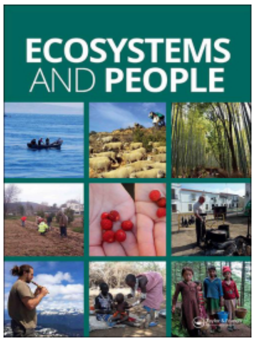

Ecosystems and People

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/tbsm22

Mapping and assessing ecosystems and their services: a comparative approach to ecosystem service supply in Suriname and French Guiana

Ina Maren Sieber, C. Sylvie Campagne, Clément Villien & Benjamin Burkhard

To cite this article: Ina Maren Sieber, C. Sylvie Campagne, Clément Villien & Benjamin Burkhard (2021) Mapping and assessing ecosystems and their services: a comparative approach to ecosystem service supply in Suriname and French Guiana, Ecosystems and People, 17:1, 148-164, DOI: 10.1080/26395916.2021.1896580

To link to this article: https://doi.org/10.1080/26395916.2021.1896580

ECOSYSTEMS AND PEOPLE
2021, VOL. 17, NO. 1, 148–164
https://doi.org/10.1080/26395916.2021.1896580

RESEARCH

Mapping and assessing ecosystems and their services: a comparative approach to ecosystem service supply in Suriname and French Guiana

Ina Maren Sieber [a], C. Sylvie Campagne [a], Clément Villien[b] and Benjamin Burkhard [a,b]

[a]Gottfried Wilhelm Leibniz Universität Hannover, Institute of Physical Geography and Landscape Ecology, Hannover, Germany; [b]Forest Program, WWF France, French Guiana Office, Cayenne, France - French Guiana

ABSTRACT
Current environmental resource management policies acknowledge the need to manage and conserve biodiversity. Sustaining good ecosystem conditions and ecosystem services (ES) is imperative at and across multiple spatial scales. The ES concept is a valuable tool to communicate the benefits that nature provides to people. In the Guiana Shield, neighbouring countries share landscapes and ecosystems, and therefore also the services they supply. This study presents the first spatial ES assessments at territorial level for Suriname and French Guiana. Expert-based ES supply matrices were used and analysed in combination with Land Use/Land Cover (LULC) data to compile ES capacity maps for the two territories. In comparison, 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 weak to moderate capacities for ES supply. 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. Comparative evaluations are essential to understand the differences in perception of ES supply capacities and to underpin future knowledge-based bilateral conservation policies and funding decisions by governments and managers.

ARTICLE HISTORY
Received 10 November 2020
Accepted 23 February 2021

EDITED BY
Catharina Schulp

KEYWORDS
Socio-cultural ES; expert-based assessment; cross-border assessment; ecosystem services matrix

1. Introduction

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). With ongoing degradation of the natural environment, destruction of habitats, intensification of land use and urbanization, the constant flow of ES to society is severely endangered in the Amazon Basin (Foley et al. 2007) – an effect that disproportionately affects poor and underprivileged members of society (Braun and Gatzweiler 2014; Kumar and Yashiro 2014; Schreckenberg et al. 2018).

In the Guiana Shield, as in many ecoregions of the world, socio-political borders criss-cross through natural ecosystems and hence intersect through ecological boundaries. As neighbouring countries share ecosystems, they also share ecosystem processes, functions and, hence, ES (Daily 1997; López-Hoffman et al. 2010). Safeguarding ecosystems and their services, therefore, requires cross- or transboundary ecosystem management (Kelly and Kusel 2015). This is one of the strengths of the ES concept, indeed (McIntyre 2014; Kelly and Kusel 2015), as it creates the potential for the framing of shared conservation goals, stakeholder inclusion and linking multiple ES and assessing their trade-offs (López-Hoffman et al. 2010).

Within the Guiana Shield, the ES concept has already been integrated into policies and frameworks to protect biodiversity at multiple scales. Guyana, Suriname (SUR) and French Guiana (FG), have committed to implementing the Strategic Plan 2011–2020 adopted by the Convention on Biological Diversity (CBD), including 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). This foresees that '*By 2050, biodiversity is valued, conserved, restored and wisely used, maintaining ecosystem services, sustaining*

CONTACT Ina Maren Sieber sieber@phygeo.uni-hannover.de
Supplemental data for this article can be accessed here.

a healthy planet and delivering benefits essential for all people' (CBD, 2011).[1] In addition, FG, as a French Overseas Department, is subject to EU legislation (Kochenov 2013). Strategies, such as the EU Biodiversity Strategy 2020 are binding, including Target 2 Action 5, which asks all EU member states to carry out Mapping and Assessment of Ecosystems and their Services (MAES) within their national territories (EC 2011).

First efforts to map and assess ES can be found on various scales in SUR (Ramirez-Gomez et al. 2013; Ramirez-Gomez et al. 2016; Anthony et al. 2019), and FG (Roger et al. 2016). However, a systematic literature review of existing MAES studies (Sieber et al. 2018) revealed that there is still potential for more thorough implementation of the ES concept. Until now, little is known about the spatial distribution of ES throughout the two territories and ES maps are scarce. Identification of relevant ES, their mapping and assessment are crucial first steps that should be the base for the development of related policies and legal frameworks (Burkhard et al. 2018; Prip 2018).

The ES matrix has proven to be a comparably quick, reliable and resourceful tool to assess and map ES (Burkhard et al. 2009, 2012, 2014; Campagne et al. 2020). The method has also been recommended by the EU MAES working group as a key tool to fulfil the EU member states' obligations of Action 5. (Science for Environment Policy 2015). Especially in areas with data scarcity, incompatible indicator data and/or limited accessibility for field work, available ES qualification and quantification approaches based on indicators or models often reach their limits (Sohel et al. 2015; Wangai et al. 2019). ES matrix assessments, however, have proven to perform well under these circumstances (Sinare et al. 2016; Campagne et al. 2020). When Land Use/Land Cover (LULC) or other geospatial data (habitat, ecosystem types) are available, mapping and assessing ES supply capacities can be executed in form of a lookup table, linking ES to geospatial units abundant in the study area. Especially in data-scarce contexts, expert knowledge can help to obtain scientifically sound results for a first estimation of ES (Jacobs et al. 2015). In this sense, ES capacity refers to 'an ecosystem's potential to deliver services based on biophysical and social properties and functions' (Villamagna et al. 2013, p. 116). ES supply was 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).

Numerous ES matrix applications can be found in the literature (Burkhard et al. 2009; Sohel et al. 2015; Hornung et al. 2019; Campagne et al. 2020; Müller et al. 2020; Tabares-Mosquera et al. 2020). However, most applications focus on a single study location. Comparative assessments that apply the ES matrix are still scarce, with first examples on the watershed scale (Boyanova et al. 2014) or on the regional and local scale in France (Campagne and Roche 2019). Hence, there is a knowledge gap on methods and approaches for cross boundary ES matrix assessments in general and also in the Guiana Shield.

This study presents a first ES assessment on the transnational scale for both SUR and FG. The objectives were the following: 1) provide a first ES assessment and first ES maps for the Guianas, applying the ES capacity matrix on the territorial level, and 2) provide a transnational comparison across borders, discussing similarities, differences and patterns between the territorial/national assessments. Special attention was paid to sociodemographic characteristics of the expert panel. Such comparative assessments are necessary to identify ES supply capacities in transboundary regions and contribute to a potential transboundary ecosystem management in the Guiana Shield.

2. Materials and methods

2.1. Case study region

The Guiana Shield is located in the northeast of the South American Plate, between the Orinoco and Amazon River basins. The Shield comprises parts of Colombia in the west, Venezuela, Guyana, SUR, the French 'Département d'Outre Mer' -FG and Brazil in the east. It is part of the Amazon basin and ecoregion with '*relatively large units of land containing a distinct assemblage of natural communities and species, with boundaries that approximate the original extent of natural communities prior to major land-use change*' (Dinerstein 1995; Olson et al. 2001, p. 933). It is one of the biodiversity- and wilderness-richest areas in the world (Olson et al. 2001; Mittermeier et al. 2003). The characteristic vegetation is tropical rainforest (Granville 1988), in largely intact patches, home to many endemic species.

SUR and FG are in the focus of this study. These two territories share borders determined by the Maroni (or Marowijne) River. A littoral belt is located at the coastline of both territories with mangrove ecosystems, littoral forest, open swamps and open patches of savanna (Gond et al. 2011; Dijn 2018; Stier et al. 2020). Both territories are covered by >90% of tropical forest with similar major landscape types (Gond et al. 2011), including hill foots of the Amazon rainforest in the South. Smaller settlements are located along the river courses within the forested areas, especially along the side arms of the Maroni. Distinct human activities, including shifting cultivation and mineral extraction activities, go along with the settlements (Figure 1). The application of a comparative approach is therefore well-founded

