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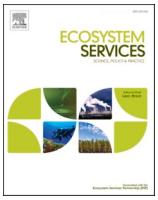

Full Length Article

Using co-creation to build knowledge on cultural ecosystem services – A tiered approach for enhanced regional economic development of Réunion Island

Cathleen Cybèle [a], Jarumi Kato-Huerta [e], Miriam Montero-Hidalgo [d], Benjamin Burkhard [b], Rekha Grimoire [a], Francesco Sica [f], Ina M. Sieber [c,*]

[a] Agence Régionale de Développement, d'Investissement et d'Innovation (NEXA), La Réunion, France
[b] Institute of Physical Geography and Landscape Ecology, Leibniz Universität Hannover, Germany
[c] Kassel Institute for Sustainability, Kassel University, Germany
[d] Chemical and Environmental Technology Department,Rey Juan Carlos University, Madrid, Spain
[e] Department of Civil, Environmental and Mechanical Engineering, University of Trento, Trento, Italy
[f] Department of Architecture and Design, Sapienza University of Rome, Italy

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ABSTRACT

Cultural Ecosystem Services (CES) are highly context-specific and inherently linked to local identity, which challenges their assessment. Participatory methods have proven to capture the multiple values and aspects of CES for local communities. This paper presents an attempt to understand the different dimensions of CES in the Saint-Philippe municipality, Réunion Island, France. We applied a tiered, participatory approach that utilises knowledge co-creation processes over a period of 3 years. First, we co-created the aim of the research and brought together focus groups and participatory GIS mapping. In a second step, we used an expert-based matrix assessment to estimate CES supply capacities and added social big data using InVEST modelling of CES flows. Outputs of these processes are 1) the mapping of important landscape features, 2) ecosystem capacities for CES supply and 3) modelled use of CES. Results of the participatory GIS mapping show 110 features linked to CES supply in the municipal area, including historic sites, recreational areas, and non-timber forest products such as pandanus leaves and vanilla production. Based on land use classes, the capacities of the landscapes to supply emblematic or symbolic values, landscape aesthetics and recreational activities were assessed. Ten experts contributed to the assessment in workshop format in February 2023. Spatial information on recreation patterns show that visitation mostly took place alongside the coast and along hiking trails, mainly corresponding with landscape aesthetics. Accessibility of sites close to infrastructure was found to be an important governing factor. The coastline, with its rocky basaltic shores, was highly appreciated. The outcomes of this co-creation approach show the value of ES for tourism and regional economic activities. Bringing this information together allows identifying the contribution of ecosystems to regional economic activities and informing policy and decision-makers with recommendations for enhanced land use planning and economic development.

1. Introduction

Cultural Ecosystem Services (CES) are defined as "the non-material benefits people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation, and aesthetic experiences'' (MEA et al., 2005). CES are closely interconnected to human physical and mental health, perception and meaning of landscapes and nature in general, including emotions, identities and sense of belonging (Chen et al., 2019; Slovák et al., 2023). People's behaviour, recreation and engagement with nature are inherently linked to CES. Understanding CES also contributes to understanding the tourism–nature–wellbeing nexus (Willis, 2015) and can be central to regional economic activities (Seidl, 2014; Arbieu et al., 2018; Drius et al., 2019).

Mapping and Assessment of Ecosystems and their Services (MAES) has become an EU-wide initiative for bringing biodiversity and

* Corresponding author at: Kassel Institute for Sustainability, Mosenthalstrasse 8, 34117 Kassel, Germany.
E-mail address: ina.sieber@uni-kassel.de (I.M. Sieber).

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ecosystem services (ES) into policy- and decision-making in the context of the EU Biodiversity Strategies to 2020 and 2030 (Maes et al., 2012; Maes et al., 2013, Schröter et al., 2016; Vári et al., 2024), including spatial information (Burkhard and Maes, 2017; Burkhard et al., 2018a; Burkhard et al. 2018b). The incorporation of CES research into policy- and decision-making is promising, yet still challenging (Plieninger et al., 2013; Gould et al., 2019). As CES substantially differ from provisioning and regulating ES in their intangibility (Milcu et al., 2013), their classification and assessment prove difficult (Chan et al., 2012, cop. 2011). Therefore, much research has focussed on embracing the multiple values related to ES and Natures Contributions to People (NCPs) through contributions of "spiritual enrichment, cognitive development, reflection, recreation, and aesthetic experience, including knowledge systems, social relations, and aesthetic values" (IPBES, 2023). Scholars have identified a growing diversity of assessment methods as well as their strengths and weaknesses in capturing CES (reviews by Hirons et al., 2016, Hølleland et al. 2017, Cheng et al. 2019) for better uptake for policy and decision making.

