations vary between ecosystem clusters and between the different ES. For example, the highest standard deviation was obtained for Aquatic ecosystems (mean standard deviation of 1.46), which means that the expert panel scores differed greatly. On the other hand, there was high consensus amongst experts in capacities of urban ecosystems (mean standard deviation of 1.1).

The confidence indices are heterogeneous between the types of ecosystems. Experts indicated high confidence in Forest ecosystems (H9; 2.57), whilst confidence in grasslands, thus Savannas, scored lowest (H13, confidence index of 1.62). For the ES, the confidence indices are rather homogenous. Experts were least confident with their scoring on ES “Disease control” (SR3; 1.5) and “Pest control” (SR4; 1.55). Highest confidence existed in the scores on “Flood protection” SR11 (2.36), followed by 2.27 on “Hydrological cycle and water quality and flow maintenance” SR7 and “Recreational activities including (eco-) tourism” SC4.

Table 3: representation of the final ecosystem services capacity matrix of Suriname of 2019, based on expert evaluation (n=22). Confidence index is included (C), colour-coding corresponds to the final matrix score for each cell (white =no to weak capacity, blue =very strong capacity)

Final ecosystem service capacity matrix at national scale for Suriname				Provisioning Services							Regulating Services											Cultural Services			
				Biomass for nutrition				Water	Materials		Maintaining biological, physical and chemical conditions								Mediation of mass flows - risk reduction			REPRESENTATIONS- subjective			objective
				Cultivated crops/Food	Reared animals and their outputs	Wild plants, algae and their outputs	Wild animals and their outputs	Freshwater supply for drinking purposes	Materials and fibres	Plants and resources for medical use	Carbon Sequestration	Global and local climate regulation	Disease control	Pest control	Maintaining nursery populations and habitats	Pollination and seed dispersal	Hydrological cycle and water quality and flow	Maintaining soil quality	Mass stabilisation and control of erosion rates	Storm protection	Flood protection	Emblemic or symbolic	Heritage (past and future) and existence	Aesthetic	Recreational activities including (eco-) tourism
	Ecosystem type	Code	C	SA1	SA2	SA3	SA4	SA5	SA6	SA7	SR1	SR2	SR3	SR4	SR5	SR6	SR7	SR8	SR9	SR10	SR11	SC1	SC2	SC3	SC4
Marine and littoral ecosys-tems	Ocean	H1	1.90	0.91	2.59	2.45	4.00	0.68	1.23	1.00	3.05	3.95	1.59	0.91	3.23	1.64	3.95	1.14	1.50	0.68	0.82	2.95	2.77	3.55	3.45
	Mangroves	H3	2.43	1.36	2.59	2.86	3.64	0.73	2.41	2.45	4.36	4.14	2.32	2.05	4.68	4.00	4.00	3.73	4.59	4.45	4.73	3.77	3.45	3.77	3.55
Aquatic ecosys-tems	Rivers and creeks	H4	2.14	2.23	2.82	2.82	4.14	4.00	1.86	2.09	2.36	3.14	1.82	1.64	3.50	2.68	4.32	3.05	2.59	1.55	2.73	3.64	3.77	4.09	4.36
	Lakes	H5.1	2.10	1.32	2.14	2.23	2.73	2.55	1.14	1.32	1.45	1.68	1.23	1.09	2.32	1.36	2.77	1.91	1.27	1.00	1.77	2.14	1.95	2.50	2.95
	Inland water bodies - semi natural	H5.2	1.90	1.32	2.18	2.41	3.05	2.82	1.73	1.36	1.73	1.73	0.95	0.86	2.55	1.59	3.09	1.95	1.45	1.27	2.41	2.50	2.82	3.05	3.68
	Open swamp	H6	2.14	1.77	2.73	2.86	3.45	2.77	2.14	2.18	2.41	2.91	1.45	1.68	3.55	2.27	3.68	2.86	2.00	1.55	2.14	2.36	2.82	3.00	3.41
Forest ecosys-tems	Open savanna	H7	2.00	2.05	1.95	2.55	3.23	2.23	2.32	2.41	1.82	2.45	1.86	1.73	2.64	2.41	2.77	2.45	2.00	1.23	1.36	2.32	3.09	3.09	3.64
	Inselbergs	H8	1.86	0.59	0.32	1.77	1.77	0.41	1.00	1.82	0.64	0.91	0.55	0.73	2.41	1.36	1.14	1.18	1.77	0.77	0.91	2.95	2.91	3.73	3.59
	Forest tree cover	H9	2.57	2.00	1.86	3.59	3.82	2.86	4.18	4.41	4.55	4.68	3.09	3.32	3.77	4.18	3.59	4.18	4.23	3.59	3.59	4.00	4.09	4.23	4.14
	Planted forest	H10	2.10	2.00	1.59	2.86	2.77	1.77	3.36	2.45	3.73	3.64	2.55	2.50	2.91	3.05	2.77	3.64	3.59	3.05	3.00	2.55	2.77	2.91	2.91
Agricul-tural ecosys-tems	Small scale agriculture	H11	1.95	4.41	2.55	1.27	1.50	0.68	2.64	2.14	2.09	1.73	1.77	2.36	1.59	2.45	1.86	2.50	2.05	1.05	1.09	1.82	2.18	2.00	1.64
	Large scale agriculture	H12	1.95	4.45	2.23	0.95	1.23	0.59	2.68	1.82	1.95	1.77	1.68	2.14	1.36	2.18	1.73	2.14	2.05	1.09	1.14	1.68	1.91	1.95	1.32
	Grasslands	H13	1.62	2.00	3.14	1.32	1.50	1.05	1.55	1.41	2.00	2.09	1.41	1.59	1.09	2.23	2.05	2.68	2.41	1.09	1.36	1.82	2.14	2.59	2.09
	Shifting cultivation	H14	1.95	4.36	2.00	2.18	2.18	0.64	3.14	2.41	2.59	2.09	2.09	2.45	1.55	2.36	1.91	2.73	2.50	1.41	1.59	2.41	2.91	2.41	1.73
Urban ecosys-tems	Bare soil	H15	2.00	1.36	0.91	0.86	0.82	0.55	0.59	0.32	0.77	1.27	1.36	0.64	0.45	0.77	0.95	1.23	0.82	0.36	0.55	0.64	0.32	0.73	1.00
	Built Areas	H16.1	2.24	0.95	1.05	0.55	0.36	0.55	0.73	0.55	0.41	1.36	1.23	0.82	0.59	0.68	0.55	0.91	1.14	1.64	1.32	1.59	2.50	2.95	2.68
	Infrastructure	H17	2.19	0.73	0.64	0.27	0.27	0.91	0.32	0.45	0.45	1.23	1.00	0.68	0.36	0.41	0.91	1.05	1.41	1.95	2.05	1.23	2.14	2.41	2.27
	Mineral extraction sites	H18.2	2.24	0.18	0.36	0.36	0.27	0.23	0.86	0.36	0.50	1.09	0.77	0.55	0.27	0.36	0.36	0.32	0.45	0.09	0.32	0.73	0.77	0.45	0.91
			C	2.09	1.91	1.95	1.95	2.14	2.05	2.05	2.09	2.09	1.50	1.55	2.00	1.95	2.27	2.00	2.09	2.23	2.36	1.91	2.00	2.14	2.27

Table 4: Overview of the expert scores, the size of the bullet indicates the mean expert score, the colour of the bullet indicates the mean standard deviation and the smileys represent the confidence index (1-3) of all 22 experts, red bullet <1,6, yellow bullet <2,3, green bullet >2,3.



In the following, the scores will be interpreted, showing examples on how to read the matrix.

3.1 Ecosystem services across ecosystem types

In this section, the mean capacity score, the standard deviation and the confidence index are taken into consideration for the interpretation of the matrix. The matrix included altogether 396 scores. Explaining all ES would go beyond the scope of this report. Therefore, we will discuss the 10 ES that are of greatest interest for WWF and SBB in detail.

The provisioning service **"cultivated crops/food" (SA1)** was estimated to be supplied with overall good capacity (mean 2.1). Experts scored their confidence in this score at 2.09 – a mean score indicating moderate confidence amongst the experts. The standard deviation for this service is 1.35. Especially agricultural ecosystems contribute to the provision: Small and large scale (agro-) ecosystems (H11, H12) and Shifting cultivation (H14) contribute significantly to the supply of this service (4.41, 4.45 and 4.36). Also, Urban areas (H15), especially with low densities, contribute to food provision (mean of 1.36). However, at this point, settlement density is not included in the assessment. This highlights the dependence of the local population on such land uses for cultivated food.

The service **"Wild animals and their outputs" (SA4)** entails the capacity of ecosystems to supply wild foods, such as game meat and wild fish for consumption. This service obtained a mean supply of all ecosystems of 2.07, thus a moderate capacity. The given scores varied per ecosystem type with standard deviation of 1.21. Especially Marine and littoral ecosystems are important for the provision of this ES. The Ocean (H1), Mangroves (H3), and Rivers and creeks (H4) show a strong to very strong capacity (4.0, 3.36 and 4.14 respectively). Infrastructure (H17) and Mineral extraction sites (H18.2) had the lowest capacity to supply this service (0.27 both). For this ES, experts indicated a mean confidence of 2.14, thus a moderate comfortability (see Table 3).

The service **"Materials and fibres" (SA6)** entails the capacity of ecosystems to supply timber for construction and cooking, fodder, etc. On average, ecosystems had a weak capacity to supply this service (mean of 1.69). This capacity varied between ecosystem types with a standard deviation of 1.16. The highest capacity to supply this ES comes from natural forest ecosystems including planted forest (H9 and H10, 4.18, 3.36 respectively). Shifting cultivation (H14) had the third highest capacity to supply this service (3.14). The mean confidence index for this service was 1.95, a moderate to strong certainty of experts in their evaluation.

The regulating service **"Carbon sequestration" (SR1)** is of utmost importance as it comes to climate change mitigation. Whilst ecosystems in the territory have an overall weak capacity to sequester carbon (mean of 1.93, standard deviation of 1.23), few ecosystems show strong tendencies to supply this service. Forest (H9) and Mangrove ecosystems (H3) are contributing most to its provision (4.55, 4.36 respectively), followed by Planted forest (H10), Ocean (H1) and Shifting cultivation (H9). The confidence index for this service averaged 2.09.

The service **"Maintaining nursery populations and habitats" (SR5)** refers to the capacity of ecosystems to provide habitats for species and biodiversity, as well as providing nesting sites and reproduction potential. The average value for all Surinamese ecosystems was 2.00 with a standard deviation of 1.23. Mangroves (H3) scored highest in the provision of this service (4.68), the highest score within the whole matrix, indicating a strong to very strong capacity. Forest ecosystems (H9), Open swamp (H6) and Rivers and Lakes (H3) follow, all with good capacity to provide habitats and nursery populations. The lowest value for providing this regulating service reached urban ecosystems, followed by agricultural ecosystems. Here, experts indicated their confidence to be moderate (confidence index of 2.00).