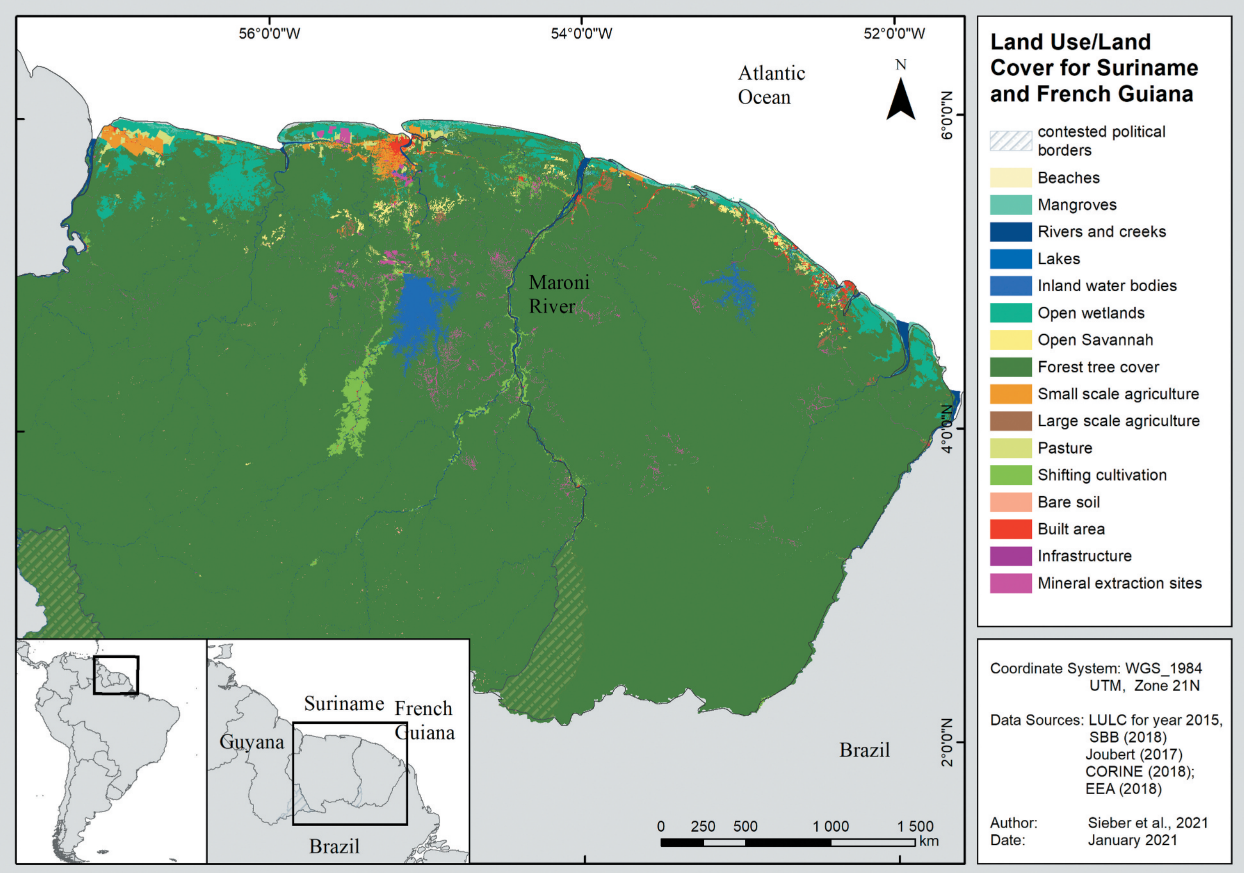

Figure 1. Location and land use/land cover types in the case study region in Suriname and French Guiana, based on CORINE 2018, Joubert (2017) and SBB (2017). Internationally recognized borders are shown for orientation only. They do not reflect any political views of the authors.

due to the geographic and ecological resemblances of the two territories (Smith et al. 2020).

The Republic of SUR gained sovereignty from the Netherlands in 1975. SUR has an approximate population of 586,632 (2020), of which roughly two-thirds reside in urban areas. Population growth rates reach roughly 1% annually. SUR's extensive natural resources have been described as 'prerequisite for the development of national economies' (Haden 1999, p. 1), with beneficiaries from local to international level. Primary and extractive industries have long dominated the national economy, based on intensive commercial timber and mineral extraction practices, including bauxite and gold mining (Haden 1999). The country covers 163,821 km^2. 93% of SUR's surface area is covered by forest of which 15% is issued for timber harvest (Government of Suriname 2018). Nearly 3% of the surface area is covered by agriculture and shifting cultivation. In SUR, the surface area of protected lands is increasing. By 2018, 14.5% of the national surface area was protected, and conservation strategies were and still are being crafted (Government of Suriname 2018).

FG, as Outermost Region of the Republic of France, is politically integrated into the European Union and covers a surface area of 83,534 km^2. The territory is home to 298,682 inhabitants, and its population is expected to double by 2040 (European Commission 2017). FG's population is a mix of different ethnic communities who predominantly settled on the coastal plain, mainly in the capital of Cayenne. The inland area is largely uninhabited, smaller settlements are found among the inland rivers, such as the Maroni River. France ensures strong environmental protection standards and is bound to implement EU legislation, such as the EU Biodiversity Strategies 2020 and 2030 or the Water Framework Directive. Almost 95% of the territory's surface cover are forested (Figure 1). 48% of land area is protected, either as a national park or a sustainable use area. Especially timber extraction or mineral extraction practices face much stricter regulations than in SUR.

2.2. Geodata

The delineation of ecosystem types for SUR was based on the 'Land Use Land Cover 2015' map layer available on the Gonini Portal,[2] the National Land Monitoring System of SUR. Their LULC data is the result of the classification of Landsat 8 satellite images from the years 2000–2015; Sentinel 2A satellite images of 2015; Google Satellite and Bing Satellite imagery (SBB 2018), which have been validated and ground-truthed (SBB 2017). Spatial data for the FGs littoral belt were obtained through CORINE LULC[3] data for 2012. These CORINE data were classified based on Sentinel-2 imagery supplemented by Landsat-8 satellite imagery for gap filling. The final CORINE LULC has an approximate resolution of 30 m per pixel. For the hinterland, where CORINE data were missing, gap filling was performed with territorial geodata available on the regional geoportal Geoguyane.[4] Their geospatial dataset "Synthèse occupation du sol 2015"[5] consists of information on the littoral belt from 2015, Land Use data for the National Park Area from 2015 and information on impacts of gold mining activities 2015 (Joubert 2017). As land use classes in both LULC datasets for SUR and FG differed in language and class names, a harmonized classification was set up to allow comparison (see Table 1). Five major LULC types with a total of 18 LULC types were identified. As beaches (E2) were only present in the FG LULC, this class was left out in the comparative assessment. The respective LULC map was compiled for the region (Figure 1), using ArcMap 10.6.

2.3. Expert-based ES assessment using the ecosystem services capacity matrix

The ES capacity matrix development for this assessment followed the methodological steps described by Campagne and Roche (2018). As ES supply strongly correlates with landscape structures and ecosystem functions (Burkhard et al. 2012), major landscape types were abstracted from available georeferenced maps of both territories (see Chapter 2.2). For a comparable ES mapping implementation, key experts from both territories were consulted individually. We asked them to select the most relevant ES for their country and territory based on the full lists of the two last versions of the Common International Classification of Ecosystem Services (CICES 4.3 and 5.1 (Haines-Young and Potschin-Young 2018)). For simplification, class descriptions were obtained from CICES 4.3. The resulting list of ES comprised 7 provisioning ES (PS1 – PS7 in Table 2), 11 regulating ES (RS1 – RS11) and 4 cultural ES (CS1 – CS4).

Based on the LULC types and the list of selected ES, an ES capacity matrix was developed linking the 22 ES (on the x-axis) with the 18 LULC types (on the y-axis), resulting in altogether 396 cells at the intersections of LULC types and ES per matrix. The respective LULC types' capacities to supply ES were assessed on a scale from 0 to 5, where 0 = no to very weak capacity, 1 = weak capacity, 2 = moderate capacity, 3 = good capacity, 4 = strong capacity and 5 = very strong capacity to supply ES (Burkhard et al. 2009). In addition to the capacity scores, experts were asked to express their confidence on their ES capacity scores with a confidence index per LULC type and ES (Jacobs et al. 2015), ranging from 1 (not confident) to 3 (very confident).

The scoring was based on expert knowledge collected through comparative participatory workshops using empty ES matrices for individual scoring in Cayenne (FG) and Paramaribo (SUR) in October 2019. We chose the ES matrix approach starting with empty matrices and asked each expert to fill in the matrix individually in order to enable subsequent statistical analysis and to identify the variability of the scores depending on the experts and their profiles (Campagne et al. 2018). In addition,

Table 1. LULC types for Suriname and French Guiana, including surface cover area (in percent), adjusted from (Joubert 2017; SBB 2017).

Land Cover		LULC type	Suriname Surface Cover (in percent)	French Guiana Surface Cover (in percent)
Marine and littoral land cover	Ocean	E1		
	Beaches	E2	-	0.02
	Mangroves	E3	0.26	0.75
Aquatic land cover	Rivers and creeks	E4	1.07	1.02
	Lakes	E5.1	0.97	0.43
	Inland water bodies -semi natural	E5.2	<0.01	<0.01
	Open wetlands	E6	2.31	1.54
Forested land cover	Open Savannah	E7	0.61	0.31
	Inselbergs	E8	<0,01	<0,01
	Forest tree cover	E9	91.43	94.39
	Planted Forest	E10	unknown	unknown
Agricultural land cover	Small scale agriculture	E11	0.63	0.08
	Large scale agriculture	E12	0.04	0.23
	Pasture	E13	0.39	0.11
	Shifting cultivation	E14	1.28	0.26
Urban and largely modified land cover	Bare soil	E15	0.06	0.01
	Built area	E16	0.21	0.41
	Infrastructure	E17	0.17	0.08
	Mineral extraction sites	E18	0.57	0.35

Table 2. List of assessed ES in Suriname and French Guiana.

CICES Section	Division	Class	Code
Provisioning Services	Biomass	Cultivated crops/food	PS1
		Reared animals and their outputs	PS2
		Wild plants, algae and their outputs	PS3
		Wild animals and their outputs	PS4
	Water	Freshwater supply for drinking purposes	PS5
	Raw materials	Materials and fibres	PS6
		Plants and resources for medical use	PS7
Regulation and Maintenance Services	Regulation of biological, physical and chemical conditions	Carbon Sequestration	RS1
		Global and local climate regulation	RS2
		Disease control	RS3
		Pest control	RS4
	Lifecycle maintenance, habitat and gene pool protection	Maintaining nursery populations and habitats	RS5
		Pollination and seed dispersal	RS6
	Regulation of baseline flows and extreme events	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	Indirect, remote interactions with living systems that do not require presence in the environmental setting	Emblematic or symbolic	CS1
		Heritage (past and future) and existence	CS2
		Aesthetic	CS3
	Direct, in-situ and outdoor interactions with living systems	Recreational activities including (eco-) tourism	CS4

this process prevented experts from being influenced by predefined scores or by other experts. The workshop allowed the experts to meet and exchange information on the method and the ES and LULC types in the matrix.

Both workshops followed the same structure and contained the same ES capacity matrix, translated to Dutch and French. Following the recommendation by Burkhard et al. (2015), the experts were selected on the basis of their knowledge of the territories and in order to involve different management entities. In addition, the selection brought together the expertise on the different types of ecosystems. Experts were recruited with help of local institutions through open invitations on local websites, geoportals and emails.

2.4. Sociodemographic analysis of the expert panels

Each workshop entailed a questionnaire on sociodemographic aspects for each participant, including questions on gender, institutional environment and scale of expertise (Table 3). Both panels included experts from diverse fields of expertise such as water authorities, wildlife ecologists and management authorities, nature conservationists, forest specialists, planning officers and consultants. 22 participants attended the expert workshop in SUR, 17 experts participated in FG. Both expert panels were heterogeneous with respect to age and gender (48% (FG), 50% (SUR) female participating experts). The majority (33%) of experts were between 35 and 49 years old. Only six young experts (<35 years) were present. Notably, only one expert was above 60 years old. The sectoral expertise was also balanced.

