Ecosystem Services Observatory of the Guiana Shield

ECOSEO

ECOSYSTEM SERVICES IN THE MARONI RIVER BASIN

Mapping and assessment of ecosystem services

SUMMARY REPORT

Leibniz Universität Hannover

Physische Geographie und Landschaftsökologie

Ecosystem Services Observatory of the Guiana Shield

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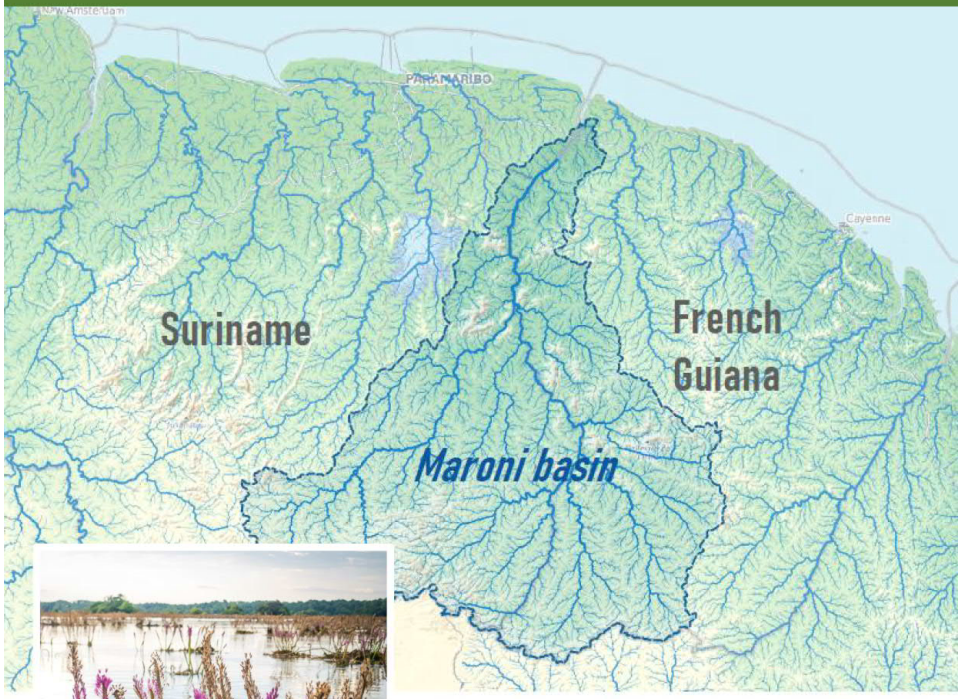

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SUMMARY REPORT

Ina M. Sieber

Benjamin Burkhard

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ECOSEO

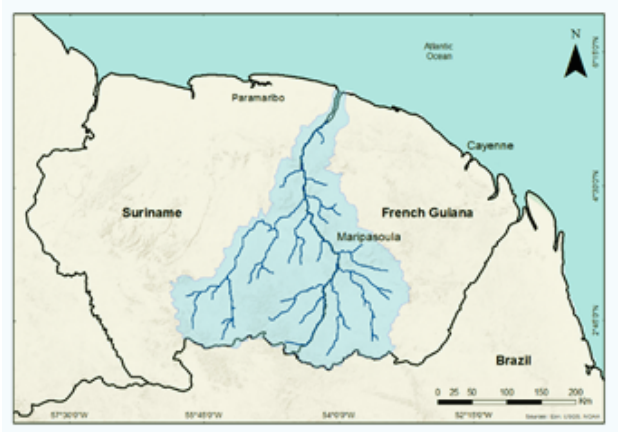
THE MARONI RIVER BASIN

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. This region is declared as an eco-region of "regional and global significance" and home to a variety of ecosystems and "keystone species of biodiversity" (UNDP 2020). In the Guiana Shield, socio-political borders criss-cross through natural ecosystems and hence, ecological boundaries. As neighboring countries share ecosystems, they also share ecosystem processes, functions and hence, ecosystem services (Daily, 1997; López-Hoffman et al., 2010).

The Maroni River Basin is one of the biggest river basins within the Guiana Shield. The Maroni River, with its more than 600 km in length, demarcates the border between Suriname and French Guiana. The region is a true cultural melting pot (Hidair and Ailincai 2015; INDIGENOUS WORLD 2020).

Within the Maroni River Basin, the livelihoods of many people strongly depend on nature and hence, well-functioning ecosystems.

Figure 1: Location of the Maroni River Basin



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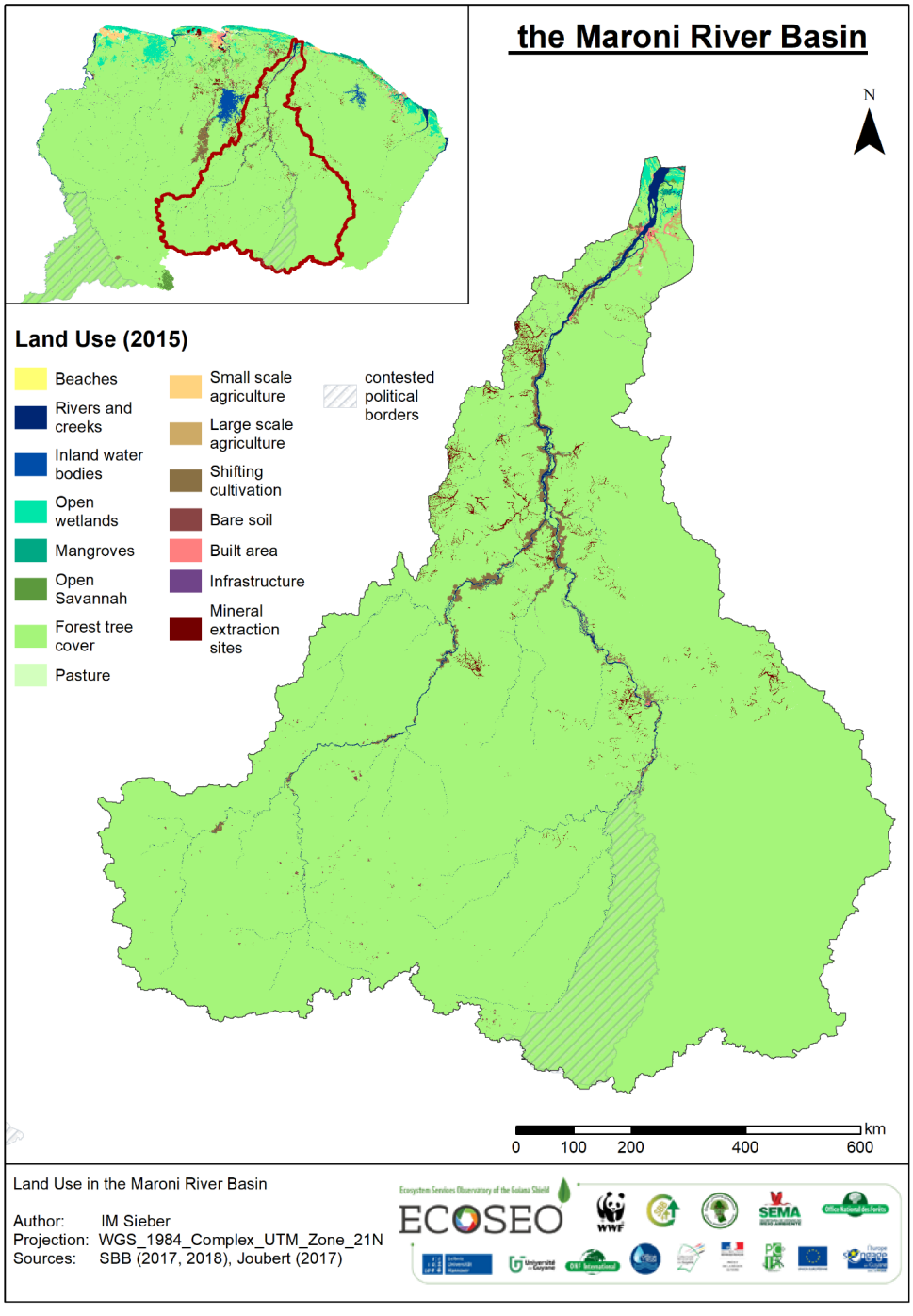
THE MARONI RIVER BASIN



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ECOSYSTEM SERVICES

The concept of Ecosystem Services (ES) has found increasing application globally, also on the South-American continent. It describes the multiple values of nature and biodiversity in terms of direct and indirect contributions to human well-being, such as food provision, timber, clean water, flood control or climate regulating services (MEA 2005).