Many scholars acknowledge that CES are inherently produced and co-created outcomes of peoples' interaction with ecosystems (Fish et al., 2016; Fischer and Eastwood, 2016). This implies that an assessment of CES on a regional scale requires the active involvement of stakeholders throughout the process. Such knowledge co-creation can be defined as "iterative and collaborative processes involving diverse types of expertise, knowledge and actors to produce context-specific knowledge and pathways towards a sustainable future" (Norström et al., 2020, p2). Jointly created knowledge requires qualitative and participatory research capturing people's multiple views, perceptions and the relational values they hold towards nature (Chan et al., 2018). Sociocultural participatory research methodologies towards CES are plentiful and include interviews (Fischer and Eastwood, 2016) and focus groups (Slovák et al., 2023). Participatory GIS (PGIS) mapping methods can also be utilised for co-creation to visualise the spatial component of CES throughout landscapes (Fagerholm and Käyhkö 2009; Palomo-Campesino et al., 2018; García-Díez et al., 2020). Similarly, stakeholder and expert-based assessments can rely on applying an ES capacity matrix, which is a table consisting of a list of ecosystem services scored by their potential availability per land cover type (Campagne et al., 2017). Capacity matrix approaches can build upon local knowledge through stakeholder or expert elicitation of ES, including CES, in a geospatial context (Burkhard et al., 2009; Sieber et al., 2021a). Such, participatory approaches in CES research are increasing (Spangenberg et al., 2015; Palomo-Campesino et al., 2018; Frantzeskaki, 2019; Peña et al., 2020), but could be enhanced. Spangenberg et al. argue that stakeholder involvement in the definition of the research question enhances the relevance of the research (Spangenberg et al., 2015). Further, the application of different approaches within a research study, including a pre-assessment of the results in collaboration with societal stakeholders has a direct impact on the outreach capacity of the project scientist (Spangenberg et al., 2015).

Tiered approaches have gained popularity to analyse and understand complex patterns of ES supply and demand. Such tiered approaches combine different ES indicators and can comprise qualitative and quantitative methods at different levels (Grêt-Regamey et al., 2015; Grêt-Regamey et al., 2017). Where tiered approaches combine different ES dimensions, a coherent terminology definition is needed. CES supply capacity can be defined as "Biophysical and social capacity; feature- and process-based (e.g. potential to provide experience)" (Villamagna et al. 2013; p116), acknowledging the importance of landscape features to guide the magnitude and intensity of CES supply capacity (Plieninger et al., 2013). We expand the definition of landscape features from Oteros-Rozas et al. (2017) as natural delineations towards a broader notion, including cultural features, often considered of less importance for cultural ES such as agricultural uses and historic structures, including built features (Kent & Elliott, 1995). The flow of CES represents the "amount of service used measured in units of time and/or space (e.g. total visitor-days from the current year; individual visitation rates)" (Villamagna et al. 2013; p116). While the combination of different, complementary methods to capture and understand the multiple dimensions of CES sounds appealing, few truly tiered approaches are documented in the literature.

The EU has dedicated funding for research on incorporating ES into regional policy- and decision-making under the EU Biodiversity Strategy for 2020. In this context, the EU MOVE-ON Project[1] (2020–2023) transferred MAES to EU Overseas Countries and Territories and in EU Outermost Regions. The French island of Réunion was one Anchor Region within MOVE-ON that aimed to further develop the conceptual foundations and evidence base of MAES, identify suitable approaches for planning and governance, and further integrate biodiversity and ES into policy- and decision-making. Despite efforts to map ES in the French National Assessment (CGDD, 2016), little is known about the spatial distribution of CES on Réunion Island, and no detailed ES maps exist so far. Furthermore, the ecosystem service framework has not been applied to the assessment of the potential of ecosystems to contribute to regional economic development on islands.

This study presents the first CES assessment on Réunion Island, aiming for a holistic understanding of local CES supply by testing a deliberative, participatory tiered approach in the municipality of Saint-Philippe of Réunion Island. Considering the high level of flora endemicity and the unique vegetation with a high value for biodiversity in Réunion Island (Boullet and Picot, 2017), the Mare-Longue Nature Reserve within the municipality of Saint-Philippe presents an ideal case study area to assess the multidimensionality of CES. Against the background provided in the above paragraphs, the following research questions shall be addressed by this study:

- What are the main features guiding CES supply at the municipal level of Saint-Philippe, Réunion Island?
- How can we combine multiple dimensions of CES supply features, capacity and flow for informed regional economic development?
- What is the ideal approach to engage stakeholders through a collaborative process in the first evaluation of CES on Réunion Island?

Based on a participatory collaborative creative process of "co-creation", three types of relevant CES were identified: emblematic or symbolic values, landscape aesthetics and recreational activities including tourism. Focus groups and Participatory mapping approaches (PGIS) were conducted to map features important for CES provision and combined with an expert-based matrix assessment, linking geospatial land use units to ecosystem services to map the capacity of ecosystem types to supply CES. In addition, the flow of CES was modelled using social big data based on the InVEST recreation model for the municipal area. Bringing together these different tiers allows for the identification of the features, flow, and use of ecosystem services on a spatial scale. The outcomes of this participatory, process-based approach show the importance of CES for Saint-Philippe and allow the identification of areas for enhanced economic development in the region.