2.5. Statistical comparison of the matrices

To evaluate the individual matrices, a descriptive analysis of arithmetic means has been the preferred method in the ES capacity matrix literature (Müller et al. 2020). The scores obtained from the expert assessments were inserted in two independent data frames as ordinals (0–5). Data were transformed to a scale format from 0 to 1 to calculate the arithmetic mean scores and statistics for each LULC and ES of the two assessments. To find out whether the individual expert matrices were homogenous within SUR and FG, hierarchical clustering was applied. This allowed to identify similarities between the individual expert scorings ($n = 39$). Experts were anonymized and received a code based on the two assessments, gender and age group. Based on interval data, the distance metric 'Euclidean distance' was applied and clusters were formed using Ward variance minimization algorithm. The analysis was done using Python 2.7 and the Seaborne package.

For the comparative statistics, expert scores for both territories were tested for homogeneity of variances (Levene's test) and normal distribution (Chi square). As these criteria were violated for the majority of scores, the Mann-Whitney U test was applied to identify statistical differences in the matrix datasets. A U-test establishes the null hypothesis that two populations are identical. The U-test is recommended for a non-parametric, rank-based statistical analysis, as needed for each set of values of the two data

Table 3. Sociodemographic characteristics of the two expert panels.

		% of experts		
	Categories	Suriname (SUR)	French Guiana (FG)	All experts
Sociodemographic variables				
Gender	Female	50	48	49
	Male	50	52	51
Age	<30	17	5	11
	30-<45	54	54	54
	45–55	29	32	30.5
	>55	0	9	4.5
Field of expertise	Governmental sector	54	59	56.5
	Private sector	6	18	12
	Non-governmental sector	11	14	12.5
	Academia	29	9	19
Scale of expertise	Local	5	4	4.5
	Regional	29	32	61
	Territorial	54	-	59 (-)
	National (incl. France)	-	59	59 (-)
	Supranational	11	4	10.5
	Number of experts	22	17	39

frames. This was done using Python 2.7 and the Python scipy.stats package (Strangman 2002).

An additional analysis of the strength of correlation for each cell in the matrices was performed. Correlation effect sizes can be calculated with Pearson (parametric data), Spearman (non-parametrical data and pairwise comparison) and Cohen Effect size (*d*) (Figure 3). Due to the different expert panel size (22 versus 17 expert estimations), a Spearman correlation could not be performed. The Cohen Effect size (*d*) has been used to identify the *magnitude of the difference between data sets*. Cohen classified effect sizes as *small* ($d = 0.2$), *medium* ($d = 0.5$) and *large* ($d \geq 0.8$) (Cohen 1988). Such an assessment is useful, as it quantitatively compares results from different data sets (Sullivan and Feinn 2012).

2.6. ES map compilation

ES maps have become a major tool to illustrate, analyse and communicate the spatially explicit supply of ES (Maes et al. 2012). ES maps in this study were compiled using ArcMap 10.6 through linking the geospatial LULC units to the ES capacity scores from 0 to 5 in the matrices.

3. Results

Altogether 22 individually completed matrices for SUR and 17 matrices for FG were obtained through the workshops. ES capacity scores for both territories were heterogeneous in variances, normal distribution was not given.

3.1. Quantification of ES supply capacities

The ES capacity matrices with mean arithmetic scores in Figure 2 show that mangroves, rivers and creeks, open swamp and forest LULC types comprised the highest capacities to supply ES. The results imply that the more strongly impacted by humans the LULC, the lower ES supply capacities have been attributed by the experts, with exception of agroecosystems. The SUR matrix showed an overall moderate to good ES supply, with clusters of weak and strong supply capacities across different LULC types (Figure 2). Strongest supply capacities were found in mangroves (E3), rivers and creeks (E4), forests (E9) and planted forests (E10). Overall, marine and littoral LULC types showed more variation, with low scores for 'Freshwater for drinking purposes' (PS5, >1) and high scores for regulating ES in mangroves, and high cultural ES capacities. Aquatic LULC showed a range of scores between 0.8 and 3.7 for multiple ES. Forests obtained the overall highest supply capacity scores for all supplied ES with scores between 1.2 and 4.7. The exception were Inselbergs (E8), which were rated with weak supply capacities (maximum 2.4, majority >1), and strong capacities to supply cultural ES (2.9–3.71.2 and 4.7).

The ES matrix of FG presents a strong variance in expert scores, with strong differences in ES supply capacities between LULC types (Figure 2b). Marine and littoral LULC, especially mangroves (E3), received high supply capacities. Among the aquatic LULC types, rivers and creeks (E4) and open swamps (E6) were ranked highest, especially for 'Maintaining nursery populations' (RS5, maximum mean score of 5) and 'Pollination and seed dispersal' (RS6). Forests (E9) covering 94.4% of the territory, showed the highest overall ES supply, with average mean values between 0.47 for 'Cultivated crops/food' (PS1) and 4.9 for 'Maintaining nursery populations' (RS6). Anthropogenic modified LULC types scored no to very weak ES supply capacities. Built areas (E15) marked an exception with weak to good cultural ES supply.

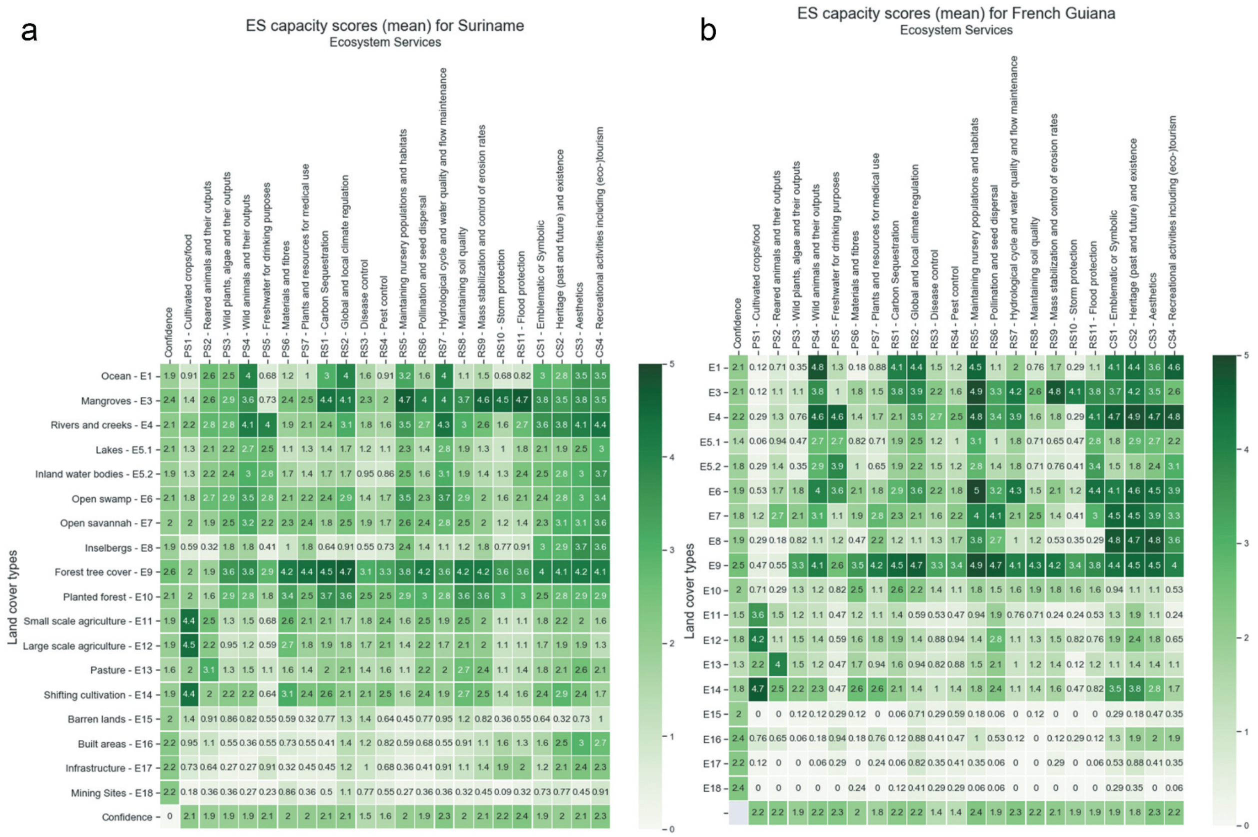

Figure 2. ES supply capacity matrix for Suriname (a) and French Guiana (b) showing arithmetic means of the 22 (Suriname) and 17 (FG) individual capacity scores and the means of the confidence index (column and line 'confidence' on a scale from 0 to 3).

A visual comparison of the two matrices revealed similar trends for most of the assessed LULC and ES. Among the provisioning ES, 'cultivated crops/food' (PS1) and 'reared animals and their outputs' (PS2) showed low supply capacities throughout all LULC types in SUR and FG, except (agro-) ecosystem types. The ES 'Wild animals and their outputs' (PS4) was supplied with strong capacities in coastal and marine as well as in aquatic LULC (dark cluster for E1, E3 and E4). The ES 'freshwater supply for drinking purposes' (PS5) also showed high capacities in aquatic LULC types and forest LULC. PS1, 'cultivated crops' revealed very strong capacities in shifting cultivation (E14) (mean scores of 4.4 for SUR, 4.7 for FG). All provisioning ES scored low in urban LULC (all <1, light cluster on the bottom of Figure 2) except for 'reared animals and their outputs' (PS2) in built areas (E16, mean of 1.1 in SUR and 0.65 in FG), reflecting the capacities of urban or homestead gardens for livestock cultivation. Among the regulating ES, the highest capacities were found for 'Carbon storage' (RS1) and 'Global and local climate regulation' (RS2) in coastal and marine LULC as well as in forests. The regulating ES 'maintaining nursery populations and habitat function' (RS5) stood out, with very strong capacities in natural LULC in FG, and slightly lower values for SUR. 'Flood protection' (RS11) was supplied with high capacities in E3-E7 and E9, with mean scores for FG exceeding those for SUR. Cultural ES showed overall high capacities throughout coastal and marine, aquatic and forest LULC types (dark cluster in the upper right of Figure 2c) in both territories. Especially CS1 and CS2 received high scores, with mean scores for FG being slightly higher than for SUR. However, SUR scores for cultural ES in urban LULC showed higher means.

This comparison highlights the disparities of experts in their evaluations for each territory. Mean capacity scores between both territories especially differed in forest LULC types: differences in mean scores were specifically high for forest (H9), with differences of 3.4 for 'Maintaining soil quality' (RS08), 3.6 for 'Storm protection' (SR10) and 3.3 for 'cultivated corps/food' (SA1) (Figure 2a). However, ES capacities ranked higher in SUR by >0.86 for all services.