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, and 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).

Figure 3: Overview of ecosystem services (WWF 2016)

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.

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METHODOLOGY

FROM THE BROAD RANGE OF METHODS TO MAP AND ASSESS ECOSYSTEM SERVICESTWO COMPLEMENTARY METHODS WERE APPLIED IN THE MARONI BASIN.

1) Participatory Expert Elicitation

To map and assess ES in the transboundary Maroni Basin, a participatory, expert based matrix approach was applied (Burkhard et al., 2007; Burkhard et al., 2009; Sieber et al., 2021). This approach integrates maps with geospatial units (such as land use/land cover or ecosystem types), and ecosystem services in a look-up table. This semi-quantitative method involves a quick and integrative ES scoring, ranking the supply or demand of selected ES on a scale from 0 to 5. For the Maroni Basin, 22 ecosystem services were mapped and assessed. To quantify the ES, two workshops were organized in October 2019: 17 experts participated in Cayenne, French Guiana and 22 participants attended the expert workshop in Paramaribo, Suriname. The expertise of experts from various fields and dicsiplines allowed a first overview of ecosystem services supply as well as possible trade-offs between different ecosystem services (Sieber et al. 2020a; Sieber et al. 2020b).

2) Interviews

To capture socio-cultural notions and perceptions of ecosystem services from the inhabitants of the region, a field mission to the upper Maroni Basement took place in September 2019. For this, 14 interviews with the local population of the cities of Maripasoula, Papaichton and smaller settlements up to Abattis Kottika were conducted. Conversations with village kapteins, local farmers, artisanal craftsmen and -women and administrative authorities allowed to capture views and narratives around the relation of inhabitants of the River Basin to nature, the ecosystem services it provides and the current trends and changes in ecosystem services supply (Sieber et al., 2020c).

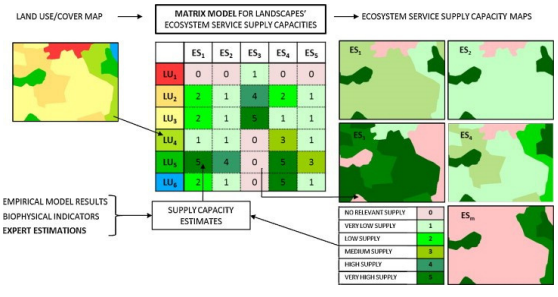

Figure 4: Ecosystem Services Matrix (after Burkhard et al, 2009)

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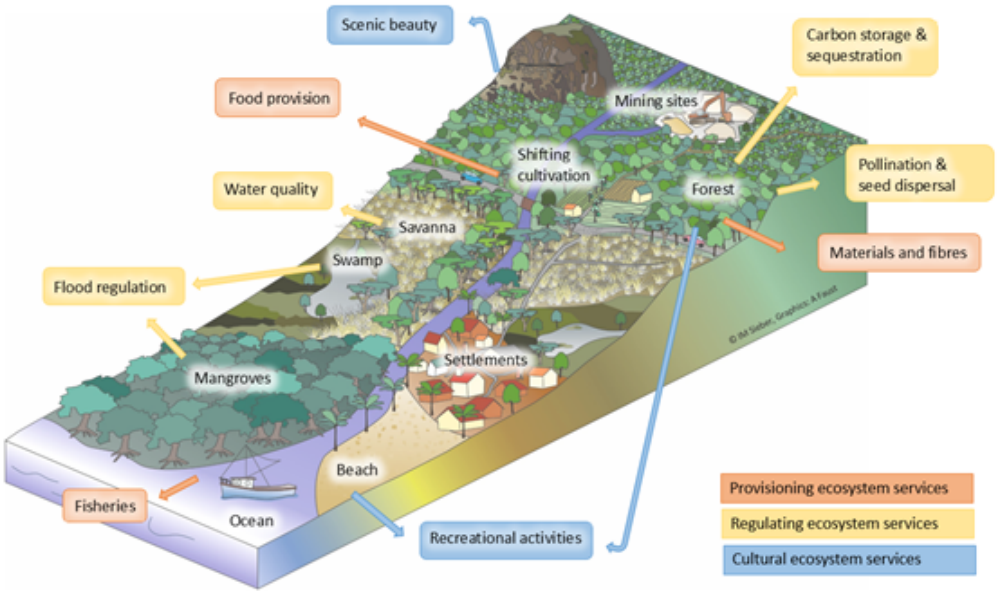
RESULTS (1)

Ecosystem services of local and global importance are supplied by the large amount of forest, the green lung of the world. Global and local climate regulation, carbon storage and sequestration, wild foods, materials and fibres provide a crucial contribution to human well-being. Mangroves protect the coastal fringe and provide habitats and nursing grounds for numerous wild animals and fish species. Savannas and swamps contribute to good water quality and buffering of extreme events, such as droughts and floods.

In the Maroni Basin, agricultural land use, especially shifting cultivation, provides food for human consumption. Rivers provide fresh water, fishing grounds and serve as major transportation pathways in the back country.

Figure 5: Overview of ecosystem services in the Guiana Shield



Results in detail

EXPERT EVALUATION

Both in Suriname and French Guiana, participatory expert workshops took place. Comparing the results helps to understand the differences in perception of ecosystem service supply capacities and bears potential to underpin future knowledge-based bilateral conservation policies and funding decisions by governments and managers.

Both ES supply matrices showed a high degree of similarity – forest ecosystems scored the highest ES capacities, followed by aquatic and marine ecosystems. Agricultural and urban land cover showed overall weak to moderate capacities for ES supply (Figure 6). A statistical analysis revealed a 30% difference of the two matrix assessments. Expert scores given for ES in Suriname exceeded those in French Guiana, especially for urban LULC and planted forests. Sociodemographic factors such as age, gender and institutional environment were analysed to explain this difference. The diverging scores can also be attributed to the distribution and the degree of similarity of the different LULC types and, hence, ES capacities and different governance and institutional contexts of the assessments (Sieber et al., 2021).