2. Methodology

2.1. Study area

Réunion Island is a French Outermost Region (Région d'Outre Mer Française) found within the Mascarene Archipelago of the Indian Ocean and located at Lat −21° 07′ 50″ S · Long 55° 31′ 35″ E. The tropical island covers 2512 km^2 and has a characteristic complex topography with active volcanism and a high diversity of native habitats distributed along sharp elevation gradients from sea level to 3070 m above sea level. The

[1] https://moveon-project.eu/homepage/

climate is a tropical maritime climate (Baldy et al., 1996), with summer rains exceeding winter precipitation. Due to the uneven topography, local microclimates occur, including oceanic climate for high altitudes and humid subtropical climate in mid-altitudinal areas (Leroux et al., 2023). The island is prone to tropical cyclone activity each year, with an average amount of 9.7 tropical cyclone systems per year (Leroux et al., 2018). Réunion Island is part of the biodiversity hotspot of Madagascar (Myers et al., 2000) with a high level of endemism in the island biota. Native flora is highly threatened (Petit and Prudent, 2008), mainly by biological invasions (Tanguy et al., 2017). Due to the vulnerability of habitats and native species, 40 % of Réunion Island has been protected as a Natural Park under UNESCO Natural World Heritage. The island is home to almost 865 000 people (INSEE, 2023) and hosts a rich culture between Creole language (81 %), a strong regional sense of belonging to the Mascarenes and international influence (Dehon and Louguet, 2022). Abundant natural resources contribute to the region's tourism attractiveness and can spark new business endeavours. Internationalisation is a vital economic lever for this region because of its proximity to the Indian Ocean, particularly in terms of importing and exporting.

The case study site of Saint-Philippe is located at the south-east of the island, covering an area of 153.9 km^2 (Fig. 1). With a population of 5198 people in 2019 (INSEE, 2022), it is one of the least populated municipalities on the island. Settlements and built-up areas are located on the coastal fringe. Agricultural activities, especially sugarcane cultivation, take place on the lower slopes. The cultivation of woody crops includes fruit orchards and vanilla, which are the area's major emblematic and economic activities. Most of the area is covered by lowland tropical forests, secondary forests, and lava flows. Small spots of humid forest or wetlands can be found at higher altitudes. The municipality also comprises the Mare Longue Nature Reserve, a UNESCO World Heritage Site (Tanguy et al., 2011) of 68 ha located on old basaltic lava flows of approximately 500 years of age (Albert et al., 2020), having a thin layer of soil. This nature reserve comprises the last remnants of a hygrophilous forest located at the low altitudinal level of the island and one last remnant of the lowland tropical forest of the Mascarene Archipelagos.

2.2. Deliberative co-creation process

This study presents a transdisciplinary, tiered stakeholder engagement process initiated and coordinated between 2019 and 2023 under the umbrella of the MOVE-ON EU Project "From Case Studies to Anchor Projects –Setting the ground to advance MAES in Europés overseas" (Grant Agreement No. 07.027735/2019/808239/SUB/ENV.D2). With two to five meetings annually, establishing a community of practice, referred to as a *sentinel community,* has become a relevant opportunity for knowledge exchange, co-creation, capacity building and formulation of future scenarios for ES governance in the municipality. Established in 2019, the project coordinator of the MOVE-ON project in La Réunion regularly met the community through a research role besides the official project's meetings. The aim of this community of practice was to inform

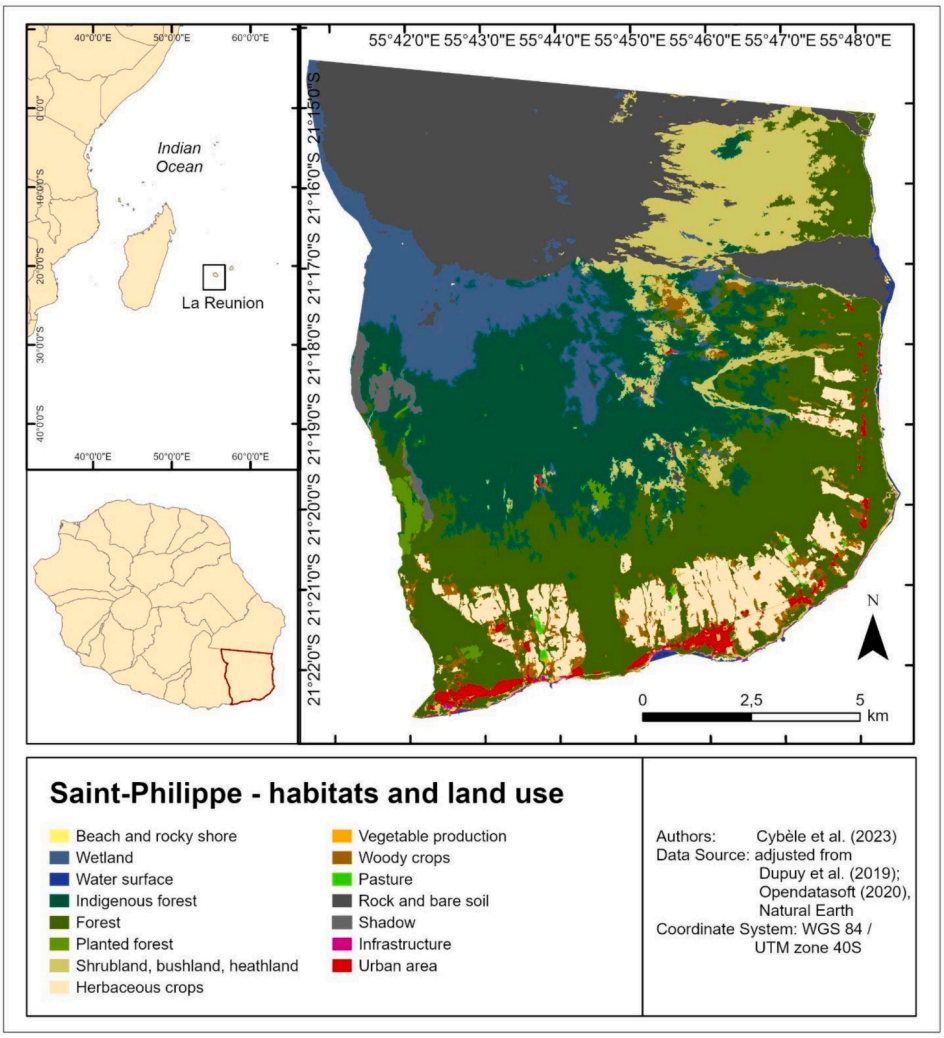

Fig. 1. Land use in the municipality of Saint-Philippe, Réunion Island, simplified after Dupuy et al. 2019. Shadows depict missing LULC information.

local and regional planning initiatives with co-developed insights relevant to the economic development of the municipal area, including follow-up on the MOVE-ON project's inception and implementation.