3.2. Statistical analysis: transboundary differences and similarities

A statistical analysis of the expert evaluations indicated that the distribution of the majority of scores (70%) for the two matrices were significantly similar based on the U-test (Figure 3). Expert scores were significantly similar in their scores for mineral

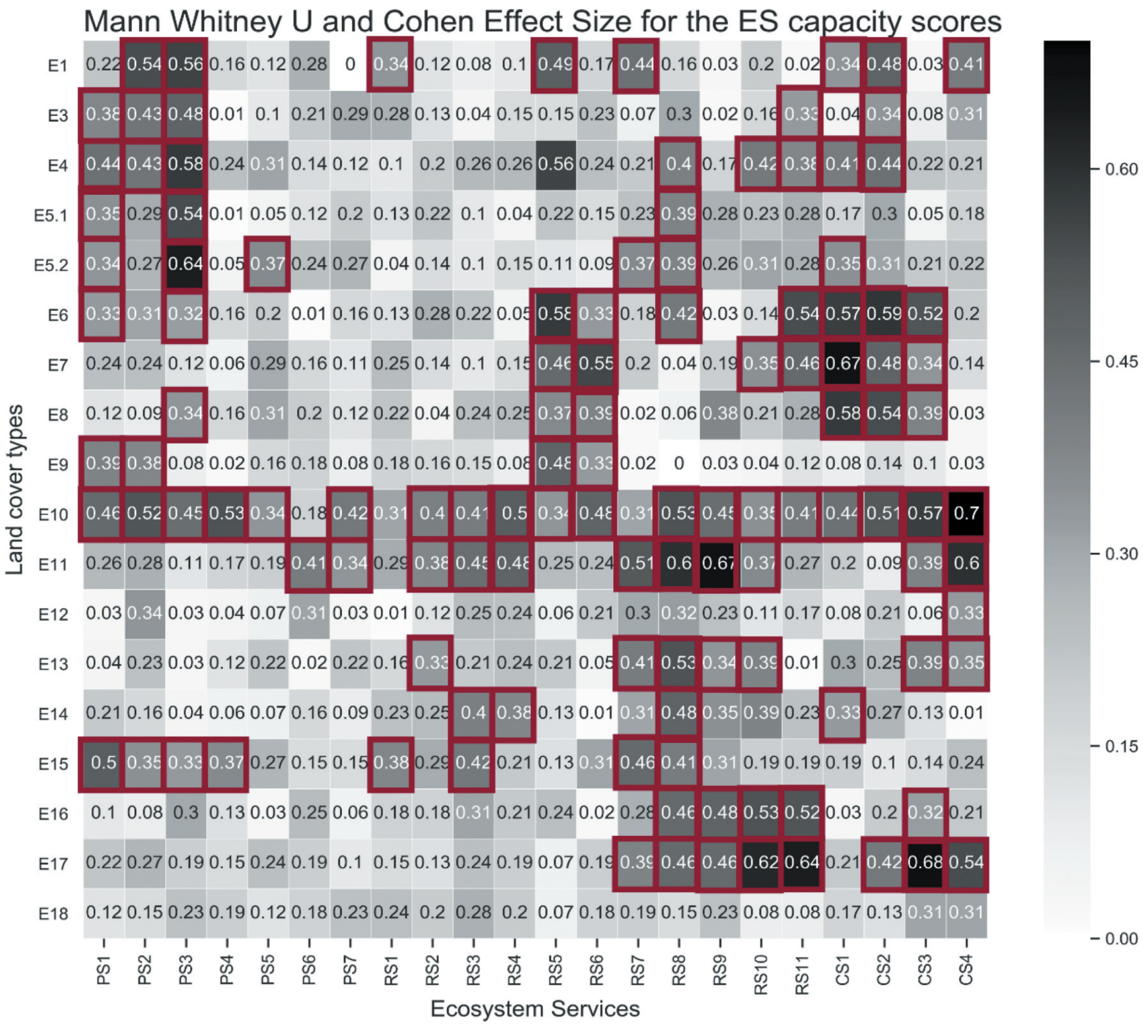

Figure 3. Statistical differences between the SUR and FG matrix cells using Mann Whitney U (statistical differences outlined in red) and the Cohen effect size showing the magnitude of the statistical effect where scores <0.2 indicate no to weak effect, between 0.2 and 0.5 a moderate effect and >0.8 a strong effect size.

extraction sites (E18), with differences <0.85 and with strongest effect size for 'disease control' (RS3), 'aesthetics' (CS3) and 'recreational activities including (eco-)tourism' (CS4). Also, the scores for large scale agriculture (E12) showed a close similarity for the assessed LULC and ES.

Thirty percent of the scores were significantly different, as marked in red in Figure 3 (U-test, alpha = 0.05). In terms of LULC, significant difference was found for planted forest (E10, 19 scores significantly different out of 22), small scale agriculture E11 (11), followed by E1, E4, E15, E17 (8). The majority of scores differed with medium effect size (d = 0.5), no strong effect size was found. This indicates that even though the scores of both assessments were significantly different, this difference was medium to insignificant (Cohen 1988). The differences between the two matrix assessments were most distinct for ES 'Maintaining nursery populations' (RS8) with 11 out of 18 scores being significantly different, followed by 'wild plants, algae and their outputs' PS3 (9), 'cultivated crops/food' PS1, 'Heritage' CS2 (8).

3.3. Sociodemographic differences and similarities of the expert panels

A clustering of the 39 individual expert scores revealed that scores from participants in SUR could be distinguished as separate group from the scores of participants in FG, based on Euclidean distance metrics. The analysis showed four distinct clusters (Figure 4): the first cluster (1) comprises 13 experts from FG and two experts from SUR (S06 and S05). A second cluster (2) entails two SUR experts with nearly identical scoring. Cluster 3 presents a homogenous group of 13 SUR experts. In cluster 4, a mix of five SUR and three FG experts is grouped, whose scores showed high similarity. Hence, there seems to be an underlying difference between territorial ES capacity scores between FG and SUR.

The clustering (Figure 4) does not show clear tendencies in the effect of gender of the participants on their ES scoring. A closer analysis at the gender reveals that indeed, scores for all 39 experts show no significant gender biases in territorial comparison

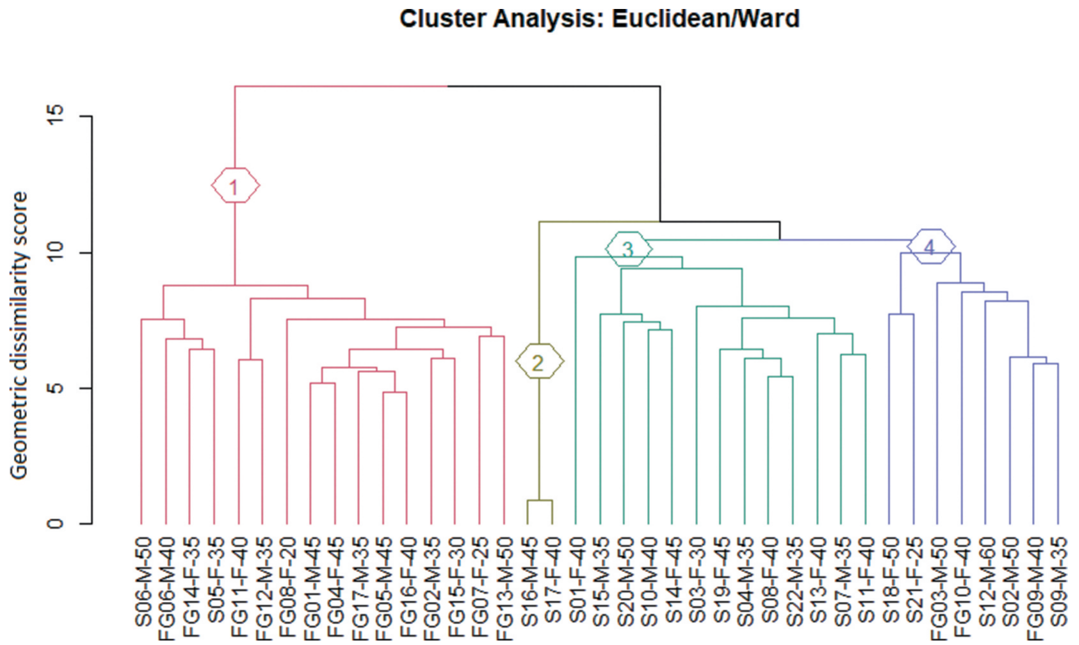

Figure 4. Individual scores of all 37 participants clustered according to similarity of ES scores using Euclidean distance metric. Codes S and FG refer to Suriname and French Guiana, respectively. F = Female, M = Male, last two numbers indicating approximate age of experts.

(Figure 5). In both FG and SUR, male respondents tended to rate provisioning ES higher than female respondents (F mean 0.31; M mean 0.35). The same was observed for regulating ES (F mean 0.35; M mean 0.38). For cultural ES, no differences between gender scores existed (F mean 0.51; M mean 0.51).

The clustering of experts (Figure 4) also suggests that age affects scoring behaviours. The dendrogram shows that the closer the similarity between two scores, thus the smaller the geometric dissimilarity score, the smaller the age difference of the respective participants, irrespective of their nationality. An example of this can be found in clusters 1 and 2, where the scores of participants with age differences of up to 5 years show the highest degree of similarity. An analysis of the age structure shows that young experts tend to score lower (Table 4). On the contrary, the older the experts, the higher their mean scores for provisioning and regulating ES. Only for cultural ES, our expert panel did not show age-based scoring differences.