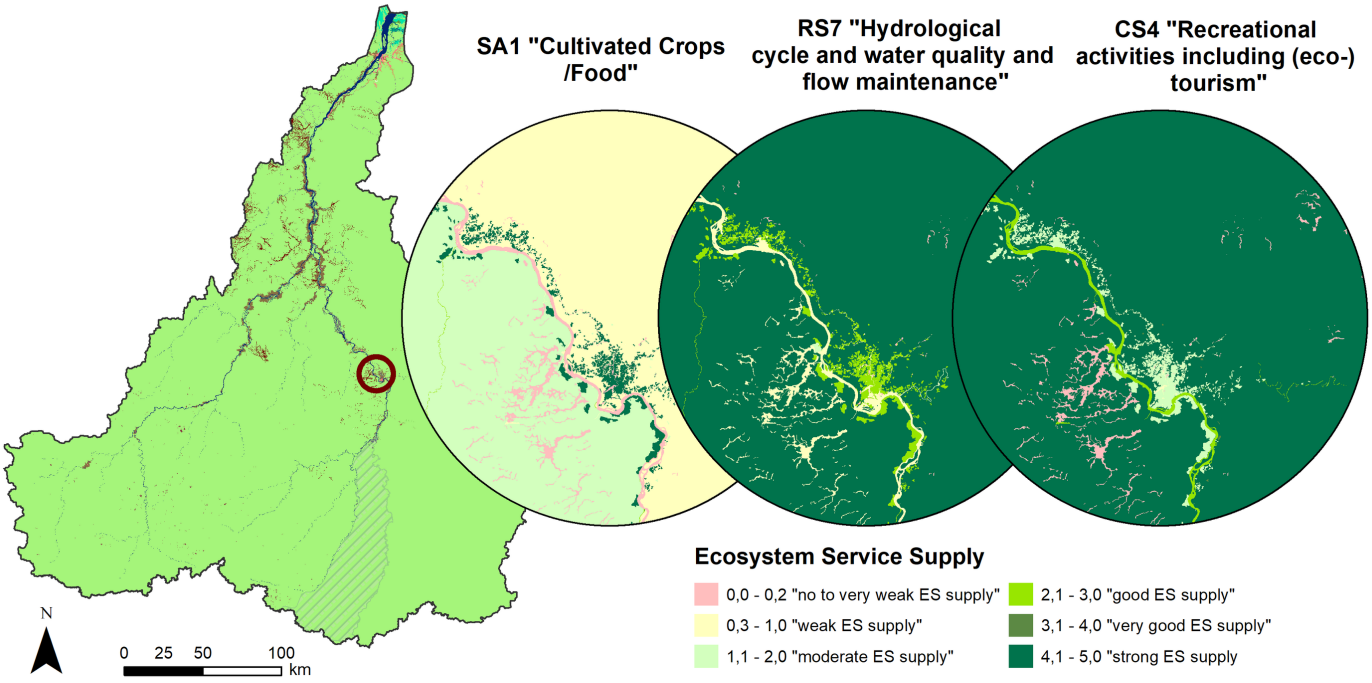
2
national ecosystem services assessments

22
ecosystem services assessed

39
experts from Suriname and French Guiana

70 %
shared agreement on ecosystem service supply capacities

Figure 6: **Ecosystem Services in the Maroni River Basin**



ECOSEO

RESULTS (2)

Local livelihoods are closely conntected to their natural environment. The inteviews in the upper Maroni Basin, especially in the area of Kotika up to Maripasoula revealed this (Figure 7). Not surprisingly, village life is dependent on materials and fibres, timber for building and craftsmanship. The traditional canoes are still major transportation vehicles, as roads connecting the hinterland with the coastal fringe are still scarce. Therefore, the supply of foods, especially wild food and game meat from forest ecosystems, but also from traditional shifting cultivation, so called "abbatis", is crucial. Also, the local population heavily depends on food supplied by the river - local fishing activities contribute a major source of proteins for the local population. The river is also a most important source of freshwater. Through increasing mining activities on both sides of the river, foremost on the Surinamese side - where regulations are less strict, the riverine water is enriched with pollutants such as heavy metals. This puts a severe threat to health in the communities along the river.

Figure 7: word cloud analysis based on 14 interviews in the Maroni River Basin

With decreasing condition of ecosystems, for example through deforestation, degradation or pollutants, the services they supply decreases. Interviewees reported decreasing fish populations, decreasing numbers of wild animals in the forest and changing rainfall patterns and decreasing resilience of argricultural areas to droughts. Only the supply of materials for energy, such as provided by the oil palm, was reported to increase on the Surinamese side of the River Basin.

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POTENTIALS, CHALLENGES, FUTURE

In the Maroni River Basin, ES such as wild foods, wild animals, fish and game meat, and materials and timber are supplied. 90% of the Maroni Basin are covered by forest, ES such as carbon storage and global climate regulation are well renowned (Guitet et al. 2015). However, many ES are supplied without direct noticing, such as the regulation of climate, weather extremes, pests and diseases. These ES are less obvious and easily overlooked in daily life, but also, when considering ES in land use planning.

Pressures on ecosystems, and hence the services they supply in the Guiana Shield are rising. With increasing need for land, intensification of agricultural practices and increasing gold mining activities, ecosystems are more and more threatened. In addition, the rising gold prices linked to the COVID-19 outbreak in early 2020 might accelerate the run for gold (Rahm in progress), an effect observed during earlier increases of demand on the world market (Hammond et al., 2007; Dezécache et al., 2017).

Through applying this positivistic ecosystem services approach, it was possible to quantify the ecosystem services supplied by local ecosystems for the first time without taking a commodifying, monetary approach. The visualisation in ecosystem service maps has numerous advantages (Burkhard and Maes 2017). It presents the entirety of ES supplied by different land covers at a glance, clearly understandable for a broad audience.

Only effective land use planning and conservation management policies, including law enforcement, have proven successful to protect ecosystems and control and manage land encroachment and illegal deforestation activities (Dezécache et al. 2017). The consequences of such uncontrolled mining and deforestation activities are affecting the entire water system within a watershed, and hence, the whole river basin, joint collaboration and transboundary land and water management is needed (McPherson and Boyer 2015).

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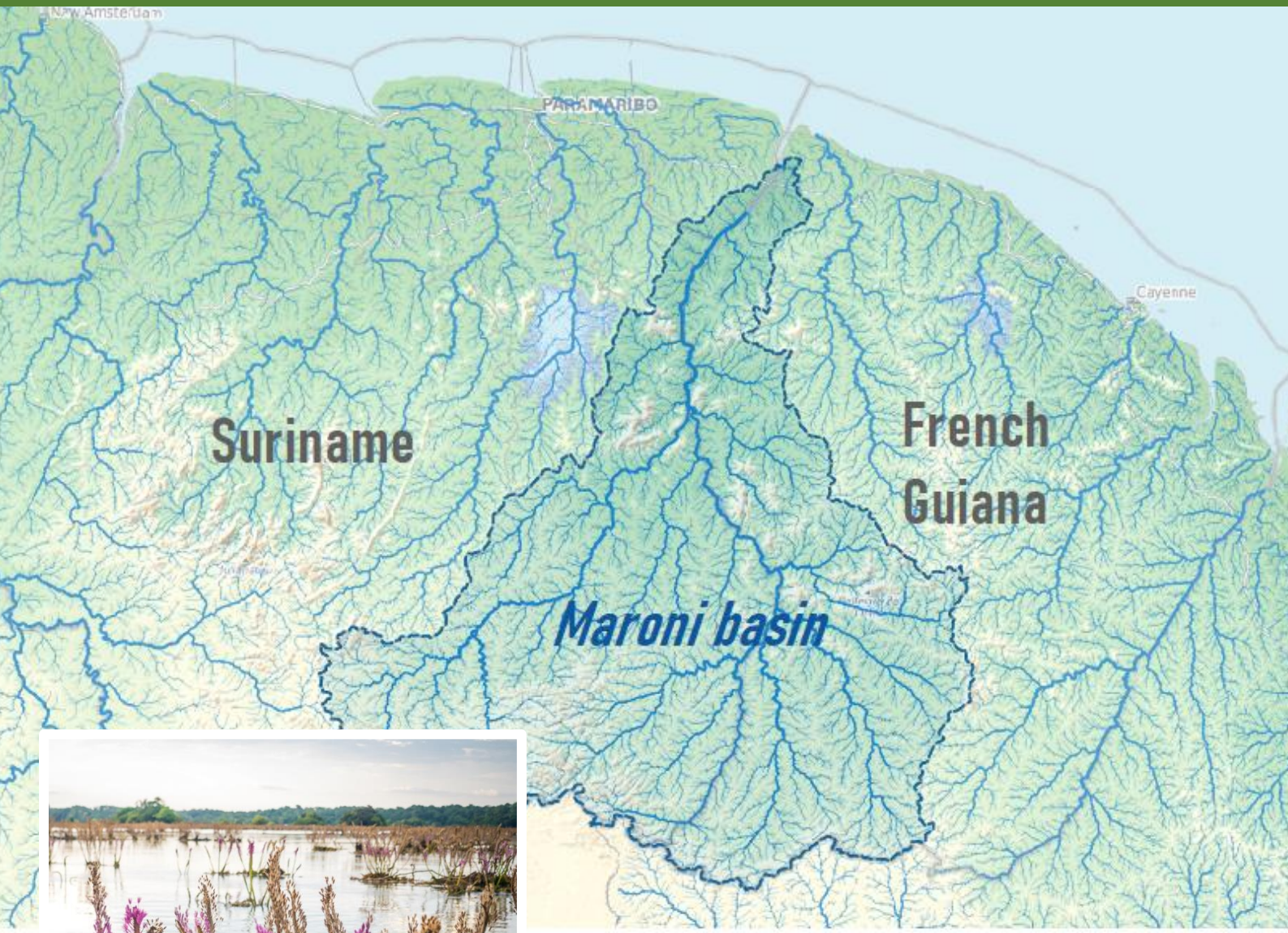
Ecosystem Services Observatory of the Guiana Shield

ECOSEO

ECOSYSTEM SERVICES IN THE MARONI RIVER BASIN



Mapping and assessment of ecosystem services

MAIN REPORT

This work was 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 Water agency of French Guiana and coordinated by the French Guiana office of WWF-France.