The regulating service **"Hydrological cycle and water quality and flow maintenance" (SR7)** is supplied with a mean of 2.18 by all ecosystem types, with standard deviation of 1.36. Especially Rivers and lakes (H4, 4.27), Mangroves (H3, 4.00), Ocean (H1, 3.95) and Open swamp (H6, 3.68) contribute to an intact hydrological cycle. Urban ecosystems contribute least to this service. Experts stated an overall high confidence index for this service - with a confidence index of 2.27, it is the highest confidence score given in this assessment.

In terms of cultural services**, "Aesthetics" (SC3)** and **"recreational activities including (eco-) tourism" (SC4)** will be highlighted. Ecosystems throughout Suriname supply aesthetic values with an average score of 2.51. Here, Marine and littoral, Aquatic and Forest ecosystems supply the strongest capacity to supply this ES (between 2.50 for Lakes (H5.2) and 4.23 for forest tree cover (H9)). Inselbergs (H8) contribute significantly to landscape aesthetics (3.73), the highest value obtained for this ecosystem type. The great deviation (SD 1.21) amongst values for SC3 can be explained by the weak to moderate capacity of agricultural and urban ecosystems to supply this service. The confidence index for this service reached 2.14. The only service that scores a higher average is SC4, with mean of 2.54 it is the service with the highest overall capacity in the territory – it also is the service with highest standard deviation between the different ecosystems (SD 1.43). Especially Marine and littoral, Aquatic and Forest ecosystems showed a high capacity for recreational activities (between 2.90 and 4.34, this reflects a good to strong capacity). Agricultural and urban ecosystems supply this service to a weak degree, only built areas reach a moderate capacity (2.68) – which might be due to urban green, parks and nature creation in the vicinity of settlements. The average expert confidence in this service reached 2.27.

3.2 Ecosystem types

In the following, the scores will be presented per ecosystem cluster. We will discuss the main findings, however, it should be noted that the confidence index will give additional information.

Marine and littoral ecosystems, comprising Ocean (H1) and Mangroves (H3), have an overall moderate capacity to produce ES (mean of 2.77). The Ocean (H1) has a high capacity to supply cultural services: experts ranked these between good and strong capacity (2.77 for "Heritage and existence" (SC2) to 3.55 for "Aesthetics" (SC3). Amongst provisioning services, "Wild animals and their outputs" (SA4) was ranked highest at 4.0 and the strongest regulating services "Global and local climate regulation" (SR2) at 3.95 and "Hydrological cycle and water quality and flow maintenance" (SR7) at 3.95. Mangrove ecosystems (H3) have a good capacity for ES in general. Regulating ES were ranked with strongest capacity – "Maintaining nursery populations and habitats" (SR 5) at 4.68, "Mass stabilization and control of erosion rates" (SR9) at 4.59 and "Storm protection" (SR10) at 4.45. From the provisioning services, "Freshwater supply for drinking purposes" (SA5) scored least (Table 3), with only 0.73. Cultural services received average values between 3.45 (SC2) and 3.77 (SC1, SC3).

Aquatic ecosystems, including Rivers and creeks (H4), Lakes and Semi-natural inland water bodies (H5.1, H5.2) and Open Swamp (H6) have an overall moderate capacity for ES (mean of 2.37).
Rivers and lakes (H4) have a good to strong capacity to supply cultural ES (between 3.64 for "Emblematic or symbolic" (SC1) and 4.36 for "recreational activities" (SC4). Out of all assessed ecosystems, Rivers contribute most to provision of "Wild animals and their outputs" (SA4; 4.14). Their regulating services, especially "Hydrological cycle" (SR7; 4.32) and "Maintaining nursery populations and habitats" (SR5; 3.5) should be highlighted. Surprising, "Disease control" (SR3) and "Pest control" (SR4) scored comparably low (1.82, 1.64 respectively).

Lakes (HZ5.1) and semi-natural water bodies (H5.2) show a strong similarity in their capacity to supply ES, with overall means of 2.1 and 2.54. The biggest difference could be found in “Flood protection” (SR11; 1.77 versus 2.41). Experts indicated less confidence in their scores of H5.2.
Open Swamps (H6) reached a mean of 2.33, a moderate capacity thus. Cultural services ranked between 2.36 (SC1) and 3.41 (SC4). In terms of regulating services, swamps score highest for their “Maintaining nursery populations and habitats” (SR5) and “Hydrological cycle” (SR7), (3.55, 3.68 respectively).

Forest ecosystems, including Open Savanna (H7), Inselbergs (H8), Forest tree cover (H9) and Planted forest (H10) have an overall moderate capacity to supply ES (2.60).
Open Savanna (H7) reached a mean of 2.33 on overall ecosystem service provision. It equally contributes to provisioning, regulating and cultural services –hence a true all-rounder in terms of multiple ES supply (lowest values for “Pest control” (SR4) at 1.73, “storm protection” (SR10) at 1.23 and “Flood protection” (SR11) at 1.36). Strongest capacities of swamps are to supply “Wild animals and their outputs” (SA4; 3.23) and “recreational activities (including (eco-) tourism)” (SC4; 3.63).
Inselbergs (H8) score little in provisioning ES (SA1, SA2, SA5, SA6 <=1) as well as regulating ES (SR1-4, SR10, SR11 <1, Table 3). Nonetheless, they provide unique habitats, the service “maintaining nursery populations and habitats” SR5 was ranked with 2.41. Also, forests have a strong capacity for cultural ES, especially “Aesthetics“ SC3 (3.73) and “recreational activities” SC4 (3.64).
Forest tree cover (H9) has the largest percentage of land cover in the study area. This ecosystem type showed the overall strongest capacity for ES (average of 3.68). All ES are supplied with good to strong capacity. Only its contribution to “Cultivated crops/food” (SA1) and “Reared animals and their outputs” (SA2) remained weak to moderate. Planted forest (H10) reflected these tendencies as well. It scored slightly lower, with an average of 2.8. The biggest discrepancy lied in the provision of “Wild animals and their outputs” SA4 (3.36) and cultural services, e.g. “Emblematic or symbolic” (SC1; 2.55, whilst natural forest scores 4.09).

Agricultural ecosystems contain Small and Large scale agriculture (H11, H12), Grasslands (H13) and Shifting cultivation (H14). These (agro-) ecosystems obtained an average of 1.97. Overall, the values for these four ecosystem types showed similarities: they all have a strong capacity for food provisioning services, especially “Cultivated crops/food” and “Reared animals and their outputs” (SA1, SA2). All agricultural ecosystems scored lowest in “Freshwater supply for drinking purposes” (SA5; between 0.59 and 1.05), reflecting no or very weak capacities for the supply of this service. Regulating and cultural services scored overall weak, with SR5, SR10, SR11 and SC4 between 0.5 and 1.59. Shifting cultivation was scored slightly higher in overall provision of services (average of 2.24 compared to 1.84-1.97, H11, H12, H13).

Urban ecosystems comprise Bare soil (H15), Built areas (H16.1), Infrastructure (H17) and Mineral extraction sites (H18.2). Ecosystems in this group are strongly impacted and altered by humanity, thus the overall capacity to supply ES was scored at 0.74 - at 0.99 for urban areas and 0.56 for mineral extraction sites. Provisioning and regulating services scored overall low – with no to weak capacity.
Bare soil (H15) scored lower than weak (a mean < 1) in the supply of all services, except SR2, SR3 and SR8. This ecosystem type supplied the second least services in comparison to all other ecosystems.
Built areas (H16.1) showed similar values. Overall service supply showed no to weak capacity, however, cultural services stood out. SC1 received a mean value of 1.59, SC2 at 2.5, SC4 at 2.68 and SC3 at 2.9 – the highest service supplied by this ecosystem type.

Mineral extraction sites (H18.2) was the ecosystem type that scored lowest in ecosystem service provision. With a mean of 0.56, this ecosystem type showed no to weak capacities for ES supply.

3.3 Ecosystem service bundles in Suriname

The concept of ES bundles allows to discover the relationships and trade-offs between different ES, also across various ecosystems and landscapes (Raudsepp-Hearne et al. 2010). Whilst a correlation analysis (Chapter 3.4) might be difficult to read, ES are presented in an easily understandable, visual bundle. This allows to show patterns of the supply of ES derived from the different ecosystems, LULC types, as well as the possibility to map and assess multiple ecosystem service capacities for the respective LULC classes. Prioritizing or increasing the provision of services favourable for societies, e.g. food production and timber, has often led to the decline and even depletion of other ES, for example regulation of water balances, maintaining soil quality or the amelioration of infectious diseases (Bennett and Balvanera 2007; Foley et al. 2007). At the same time, positive relationships can be possible, so called synergies between different ES, often those responding to same drivers, e.g. through reforesting barren land, vegetation increases, leading to increased carbon storage capacity. At the same time, such an increase in vegetation can lead to enhanced nursery population maintenance services, biodiversity and species richness (Strassburg et al. 2010), which can for instance result in increased pollination services.

Applying the expert-based matrix approach has its advantages: it allows to assess and compare different ES supplied by different ecosystems, thus the capacity to supply ES on a scale from 0 to 5. This allows to compare service supply between the different ecosystem clusters and ecosystem types assessed.

3.3.1 Ecosystem services bundles per ecosystem type in Suriname

ES bundles as a graphic representation allow an overview of all ES supplied by one or several ecosystem types (Figure 7). Figures of ecosystem service bundles can be compiled for each ecosystem type, depicting one row in the final capacity matrix (Table 3).

In Figure 8 we present the ES bundles of each ecosystem cluster, so six bundles for the six ecosystem clusters. For the compilation of these ES bundles, the mean score of the ecosystem types within an ecosystem cluster was calculated, weighted by the surface area of each ecosystem type (see details in the Method 2.4). Such a weighted factor ensured to account for the fact that some ecosystems only cover small areas. For example, ecosystem type Inselbergs (H8) covers less than 1% of the territory. Inselbergs have a very weak to weak capacity to supply in provisioning and regulating ES within the forested ecosystem types, e.g. “Freshwater supply for drinking purposes” (SA5, value of 0,41) or “carbon sequestration” (SR1, value of 0,64). Without such a weighting factor, the impact of Inselbergs in the bundles would be overestimated, reflecting a skewed picture of the actual supply of ES for forest ecosystems.