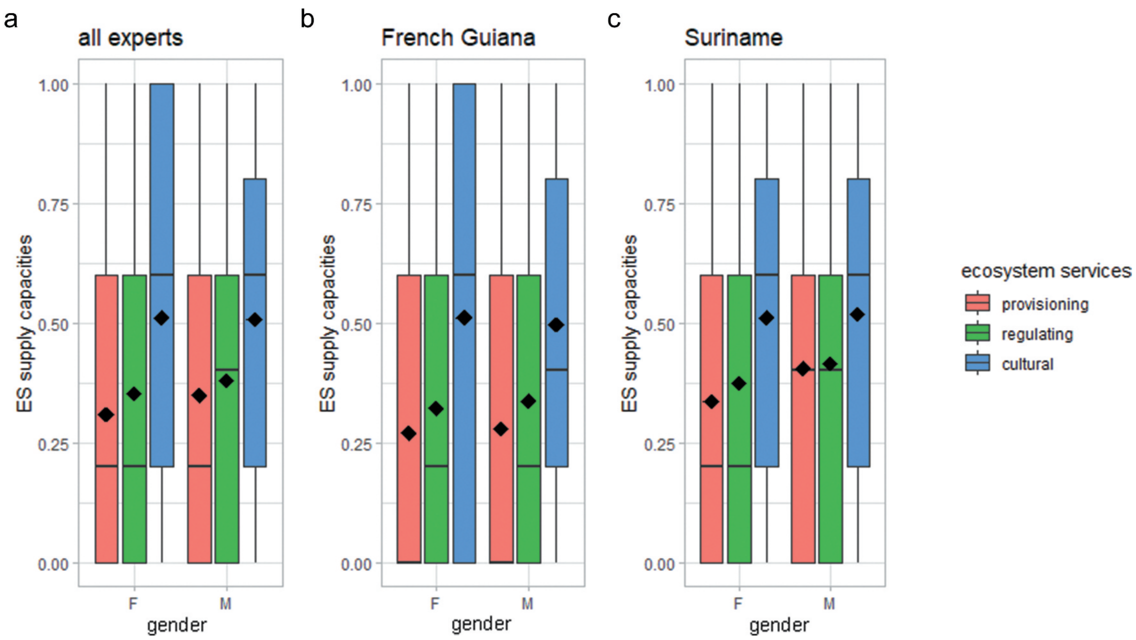

Figure 5. ES supply capacity scores on interval scale from 0 = no to very weak supply to 1 = very strong supply capacities, based on gender (the straight bar shows the median scores).

Table 4. Age structure and trends towards ES capacity scoring on interval scale from 0 = no to very weak supply to 1 = very strong supply capacities.

	Age structure of the experts			
	20- <35 (6)	35- <50 (20)	50- <60 (13)	>60 (1)
Provisioning ES	0.29	0.30	0.37	0.45
Regulating ES	0.28	0.35	0.40	0.44
Cultural ES	0.51	0.48	0.54	0.50

Next to gender and age, the institutional environments of the experts were analysed to see whether their work in the public or the private sector, academia or NGOS caused observable bias to the expert's scores and hence affect their appreciation of different ecosystems. Therefore, we looked at the impact of expertise on the scoring of the different land uses. Whilst territorial differences between expert scores from the different fields for SUR and FG were not reflected in the data, general differences between the institutional environments in general were evident (Figure 6). Experts from all fields showed similar median for provisioning ES with exception of the private sector with higher scores for agricultural and urban LULC. For regulating ES, academic experts tended to rate coastal and forest habitats highest. Cultural ES were rated strongest by experts from NGO's, followed by those from public and private sectors. Academic experts' scores showed a low median, with especially weak scores for ES in urban areas in comparison to experts from governmental, private sectors and NGOs.

3.4. Mapping ES supply capacities

Based on the arithmetic mean supply capacity scores (Figure 2), the ES supply capacity maps for SUR and FG were compiled, as shown in Figure 7. The maps highlight the patterns of ES supply based on the spatial distribution of the different LULC types throughout the territories. The large amount of forest cover is clearly visible on all maps, with strong to very strong ES supply capacities for 85% of the maps. LULC types in the littoral belt tend to disappear in the cross-border comparison, however, this is where the majority of human settlements are found. Especially when comparing the scores of SUR and FG, the 30% significant difference between the expert assessments becomes invisible on the maps.

4. Discussion

The case study regions of SUR and FG show a high degree of similarity in location, climate and many other human-environmental factors. A descriptive analysis of the mean values of the individual scores revealed high degrees of similarity between expert scores for the two independent

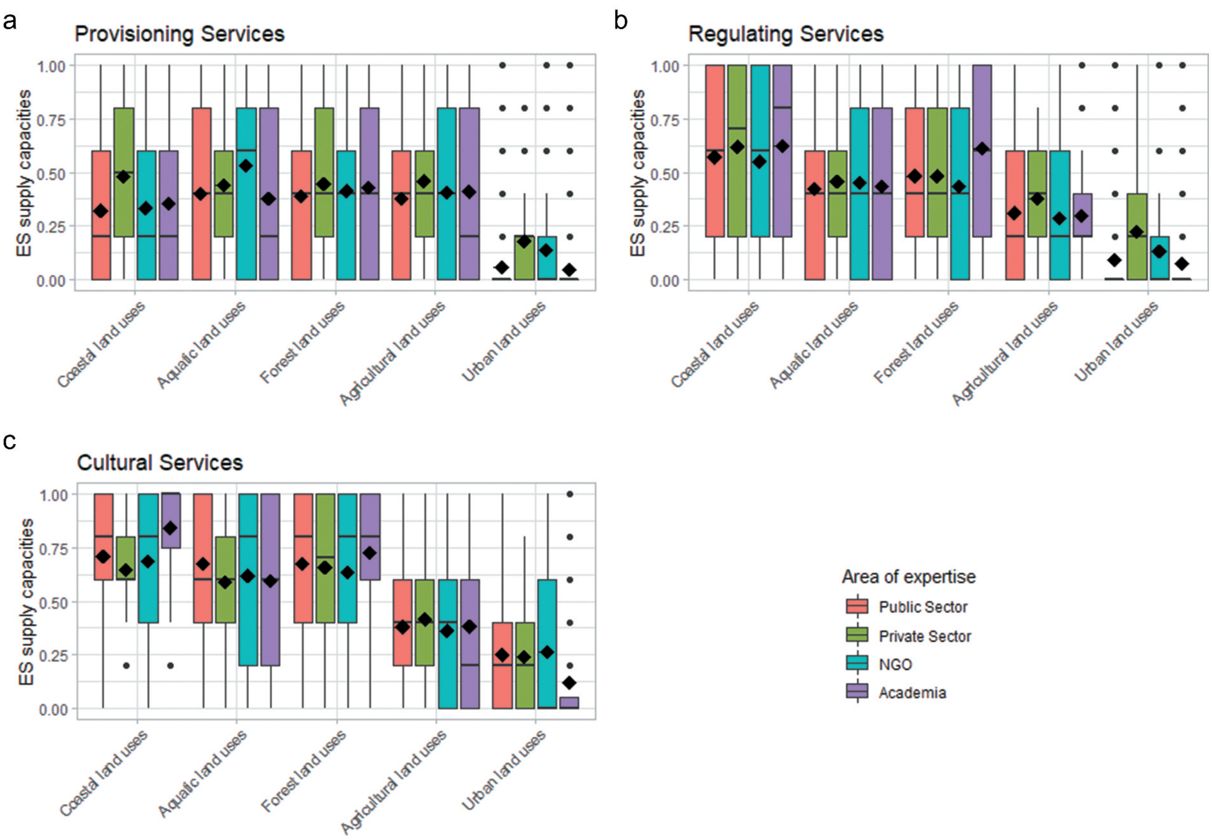

Figure 6. ES capacity scores per institutional environment of experts (on interval scale from 0 = no to very weak supplies to 1 = very strong supply capacities).

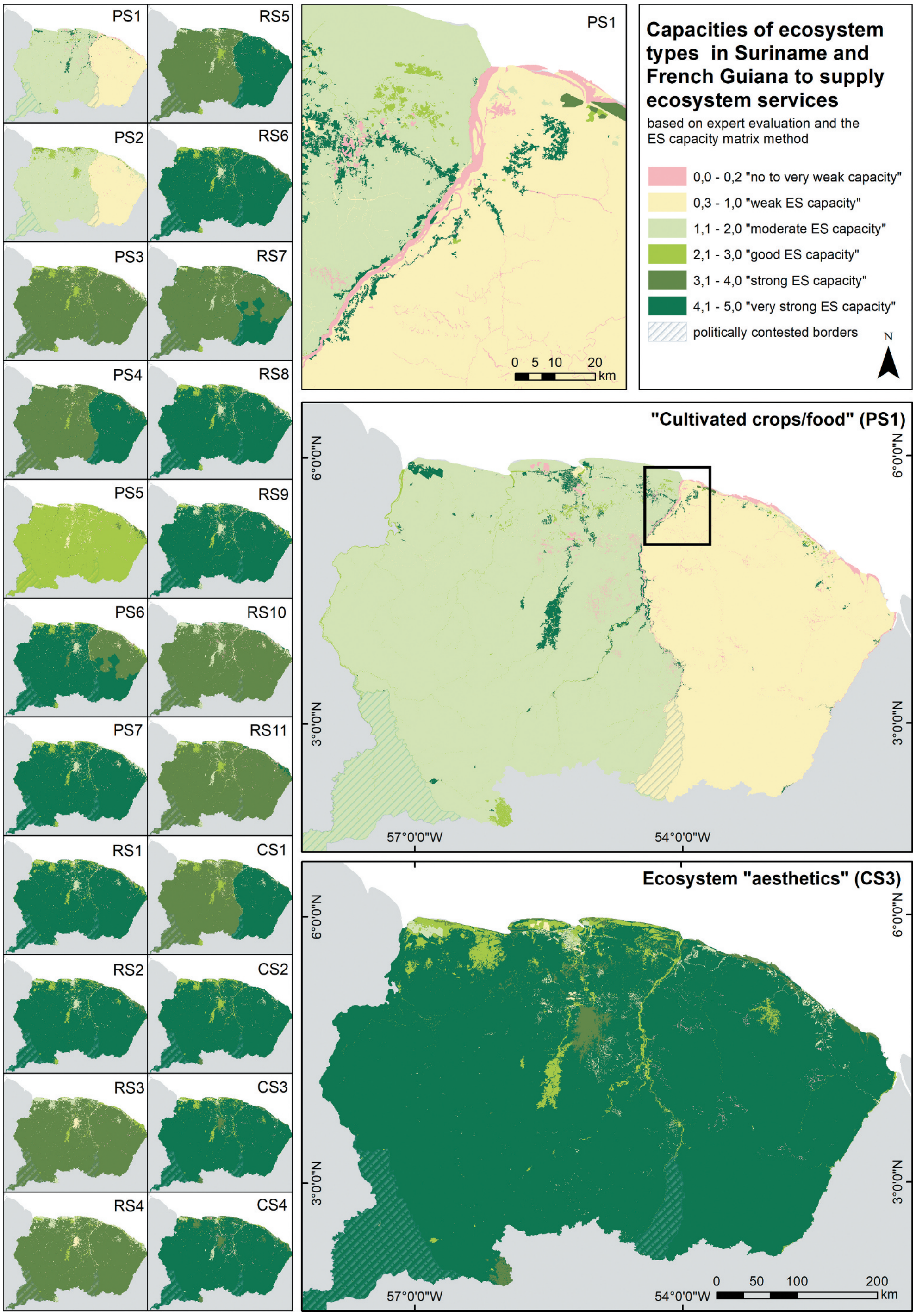

Figure 7. Ecosystem services supply capacities based on LULC data in Suriname and French Guiana based on expert-assessment. Borders are shown for orientation purposes only. They do not reflect any political opinion of the authors. Individual maps of each ES are available in the supplementary material.