2.3. Co-creation – Using a tiered, participatory approach

To co-create knowledge on CES in the municipality, we adjusted the participatory framework proposed by Palomo-Campesino et al. (2018) and embedded phases of divergence and convergence of the co-creation prism (Labib et al., 2023), including a time to consolidate the co-creation actions. The Biocorridor Forums were a platform in which divergence and convergence of opinions were expressed. Our participative process follows four main phases: (1) co-creation of the aim and scope of the study, including identifying the main ES and interviews with local stakeholders during informal meetings and (2) focus groups. The second step included the development of the participatory mapping workshops (PGIS). In the third step (3a), the workshop results were analysed, which included digitalization, rasterization, map creation, and statistical analysis. Moreover (3b), different tiered methods in support of the analysis were added after step 3a was closed. Finally, step four (4) included an evaluation of the territory regarding ES supply, including CES supply features, CES supply capacities and CES use in the municipal area. A detailed overview of the methods is shown in Table 1. Fig. 2 shows the process and the main outcomes at each step, covering a time span of almost three years for the entire process.

Such a tiered approach allows to combine the methodologies' strengths and balance their weaknesses (Table 1), combining participatory approaches with stated and revealed preferences and static and more dynamic methods. However, combining approaches is often cost- and time-intensive and rarely applied (e.g. Sagie and Orenstein, 2022), hence leading to an under-representation of holistic, truly integrative ES assessments.

2.3.1. Stakeholder engagement

Informal and steering committee meetings for creating a sentinel community (Step 1)

The National Park of Réunion Island was in the process of developing a management plan for the Mare Longue Nature Reserve, with a technical committee and a steering committee during the launching of the MOVE-ON project. To set the base for this study, the MOVE-ON project representative took part in steering committee meetings, including meetings with stakeholders from the municipality and the socio-economic technical group, to create a concerted action plan for the management of the Nature Reserve. This steering committee met four times during the co-creation process to define the scope of the study, the spatial extent (at the Mare Longue Nature Reserve level and then of the municipality itself), and the thematic focus on CES. The participation of the MOVE-ON project representatives in the various steering committee meetings enabled stakeholders to better understand the objectives of the MOVE-ON project. The socio-economic stakeholders within the municipality of Saint-Philippe were inspired to join the MOVE-ON project as members of the *sentinel community*. As a form of qualitative interviews, informal interviews were undertaken to establish a foundation for trust for both socio-economic stakeholders within the implementation of the project by following Newing (2020). Informal interviews have been undertaken and entailed regular conversations with a stakeholder on their work related to the Mare Longue Nature Reserve.

Consulting institutional and local authorities through semi-structured meetings

Semi-structured interviews were used to identify the relevant ES for the different sectors and economic activities in the municipality, as well as to select participants for the focus groups. For this, 12 interviews have been conducted between November and December 2021, lasting between 45 and 90 min each. Interviewees were comprised of socio-economic actors, the municipality, local institutions with administrative roles, NGOs and scientists. Interviewees were asked to score the importance of co-defined ecosystem services for their field of work and the municipal area. All interviewees expressed their priority for cultural services and ecosystem services for biodiversity related to economic development.

Participatory GIS-mapping through Focus group meetings (Step 2)

Focus group meetings were used to create a participatory map of the features relevant to CES supply in the municipality. The groups were composed of two to six people, comprising a total of 22 participants in five groups identified in the interviews. Three themes of agriculture, forestry and tourism, including horseback riding, were identified. To encourage the active engagement in the participatory process, one representative per focus group hosted the focus group meetings locally within his/her workplace. Before starting the workshop, the organisers explained to all the participants the theoretical framework and objectives of the project, as well as the "scientific meaning" of the ES selected. They also explained the exercises they would have to carry out and how they would analyse the results after the workshop. Two printed maps of A0 size were used in the mapping process, concentrating on the extent of the municipality of Saint-Philippe and the Mare-Longue Nature Reserve. First, the participants were asked to individually fill out an A3 version of the maps, with different stickers and colour codes to help differentiate the socio-economic activities. In addition, historical sites of importance, according to the stakeholders' knowledge, were added to the map. After 15 min of discussion regarding each participant's contribution to the map, and once consensus was reached regarding map components, the larger A0 map featuring the socio-economic conditions was completed. The focus group activity, on average, was held for two to three hours. Afterwards, the maps were transcribed and digitalized using QGIS.

During a public meeting in October 2022 (Biocorridor Meeting, Table 2), the results of the Focus Groups were presented to participants of the steering committee, project partners and the general public for consolidation and validation. This meeting identified additional tools to further support the municipality, opening up the agenda for a broad discussion on the local needs (Step 3a).