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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 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. This region is declared as an eco-region of "regional and global significance" and home to a variety of ecosystems and "keystone species of biodiversity" (UNDP 2020[1]). In the Guiana Shield, as in many ecoregions of the world, socio-political borders criss-cross through natural ecosystems and hence ecological boundaries. As neighbouring countries share ecosystems, they also share ecosystem processes, functions and hence, ecosystem services (Daily, 1997; López-Hoffman et al., 2010).

The Maroni River basin is one of the biggest river basins within the Guiana Shield. The Maroni River, with its more than 600 km in length, demarcates the border between Suriname and French Guiana. The region is a true cultural melting pot (Hidair and Ailincai 2015; INDIGENOUS WORLD 2020).

Figure 1: Location of the Maroni River basin (modified based on ESRI, 2019). Borders are used for orientation only, they do not reflect any political views of the authors.

Within the Maroni River Basin, the livelihoods of many people strongly depend on nature. Most inhabitants live in small settlements and villages, remotely from the coast and the large cities in both Suriname and French Guiana. Ecosystems and the services they supply are of vital importance for the population. Hence, ecosystems and their services (ES) are at the core of human livelihoods. They entail "all the contributions, both positive and negative, of living nature (diversity of organisms, ecosystems, and their associated ecological and evolutionary processes) to people's quality of life" (IPBES, 2017). Especially rural and indigenous communities are closely connected to their natural environment. Hence, their knowledge is based on their dependency on their surrounding ecosystems, on generations of observations and measures, creating, soring, applying and transmitting knowledge to others.

Land use changes and resource extraction, such as mineral and gold mining activities directly and indirectly affect the water quality of the entire water system (Boudou et al. 2006), unstopped by political constructs of borders. Safeguarding of (forest) ecosystems and their services therefore requires regional cross- or transboundary ecosystem management (Dezécache et al. 2017; Kelly and Kusel 2015; Kark et al. 2015).

For the Guiana Shield, human-nature relations have not yet been assessed through the ES concept. Little is known about the ecosystem services that local, indigenous communities receive. This report presents a first assessment of ecosystem services in the Maroni River basin, mapping and assessing the capacity of ecosystems to supply ecosystem services.

1.1 The ecosystem services concept

The term ”ecosystem service” was first used in 1981 and has become more and more common in scientific literature 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 an approach 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.

Therefore, ecosystems and their services (ES) are at the core of human livelihoods. They entail “all the contributions, both positive and negative, of living nature (diversity of organisms, ecosystems, and their associated ecological and evolutionary processes) to people's quality of life” (IPBES, 2017). Especially rural and indigenous communities are closely connected to their natural environment. Hence, their knowledge is based on their dependency on their surrounding ecosystems, on generations of observations and measures, creating, soring, applying and transmitting knowledge to others.

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, and 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.

To qualify and quantify the different ES means to estimate where and when which ES are supplied. This knowledge, and hence the ecosystem services concept, 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.

1.2 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[1]). The Guiana

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

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, a vast rainforest stretches down south, the canopy only broken by large Inselbergs and mountainous formations in the hilly hinterland (Dijn 2018).

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 (Boudou et al. 2006; Dezécache et al. 2017).

For the Guiana Shield, human-nature relations have rarely been assessed through the ES concept. Efforts to understand the links between ecosystems in the Guiana Shield and the services they provide have recently started and are growing (see e.g. Sieber et al. 2018). 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[2], ecosystem services have been described on national level for French Guiana (Roger et al. 2016).

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:

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

- to highlight and promote the need for considering ecosystems values in decision-making; and,
- 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[3] (MAES), 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.

1.4 Scope and Objective of this report

This report presents a holistic ES assessment for the transboundary Maroni River basin. It outlines the outcomes of the expert-based ecosystem services assessment in both French Guiana and Suriname. Second, it presents the outcomes of a field mission to the Maripasoula region, presenting the views and trends on ES supply based on stakeholder interviews of inhabitants of the river basin.

2. Methods and Materials

In this section, the Maroni River Basin, the methods and data for the ecosystem services assessment will be described.

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

2.1 The Maroni River Basin

The Maroni (or Marowijne) river marks the natural border between Suriname and the French Departement d'outre mer French Guiana. It has a length of 610 kilometres and a watershed area of 68,700 km². Based on Land Use Land Cover (LULC) data from 2015, 96% of the watershed is covered by tropical rainforest (SBB 2017, 2018; Joubert 2017). Agricultural practices cover 1% of the basin (Table1). Shifting cultivation is the dominant agricultural practice, and covers twice as much area in Suriname then in French Guiana. Human settlements can be found on both sides of the river, with official borders largely ignored (Douine et al. 2017). Strongly modified land cover, in the form of mineral extraction sites, can be found at the side arms of the Maroni, encroaching deeper and deeper into the forest.

Table 1: LULC types for the Maroni River Basin, including surface cover area (in percent), adjusted from SBB 2017; Joubert 2017).

Land Cover		LULC type	Suriname Surface Cover (in percent)	French Guiana Surface Cover (in percent)	Total percent
Marine and littoral land cover	Ocean	E1			
	Beaches	E2	-	< 0.001	**<0.001**
	Mangroves	E3	<0.001	0.03	**0.03**
Aquatic land cover	Rivers and creeks	E4	0.82	0.55	**2.37**
	Open wetlands	E6	0.08	0.07	**0.15**
Forested land cover	Open Savannah	E7	<0.01	0.01	**0.01**
	Inselbergs	E8	<0,01	<0,01	**<0.01**
	Forest tree cover	E9	57.47	39.20	**96.67**
	Planted Forest	E10	unknown	-	**Unknown**
Agricultural land cover	Small scale agriculture	E11	0.01	<0.01	**0.01**
	Large scale agriculture	E12	-	0.06	**0.06**
	Pasture	E13	<0.01	<0.01	**<0.01**
	Shifting cultivation	E14	0.66	0.27	**0.93**
Urban and largely modified land cover	Bare soil	E15	0.07	< 0.01	**0.07**
	Built area	E16	0.02	0.07	**0.09**
	Infrastructure	E17	0.04	0.02	**0.06**
	Mineral extraction areas	E18	0.43	0.13	**0.56**

The baseline data of the year 2015 were chosen as detailed LULC data for both territories was present at a comparable level of detail. Nonetheless, the current rate of land use changes has to be acknowledged. Since, forest losses have continued. Between 2015 and 1028, deforestation has proceeded with 5200 ha forest loss annually in Suriname. In the same period, French Guiana witnessed annual deforestation rates of 935 ha annually (Rahm in progress). In 2020, actual forest losses in the Maroni River Basin amounted to roughly 3600ha in Suriname and 1500 ha in French Guiana, as forest loss data bases show (Hansen et al. 2016).