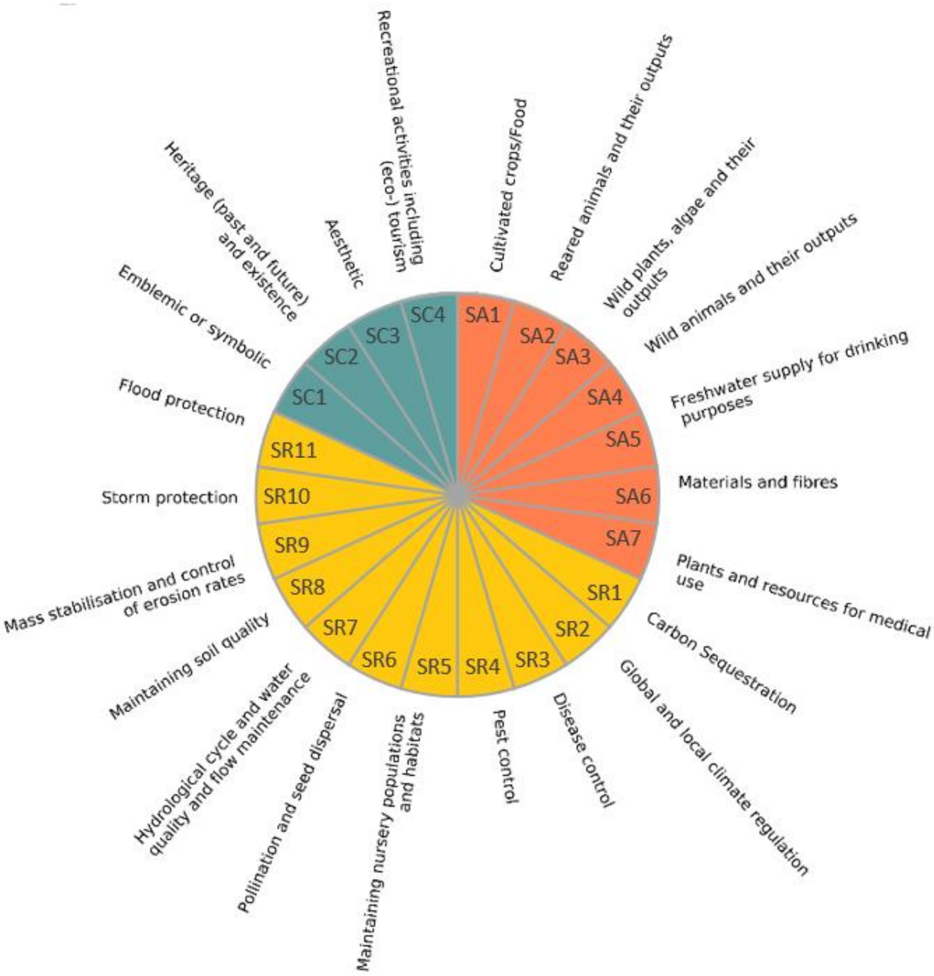


Figure 7: reading instruction for the ecosystem services bundles used in this report

The weighted ES capacity for the six different ecosystem clusters is shown in Figure 8. We separated the urban and largely modified ecosystems for this purpose, combining settlements, infrastructure and barren lands as "Urban". Mineral extraction sites we separated as largely modified ecosystems and hence as individual bundle.

How to interpret bundles of ecosystem services?

In a bundle of ecosystem services, each share (differentiated by colors) refers to an ecosystem service (provisioning ecosystem services in yellow, regulating ecosystem services in orange, cultural ecosystem services in blue). The codes are referring to the different services in the matrix. The colors in the radar plots are presented in Figure 7. The length of the bars shows the capacity score, i.e. the score of the matrix on a scale from 0 (center of the bundle, no to very weak capacities to supply a certain service) to 5 (the outer circle of the bundle), thus, a very strong capacity to supply the individual services.

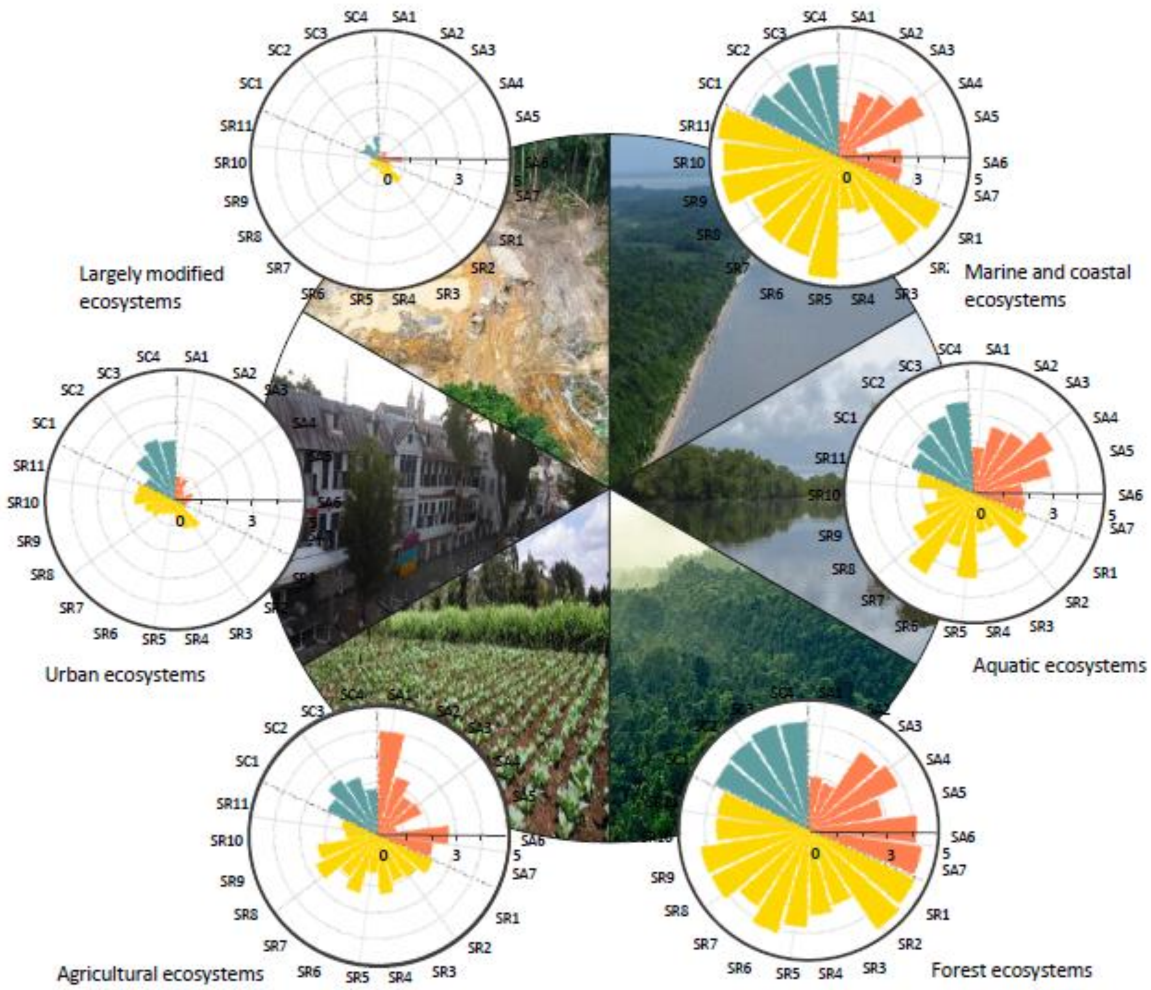


Figure 8: Ecosystem services bundles for the 22 assessed ecosystem services and the major ecosystem clusters in Suriname based on expert evaluation (n=22)

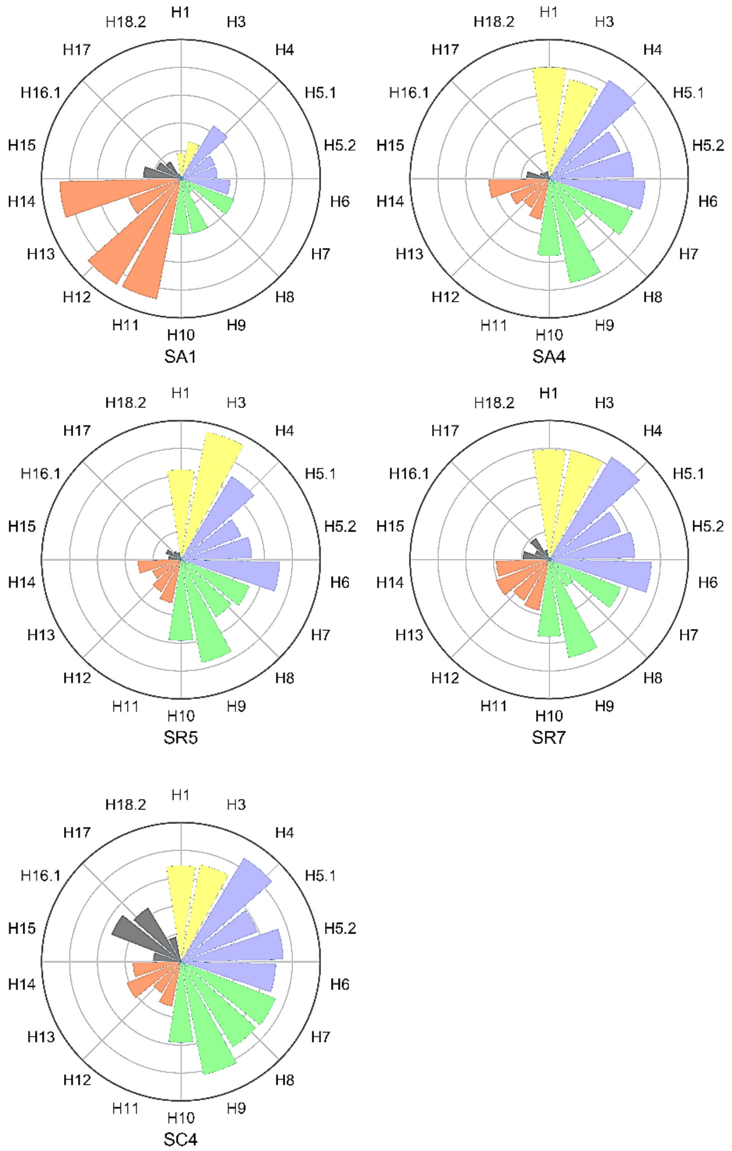
More visual than the matrix, the bundles allow to analyse the differences between ES capacities. A quick comparison of ecosystem clusters strongly altered by mankind and natural ecosystems shows the variation of services supplied. Marine and littoral, Aquatic and Forest ecosystems supply an overall varied, moderate to strong capacity for ES supply. They show a high capacity for cultural representations as well as recreational activities (blue bars depicting cultural ES).

These bundles highlight synergies and trade-offs between ES. Agricultural ecosystems, for example, show a high capacity for “cultivated food” (SA1), “Reared animals and their outputs” (SA2) and provision of “Materials and fibres” (SA6). On the contrary, their capacity to contribute to regulating services (SR1-11) and cultural ES were perceived to be weak to moderate (SC1-4).

3.3.2 Ecosystem bundles for ecosystem services across ecosystem types

The same type of bundle representation can be inversed and depict the distribution of individual services across ecosystem types. In the pie charts below (Figure 9), the following ES are highlighted: “Cultivated crops/food” (SA1), “Wild animals and their outputs” (SA4), “Maintaining nursery populations and habitats” (SR5), “Hydrological cycle and water quality and flow maintenance” (SR7) and Recreational activities including (eco-) tourism” (SC4).

“Cultivated crops/food” (SA1), upper left chart, is mainly supplied by agricultural ecosystems (reddish petals). Aquatic ecosystems, especially rivers and creeks (H4) also contribute to the provision of cultivated food. Urban ecosystems contributed least to the supply of this service.