2.3.2. Expert-based ecosystem services capacity assessment (Step 3b)

To assess the capacity of habitats to supply ES, the ES capacity matrix method was applied. This capacity matrix is a comprehensive and flexible method in the form of a look-up table combining ecosystem types and ES (Burkhard et al., 2009). Geospatial units such as Land Use/Land Cover (LULC) data can be used to delineate the ecosystem types. These geospatial units are then linked to ES that are relevant to the study region. At the intersections in the matrix table, the supply of ES within the particular units (e.g. LULC types) can be assessed on a scale from 0 (no or very weak capacity) to 5 (very strong/maximum capacity). The normalisation to a relative scale allows comparing different ES (usually assessed by different indicators and units). In addition, a confidence level was included to capture the experts' ease in filling the matrix per habitat and ecosystem type (Campagne et al., 2017; Campagne and Roche, 2018). The matrix method is well-suited to express values from different domains, including biophysical, socio-cultural, and non-monetary and monetary values of multiple ES.

One approach to conducting such a matrix assessment is by assessing expert knowledge. Expert estimations deliver a good overview by integrating different sources of expertise while simultaneously being a strong capacity-building tool. As with all expert-based assessments, the scoring values strongly depend on the experience, knowledge as well as the objectivity of the evaluators (Burkhard et al. 2012). Yet, numerous applications show the robustness and effectiveness of the method (see e.g.: Campagne and Roche, 2018, Sieber et al., 2021a), also compared to biophysical estimates (Roche and Campagne, 2019).

For this assessment, a workshop was organised at the municipality of Saint-Philippe on the 27th of January 2023. Prior to the workshop, a matrix was developed in collaboration with the main stakeholders, including the 13 most dominant land use classes and three cultural ES of

Table 1
Selection of methods for the ES assessment, expanded from information from Hiron et al (2016).

Method	Aim	Participation	Preferences: stated or revealed	Strengths	Weaknesses	Sources
Focus Groups	A qualitative research approach to organise small group discussions among participants who possess shared characteristics or relevant experiences pertaining to the research topic. The objective is to gain insights through group dialogue and observation of interpersonal dynamics.	Yes	Stated	– representation – time intensive (design, discussions, data analysis etc.) – complementary with other methods	– prone to power imbalances – prone to reduction to group interviews – small groups recommended (>13)	Slovák et al., 2023, Santos-Martin et al. **2018**
PGIS	Used to scope the scientific aim of the assessment, identification of relevant ES Refers to the collaborative development of maps based on local knowledge and perception. PGIS integrates modern geospatial information systems (GIS) with participatory techniques to map complex spatial phenomena. Individuals or groups can be invited to identify locations on a provided map.	Yes	Stated	– awareness raising component – place-based spatial information – takes ILK into consideration	– to be mapped ES often blurry (supply, demand, flow?) – validation and verification of results through triangulation of methods	Cox et al., 2014, Brown & Fagerholm, 2015
ES Capacity Matrix approach	Applied to identify spatial dimension of a phenomenon Rapid, reliable, and resourceful tool used to assess and map ecosystem services (ES) by linking ES to geospatial units using Land Use/Land Cover (LULC) or other geospatial data. The method facilitates the mapping and assessment of ES supply capacities, providing valuable insights into ecosystem functions and their potential to deliver services.	Either	Stated	– quick – participatory – based on expert elicitation – visualisation of ES in form of maps	– static	Burkhard et al., 2009, Hou et al., 2013, Campagne et al. 2018, Sieber et al., 2021a
InVEST Model "recreation"	Applied to assess the capacity of ecosystems to supply ES To assess the value of natural environments, the InVEST recreation model forecasts the distribution of person-days spent on recreation, considering the locations of natural habitats and other factors influencing recreation choices based on geotagged photographs from the website Flickr.	No	Revealed	– GIS based spatial approach – quick – high accuracy	– last update 2017 – black box	Sharp et al. 2016 Wood et al., 2013, Sieber et al., 2021b

emblematic and symbolic aspects of landscapes, landscape aesthetics and recreational activities, including eco-tourism. The expert panel included experts from government officials, land use planners, national park authorities and environmental specialists (Annex 1). Notably, 30 % of the experts were female (Annex 1). The majority of experts identified their expertise as related to forests (40 %), followed by agriculture (30 %), and marine and urban habitats (20 %). Only one expert on aquatic ecosystems was present. The expert panel comprised 40 % management authorities, 30 % environmental agents and 20 % decision-makers. Experts individually filled out the matrix during the workshop and online. Altogether, 10 matrices were obtained. According to Campagne et al. (2017), this number is sufficient to reach reliable information with low intrasample variability.

Expert scores were statistically analysed using arithmetic means and standard deviation.

2.3.3. Modelling the flow of cultural ES (Step 4)

To quantify the CES flow of ecosystems, hence the amount of service used in the Saint-Philippe municipality, the assessment draws on social big data. For this purpose, the InVEST Recreation model was applied from the InVEST Model Suite[2] (Sharp et al., 2014). The model allows quantifying the flow of CES from natural environments based on the distribution of annual person-days of recreation related to the locations of ecosystems, land uses and other features that impact people's decisions about where to recreate. The model applies a proxy for visitation and recreation, drawing upon geotagged photographs uploaded to the website Flickr. With this information, the model can specify the spatial patterns of recreation annually or over a period of time (Sharp et al., 2014).