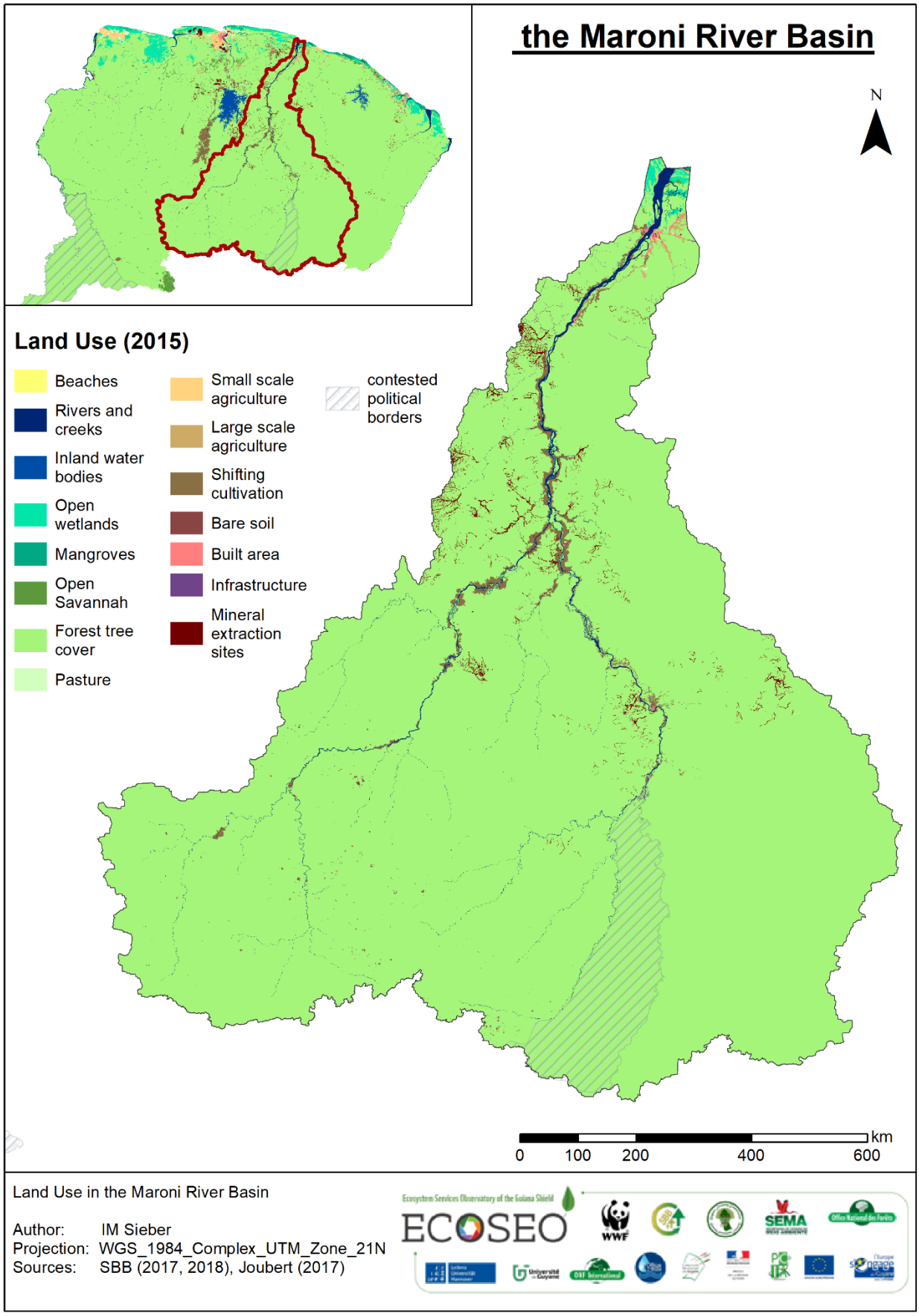

Figure 3: LULC in the Maroni River Basin

2.2 Methodology

To assess ES in the Maroni River Basin, different methodologies were applied: an expert-based ES assessment at National/territorial scale and a social ES assessment...

2.2.1 National/Territorial ES capacity matrix

Firstly, we draw upon two national/territorial ecosystem services capacity matrix assessments that were conducted in both Cayenne, French Guiana and Paramaribo, Suriname on October 2nd and 8th, 2019 based on expert knowledge (Sieber et al. 2020a, 2020b). This expert-based approach allows to consider different types of ecosystems and services in a participatory approach integrating the knowledge of the actors of the territory. In addition, it takes a 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. Altogether, this assessment considered 22 ES that were selected with local stakeholders (Table 1). This 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. We used the data of this National/territorial ES assessment in order to have the ES capacities at the Maroni River Basin. Data from the two matrices were extracted for the Maroni River Basin using ArcMap 10.6.

2.2.2 Social ES assessment

Secondly, we draw upon data collected during a field trip to the Maroni River Basin in September 2019 (Sieber et al. 2020c). Between 23. and 27th of September 2019, the cities of Maripasoula, Papaïchton and smaller settlements up to Abattis Kottika were visited. Interviews were conducted with the local population, village kapteins and administrative authorities to capture views and narratives around the relation of inhabitants of the River Basin to nature, the ecosystem services it provides and the current trends and changes in ES supply. The methodology for this was tripartite and consisted out of 1) semi structured interviews, 2) transect walks and 3) field observations. Based on 14 interviews, ES were rephrased according to the CICES 4.3 classification (Haines-Young and Potschin 2013) for comparative purposes. This allows to bring together the matrix assessment and the social assessment component. Whether the supply of minerals, including gold ores, is an ES in itself is highly debated. In former CICES versions, this service was listed among the abiotic ES but has been removed (Haines-Young and Potschin, 2018). The updated version only contains Mineral substances used for material purposes related to nutritional value, pigments or energy production.

For the visualization in ES supply maps, trends from the interviews were quantified (Sieber et al. 2020c) and visualized in the ES Supply maps.

Table 2: Assessed ES on national/territorial level for Suriname and French Guiana (Sieber et al, 2020)

Section	Division		Group	Code
Provisioning Services	Nutrition	Biomass for food consumption	Cultivated crops / food	PS1
			Reared animals and their outputs	PS2
		Biomass	Wild plants, algae and their outputs	PS3
			Wild animals and their outputs	PS4
		Water	Freshwater supply for drinking purposes	PS5
	Materials	Raw materials	Materials and fibres	PS6
			Plants and resources for medical use	PS7
Regulating Services	Maintaining biological, physical and chemical conditions		Carbon sequestration	RS1
			Global and local climate regulation	RS2
			Disease control	RS3
			Pest control	RS4
		Maintaining nursery populations and habitats	Maintaining nursery populations and habitats	RS5
			Pollination and seed dispersal	RS6
			Hydrological cycle and water quality and flow maintenance	RS7
			Maintaining soil quality	RS8
	Mediation of mass flows - risk reduction		Mass stabilisation and control of erosion rates	RS9
			Storm protection	RS10
			Flood protection	RS11
Cultural Services	REPRESENTATIONS-subjective		Emblematic or symbolic	CS1
			Heritage (past and future) and existence	CS2
			Aesthetic	CS3
	USE-objective		Recreational activities including (eco-) tourism	CS4

3. Results

3.1 National/Territorial results

The results of the matrix assessments from Suriname and French Guiana are shown in Figure 4. The mean arithmetic scores of the two national/territorial ES assessments resemble each other. Patterns of strong ES supply can be found among the marine and aquatic ecosystems as well as among forest ecosystems in both territories. A statistical analysis showed a significant similarity of 70% of the matrix (Sieber et al, 2021). Statistical differences within the scores of both expert panels were visible in the scores of anthropogenically impacted ecosystem and land use types. This could reflect the strong dependence of the national Surinamese economy on resource extraction and the primary sector and comparatively strict nature protection regulations of French Guiana and the European Union (Sieber et al, 2021).