ES matrix assessments. Adding a comprehensive statistical analysis allowed to identify where experts agreed in transnational comparison. 70% of the two capacity matrices, thus 277 out of 396 scores, showed significant similarity. This indicates a shared perception on the ES supply capacities in both territories. However, the remai ning 30% of the matrix scores entailed significant differences in ES capacity evaluations. These differences were reflected in the cluster analysis of all individual matrix results, revealing distinct groups of SUR and FG experts.

4.1. Interpretation of the results

To answer the question of where such differences come from, we investigated three potential reasons: 1) the distribution and the degree of similarity of the different land cover types and the resulting effect on ES supply capacities, 2) the composition and sociodemographic characteristics of the expert panels, and 3) the different cultural, governance and institutional contexts in which the expert evaluation took place.

1) The distribution and the degree of similarity of the different LULC types

The Guiana Shield is characterized as an ecoregion, which per definition describes areas with similar natural flora and fauna communities prior to land use changes (Olson et al. 2001). Due to the close geographic context of SUR and FG (Noonan 2018) and exhaustive studies on ecoregion homogeneity (Dinerstein 1995; Olson et al. 2001), landscape homogeneity was expected to be strong. It seems unlikely that the 30% difference in the ES assessment are caused by heterogeneities in the types and spatial distribution of the different LULC. Specifically for ecosystem types such as rivers and creeks (E4), planted forest (E10), small scale agriculture (E11) or bare soil (E15), significant differences were observed. Notably, ecosystems in SUR are much more agriculture-oriented with high land use intensity. Only 9% of the surface of SUR are not covered by forest, of which 15% is actively used for timber production and forest concessions (Government of Suriname 2018). In FG, only 5% non-forest LULC is present, and exploitation of natural resources underlies stricter regulations. The perceived difference in land use intensity could contribute to the diverging expert scores, especially for land cover types with anthropogenic influences in SUR and FG. Other land use classes, such as pastures or lakes, cover a much smaller surface area in FG than in SUR, and experts could therefore be less familiar with LULC types of smaller spatial distributions. Confidence indices in both territories however did not indicate such a potential insecurity of experts with their scores for ES supply in LULC types of a small surface cover (differences <0.1).

2) Sociodemographic variables of the expert panel: age, gender, institutional environment

Expert-based ES assessments are strongly dependent on the experience, knowledge, current and past living conditions and attitude (Fagerholm et al. 2012; Jacobs et al. 2015). According to Martín-López et al. (2012), aspects such as the age and gender can induce preference or selective biases. Studies found that male respondents perceived provisioning ES higher and women emphasized regulating ES (Martín-López et al. 2012). Our assessment showed a low average difference between male and female experts for provisioning ES (<0.2 in arithmetic mean), regulating ES (<0.15) and cultural ES (0.014). Expert scores from male and female experts in FG differed by a maximum of 0.08, indicating similar scoring behaviour. In SUR, males provided higher scores than female experts for both provisioning and regulating ES (<0.4). However, these findings are not sufficiently significant to prove the presence of gender bias in our assessments.

The age of experts can impact the ES scores. According to Martín-López et al. (2012), elderly respondents tend to rate provisioning services high whereas younger respondents (<30) tend to prefer regulating services. Following this, our assessment found that the older the expert, the higher his/her respective capacity scores for both provisioning and regulating ES, whilst young experts (<35) scored lowest for provisioning and regulating ES. Only for cultural ES, experts of all ages obtained similar mean scores. This is interesting, as cultural ES tend to be the most subjectively perceived category of ES (MEA 2005).

The institutional environment of experts also proved to influence experts' scoring. Overall, experts from public and private sectors had the highest scores. Experts from the public sector tended to allocate high capacity scores to cultural values of natural ecosystems (e.g. marine and littoral, aquatic and forest LULC). Academic experts tended to score low for provisioning ES (on average −0.5 lower). Also, their scoring for cultural ES was lower compared to all other experts. Humanly altered ecosystems received scores of no to very weak capacity on average.

Other studies suggest that respondents tend to give lower scores to less well-known ES (Kaiser et al. 2013). This could explain the low mean scores for e.g. 'Pest control' (RS3) and 'Disease control' (RS4) in both territories. Independently, experts gave the lowest confidence indices on those ES (1.5 for SUR, 1.25 for FG, respectively, Figure 3). Also, less well-known ecosystem or LULC types could be prone to this bias. However, to the best of our knowledge, this is the first matrix application explicitly paying attention to socio-demographic and socio-cultural aspects of expert panels. Therefore, comparison to other matrix studies proves difficult.

As expert panels in both SUR and FG were rather heterogeneous in gender, age and institutional environment, such selective biases and preferences should be minimal.

3) Different cultural, governance and institutional contexts

Sociocultural factors and conservation management strategies affect the evaluation of ES (Martín-López et al. 2012).Studies suggest that national and territorial governance and institutional contexts shape conservation management strategies, which in turn effects the societal preferences (Martín-Lopéz et al. 2012). This impacts the way in which experts perceive ecosystems and hence, the magnitude of scored ES supply capacity.

In SUR, the economy largely relies on the extraction of natural resources (Government of Suriname 2018). Forest concessions cover 14% of the forested area. Roughly 3% of the 8% non-forest surface cover are used for (intensive) agriculture and shifting cultivation. In FG, this only adds up to 0.7% of the territorial area. Instead, FG is heavily dependent on imported agricultural produce, with little large scale agriculture taking place. As part of the EU, regulations concerning environmental protection and conservation in FG are imposed by the European Union (Grenand et al. 2006). Through this, regulations are much stricter in FG than in SUR.

These structures can explain the overall moderate to good ES supply across LULC types in SUR, and the high appreciation of provisioning services, for example 'Cultivated crops, food' or 'materials and fibres'. The moderate to high ES capacity scores for planted forests (E10) in SUR could be caused by a comparably lower environmental concern in SUR then in FG. In FG, experts rated the ES capacities much more selectively. The FG matrix presented higher extremes for natural LULC types, where ecosystems could be perceived as being more intact, resulting in high ES supply capacities. Lower scores were given for humanly impacted or strongly altered LULC, such as small- and large-scale agriculture or urban LULC. Likewise, FG experts showed lower appreciation for planted forest (E10) and low scores linked to mineral extraction LULC (E18). If the ES capacity scores are a result of the societal environmental concerns or national natural resources governance, this could also explain the diverging scores in both assessments.

4.2. Bringing it all together

All three components, the sociodemographic composition of the expert panel, the ecosystems through the two territories and the overarching cultural and institutional landscape in which the ES evaluations took place could explain the differences in the matrix scores in both SUR and FG.

In the ES maps, the spatial distribution of the 22 ES is presented. Due to the large amount of forest cover, smaller patches of LULC types tend to disappear on the territorial maps. Nonetheless, it becomes visible through the expert scores that the functionality of ES in total is largely dependent on the variety of different land uses and land covers. These maps present the first holistic overview of ES in both territories.

The ES maps highlight that ES are supplied across political and institutional borders. In transboundary river basins, such as the Maroni River at the border between SUR and FR, LULC is a key determinant for the ES supply patterns, with direct consequences for the livelihoods of the people on both sides of the national borders. Especially mining sites and shifting cultivation, though hardly visible on national scale maps, cover larger areas on the SUR side of the upper river basin, with strong negative consequences on the downstream river basin. In contrast, the entire French upper river basin is a protected area, which might be related to a stronger momentum of strategies such as the EU Biodiversity Strategy or the CBD in the European Outermost Regions. Such asymmetries in the environmental protection status may hijack the effectivity of environmental protection and call for joint transboundary river management policies. The collaboration of national actors and environmental protection agencies should be promoted in the face of the potential benefits of well-functioning cross-border protection areas (McPherson and Boyer 2015; Thornton et al. 2020). With transboundary environmental conservation efforts, the Maroni River could provide an excellent example of protected ecoregions across borders.

The results suggest that attention needs to be paid when extrapolating the results of a single location matrix to other scales and contexts. Even though data on the capacity of ecosystems to supply ES are often scarce, it is common practice to draw upon existing data in many ES assessments, such as the use of existing matrices from another area for a local ES assessment (Gaglio et al. 2017; Campagne et al. 2020), or other ES value-transfer approaches. Such transfers could severely affect the accuracy of further studies in case non-comparable or inaccurate values are applied.

4.3. Uncertainties of the approach

Uncertainties of the expert-based matrix approach are well-documented, relating to scale and used geodata, experts and panel composition (Hou et al. 2013; Jacobs et al. 2015; Campagne et al. 2017). Future research would be required to explore differences between out experts' scorings and residents or local communities from FG or SUR. Similar assessments noted a bias caused by procedural rationality, which can affect the scoring of individuals based on hierarchical constraints in the evaluating group (Burkhard et al. 2015). Analysing the sociodemographic characteristics of our expert panel, however, no strong biases were found. Uncertainties related to maps and mapping of ES for policy making are well documented (Schulp et al. 2014). Clear communication on input data, methodologies and the process of map creation is needed. The matrix method inhibits the visualization of dynamic effects, such as upstream downstream effects of land uses such as mineral extraction sites (Mol and Ouboter 2004). Additional studies would be needed to prove the effect of upstream mining on the supply capacities of downstream riverine ecosystems. Uncertainties are also linked to the statistical approach taken. It has been suggested that comparing medians, e.g. through the U-test, results in better robustness than comparing arithmetic means (Skovlund and Fenstad 2001). The U-test is known for a robust assessment of independent data frames and the concept of ranks allows to operate with data that is not normally distributed and heteroscedastic. However, depending on variances and skewedness of data, the U-test can induce inaccuracies (Fagerland and Sandvik 2009).

5. Conclusions

This study presents the first spatial ES assessment in SUR and FG and one of the first cross-border comparisons of ES supply based on ES capacity matrices. Altogether 18 LULC types and 22 ES were assessed based on expert knowledge. As ecosystems in the Guiana Shield largely share the same properties and human-environmental characteristics, a comparative assessment allows to highlight where experts in the two territories share similar, respectively, differing views on ES supply capacities. Forest ecosystems are the major LULC type in both SUR and FG. Their capacities to supply ES were rated with medium to strong capacities, followed by coastal and marine as well as aquatic LULC with good to strong supply capacity scores on average. Humanly impacted ecosystems, however, received no to very weak capacities to supply ES, except cultural ES.