We ran the InVEST model for a timeframe from 2005 to 2017, with a square cell size of 30 m, to obtain the precise location of human activities based on LULC data (Dupuy and Gaetano, 2019). This allowed us to obtain information on the location and land use in which photos were taken. Model results were validated by manually cross-checking the uploaded photos' location, amount, and content.

2.4. Data

Data used for this study is based on the LULC dataset compiled under the CIRAD AWARE Project produced with Spot 6/7 data[3] (150 cm resolution) (Dupuy and Gaetano, 2019). A delineation of the administrative boundaries of the study area was obtained from Opendatasoft (2020). The digitalisation of the PGIS features took place using QGIS Hannover. The InVEST workbench 3.1.12 was used to model CES flow, drawing upon the Flickr website (Sharp et al., 2014). The analysis of PGIS features, the assessment of CES capacity and the compilation of the data with CES flow results took place in ArcMap 10.8.

3. Results

3.1. Focus groups and PGIS

Stakeholder involvement took place over a period of three years. In multiple meetings and workshops, municipal and regional stakeholders discussed, negotiated and developed the direction of the assessment. During the final steering committee meeting, the willingness of stakeholders' participation was set, and the joint procedure to assess CES in the municipality was settled. Based on this agreement with leading stakeholders, six focus groups with 22 participants were organised to implement PGIS. This participatory mapping exercise helped to obtain 111 features that can be grouped into broader categories of recreational activities (25), including hiking, mountain biking and horseback riding

[2] https://naturalcapitalproject.stanford.edu/invest/recreation
[3] https://www.theia-land.fr/en/product/land-cover-on-reunion-island/.

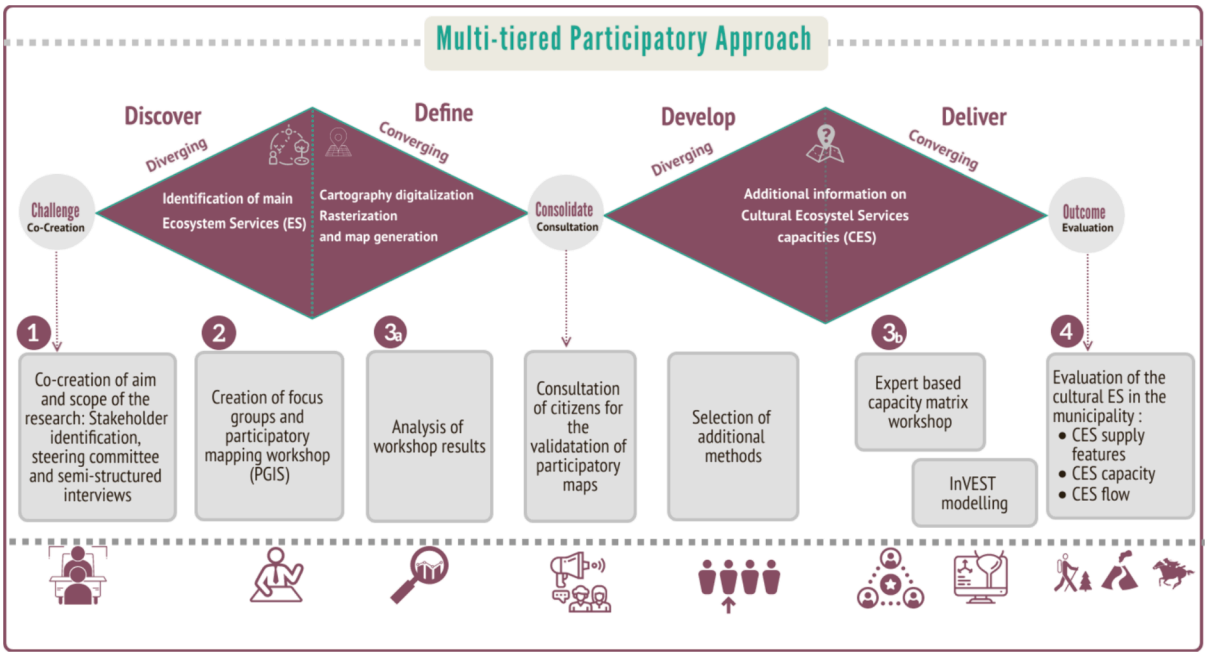

Fig. 2. Schematic representation of the participatory approach adjusted from Palomo et al. (2018) and enriched by co-creation processes shown in the diverging, converging, and tiered approaches (Labib et al., 2023) (3b).

Table 2
Overview of activities within the participatory process of co-creating knowledge on cultural ES.

Activity	Purpose	Date	Place (in-person /online)	Participants
Steering Committee 1	Co-construction of a concerted action plan for the Mare-Longue Nature Reserve: presentation of the MOVE-ON project	10/10/2019	Plaine des Palmistes	23
Steering Committee 2	Engagement in the "socio-economic" technical group	27/08/2020	Mare Longue	28
Steering Committee 3	Select strategies to be implemented within the action plan (1st workshop)	24/09/2020	Online	15
Steering Committee 4	Finalisation: the willingness of stakeholders participation was set (workshop closure)	28/09/2020	Online	4
Focus Groups	Participatory mapping of features important for CES supply	23/03/2022–25/09/2022-	Saint-Philippe	2–6 (total 22)
Bio-Corridor Forum	Presentation of the results of the participatory mapping, Feedback	28/10–29/10/2023	Saint-Philippe	60
Expert-based Assessment	Participatory matrix based expert assessment of the capacity of ecosystems to supply CES	27/01/2023	Saint-Philippe	10

trails and facilities, as well as hikes related to speleology and lava tunnels specific to the municipal area. Fishing grounds for recreational purposes are located in the southeast of the municipality and are included in this group. A second group comprises forested areas for non-timber forest products (50), such as a collection of medicinal plants, pandanus leaves, or agroforestry activities of vanilla production. A third group comprises historic sites (18), including the ancient port, a historic mill, historic plots of sugar cane processing or ancient piracy sites. A sixth group of features comprises the location of research areas (6) marked in red in Fig. 3. These features contain research plots for local and regional research institutes. Touristic infrastructure (12) comprises the location of the botanical garden, lodging, hotels and tourist shops.