Figure 4: arithmetic mean scores of the two ES assessments in Suriname and French Guiana on a scale of 0-5 (0=not to very weak ES supply, 5= very strong ES supply) (Sieber et al., 2021)

3.2 ES on Basin Scale

Visualizing the matrices in the last chapter in form of maps shows where and in which magnitude ES are supplied in a spatial context. As shown in Figure 5, the ES supply is spatially explicit, with different LULC types supplying different ES. As shown on the example of the Maripasoula region, the river has no to very weak capacities to supply “cultivated crops/food”, a weak capacity to contribute to the hydrological cycle, and a good capacity to contribute to “recreational activities including (eco-)tourism”. Abattis, surrounding the urban centres of Papaïchton and Agode (north-west) and Maripasoula (south-east of the map) shows strong capacities for food cultivation, good capacities to contribute to water quality and comparably moderate capacities for recreation. Largely modified LULC in the south-west of the Maroni River represents mining areas. This LULC scored low in ES supply capacities, with no to weak ES supply.

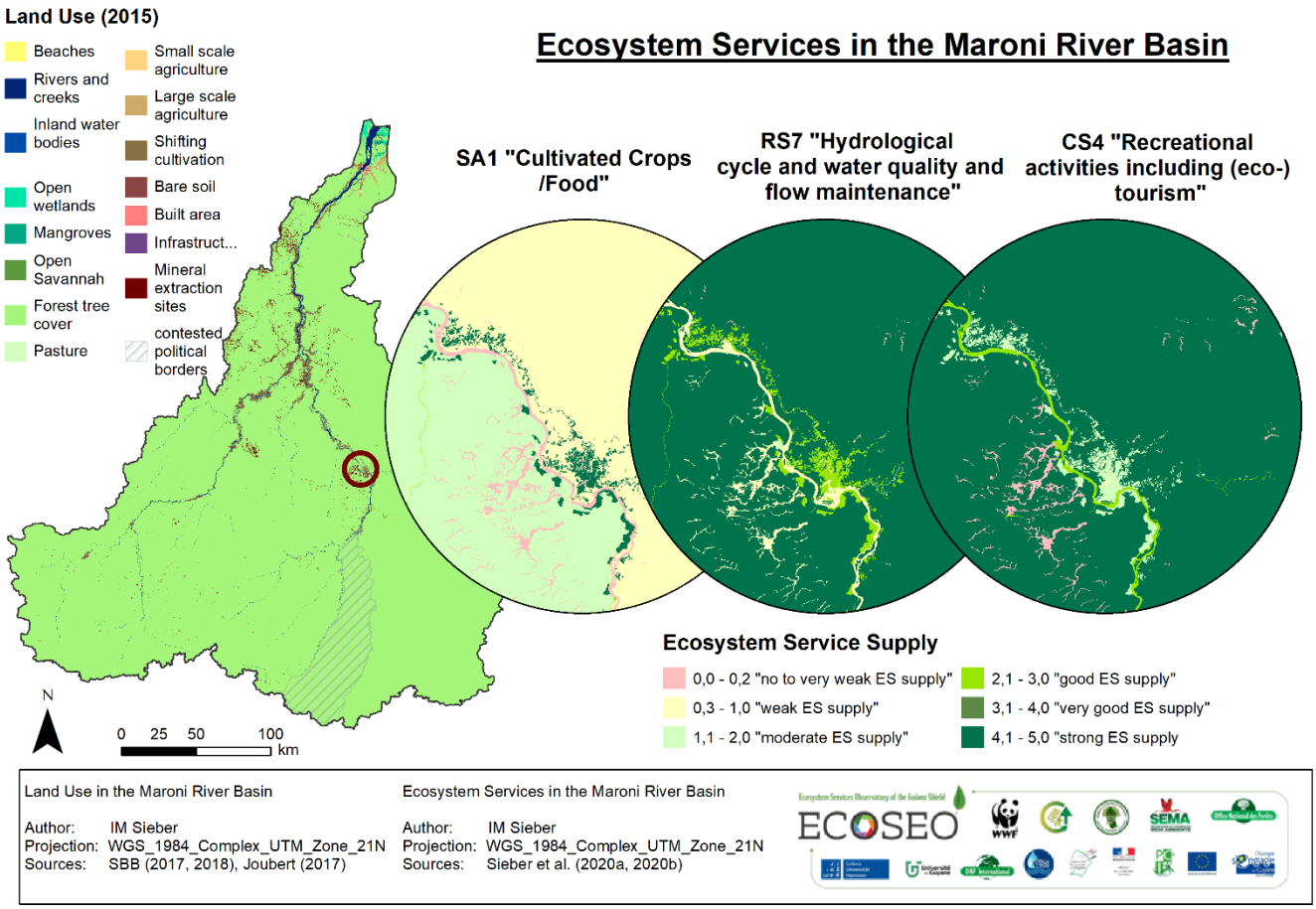

Figure 5: Ecosystem Services supply in the Maripasoula region

The overall 70% of agreement on the magnitude of ES supply in both the Surinamese and French Guianese Side of the river basin is visualized in the maps. However, on basin scale maps, this similarity is overshadowed by the large amount of forest cover dominating the river basin. Smaller LULC classes and the ES supply capacities become almost invisible on these maps, however, zoomed in, become visible. An overview of the 22 assessed ES can be found in Figure 6.

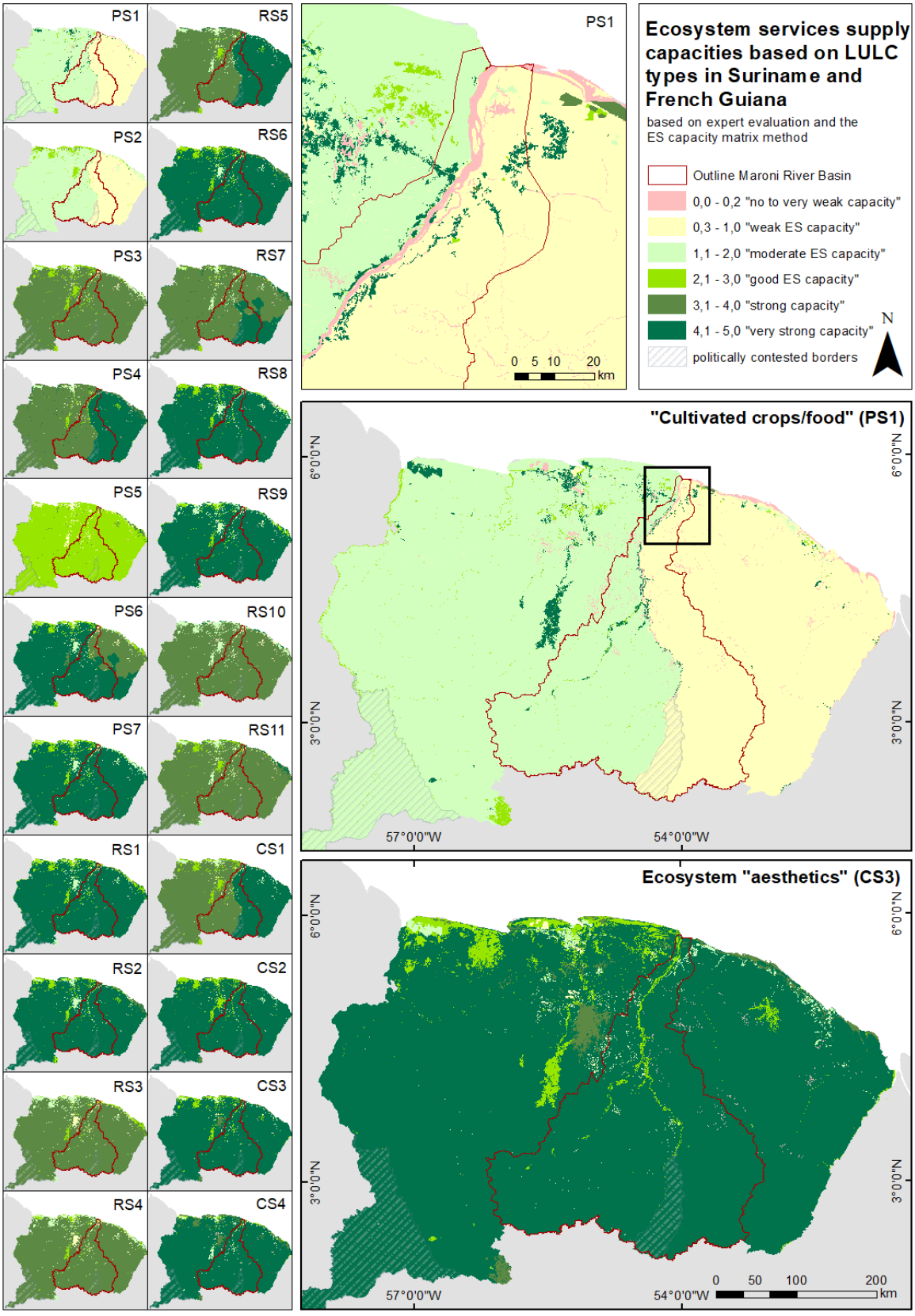

Figure 6: Overview of 22 ES for the Maroni Basin based on the matrix method and expert scoring