Code	Ecosystem type
H1	Ocean
H3	Mangroves
H4	Rivers and creeks
H5.1	Lakes
H5.2	Inland water bodies - semi natural
H6	Open swamp
H7	Open savanna
H8	Inselbergs
H9	Forest tree cover
H10	Planted forest
H11	Small scale agriculture
H12	Large scale agriculture
H13	Grasslands
H14	Shifting cultivation
H15	Bare soil
H16.1	Built Areas
H17	Infrastructure
H18.2	Mineral extraction sites

Figure 9: Ecosystem services supplied per ecosystem type, based on the expert assessment. The pie charts show SA1 “capacity of ecosystems to supply cultivated crops/food”, SA4 “Wild animals and their outputs”, SR5 “Maintaining nursery populations and habitats”, SR7 “Hydrological cycle and water quality and flow maintenance”, SC4 “recreational activities including (eco-) tourism”

The regulating service “Hydrological cycle and water quality and flow maintenance” (SR7), middle right chart, was mainly supplied by Marine and littoral, Aquatic and Forest ecosystems. Rivers and creeks (H4), Ocean (H1) and Mangroves (H3) showed the biggest capacity to supply this ES. Agricultural and urban ecosystems contributed the least to the supply of hydrological flow and maintenance of water quality.

3.4 Correlations between ecosystem services in Suriname

As the results show, one ecosystem often has capacities to supply multiple ES simultaneously. Understanding the multi-functionality of landscapes, including the relations between different ES, can help to enhance the understanding of synergies, and attenuate undesired trade-offs. Especially for decision makers and land use planners, a proper understanding of the complexity of ecosystems can improve the ability to sustainably manage landscapes and their capacity to supply multiple ES (Bennett et al. 2009). Through calculating the Pearson coefficient, it is possible to unravel ES synergies and trade-offs statistically (Jopke et al. 2015; Lee and Lautenbach 2016).

How to interpret the correlation between ecosystem services?

The Pearson correlation coefficient indicates the strength of the correlation between two elements. Positive values indicate a positive linear correlation or synergy, while negative values indicate a negative correlation or trade-off. A positive correlation implies that when one ecosystem service increases, the correlated ecosystem service will also increase – and on the other hand, a negative correlation indicates that with the increase of a certain service, the correlated ecosystem service will decrease.

The correlation coefficient (r) can range in value from −1 to +1. The larger the absolute value of the coefficient, the stronger the relationship between the variables. For the Pearson correlation, an absolute value of 1 indicates a perfect linear relationship, i.e. the two ecosystem services are strongly and positively correlated. A coefficient of 0.5 indicates a moderate linear relationship, i.e. the two ecosystem service are moderately and positively correlated. A correlation close to 0 indicates no linear relationship between the variables, i.e. the two ecosystem service are not correlated. Negative values indicate negative relationship between the different variables. The results of the analysis of the Pearson correlations between the services of the ecosystem matrix are presented in Figure 10. Blue cells indicate positive correlations, while red cells indicate negative correlations.

Figure 10 presents the statistical relationships between the different ES in Suriname. The highest value of correlation can be seen in the diagonal from top left to bottom right – each service has a strong positive linear correlation with itself. Other than this, i.e. the provisioning service “Cultivated crops/food”, SA1 does not have a strong positive linear relation to any other services. Thus, based on statistical analysis, there are no strong synergies. Rather, there is no linear relationship (pale cells, e.g. SA3-6, SR10, 11). With some other services, there is a slight negative linear relationship, for example with “Freshwater supply for drinking purposes” (SA5) and cultural services “Aesthetics” (SC3) and “Recreational activities including (eco-) tourism” (SC4) (r value of -0.27), thus a trade-off exists. Hence, where land is used for agricultural purposes, it supplies basically food, but is not suitable for supplying other ES such as landscape aesthetics or recreational activities at the same time.

Other synergies were found between SA3 and SA4, SR3 and SR4, SR5 and SR7, SR10 and SR11, and between the cultural services.

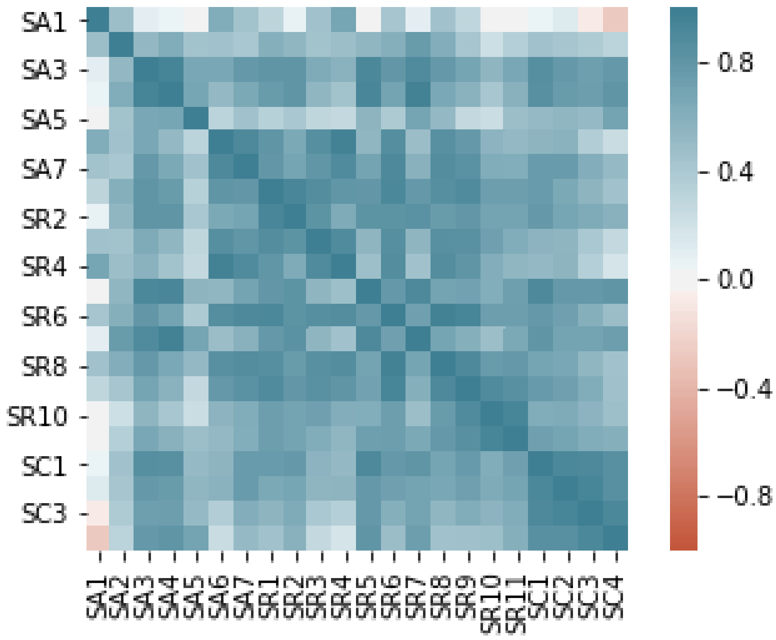


Figure 10: correlation between the 22 different ecosystem services supplied by ecosystems in Suriname, based on the Pearson correlation (r)

3.5 Ecosystem services maps

Maps are powerful tools to communicate complex spatial information. This also works for the ES concept: maps can depict the spatially-explicit provision of ES. If designed well, ES maps can be excellent intuitive and comparably simple methods to convey information to stakeholders, practitioners, citizens, policy and decision makers (Burkhard et al. 2013).

Mapping ES based on the ES matrix approach is rather straightforward through linking the geospatial units (LULC classes or ecosystem types) with ES. This way, all 22 ES assessed in this report can be visualized in form of maps for each individual ES. In Figure 11, examples of ES maps are shown at regional level in Saramacca, Wanica and Paramaribo province. The top map shows the "Capacity of ecosystems to supply cultivated crops/food" (SA1). This service is predominantly present in the (polder) landscapes that surround urban areas in the Wanica district. The urban areas in the Paramaribo province show "no" to a "very weak" capacity for this service. Forest ecosystems (H7-H10) have "moderate" capacity, while open Swamps (H6), e.g. at the surrounding of the Coesewijne river and the Boven-Coesewijne Nature Reserve, shown in the lower south of the map, only contribute with a weak capacity.

The ES "Storm protection" (SR10) is shown in the Figure 11 B. Here, the coastal mangroves are clearly visible with their strong capacity for this service, e.g. in the Coppename Monding in the north-west. The rose coloured areas in the north, above the Saramacca River, indicate mineral extraction sites. Here, for example, Staatsolie Sara Maria Operations (east) and Staatsolie Calcutta Operations are operating (west). Based on expert estimation their contribution to storm protection is weak (<1).

In Figure 11 C, the "Capacity of ecosystems to supply recreational activities including (eco-) tourism" (SC4) is presented. This ES is supplied with modest to very strong capacities throughout the three provinces. Ecosystems that contribute most to this service are for example the Suriname and

Saramacca River or the vast amount of forested area. Even though ecosystems have the capacity for this ES, their accessibility is determining for the actual ES supply. For example, access to forest is often limited through rivers, roads or trails. These provide the only possibility for recreation seekers to access the forest, restricting recreational activities to certain areas. This, in turn, leaves a vast area of inaccessible forest, with unused capacity to supply this particular service.

How to read and interpret the ecosystem service maps?

For a comprehensive interpretation and understanding of the maps it is important to consider the following aspects:

- The ecosystem type mapping scale: the compilation of the ES maps is based on a cartographic layer drawing on land use classes. The spatial resolution of this map layer determines the finest scale. For the territory of Suriname, the data used are based on a national forest inventory (SBB 2018), with initially different scales and photointerpretation for different years. The spatial map resolution obtained is around 100 m^2.

- The scale of ES: as ecosystem services are supplied by different ecological processes, the spatial scale on which they are supplied also varies. Some ES are important on local scale, other become relevant on a regional to a global level. For example, “Carbon sequestration” (SR1) provides benefits on a global scale, while the ES “Freshwater supply for drinking purposes” (SA52) is highly relevant at a watershed level. On contrary, the ES “Maintaining soil quality” (SR8) is supplied from a watershed level to a highly local scale scale (Raudsepp-Hearne and Peterson 2016). Therefore, mapping SR8 would be recommended at a local scale. An overview of suitable scales to map individual ES can be found in literature (e.g. Campagne and Roche 2019).