The participatory mapped features are agglomerated mainly in the historic lava flow that is part of the Mare Longue Nature Reserve, home to various endemic species, particularly plants, including rare orchid species. Along a forest trail on the border of the Nature Reserve, a public garden displays local spices and organic farms. The forest trails around and within the Nature Reserve are used for various recreational activities, including hiking, horse-riding, biking, and botanical tourism with its plant nurseries, botanical gardens, and collections of endemic plants. Within the Mare Longue Nature Reserve, Saint-Philippe's commune is the island's most scientifically studied site. Fig. 3 shows the features of large contributions to the economic activities of the municipality. Vanilla cultivation as epiphytes to endemic trees and the use of the coastal endemic pandanus dried leaves for hand-crafted bags and accessories are listed among non-timber forest products. Fishing, as a recreational activity, is located in the south of the study area. In the north of the study region, the recent volcanic crater of 2006 with its lava flow is visible; here, only two historical features were identified in the PGIS exercise.

3.2. Expert-based CES capacity assessment

Based on the results of the focus groups and PGIS, a matrix table was constructed, including the three CES of emblematic or symbolic value, landscape aesthetics and recreational activities, as translated into the CICES classification (Haines-Young and Potschin-Young, 2018) and a simplified LULC available for the municipality (Dupuy and Gaetano, 2019). Ten experts completed the exercise. Overall, rocks and bare soil, rocky shores and ocean and indigenous forests were ranked with the highest, strong to very strong supply capacities for CES. The lowest capacities to supply CES were indicated for infrastructure, roads and urban areas, with the latter scoring a good capacity for recreational activities,