3.3 Ecosystem Services in the Maripasoula Region based on local interviews

Ecosystems and the services they supply to the inhabitants of the Maripasoula Region are numerous. Based on 14 interviews in the Maripasoula region, ES have been distilled. Transportation was often mentioned as service of crucial importance; however, it is not listed among international ES classifications. Nonetheless, it presents an ES of utmost importance for the Maripasoula Region. Many of the ES that were assessed on national level were mentioned (Sieber et al., 2020a, 2020b)). Whether the supply of minerals, including gold ores, is an ES in itself is highly debated. In former CICES versions, this service was listed among the abiotic ES but has been removed. The updated version only contains Mineral substances used for material purposes related to nutritional value, pigments or energy production. Therefore, it is not included in the following chapters.

3.3.1 River Related ES

The Maroni River is the "lifeline" of the local population. It is almost the only possibility for transportation, the river presents habitats for fish, which serve as source of food and major source of protein in local diets for many inhabitants. Further, the role of the river in provisioning of drinking water and water for domestic use will be discussed. Even though transportation does not list among the CICES classification, it was of utmost important for the interviewees.

Transportation

In terms of transportation, the river acts as a major connection to the coastal areas and as the only connection for the people of many of the numerous villages in the river basin. Goods and materials are shipped by boats. (Traditional) canoes have supplanted all other types of boats (Price 1996; Meide 2002). Throughout the year, the water level is subject to seasonal changes. During the rainy season, water levels are high and currents strong. During the dry season, water levels drop and the rocky riverbed becomes visible. Adding to this, interviewees mentioned an increase in water turbidity in the river downstream of Maripasoula. Navigating during the dry season has become more and more difficult and requires skilled boats people with vast knowledge on the characteristics of the river.

Drinking water

The river also provides water for drinking and household consumption. Many interviewees mentioned a change in water quality, especially related to gold mining activities around, and downstream of Benzdorp. The use of heavy metals, such as mercury, was criticised by inhabitants downstream of Maripasoula. In addition, interviewees mentioned that the turbidity level had increased within the last decade, an effect strongly linked to the novel approach of river bank sediment screening for ore extraction. At the same time, species richness was observed to decrease, indicating poor water quality. Altogether, this resulted in a lack of reliable sources of drinking water.

Fishing

Fishing and fish are integral parts of the life of the interviewees. The majority of inhabitants relies on local fish for food, and many different fish species are consumed. Examples are the "coumarou, suké, piraille, wawa (poisson roche), gangou, pakousine, crabe, apépété, koumata ou kalimata" (in French).

Fishing takes place in a traditional manner - fishnets are brought out by boat (pirogue) and left overnight (Figure 4). Fishing is predominantly undertaken by village men. It bears a strong sense of culture and belonging. However, a decrease in fish species and taste of the catch has been mentioned in multiple villages.

A survey in mining camps and affected communities in Suriname and French Guiana showed that nearly half of interviewed Maroon in the Lawa and respondents were aware that consumption of fish could be linked to mercury intoxication, but this knowledge has not changed consumption patterns (Heemskerk & Olivieira, 2004).

With deteriorating catch, the main source of nutrition in daily food consumption is changing, and at the same time, the main source of proteins needs to be replaced. As a result, the import of canned goods and dried foods sold in supermarkets increases, a phenomenon also witnessed among Wayana communities (Heemskerk et al. 2007).

Figure 6: Traditional fishing practices on the Maroni River (© IM Sieber)

3.3.2 Forest related ES

Forest is the dominant ecosystem type in the Maripasoula region and the Maroni River Basin. The forest contributes to the village life in multiple ways. Notably, 1 ha of forest harbours as many tree species as the entire continental Europe together (Roger et al. 2016). The forest therefore presents a breeding ground a nursery for many different species and biodiversity. The majority of plants that grow in the forest can be used for multifunctional purposes, as food, fibres or medical purposes as herbs, for bathing or tea (see chapter below).

Wild foods

Wild food, fruits and vegetables can be collected for daily food consumption.

Raw fibres

The forest provides timber for construction of traditional houses or boats. For the traditional canoes, different wood species are used (see Chapter River). However, much of the accessible forest has been altered and valuable lumber has been taken out. According to a local carpenter, finding suitable wood for canoes involves longer travels to more and more remote forest patches and transportation on the river.

Hunting

The traditional lifestyle of Amerindian culture includes hunting practices. Bush meat has been an integral part of the nutrition for habitants of the Maroni region, including birds, monkeys, deer, tapir, sloth, peccaries, armadillos, anteaters, rodents, and agoutis. With increasing population density and human activities along the river, the macro fauna in the region has decreased. Sightings of larger mammals and birds have become rare.

On the French Guianese side of the Maroni, the establishment of the “Park Amazonien” national park and resulting regulations have prohibited hunting practices. National authorities enforce compliance to the regulations strictly. Outside the park area, however, especially on the Surinamese side of the Maroni, hunting is commonly practised.

Plants for medical use

Traditional medicine plays an important role in everyday life. Many of the species of tropical medicinal plants were introduced to the Guianas in historical times (DeFilipps et al. 2004). Many medical plants serve multiple purposes. They provide sources of medicine and herbal prepared drugs but can also be used for ornamental or decorative purposes. In addition, some medical plants can be variously used as food (fruit, stem leaves, storage roots), fibres, oils, shade providers, building material, timber, fuel or firewood. Examples for this are the coconut palm « Cocos mucifera » as source of oil for skin care, hair growth and furuncle soother. Further, coconut fibres are said to regulate blood pressure when drunk as tea. Juice is drunk with molasses and sour orange to treat colds. Oil is drunk plain or mixed with salt for gout, rheumatism, coughs and colds. Seed oil can be used as febrifuge, laxative, and to treat grippe (DeFilipps et al. 2004).

Interviewees cultivated a variety of medical plants in their abattis or collected them directly from the forest. With increasing anthropogenic impacts on the forests, many of the traditional medical plants are more and more difficult to find and remain at distance from the villages. Repeatedly, it was mentioned that knowledge of medicinal plants and traditional healing practices were mainly abundant among shamans and elders. Interviewees mentioned that such knowledge, however, was lost in younger generations. Reasons for this are the ongoing migration towards the larger cities in the littoral belt and the French school system with little focus on traditional practices.

3.3.3 Abattis related ES

The traditional way of agriculture relies on shifting cultivation, so called « abattis » (Figure 5). Here, the food for everyday life is cultivated: cassava, bananas, maize, vegetables such as peppers and eggplant and fruit trees: lemons, mombins and mango trees.

Based on traditions, young adults get their own abattis at the age of 18. Abattis have an average size of 0.3 ha and were cultivated for 2-3 years. This short use period was a result of infertile soils in the Amazon region. However, due to increased agricultural practices and settledness within the last decades, many abattis are cultivated for longer periods. With this abandonment of the traditional shifting cultivation, the fallow period lacks. This has led to a further depletion of soil fertility and to susceptibility to pests and droughts. In addition, the urban pull leads to an increased demand in abattis. New areas are burn beat at the periphery of existing cities. Sometimes, the abattis are located 4-5km outside of the village, with limited access. Often, roads are inexistent or poor, so that quads or cars cannot pass and walking remains the only option.