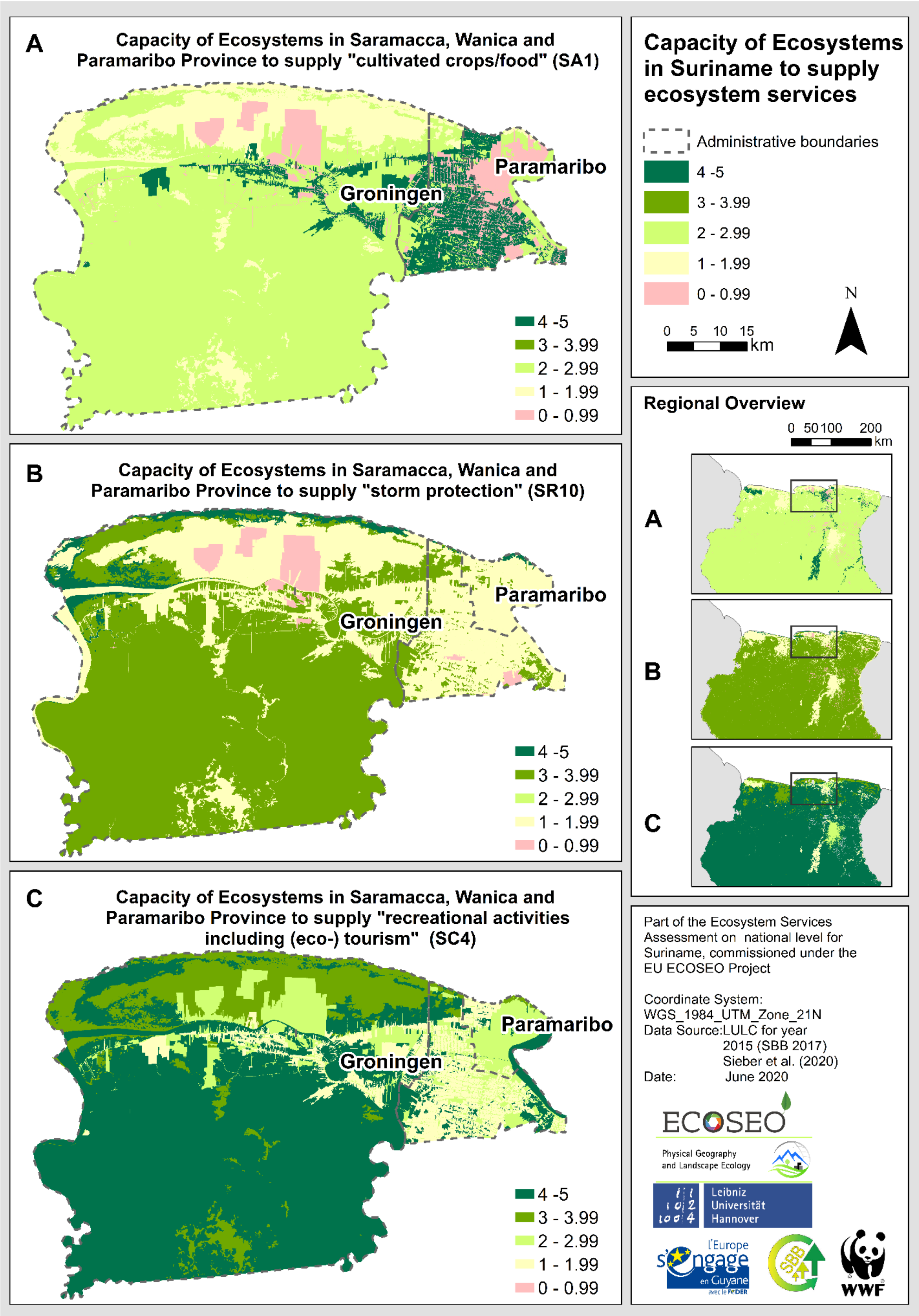


*Figure 11 A, B, C: Different **ecosystem services supplied by ecosystem types in Saramacca, Wanica and Paramaribo** Paramaribo province in Suriname, based on the participatory expert workshop (n=*

One main assumption of this ES mapping method is that LULC or ecosystem types are the main factor influencing the supply capacity of ES. However, in reality ecologic systems must be understood as heterogeneous mosaics of different ecosystem types at shifting steady states (Chapin et al. 2002), rather than uniform land use classes with sharp boundaries. This means that the thematic and spatial resolutions of the LULC types limit the degree of detail of the actual ES supply in reality. Therefore, when analysing the maps, this degree of reduced complexity should be kept in mind.

The compiled maps are very useful to provide a regional overview of ES supply, as the examples of "cultivated crops/food" (SA1), "storm protection" (SR10) and "landscape aesthetics" (SC3) show (Figure. 10). While the resulting regional maps can mainly be used for awareness-raising about ES and show general supply patterns, maps on a local scale can usually help to illustrate the ES supply in more detail (Figure 12). In Paramaribo, the capacity of ecosystems to supply cultivated crops is very limited due to the predominance of urban fabric. In Wanica, predominantly small scale agriculture and family holdings are located. Here, the structures of smaller settlements and the agricultural polder landscape becomes visible. For such local maps, however, the spatial resolution of the input data, in this case the national LULC, is important. The higher the resolution of a map, the greater is usually the level of detail shown. Hence, the more accurate should the depiction of ES be.

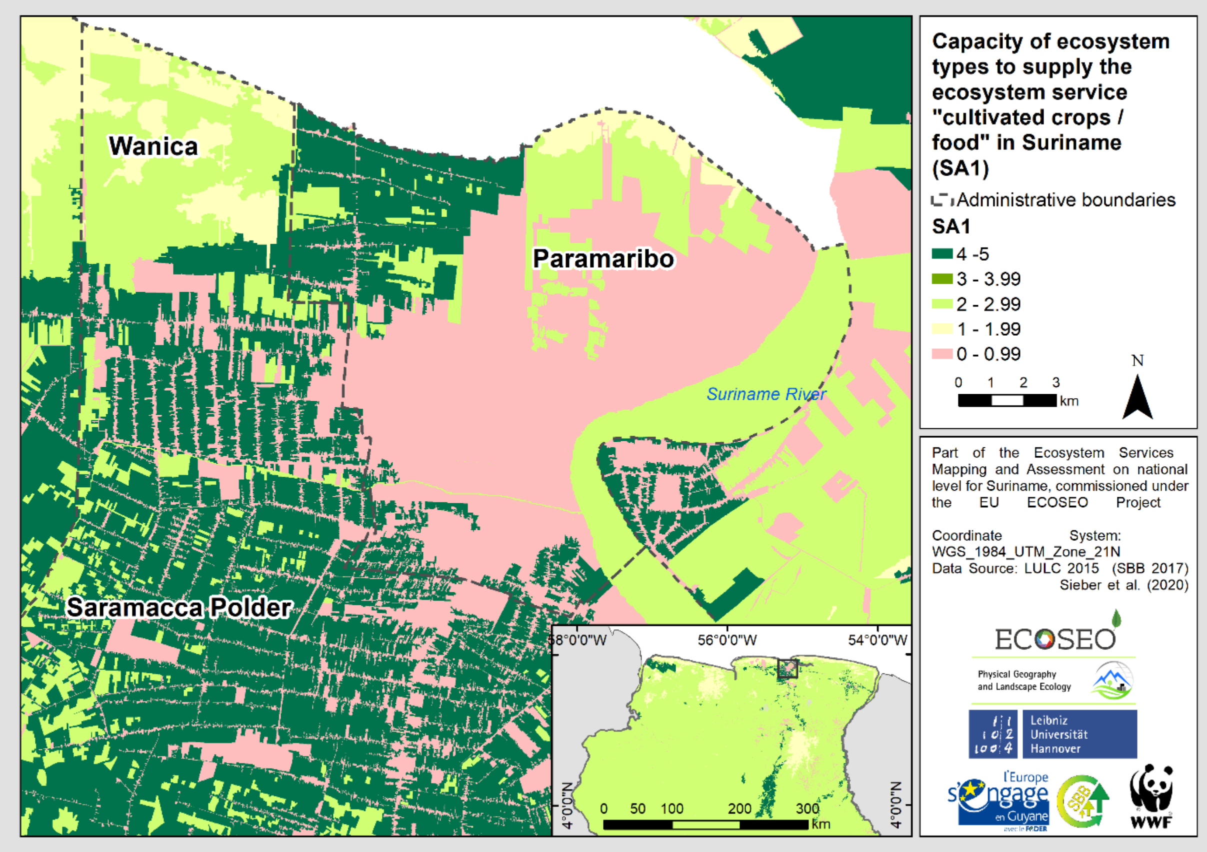


Figure 12: Capacity of ecosystems to supply cultivated crops/food at district scale, in Paramaribo district, based on a participatory workshop in October 2019.

However, a cartographic representation of single ecosystem services leads to reduced complexity – ideally, one should always look at landscape multifunctionality (e.g. through ecosystem services bundles), as depicted in Figures 8 and 9. In addition, one could combine such ES maps with other indicators, such as biodiversity and/or socio-economic data, to get further information on interactions in human-environmental systems. This way, ecosystem services maps can become a purposeful decision aid, whilst taking into account the complexity of ecosystems and their management.

4. Discussion

4.1 Discussion of the results

The main result of this ecosystem service assessment is the capacity matrix of Surinamese ecosystems. The capacity scores in the matrix are based on expert evaluations by 22 experts, obtained during an ES assessment workshop held in Paramaribo, Suriname, on October 8th 2019. This workshop obtained 22 individually filled matrices. This number usually should be sufficient to obtain scientifically sound results, as studies by Campagne et al. (2017) show. Based on these 22 matrices, the final ES matrix (Table 3) has been compiled.

Based on the final matrix, the ecosystem services supplied per ecosystem type differed. Experts rated the capacity of forests the strongest, especially the capacities to store and sequester carbon, to support pollination and seed dispersal and for the provision of materials and fibres for building or ornamental purposes. Agricultural ecosystems, i.e. Shifting cultivation were highlighted in their capacity to supply cultivated crops and food. Similarly, rivers and ocean contributed to food security through provision of wild foods, e.g. fish for consumption. Beaches and forests were important for recreational activities. Notably, urban settlements and mining sites showed no to weak capacities to supply ES, coinciding with results of international studies applying the matrix method (Burkhard et al. 2012; Sohel et al. 2015). A schematic representation of ecosystems with the highest capacities for different ES is presented in Figure 13.

The ES capacity matrix allowed to capture a mosaic of different ecosystem types which supply a richness of regulating services as well as a diverse and variable supply of provisioning services (Figure 8). The cultural services supplied by Surinamese ecosystems strongly vary per ecosystem type, for example, in terms of landscape aesthetics and scenic beauty, experts scored highest for ‘natural’ and less human impacted ecosystems, i.e. Inselbergs and Mangroves.

The results show disparities in terms of confidence of expert scores between the different ecosystems as well as between ES (Table 3). The experts were most confident in their estimation of Mangroves (H3) and Forested areas (H9). Less confidence was indicated in Grasslands (H13), thus pastures and Inselbergs (H8). In terms of ES, expert confidence was highest in scores of “Flood protection” (SR11). All other services were indicated with moderate confidence, except “Disease control” (SR3) and “Pest control” (SR4) which received a mean confidence index of 1.00, thus a weak confidence.

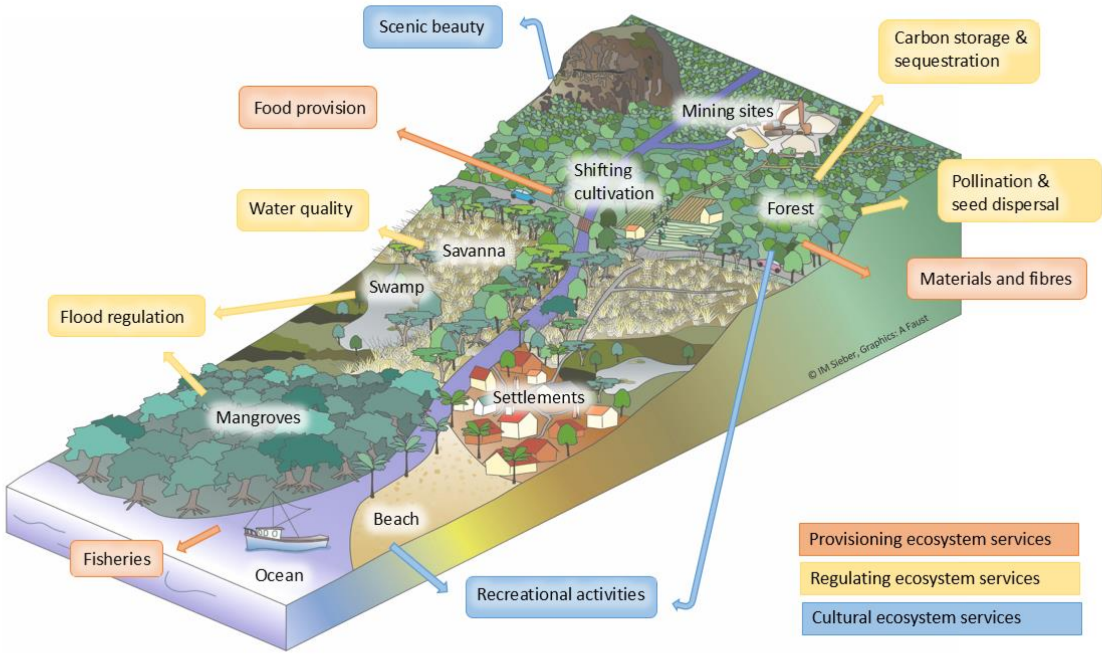


Figure 13: Schematic representation of major ecosystem types and ecosystem services they provide in the Guiana Shield (design adapted from Campagne and Roche 2019)

The variability in the ES capacity scores of the different experts for an ecosystem type to supply a specific ecosystem service can have multiple reasons. For example, disciplinary biases within the expert panel, gaps in knowledge, diverging interpretations of ecosystems and/or their services or a lack of relevant experts can lead to different capacity scores (Campagne and Roche 2018). Also, the heterogeneity of the expert panel and the multiple backgrounds of the experts can lead to such disparities for each of the ecosystems and services.