To assess differences between ES matrix assessments, a mere descriptive analysis of means is a first step. We suggest an additional statistical analysis to uncover whether two independent matrices are significantly different. Even though the similarities and differences between the ES supply in both territories seem obvious, the large amount of forest cover obscures such differences when mapping ES for SUR and FG. Future studies could be done to reveal whether ES bundles are occurring in the different LULC types, enabling further analyses of trade-offs and synergies between certain ES or groups of ES.

A statistical analysis shows that 30% of the matrices entails significant differences. Cluster analysis showed distinct groups of SUR and FG experts. An analysis of the composition and sociodemographic characteristics of the expert panels was unable to explain this divide. The age, gender and institutional environment of the experts had little influence on their ES capacity scoring. Rather, the distribution and the degree of similarity of the ecosystem types and the resulting effects on ES supply capacities and the different cultural, governance and institutional contexts in which the expert evaluation took place, provide explanations. In SUR, land use intensity and human impact on ecosystems is higher than in FG, reflected in the higher ES supply in human-modified LULC types such as agriculture and shifting cultivation. In FG, natural ecosystems showed higher ES supply, explained by strong environmental regulations and protection standards due to its EU Outermost region status. This causes generally better ecosystem conditions, which is linked to higher ES supply. Therefore, cultural, governance and institutional contexts in which matrix-based assessments are conducted are likely to impact the outcomes stronger then age, gender or institutional background of the individual expert. Future matrix studies should pay more attention to document such sociodemographic and contextual aspects of the expert panel to ensure a representative scoring assessment.

Unravelling the potential reasons for the scoring differences helps to understand the underlying evaluation of ecosystems and their services. This is a crucial first step for shared ecosystem management, particularly in cross boundary cooperation, as McPherson and Boyer (2015) call for. Especially as recent studies identified the Guiana Shield to list among the top 10% of areas of global importance for terrestrial biodiversity, carbon and water (Jung et al. 2020), and as threats to biodiversity and ecosystems are pressing, the need for enhanced conservation efforts becomes obvious.

Notes

1. Key Elements of the Strategic Plan 2011–2020, including Aichi Biodiversity Targets.
2. https://www.gonini.org/.
3. https://land.copernicus.eu/pan-european/corine-land-cover.
4. https://www.geoguyane.fr/accueil.
5. https://www.geoguyane.fr/geonetwork/srv/fre/catalog.search#/metadata/3d681d4f-b8bd-48b2-80d2-04a215a8a099.

Acknowledgments

First and foremost, we would like to thank all stakeholders in French Guiana and Suriname who took part in the workshops and shared their valuable knowledge with us. Special thanks go to Laurent Kelle and Fred, Angie Faust and Joana Seguin. Also, we would like to thank the anonymous reviewers for their diligent work and thorough feedback on earlier versions of this paper.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Funding

This work was conducted as part of the ECOSEO Project financed underthe Interreg Amazonian cooperation Program (IACP) [N°2014TC*16*RFTN010 andFEDERCTE/ 2017/N°8], as part of ARRETE N° SQC2018/34.

ORCID

Ina Maren Sieber http://orcid.org/0000-0003-2134-0429
C. Sylvie Campagne http://orcid.org/0000-0002-2566-7827
Benjamin Burkhard http://orcid.org/0000-0001-8636-9009

References

Anthony EJ, Brunier G, Gardel A, Hiwat M. 2019. Chenier morphodynamics on the Amazon-influenced coast of Suriname, South America: implications for Beach Ecosystem Services. Front Earth Sci. 7:Artikel 35. doi:10.3389/feart.2019.00035.

Boyanova K, Nedkov S, Burkhard B. 2014. Quantification and mapping of flood regulating ecosystem services in different watersheds–case studies in Bulgaria and Arizona, USA. In: Thematic cartography for the society. Springer; p. S. 237–255. doi:10.1007/978-3-319-08180-9_18.

Braun JV, Gatzweiler FW (Hg). 2014. Marginality: addressing the nexus of poverty, exclusion and ecology. Springer. doi:10.1007/978-94-007-7061-4.

Burkhard B, Kroll F, Müller F, Windhorst W. 2009. Landscapes' capacities to provide ecosystem services - a concept for land-cover based assessments. Landscape Online. 15:1–22. doi:10.3097/LO.200915.

Burkhard B, Müller A, Müller F, Grescho V, Anh Q, Arida G, Bustamante JV, Van Chien H, Heong KL, Escalada M, et al. 2015. Land cover-based ecosystem service assessment of irrigated rice cropping systems in southeast Asia—An explorative study. Ecosyst Serv. 14:76–87. doi:10.1016/j.ecoser.2015.05.005.

Burkhard B, Santos-Martin F, Nedkov S, Maes J. 2018. An operational framework for integrated mapping and assessment of ecosystems and their services (MAES). One Ecosyst. 3:e22831. doi:10.3897/oneeco.3.e22831.

Burkhard, B, Kroll, F, Nedkov, S, Müller, F. 2012. Mapping ecosystem service supply, demand and budgets. In: Ecological Indicators 21, p. 17–29. doi:10.1016/j.ecolind.2011.06.019

Burkhard, B. Kandziora, M. Hou, Y. Müller, F. 2014.Ecosystem service potentials, flows and demands-concepts for spatial localisation, indication and quantification. LO. 34:1–32.

Campagne, CS, Roche, P. 2018. May the matrix be with you! Guidelines for the application of expert-based matrix approach for ecosystem services assessment and mapping. OE. 3:e24134. doi:10.3897/oneeco.3.e24134

Campagne CS, Roche P. 2018. May the matrix be with you! Guidelines for the application of expert-based matrix approach for ecosystem services assessment and mapping. One Ecosyst. 3:e24134. doi:10.3897/oneeco.3.e24134.

Campagne CS, Roche P 2019. *Évaluation de la capacité des écosystèmes de la région Hauts-de-France à produire des services écosystémiques*.

Campagne CS, Roche P, Gosselin F, Tschanz L, Tatoni T. 2017. Expert-based ecosystem services capacity matrices: dealing with scoring variability. Ecol Indic. 79:63–72. doi:10.1016/j.ecolind.2017.03.043.

Campagne CS, Roche P, Müller F, Burkhard B. 2020. Ten years of ecosystem services matrix: review of a (r)evolution. One Ecosyst. 5:Artikel e51103. doi:10.3897/oneeco.5.e51103.

Cohen J. 1988. Statistical power analysis for the behavioral sciences–second edition. Hillsdale (New Jersey): 12 Lawrence Erlbaum Associates Inc.; p. 13.

Convention on Biological Diversity. 2011. *Strategic Plan for Biodiversity 2011-2020: Provisional.* https://www.cbd.int/doc/meetings/cop/cop-10/official/cop-10-27-add1-en.pdf

Daily GC. 1997. Nature's services: societal dependence on natural ecosystems. Island Press. http://search.ebscohost.com/login.aspx?direct=true&scope=site&db=nlebk&db=nlabk&AN=117817

Dijn BD, Hg.. 2018. Natural history and ecology of Suriname. University of Washington Press. ISBN 13: 9789460224386

Dinerstein E 1995. A conservation assessment of the terrestrial ecoregions of Latin America and the Caribbean. *World Bank*. http://elibrary.worldbank.org/content/book/9780821332955

European Commission.2011. *Our life insurance, our natural capital:* An EU biodiversity strategy to 2020.

European Commission. 2017. *The Outermost Regions - European Lands in the World: French Guiana.* https://ec.europa.eu/regional_policy/sources/policy/themes/outermost-regions/pdf/rup_2017/rup_partner_guyana_en.pdf

Fagerholm N, Käyhkö N, Ndumbaro F, Khamis M. 2012. Community stakeholders' knowledge in landscape assessments – mapping indicators for landscape services. Ecol Indic. 18:421–433. doi:10.1016/j.ecolind.2011.12.004.

Fagerland MW, Sandvik L. 2009. The Wilcoxon-Mann-Whitney test under scrutiny. Stat Med. 28(10):1487–1497. doi:10.1002/sim.3561.

Foley JA, Asner GP, Costa MH, Coe MT, DeFries R, Gibbs HK, Howard EA, Olson S, Patz J, Ramankutty N, et al. 2007. Amazonia revealed: forest degradation and loss of ecosystem goods and services in the Amazon Basin. Front Ecol Environ. 5(1):25–32. doi:10.1890/1540-9295-(2007)5[25:ARFDAL]2.0.CO;2.

Gaglio M, Aschonitis VG, Mancuso MM, Reyes Puig JP, Moscoso F, Castaldelli G, Fano EA. 2017. Changes in land use and ecosystem services in tropical forest areas: a case study in Andes mountains of Ecuador. Int J Biodivers Science Ecosyst Serv Manage. 13(1):264–279. (International Journal of Biodiversity Science, Ecosystem Services & Management, 13 (1),264-279). doi:10.1080/21513732.2017.1345980.

Gond V, Freycon V, Molino J-F, Brunaux O, Ingrassia F, Joubert P, Pekel J-F, Prévost M-F, Thierron V, Trombe P-J, et al. 2011. Broad-scale spatial pattern of forest landscape types in the Guiana Shield. Int J Appl Earth Obs Geoinf. 13(3):357–367. doi:10.1016/j.jag.2011.01.004.

Government of Suriname. 2018. Forest reference emission level for Suriname's REDD+ programme. Paramaribo (Suriname).

Granville J-J. 1988. Phytogeographic characteristics of the Guianan forests. TAXON. 37(3):578–594. doi:10.2307/1221101.

Grenand F, Bahuchet S, Grenand P. 2006. Environment and peoples in French Guiana: ambiguities in applying the laws of the French Republic. Int Soc Sci J. 58(187):49–58. doi:10.1111/j.1468-2451.2006.00593.x.

Haden P 1999. *Forestry issues in the Guiana shield region: a perspective on Guyana and Suriname: European Union Tropical Forestry Paper 3.* https://www.odi.org/publications/4652-forestry-issues-guiana-shield-region-perspective-guyana-and-suriname

Haines-Young R, Potschin-Young M. 2018. Revision of the common international classification for ecosystem services (CICES V5. 1): a policy brief. One Ecosyst. 3:e27108. doi:10.3897/oneeco.3.e27108.

Hornung LK, Podschun SA, Pusch M. 2019. Linking ecosystem services and measures in river and floodplain management. Ecosystems and People. 15(1):214–231. doi:10.1080/26395916.2019.1656287.

Hou Y, Burkhard B, Müller F. 2013. Uncertainties in landscape analysis and ecosystem service assessment. J Environ Manage. 127(Suppl):S117–31. doi:10.1016/j.jenvman.2012.12.002.