3.3.4 Culture ecosystem services

Heritage

Among the indigenous communities along the Maroni, artefacts and jewellery are a representation of cultural belonging and traditions. Traditionally, such decoration and jewellery are made out of plant and animal parts. Timber for ornamental purposes, combined with natural sediment colouring, decorates the traditional housing. In French Guiana, much of the forest is inside or close to the national park borders of the « Park Amazonien », which means that official permissions are needed to extract timber from the forest. Alternatively, timber can be acquired from the Surinamese side of the River basin. Timber for constructional purposes is for example used for the traditional housing (Figure 7) or traditional canoes. For small scale artisanal activities, such a permission is not needed. Seeds from the forest are collected and crafted into colourful bracelets, necklaces and earrings. Cotton plants provide the basis for woven fabric, clothes and handmade hang mats.

Figure 7: traditional housing in Kottika Village

Ecotourism

Recreational activities and (eco)tourism are scarce but growing in the Maripasoula region. The number of hotels and guest houses is increasing in Maripasoula, but also in smaller cities, such as Papaïchton, Guest houses are located. However, in the smaller villages, tourism is still scarce - Few restaurants exist, indicating the low touristic development within the region. Touristic activities such as scenic nature hikes, or the “Walk to the source” are actively promoted by the Collectivité Territoriale de Guyane (CTG).

3.3.5 Mining

The extraction of minerals, especially gold ore, is one of the main economic activities in the Maripasoula Region due to its location on the Greenstone Belt (Naipal and Kroonenberg 2016).

Despite the official prohibition of gold mining activities on the French Guianese side of the Maroni, gold panning activities, especially illegal gold mining, has by now impacted all the large rivers, even those within the National Park areas (Boudou et al. 2006).

Next to small-scale traditional gold mining activities, large-scale extraction can be found, dominantly in Suriname. During the field mission, large boats were observed on the Surinamese side of the river, extracting river bank sediment (Figure 7). Under the use of heavy metals such as mercury, sediment is screened, gold particles are agglomerated and extracted and the waste mud released back into the river. This has led to numerous problems – increased turbidity of the Maroni River with its consequences for transportation, significant pollution of the Maroni River and many side arms, as well as the water table. This unavoidably causes health issues due to chemical pollution of the water as well as an increase in population within the region, mainly driven by seasonal workers arriving from Brazil.

Figure 8: Gold mining activities on boats on the Surinamese Side of the River, downstream of Benzdorp, Suriname (© C. Villien).

Many of the gold miners reside illegally in French Guiana. According to Douine et al, 93 % of gold miners are of Brazilian origin, with no to little formal education (Douine et al. 2017). In Suriname and Brazil, the majority of gold workers live remotely in the forest, under poor living conditions (Douine et al. 2017). Illegal settlements can often be found in the vicinity of mining sites in the forests. Often, these go along with illegal timber extraction and hunting practices, with no to very little respect for the local indigenous people and their traditions (P7).

3.4 Trends in ES supply in the Maripasoula Region

Assessing the current status of ES supply always presents a snapshot in time. Rather, ES supply varies temporally, between wet and dry seasons, but also with changes in condition of ecosystems. Human activities, urban spread, clearing of lands for agricultural practices and mining activities deeply disturb the forests surrounding human settlements, with effects reaching up to 70 km inland (Siquiera-Ray, 2020; personal communication).

Table 3: Ecosystems, the services they supply and ES supply trends in the Maripasoula region.

Ecosystem	Ecosystem Service	ES supply trends described by interviewees	ES
River	Transportation	↘	-
	Surface water for drinking	↘	PS5
	Surface water for non-drinking purposes	↘	PS5.1
	Hydrological cycle and water quality and flow maintenance	↘	SR7
	Wild animals and their outputs (fish for consumption)	↘	SA4
	Cultural: Fishing	→	SC5
Abattis	Cultivated crops	↘	PS1
	Cultural: hunting	↘	CS5
	Plants and resources for medical use	↘	PS7
Forest	Wild animals and their outputs (game meat)	↘	Ps4
	Wild plants, algae and their outputs for consumption	→	PS3
	Fibres and other materials from plants, algae and animals for direct use or processing	→	PS6
	Fibres and other materials: Timber	↘	Ps6
	Plants and resources for medical use	↘	PS7
	Plants and resources for ornamental purposes	→	SC1
	Biomass-based energy sources (Suriname)	↗	PS8
	Maintaining nursery populations and habitats	↘	RS5
	Symbolic	→	CS1
Urban	Heritage, cultural	→	CS2
	Physical and experiential interactions: Recreational activities and eco-tourism	↗	

4. Discussion

The overview of the two national ES assessments shows the high capacities of natural LULC to supply ES in both the Surinamese and the French Guianese Side of the Maroni River basin. Especially marine, aquatic and forest ecosystems received high scores, supplying multiple ES at the same time. Anthropogenically impacted LULC types, such as agricultural areas, urban areas, infrastructure or largely modified LULC contribute to a much smaller extent to human wellbeing through ES supply.

In the Maroni River Basin, provisioning ES such as wild foods, wild animals such as fish and game meat, and materials such as timber are supplied. With 90% of the Maroni Basin being covered by forest, ES such as carbon storage and global climate regulation are well renowned (Blanc et al. 2009; Guitet et al. 2015). However, many ES are supplied without direct noticing, such as the regulation of climate, weather extremes, pests and diseases. These ES are less obvious and tend to be overlooked in daily life, but also, when considering ES in land use planning. Through applying such a positivistic ES approach, it was possible to quantify these services for the first time without taking a commodifying, monetary approach. The visualisation in so called ES maps has numerous advantages (Burkhard and Maes 2017). It presents the entirety of ES supplied by different land covers at a glance, clearly understandable for a broad audience.

However, linking these first national ES assessments for Suriname and French Guiana to actual and ongoing trends in the Maroni River Basin obtains novel insights. Livelihoods and economic activities on both sides of the river are deeply interconnected. Therefore, an analysis of relevant ES for the Maroni needs to move beyond national assessments and add local perspectives from the River Basin. Many inhabitants criss-cross the administrative borders on a daily basis. In local perception, the Maroni, as political boundary does not coincide with ethnic, linguistic and cultural boundaries. Literature suggests that this administrative construct of boundaries is still poorly understood by many of the small, historically grown indigenous communities afar from the big cities (Grenand et al. 2006). Therefore, the Maroni presents a unique opportunity to study ES in transboundary river basins.

Pressures on ecosystems in the Guiana Shield, and also the Maroni River Basin are rising. With increasing need for land, intensification of agricultural practices and increasing gold mining activities, ecosystems are more and more threatened on both sides of the border. Despite differing national laws and environmental protection, effects of environmental destruction and deforestation affect the entire river basin. Upstream activities hereby have strong effects on livelihoods downstream. The example of gold mining clearly shows this - the use of heavy metals and river barks for gold extraction on the Surinamese river banks affects the condition of the river ecosystems directly. Increased turbidity, water pollution, the decrease of habitat suitability and hence, decrease in wild foods for human consumption. At the same time, water for household consumption, supplied by the Maroni, is affected, posing a severe health issue for inhabitants on both sides of the river. The rising gold prices linked to the COVID-19 outbreak in early 2020 might accelerate the run for gold (Rahm in progress), an effect that has proven true before (Hammond et al., 2007; Dezécache et al., 2017), and can add to decreasing condition of ecosystems in the upper Maroni Basin.

Only effective land use planning and conservation management policies, including law enforcement, have proven successful to control and manage land encroachment and illegal deforestation activities

(Dezécache et al. 2017). The consequences of uncontrolled ore mining, deforestation land use intensification activities are affecting the entire water system within a watershed. Joint collaboration and transboundary land and water management can be effective in successfully addressing environmental issues (McPherson and Boyer 2015). For the Maroni River Basin, this would imply a shared vision for the River Basin and bilateral commitment to safeguard the flow of ecosystem services to its inhabitants.

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