ES bundles show the variation in the set of the 22 assessed services across ecosystem clusters. This allows to analyse how different ES interact in different ecosystems. Forest ecosystems tend to have the strongest overall capacity to provide multiple services. Marine and coastal ecosystems follow. Urban areas and mining sites show the least capacity to contribute to human well-being through the supply of ES. This reflects the need for multi-functional landscape planning if multiple ES are desired.

Statistical analysis of the expert-based scores unravels correlations between the different services. Such a correlation becomes important when assessing management options to optimize individual ES (e.g. in agro-ecosystems). The analysis of such correlations can be conducted for instance by using the Pearson coefficient, assessing linear relations between the different services, the ES synergies and trade-offs (Figure 10). For Suriname, synergies can be found, amongst others, between the services “Wild animals and their outputs” (SA3) and “Wild plants and their outputs” (SA4), suggesting that there is a linear relation between these two ES. Similar relationships can be found between many others services (Table 9), for example “Wild plants and their outputs” (SR3), “Wild animals and their outputs” (SR4), “Freshwater supply for drinking purposes” (SR5) and “Plants and resources for medical use” (SR7), or “Storm protection” (SR10) and “Flood Protection” (SR11). Such a linear correlation also exists for all cultural services (SC1-4). Major trade-offs, i.e. negative correlations can be found between ES “Cultivated crops/food” (SA1) and “Freshwater supply for drinking purposes” (SA5), “Maintaining nursery populations and habitats” (SR5) and “Recreational activities including (eco-) tourism (SC4).

Different factors can explain these results. Especially the relationships between the different regulating ES can be explained by similar underlying physical ecosystem processes (Bennett et al. 2009; Lee and Lautenbach 2016). The strong interrelationship between cultural ES can be explained by the fact that landscapes supplying “aesthetics” (SC3) or “heritage and existence” (SC2) bear great capacities for “recreational activities” (SC4) and *vice versa*, as many scholars argue (Daniel et al. 2012). Another possibility to explain such correlations can be the subjective scoring of the expert panel. The possibility exists that experts evaluated certain ecosystems more favorable to provide a set of ES than others, based, for instance, on expertise, knowledge deficits or alike. To enhance the robustness of the analysis, additional research would be needed to validate the results. For example, additional biophysical or socioeconomic indicator data could be used to verify the results and scores.

As forest is the major land use type in Suriname, a further differentiation between different forest types could help to understand the provision of ES in more detail. Large parts of the forests are under intensive management and hold logging concessions. In remote locations, primary forest can be found. Therefore it might not sufficiently accurate to combine all forest types in one LULC class. This will result in a skewed picture, as it underestimates the ES provided by natural forests and overestimates the capacities of degraded forests to supply ES. In addition, it has to be noted that this assessment only considered the current condition of ecosystems. With environmental degradation, the condition of ecosystems can deteriorate and the capacity to provide ES decreases. Therefore, the maps only show a snapshot of ecosystem service provision at a certain time. Repeated assessments and regularly updated geodata can help to address this issue.

All results, especially ES maps and ecosystem service bundles can be used to communicate the results of this study to decision makers and the broader public. They present a good tool for decision support (Campagne and Roche 2018). Together with the use of the ES bundles, the correlations can be shown in an easily understandable manner. This being said, ES maps need to be meaningfully designed for their specific purpose and their limitations and input factors should to be clearly communicated, when used.

4.2 Limitations

In this section, the limitations considering the method, the ES approach, the interpretation of the maps as well as limits related to such an expert based evaluation are discussed.

Methodological limitations

Limitations of the ES capacity matrix method have been evaluated in several studies, such as Jacobs et al. (2014), who underlined the comparably low methodological transparency and the lack of appropriate consideration of methodological uncertainties. Hou et al. (2012) listed the limitations associated with landscape and ES assessments. In two studies, Campagne et al. investigated how to take into account uncertainties in the expert scores, how to calculate the final scores and the minimum size of expert panels for a robust ES matrix assessment. In addition, they have identified various advantages and limitations inherent in the matrix approach used (Campagne et al. 2017; Campagne and Roche 2018).

Limits related to expert based assessments

- Subjectivity

For each participant, there is variability related to his/her subjectivity, confidence in knowledge and understanding of the concepts and study itself. The validity of expert-based assessments are highly dependent on the experience, knowledge, education and opinion of the participants (Hou et al. 2013). In order to take into account the participants' confidence, the participants expressed their uncertainties in the form of a confidence score (indexed from 1, no confidence to 3, strong confidence).

- Participant profiles

In a participatory process, the profile of the participants should be considered. We speak of variability between experts for the variability of expertise and more general knowledge within the chosen experts (professional or personal knowledge depending on their experiences; Hou et al., 2012). In the case of the application of the ES matrix, we consider that the profile must be linked to the type of evaluation made.

Studies have shown significant differences in appreciation between a rural and/or elderly audience - who prefer provisioning services - and an urban and young audience - who are more interested in regulating services (Martín-López et al. 2012). Other differences in assessment were related to the level of education of the experts (often, the lower the level of education, the higher the preference for provisioning services). Gender of respondents was also relevant: while men show a tendency to prefer provisioning services, women tend to value regulating services higher (Prévot and Geijzendorffer, 2016). In the context of this study, we did not observe these rating biases associated with the profiles of the experts – the gender ratio was nearly equal and age distribution was balanced.

- Limits related to understanding and interpretation

The definitions of services and ecosystems are not simple and can lead to different interpretations. In addition, there are several concepts in the evaluation of ES: supply, capacity, use, demand, and others. In order to reduce this limitation, time was taken to explain and review with the participants all the definitions related to the study during the workshop.

The limits linked to the ecosystem typology

The selection of ecosystem types used for the creation of the capacity matrix impacts the ES assessed by experts. For some ES, a typology based on ecosystem types suffices, for example, for an assessment of the carbon sequestration service. For other ES, an assessment based on such ecosystem types is insufficient. For example, for the distinction between the supply of timber (Materials and fibres services) and the supply of wood for energy purposes, it would be necessary to distinguish forest ecosystems based on species composition. Likewise, a selection of ecosystem types, e.g. agro-ecosystems (H11, H12) does not allow to distinguish between different types of cultivated crops and different management methods. However the impact of such decisions on the ES that these land use units produce can be high.

- Temporal notion

The matrix gives an annual average of the supply or use in ecosystem service. Thus, several matrices would be needed to take into account the annual and multiannual variability. Turkelboom et al. (2018) highlighted the issue of making a list of ES, as done when using the capacity matrix. The matrix gives the impression that provisioning, regulating and cultural services can be supplied at the same time. However, in most cases it is impossible to manage ecosystems so that all services are supplied at the same time with a maximum level of supply, thus trade-offs occur.

- Spatial heterogeneity

The matrix gives an average score per ecosystem type. Thus two distant locations with the same ecosystem type will have the same scores without taking into account their specificity (Jacobs et al. 2015). The protection status, the condition of the ecosystems, topographic, topological particularities, and other relevant factors are usually not taken into account. Of course, they could be taken into account with integration of additional data and further analysis. In order to take spatial heterogeneity into account an option would be to integrate the source of heterogeneities in the ecosystem types list of the matrix, i.e. Protected forest and Unprotected forest.

5. Outlook

This study will be continued by an integration of ES in Suriname and French Guiana. Comparing both matrices across national borders could highlight the different values people attach to ecosystems. Also, such a transnational comparison will help to validate the correlations between the ES supplied in the Guiana Shield.

As a next step, the ECOSEO project will conduct a comparative assessment of the capacities of ecosystems to provide ES throughout the region, taking the Maroni river basin as a case study region. A closer look at the Maroni will deepen the insights from the two national assessments. For this, the comparative setup of the workshops, the similar ecosystem types of both countries and the similarities between ecosystems and their services are advantages. In addition, an important contribution will be made by the results of a field trip to the Maroni region, including an assessment of local perceptions towards the condition of ecosystems and their services and the expertise of the ECOSEO partners in this part of the Guiana Shield.

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Ecosystem Services Observatory in the Guiana Shield

Ecosystem Services Assessment in Suriname

Invitation to a participatory workshop - October 8th 2019, 9.00h-12:30h, at SBB in Paramaribo

The interregional project **ECOSEO** (Establishing an Ecosystem Services Observatory in the Guianas), cordially invites you to participate in a first national ecosystem services assessment in Suriname.

The ECOSEO regional cooperation project, led by WWF, aims to assess, map and ultimately better preserve ecosystem services throughout the Guiana Shield. Specific work in French Guiana and Suriname is being conducted in collaboration with the University of Hannover to evaluate ecosystem services, particularly in the cross-border area of the Maroni. It follows the work of the EU Best project, which was the first step towards an ecosystem assessment. The EU MOVE project has also resumed this work specifically for the EU's Overseas territories, testing and adapting methods for qualifying and quantifying ecosystem services. This evaluation will build on and extend this work.

What ?

Ecosystem services (ES) are the contributions that ecosystems make to human well-being.
3 categories of ecosystem services can be distinguished (Figure 1):

Provisioning Services are the material, often « final » products obtained directly from ecosystems (e.g., food, fibres, timber).

Regulating Services are defined as the indirectly obtained benefits through the regulation of ecosystem processes such as climate regulation, natural hazard regulation, water purification and waste management, pollination or pest control.

Cultural Services represent the different non-monetary values and benefits people obtain from *ecosystems*. They include aesthetic inspiration, *cultural* identity, and experiences related to the natural environment (hunting, fishing, hiking etc.).