Jacobs S, Burkhard B, Van Daele T, Staes J, Schneiders A. 2015. 'The matrix reloaded': a review of expert knowledge use for mapping ecosystem services. Ecol Modell. 295:21–30. doi:10.1016/j.ecolmodel.2014.08.024.

Joubert P 2017. Synthèse occupation du sol 2015. *Geoguyane. fr*. https://www.geoguyane.fr/geonetwork/srv/3d681d4f-b8bd-48b2-80d2-04a215a8a099

Jung, M, Arnell, A, Lamo, Xde, García-Rangel, S, Lewis, M, Mark, J, et al. 2020. Areas of global importance for terrestrial biodiversity, carbon, and water. bioRxiv. doi:10.1101/2020.04.16.021444

Kaiser G, Burkhard B, Römer H, Sangkaew S, Graterol R, Haitook T, Sterr H, Sakuna-Schwartz D. 2013. Mapping tsunami impacts on land cover and related ecosystem service supply in Phang Nga, Thailand. Nat Hazards Earth Syst Sci. 13(12):3095–3111. doi:10.5194/nhess-13-3095-2013.

Kelly E, Kusel J. 2015. Cooperative, cross-boundary management facilitates large-scale ecosystem restoration efforts. Calif Agric. 69(1):50–56. doi:10.3733/ca.v069n01p50.

Kochenov D 2013. The application of EU Law in the EU's overseas regions, countries, and territories after the entry into force of the treaty of Lisbon. 20 Mich. St. *Int'l L. Rev*, 669.

Kumar P, Yashiro M. 2014. The marginal poor and their dependence on ecosystem services: evidence from South Asia and Sub-Saharan Africa. In: Von Braun J, Gatzweiler FW, editors. Marginality: addressing the nexus of poverty, exclusion and ecology. Springer; p. Bd. 18, S. 169–180. doi:10.1007/978-94-007-7061-4_11.

López-Hoffman L, Varady RG, Flessa KW, Balvanera P. 2010. Ecosystem services across borders: a framework for transboundary conservation policy. Front Ecol Environ. 8(2):84–91. doi:10.1890/070216.

Maes J, Egoh B, Willemen L, Liquete C, Vihervaara P, Schägner JP, Grizzetti B, Drakou EG, La Notte A, Zulian G, et al. 2012. Mapping ecosystem services for policy support and decision making in the European Union. Ecosyst Serv. 1(1):31–39. doi:10.1016/j.ecoser.2012.06.004.

Martín-López B, Iniesta-Arandia I, García-Llorente M, Palomo I, Casado-Arzuaga I, Amo DGD, Gómez-Baggethun E, Oteros-Rozas E, Palacios-Agundez I, Willaarts B, et al. 2012. Uncovering ecosystem service bundles through social preferences. PloS One. 7(6): e38970. doi:10.1371/journal.pone.0038970.

McIntyre O. 2014. The protection of freshwater ecosystems revisited: towards a common understanding of the 'ecosystems approach' to the protection of transboundary water resources. Rev Eur Comp Int Environ Law. 23 (1):88–95. doi:10.1111/reel.12068.

McPherson TY, Boyer MA. 2015. Designing transboundary conservation: navigating sovereignty and ecosystem scale in the Guiana shield. Int Stud Perspect. 67(3):n/a-n/a. doi:10.1111/insp.12102.

MEA. 2005. *Ecosystems and human well-being: biodiversity synthesis; a report of the Millennium Ecosystem Assessment*. World Resources Institute.

Ministry of Labour & Technical Development and Environment. 2013. National biodiversity action plan (NBAP) 2012-2016. *Paramaribo, Suriname*. https://www.cbd.int/doc/world/sr/sr-nbsap-v2-en.pdf

Ministry of Natural Resources and the Environment. 2014. Guyana's national biodiversity strategy and action plan (2012-2020). Georgetown, Guyana. https://www.cbd.int/doc/world/gy/gy-nbsap-v3-en.pdf

Mittermeier RA, Mittermeier CG, Brooks TM, Pilgrim JD, Konstant WR, Da Fonseca GAB, Kormos C. 2003. Wilderness and biodiversity conservation. Proc Natl Acad Sci U S A. 100(18):10309–10313. doi:10.1073/pnas.1732458100.

Mol JH, Ouboter PE. 2004. Downstream effects of erosion from small-scale gold mining on the instream habitat and fish community of a small neotropical rainforest stream. Conserv Biol. 18(1):201–214. doi:10.1111/j.1523-1739.2004.00080.x.

Müller F, Bicking S, Ahrendt K, Kinh Bac D, Blindow I, Fürst C, Haase P, Kruse M, Kruse T, Ma L, et al. 2020. Assessing ecosystem service potentials to evaluate terrestrial, coastal and marine ecosystem types in Northern Germany – an expert-based matrix approach. Ecol Indic. 112:106116. doi:10.1016/j.ecolind.2020.106116.

Noonan B. 2018. Biogeography. In: Dijn BD, editor. Natural history and ecology of Suriname. University of Washington Press; p. S. 52–63.

Olson DM, Dinerstein E, Wikramanayake ED, Burgess ND, Powell GVN, Underwood EC, D'amico JA, Itoua I, Strand HE, Morrison JC, et al. 2001. Terrestrial ecoregions of the world: a new map of life on earth: a new global map of terrestrial ecoregions provides an innovative tool for conserving biodiversity. BioScience. 51(11):933–938. doi:10.1641/0006-3568(2001)051[0933:TEOTWA]2.0.CO;2.

Prip C. 2018. The Convention on Biological Diversity as a legal framework for safeguarding ecosystem services. Ecosyst Serv. 29:199–204. doi:10.1016/j.ecoser.2017.02.015.

Ramirez-Gomez SOI, Brown G, Fat ATS. 2013. Participatory mapping with Indigenous communities for conservation: challenges and lessons from Suriname. Electron J Information Sys Dev Countries. 58(1):1–22. doi:10.1002/j.1681-4835.2013.tb00409.x.

Ramirez-Gomez SOI, Brown G, Verweij PA, Boot R. 2016. Participatory mapping to identify indigenous community use zones: implications for conservation planning in southern Suriname. J Nat Conserv. 29:69–78. doi:10.1016/j.jnc.2015.11.004.

Roger M, Cohen-Nabeiro A, Lopez R, Kelle L 2016. *Profil d'écosystèmede la Guyane Française – Région Amazonie Européenne: Union européennes Régions Ultra-pèriphériques et Pays et Territoires d'Outre-mer*. BEST, contract de service 07.0307.2013/666363/SER/B2, Commission Européenne, 2016, 167 p + 11 annexes.

SBB. 2017. *Forest cover monitoring in Suriname using remote sensing techniques for the period 2000-2015*.

SBB. 2018. *Protocol for the preparation of the Land Use Land Cover map 2015*.

Schreckenberg K, Mace G, Poudyal M, Hg.. 2018. Routledge studies in ecosystem services. Ecosystem services and poverty alleviation (OPEN ACCESS): trade-offs and governance. Taylor and Francis.

Schulp CJE, Burkhard B, Maes J, Van Vliet J, Verburg PH. 2014. Uncertainties in ecosystem service maps: a comparison on the European scale. PloS One. 9(10): e109643. doi:10.1371/journal.pone.0109643.

Science for Environment Policy. 2015. *Ecosystem Services and the Environment.: In-depth Report 11 produced for the European Commission, DG Environment by the Science Communication Unit*. UWE, Bristol.

Sieber IM, Borges P, Burkhard B. 2018. Hotspots of biodiversity and ecosystem services: the outermost regions and overseas countries and territories of the European Union. One Ecosyst. 3(1):e24719. doi:10.3897/oneeco.3.e24719.

Sinare H, Gordon LJ, Enfors Kautsky E. 2016. Assessment of ecosystem services and benefits in village landscapes – a case study from Burkina Faso. Ecosyst Serv. 21:141–152. doi:10.1016/j.ecoser.2016.08.004.

Skovlund E, Fenstad GU. 2001. Should we always choose a nonparametric test when comparing two apparently nonnormal distributions? J Clin Epidemiol. 54(1):86–92. doi:10.1016/S0895-4356(00)00264-X.

Smith JR, Hendershot JN, Nova N, Daily GC. 2020. The biogeography of ecoregions: descriptive power across regions and taxa. J Biogeogr. 47(7):1413–1426. doi:10.1111/jbi.13871.

Sohel MSI, Mukul SA, Burkhard B. 2015. Landscape′ s capacities to supply ecosystem services in Bangladesh: a mapping assessment for Lawachara National Park. Ecosyst Serv. 12:128–135. doi:10.1016/j.ecoser.2014.11.015.

Stier A, Carvalho WD, De, Rostain S, Catzeflis F, Claessens O, Dewynter M, McKey D, Mustin K, Palisse M, Thoisy BD. 2020. The Amazonian Savannas of French Guiana: cultural and social importance, biodiversity, and conservation challenges. Trop Conserv Sci. 13(1):194008291990047. doi:10.1177/1940082919900471.

Strangman G (2002). MannWhitneyU package for python [Computer software]. *SciPy Stats*. https://github.com/scipy/scipy/blob/adc4f4f7bab120ccfab9383aba272954a0a12fb0/scipy/stats/stats.py#L6334-L6429

Sullivan GM, Feinn R. 2012. Using effect size-or why the P value is not enough. J Grad Med Educ. 4(3):279–282. doi:10.4300/JGME-D-12-00156.1.

Tabares-Mosquera M, Zapata-Caldas E, Buitrago-Bermúdez O. 2020. Valoración de servicios ecosistémicos para la identificación de estructuras ecológicas metropolitanas: el caso de Cali, Colombia. Cuadernos De Investigación Geográfica. 46(2):603–631. doi:10.18172/cig.3952.

Tallis, H, Mooney, H, Andelman, S, Balvanera, P; Cramer, W, Karp, D. et al. 2012. A global system for monitoring ecosystem service change. BioScience. 62(11):977–986. doi:10.1525/bio.2012.62.11.7

Thornton D, Branch L, Murray D. 2020. Distribution and connectivity of protected areas in the Americas facilitates transboundary conservation. Ecol Appl Publ Ecol Soc Am. 30(2): e02027. doi:10.1002/eap.2027.

Villamagna AM, Angermeier PL, Bennett EM. 2013. Capacity, pressure, demand, and flow: a conceptual framework for analyzing ecosystem service provision and delivery. Ecol Complexity. 15:114–121. doi:10.1016/j.ecocom.2013.07.004.

Wangai PW, Burkhard B, Müller F. 2019. Quantifying and mapping land use changes and regulating ecosystem service potentials in a data-scarce peri-urban region in Kenya. Ecosyst People. 15(1):11–32. doi:10.1080/21513732.2018.1529708.