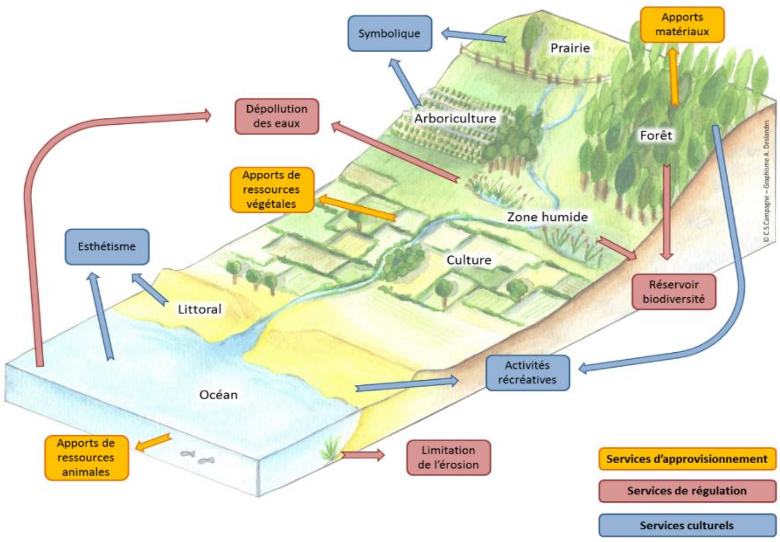

Figure 1 : Example of ecosystem services ©C.S. Campagne- Graphisme A. Deslandes

How ?

There is a broad range of methods to assess ecosystem services. In this workshop, we will apply the **ecosystem services capacity matrix,** a method that allows to evaluate bundles of ecosystem services. The matrix combines land use/land cover units and ecosystem services in a look-up table (Figure 2). Through a quick and integrative ES scoring, the provision of selected ES can be assessed.

Every score gives an estimation of the capacity of an ecosystem to provide a certain service, based on expert estimation.

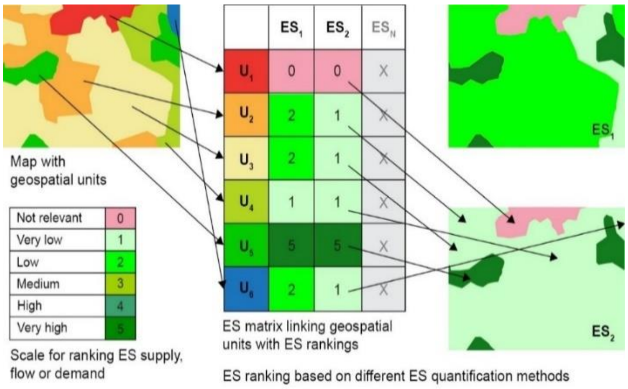

Figure 2: Construction d'une matrice à partir de l'occupation du sol et création de cartes de services produits par les types d'occupation du sol (Burkhard & Maes, 2017).

Since 2009, this method has been increasingly tested throughout the world, and since 2014, many studies have been conducted in France –examples of its application can be found in the numerous regional natural parks (Baronnies Provençales in 2014, Scarpe-Escaut in 2015, 2016 and 2017, the Alpilles in 2018, etc.). Recently, a first ES assessment has been conducted in the Hauts-de-France region by IRSTEA and DREAL (more information on the website of DREAL).

To conduct a capacity matrix assessment for Suriname, we are preparing following lists:

- Overview of ecosystems present in the territory of Suriname;
- Overview of ecosystem services provided by these ecosystems.

What is your contribution?

To conduct this first assessment, we need to take into account each expertise present in Suriname: your contribution is important! During a workshop, we need **you** to **fill the matrix with your expertise** via a score of 0 to 5 (0 no capacity to provide this service - 5: a very strong capacity to provide this service). This capacity is the maximum annual capacity of ecosystems to produce ecosystem services.

When ?

Tuesday, October 8th, 2019 – 9:00h – 12:30h at SBB,

Ds. Martin Luther Kingweg perc. no. 283 Paramaribo, Suriname

To better understand the ecosystems and their services in the Maroni region, a similar workshop was hosted in French Guiana on October 1st.

Which results ?

The scores of the matrix already allow many results and direct interpretations. In a next step, the matrix results are combined with spatial data. This allows to create maps that show the services produced, from regional to national level of Suriname. Finally, it is possible to create ecosystem services bundles per Land use class, as shown in Figure 3, exemplary for the Hauts-de-France Region (the larger the petal, the more service provision).

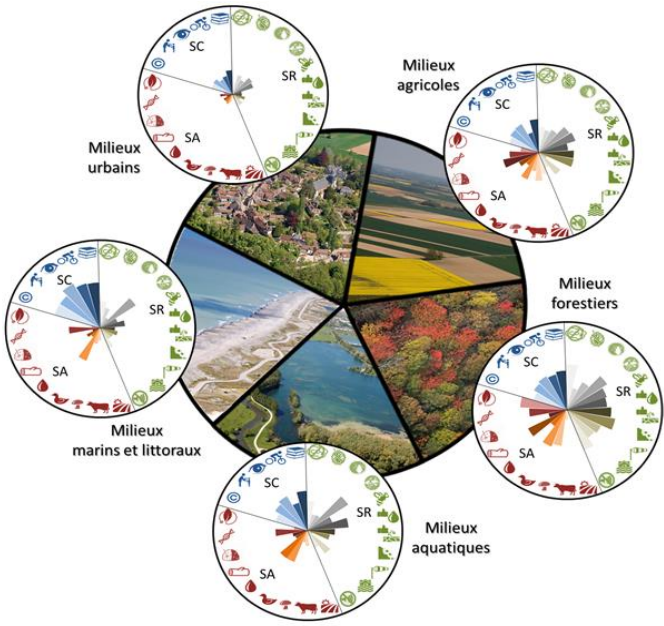

Figure 3: Bouquets des services rendus par les 5 grands types d'écosystèmes de la Région Hauts-de-France (C.S. Campagne 2019 link))

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Thank you for confirming your participation by inscribing via the following online form!

Annex 2: Overview of assessed ecosystem types in this assessment

	Code	Suriname	Definition	Grouping for this assessment	French Guiana
Marine and littoral	H1	Ocean	Ocean	Ocean	Océan
	H3	Mangroves	Mangroves, almost perennial, subject to the swaying tides and regularly flooded during high tide.	Mangroves	Mangroves
Aquatic ecosystems	H4	Rivers and creeks	Network of rivers, streams, and waterways greater than 5m wide. May be subject to ocean tide rising 30 to 50 km inland	Rivers	Fleuves et criques
	H5.1	Lakes	Natural ponds and lakes	Inland water bodies	Eaux stagnantes
	H5.2	Inland water bodies - semi natural	Artifical ponds and lakes, including water bassins, pisciculture and artifical canals.		Zones aquatiques artificielles
	H6	Open swamp	Inland swamps and wooded swamps, often bordering mangrove swamp. Mostly located in flat, poorly drained coastal areas, on clay soils (old consolidated marine silts). riparian swamps maritime wetlands	Wetlands	Zones humides, marais
Forest ecosystems	H7	Open savanna	Broad range of lands with dominant shrubby and bushy vegetation, including dry and humid savannes.	Shrubland, bushland, heathland	Savanes
	H8	Inselbergs	Inselbergs, Savanna-rock	Inselbergs	Inselbergs
	H9	Forest tree cover	All types of natural forest, including disturbed forests	Forest tree cover	Forêts littorales
					Forêts continentales
					Forêts inondées ou marécageuses
	H10	Planted forest	Forest plantations solemnly used for timber extraction, with little biodiversity.	Woody crops	Plantations forestières
Agricultural ecosystems	H11	Small scale agriculture	Arable land with possibility for irrigation Cultivation of rice, cereals etc.	Herbaceous crops	Terres arables
	H12	Large scale agriculture	Intensive agricultural patterns, permanent plantations	Agriculture	Cultures permanentes
	H13	Grasslands	Pasture used for animal husbandry	Pasture	Prairies
	H14	Shifting cultivation	Complex agricultural patterns and parcel systems (Abattis) Territories mainly occupied by agriculture with presence of vegetation	Shifting cultivation	Zones agricoles hétérogènes - abattis
Urban ecosystems	H15	Bare soil	Bare soil due to anthropogenic interference	Barren lands	Sol nu
	H16	Urban areas	Continuous and discontinuous urban fabric, isolated building, heterogeneous settlements with limited green areas	Urban areas	Zones urbanisées
	H17	Infrastructure	Industrial or commercial zones		Zones industrielles ou commerciales
			Road networks, communication networks and associated spaces Ports, airports	Infrastructure	Infrastructures routiéres
	H18	Mineral extraction sites	Gold mining sites, legal extraction activities	Mineral extraction sites	Activitées minières légales
			Gold mining sites, unauthorized extraction activities		Activitées minières illégales

Annex 3: Overview of assessed ecosystem services in this assessment

	Ecosystem Services			*Code*	*Definitions*	*Potential Indicators - examples*
Provisioning Services	**Nutrition**	**Biomass for food consumption**	**Cultivated crops / food**	**SA1**	Potential capacity of a habitat to **provide nutrition for human consumption in form of agricultural produce and cultivated crops**	Sort, qualtity and quantity of food derived from plant species cultivated through agricultural practices. *Corn, rice, cassava (tapioca), sugar, cocoa, vegetables, bananas etc.*
			Reared animals and their outputs	**SA2**	Potential capacity of an ecosystem to **provide nutrition for human consumption in form of reared animals and their outputs**	Type and quantity of food derived from species raised on farms or in aquaculture. *Pork, chicken, cows, etc.*
		Biomass	**Wild plants, algae and their outputs**	**SA3**	Potential capacity of an ecosystem to **provide nutrition for human consumption in form of wild plants, vegetables and/or mushrooms.**	Type and quantity of food for human consumption derived from ecosystems: *wild plant and fungal species gathered, e.g. Acaii, wild vegetables and fruit.*
			Wild animals and their outputs	**SA4**	Potential capacity of an ecosystem to **provide nutrition in form of wild animals and their outputs**	Type and quantity of food from hunted animals for human consumption. *Meat from hunting, fish and seafood from fishing*
		Water	**Freshwater supply for drinking purposes**	**SA5**	Potential capacity of an ecosystem to **provide water (surface water, groundwater recharge) for human consumption** (not including water retention and storage)	Quantity of water withdrawable for *irrigation, domestic consumption and / or industrial / energy use*
	Materials	**Raw materials**	**Materials and fibres**	**SA6**	Potential capacity of an ecosystem to **provide fibres and other materials from plants, algae and animals for direct use or processing**; **Materials from plants, algae and animals for agricultural use**; and/or b**iomass-based energy sources**	Quantity of wild or cultivated natural materials used for non-food purposes such as *lumber, fibers for stationery, textile fibers, decorative bouquets of flowers, etc* . Quantity of material used for forage and fertilization purposes. *Hay, alfalfa, pastures, green manures, nectar for bees, etc.* *Also, materials used for energy purposes, such as fuelwood, cereals or beetroot for ethanol production, etc.*
			Plants and resources for medical use	**SA7**	Potential capacity of an ecosystem to **provide natural resources and materials for medical purposes, and/or to unique pool of genetic resources** used for scientific, industrial, agricultural or agri-food purposes.	Quantity of species used for pharmaceutical, aromatic, and other medicinal purposes, e.g.

	Ecosystem Services			Code	Definitions	Potential Indicators - examples
Regulating Services	**Maintaining biological, physical and chemical conditions**		**Carbon Sequestration**	**SR1**	Potential capacity of an ecosystem to **sequester and store carbon dioxide out of the atmosphere in the long term**	Storage of carbon in *plant biomass above and belowground*
			Global and local climate regulation	**SR2**	Potential capacity of an ecosystem to **influence the local and global climate**	Contribution to climate variability *(influence on temperature, humidity, regulation of wind and local climate by hedges or other vegetation ... etc.).*
			Disease control	**SR3**	Potential capacity of an ecosystem to **regulate and limit the spread of harmful animal vectors transmitting diseases for humans**	Some environments are less favorable than others for the spread of animals acting as vectors for harmful diseases to humans such as *mosquitoes, ticks, etc.*
			Pest control	**SR4**	Potential capacity of an ecosystem to **regulate pests affecting agricultural production**	Presence of species regulating pest species such as the presence of *ant eating animals, presence of parasitic wasps, etc.*
		Maintaining nursery populations and habitats	**Maintaining nursery populations and habitats**	**SR5**	Potential capacity of an ecosystem to **provide suitable habitats for different wildlife as nesting, breeding sites or refuges.**	Habitat used as *nesting, breeding, refuge, foraging, etc.*
			Pollination and seed dispersal	**SR6**	Potential capacity of an ecosystem to **provide habitats for pollinating or seed dispersing species**	*Presence of pollinators and species dispersing seeds such as birds, mammals and insect* s. Note: This service focuses primarily on pollinator abundance.
			Hydrological cycle and water quality and flow maintenance	**SR7**	Potential capacity of an ecosystem to **maintain and preserve a good chemical status of fresh and saline water by filtration and self-purification functions**	Ecosystems, ecosystem features or organisms that contribute to *water filtration or purification.*
			Maintaining soil quality	**SR8**	Potential capacity of an ecosystem to **maintain a naturally productive soil contributing to soil fertility**	Ecosystem activities related to *nutrient storage, maintenance of good biogeochemical soil conditions and soil biological activity*
	Mediation of mass flows - risk reduction		**Mass stabilisation and control of erosion rates**	**SR9**	Potential capacity of an ecosystem to **stabilize and mitigate mass flows, store sediments and/or provide vegetation cover that limits erosion**	Combination of two functions: erosion control and sediment storage. *Presence of vegetative cover, root systems and other elements limiting all forms of erosion*
			Storm protection	**SR10**	Potential capacity of an ecosystem to **protect against and limit the impact of storms**	Presence of natural elements that regulate and prevent the impact and damage caused by storms such as *hedgerows, tree lines, etc.*
			Flood protection	**SR11**	Potential capacity of an ecosystem to **maintain water flows and regulate floods and inundations**	Presence of natural elements regulating floods and inundations such as *buffer zones, riparian forests, natural retention basins, etc.*

	Ecosystem Services			Code	Definitions	Potential Indicators - examples
Cultural Services		evaluation of the actual value based on collective and societal notions	**Emblemic or symbolic**	**SC1**	Refers to ecosystems themselves or the species they entail which have a emblematic or symbolic notion for certain social or institutional groups in the present time	Places of natural heritage or ecosystems housing an emblematic or symbolic species for the territory. Examples: *mangroves, forests, coastal environments etc.*
	REPRESENTATIONS- subjective : spiritual, symbolic, religous & historic interactions	evaluation of the values based on long term perspectives - subjective	**Heritage (past and future) and existence**	**SC2**	Ecosystems and their elements that create inspiring pleasure by their pure existence and create a willingness to preserve them for us and future generations	Example valuation methods: *societal costs to preserve a habitat or one of its elements; socio-cultural preferences expressed, value of attachment, etc.*
		evaluation of the actual value based on personal notions of aesthetics - subjective	**Aesthetic**	**SC3**	Ecosystems and elements of ecosystems that are considered aesthetic, direct or indirect notion	Example evaluate method: *Number of photos taken from an ecosystem or one of its elements*
	USE- objective : physical and intellectual interactions with ecosystems and landscapes	evaluation of the actual value based on collective/societal notions	**Recreational activities including (eco-) tourism**	**SC4**	Physical interactions with ecosystems for tourism, art and recreational activities such as outdoor sports, hunting, recreational fishing etc.	Inspiration of natural or cultural landscapes for culture, art and design (*books, films, paintings, folklore, national symbols, architecture, advertising, etc.) Ecotourism, leisure activity as outdoor sports, hunting, recreational fishing, etc.*
	Characteristics		*Ecosystem Services*	*Code*	*Definitions*	*Potential indicators - examples*

Annex 4:: Final matrix showing the mean scores of all 22 experts based on a participatory ES assessment in October 2019. . Confidence scores are depicted in the dark grey cells

Results of the Ecosystem Services Assessment in Paramaribo, 8th October 2019

Capacity of ecosystems to provide ecosystem services	5	Very strong capacity	3	Good capacity	1	Weak capacity
	4	Strong capacity	2	Moderate capacity	0	no or very weak capacity

				Provisioning Services							Regulating Services											Cultural Services			
				Biomass for nutrition				Water	Materials		Maintaining biological, physical and chemical conditions								Mediation of mass flows - risk reduction			REPRESENTATIONS- subjective			USE- objective
	Matrix at national scale for Suriname		Ecosystem Services	Culti-vated crops/ Food	Reared animals and their outputs	Wild plants, algae and their outputs	Wild animals and their outputs	Fresh-water supply for drinking purposes	Materi-als and fibres	Plants and resour-ces for medical use	Carbon Seques-tration	Global and local climate regu-lation	Disease control	Pest control	Maintain-ing nursery popula-tions and habitats	Pollina-tion and seed dispersal	Hydrolo-gical cycle and water quality and flow	Maintain-ing soil quality	Mass stabilisa-tion and control of erosion rates	Storm protec-tion	Flood protec-tion	Emblem-atic or symbolic	Heritage (past and future) and existen-ce	Aesthe-tic	Recrea-tional activities including (eco-) tourism
	Code	HABITAT	Confidence	SA1	SA2	SA3	SA4	SA5	SA6	SA7	SR1	SR2	SR3	SR4	SR5	SR6	SR7	SR8	SR9	SR10	SR11	SC1	SC2	SC3	SC4
Marine and littoral ecosystems	H1	Ocean	1.90	0.91	2.59	2.45	4.00	0.68	1.23	1.00	3.05	3.95	1.59	0.91	3.23	1.64	3.95	1.14	1.50	0.68	0.82	2.95	2.77	3.55	3.45
	H3	Mangroves	2.43	1.36	2.59	2.86	3.64	0.73	2.41	2.45	4.36	4.14	2.32	2.05	4.68	4.00	4.00	3.73	4.59	4.45	4.73	3.77	3.45	3.77	3.55
Aquatic ecosystems	H4	Rivers and creeks	2.14	2.23	2.82	2.82	4.14	4.00	1.86	2.09	2.36	3.14	1.82	1.64	3.50	2.68	4.32	3.05	2.59	1.55	2.73	3.64	3.77	4.09	4.36
	H5.1	Lakes	2.10	1.32	2.14	2.23	2.73	2.55	1.14	1.32	1.45	1.68	1.23	1.09	2.32	1.36	2.77	1.91	1.27	1.00	1.77	2.14	1.95	2.50	2.95
	H5.2	Inland water bodies - semi natural	1.90	1.32	2.18	2.41	3.05	2.82	1.73	1.36	1.73	1.73	0.95	0.86	2.55	1.59	3.09	1.95	1.45	1.27	2.41	2.50	2.82	3.05	3.68
	H6	Open swamp	2.14	1.77	2.73	2.86	3.45	2.77	2.14	2.18	2.41	2.91	1.45	1.68	3.55	2.27	3.68	2.86	2.00	1.55	2.14	2.36	2.82	3.00	3.41
Forest ecosystems	H7	Open savanna	2.00	2.05	1.95	2.55	3.23	2.23	2.32	2.41	1.82	2.45	1.86	1.73	2.64	2.41	2.77	2.45	2.00	1.23	1.36	2.32	3.09	3.09	3.64
	H8	Inselbergs	1.86	0.59	0.32	1.77	1.77	0.41	1.00	1.82	0.64	0.91	0.55	0.73	2.41	1.36	1.14	1.18	1.77	0.77	0.91	2.95	2.91	3.73	3.59
	H9	Forest tree cover	2.57	2.00	1.86	3.59	3.82	2.86	4.18	4.41	4.55	4.68	3.09	3.32	3.77	4.18	3.59	4.18	4.23	3.59	3.59	4.00	4.09	4.23	4.14
	H10	Planted forest	2.10	2.00	1.59	2.86	2.77	1.77	3.36	2.45	3.73	3.64	2.55	2.50	2.91	3.05	2.77	3.64	3.59	3.05	3.00	2.55	2.77	2.91	2.91
Agricultural ecosystems	H11	Small scale agriculture	1.95	4.41	2.55	1.27	1.50	0.68	2.64	2.14	2.09	1.73	1.77	2.36	1.59	2.45	1.86	2.50	2.05	1.05	1.09	1.82	2.18	2.00	1.64
	H12	Large scale agriculture	1.95	4.45	2.23	0.95	1.23	0.59	2.68	1.82	1.95	1.77	1.68	2.14	1.36	2.18	1.73	2.14	2.05	1.09	1.14	1.68	1.91	1.95	1.32
	H13	Grasslands	1.62	2.00	3.14	1.32	1.50	1.05	1.55	1.41	2.00	2.09	1.41	1.59	1.09	2.23	2.05	2.68	2.41	1.09	1.36	1.82	2.14	2.59	2.09
	H14	Shifting cultivation	1.95	4.36	2.00	2.18	2.18	0.64	3.14	2.41	2.59	2.09	2.09	2.45	1.55	2.36	1.91	2.73	2.50	1.41	1.59	2.41	2.91	2.41	1.73
Urban ecosystems	H15	Bare soil	2.00	1.36	0.91	0.86	0.82	0.55	0.59	0.32	0.77	1.27	1.36	0.64	0.45	0.77	0.95	1.23	0.82	0.36	0.55	0.64	0.32	0.73	1.00
	H16.1	Built Areas	2.24	0.95	1.05	0.55	0.36	0.55	0.73	0.55	0.41	1.36	1.23	0.82	0.59	0.68	0.55	0.91	1.14	1.64	1.32	1.59	2.50	2.95	2.68
	H17	Infrastructure	2.19	0.73	0.64	0.27	0.27	0.91	0.32	0.45	0.45	1.23	1.00	0.68	0.36	0.41	0.91	1.05	1.41	1.95	2.05	1.23	2.14	2.41	2.27
	H18.2	Mineral extraction sites	2.24	0.18	0.36	0.36	0.27	0.23	0.86	0.36	0.50	1.09	0.77	0.55	0.27	0.36	0.36	0.32	0.45	0.09	0.32	0.73	0.77	0.45	0.91
		1: weak confidence, 3: strong confidence	Confidence	2.09	1.91	1.95	1.95	2.14	2.05	2.05	2.09	2.09	1.50	1.55	2.00	1.95	2.27	2.00	2.09	2.23	2.36	1.91	2.00	2.14	2.27

Sieber et al. (2020). Mapping and assessment of the capacity of ecosystems in Suriname to supply ecosystem services. ECOSEO Project Report.