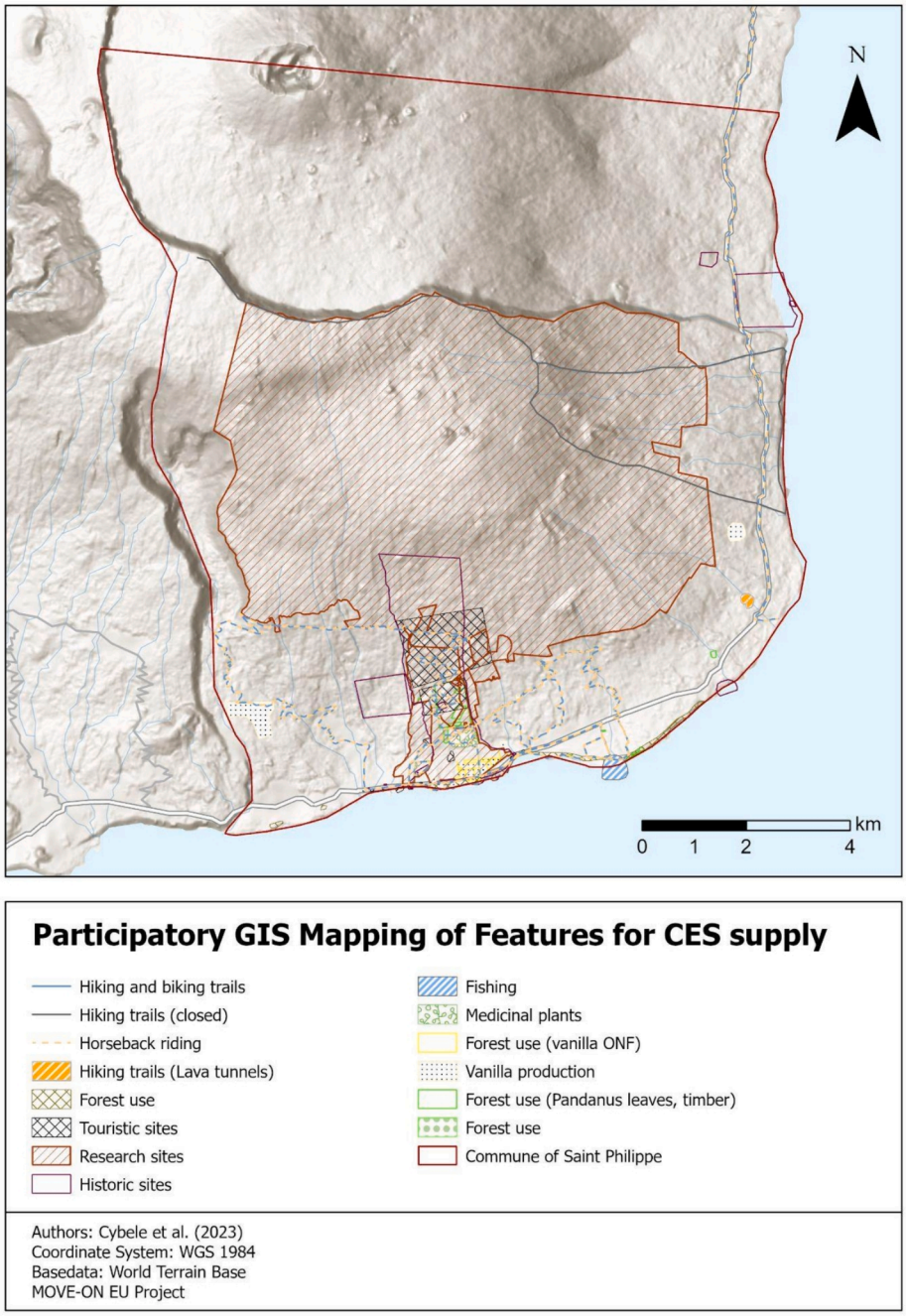

Fig. 3. Outcomes of the participatory mapping process based on 22 participants from 6 thematic groups for the municipal area of Saint-Philippe, Reunion Island.

including eco-tourism (Fig. 4). Experts showed overall highest confidence in their scores for forest ecosystems (2.1–2.2) and coastal and aquatic ecosystems (2.0–2.1). The lowest confidence was found for Savannah and Infrastructure. Scores for all CES were ranked with strong confidence.

Compared to other similar matrix exercises, including the French Outermost Regions, stakeholders in Saint-Philippe showed a very high valuation of coastal land uses of rocky shores and ocean (>4.5). Experts also expressed a high valuation of CES supply capacity by urban land uses of built-up areas and infrastructure (see Burkhard et al., 2009, Campagne and Roche, 2019; Sieber et al., 2021a).

Fig. 5 shows a compilation of CES features, capacity and flow generated by different methods. It depicts the capacity of ecosystems to supply landscape aesthetics within the municipality of Saint-Philippe, ranging from rose (no relevant supply capacity) to dark green (very strong supply capacity). The Mare Longue Nature Reserve, as a component of the municipality of Saint-Philippe, with its historic and scientific research site, is shown as well as the vanilla production zones (including management zones from the French National Forest Office (ONF)) and hiking, horseback riding and mountain biking trails. The InVEST Model presents the actual use of the landscape and obtained 1030 uploaded pictures for the community of Saint-Philippe. The Flickr Photo User Days (PUD) were averaged per year for the timeframe from 2005 to 2017. Their spatial distribution is shown in Fig. 5, whereby the number of PUDs is reflected in size of the dots. The landscape attractivity at the coastline is especially visible in the high agglomeration of PUDs on the shore to the west of the Mare Longue, with historic sites and spectacular coastal views. Similar to Plieninger et al. (2013), our study finds that CES supply follows specific patterns and features in the landscape in terms of the capacity and flow of their provision.

Matrix based Ecosystem Service Capacity Assessment in Saint Philippe, La Réunion				
Habitats \ Ecosystem Services		Emblematic or symbolic	Landscape aesthetics	Recreatio-nal activities incl. (eco-) tourism
Rocky shores and ocean	2,1	4,65	4,9	4,5
Rivers	2,2	3,4	3,6	3,3
Wetlands	2,0	3,1	3,4	2,3
Agricultural areas - herbaceous crops	1,9	3,5	3,2	2
Agricultural areas - woody crops	1,9	3,4	3	2,5
Agroforestry	1,9	3,9	3,6	3,1
Indigenous forest	2,2	4,8	4,8	4,3
Mixed and planted forest	2,2	3,8	4,3	3,7
Shrubland, bushland, heathland	2,1	2,7	2,7	3,3
Savanna	1,8	2	2,9	2,5
Rocks and bare soil	1,9	5	5	4,4
Urban areas	2,0	2,3	2,7	3,9
Infrastructure and roads	1,8	1,5	1,8	2,6
	Confidence Index	2,2	2,2	2,2

Fig. 4. Expert-based ES matrix for the commune of Saint-Philippe, based on n = 10 responses (cells with red text: standard deviation ≥ 1.5), confidence index represents the certainty of participants with their scores (0 = very uncertain – 3 high certainty). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

4. Discussion

- **What are the main features guiding CES supply at the municipal level of Saint-Philippe, Réunion Island?**

CES supply in Saint-Philippe is multidimensional and multifaceted. During the first Bio-corridor forum discussion session, the institutional stakeholders along with the audience, expressed their willingness to raise awareness at the island level on the unique features of their municipality, including the level of endemicity. Furthermore, the stakeholders shared their thoughts regarding sustainable eco-tourism development, along with amenities, while protecting their natural and cultural heritage. Such a co-creation and mapping exercise, together with additional methods, allows us to identify the different cultural dimensions of the municipal area and its potential for future economic development. This assessment brings together recreation features such as hiking trails, botanical gardens with landscape aesthetics and the locations where tourists spend their time. Many of the participatory mapped features depend on, or interact with, biophysical components of ecosystems – providing, for example, the infrastructure to access nature and to physically experience landscapes and heritage. This can be partially attributed to the PGIS method, using polygons rather than points – which is known to influence the resulting data quality (Brown & Fagerholm, 2015). Here, flexibility is needed to integrate plural values into the ES assessment, as such process-based assessments serve the purposes of awareness raising and joint knowledge creation rather than following any predefined classification of CES definition.

Supporting this with social big data by the InVEST model shows that to a large extent, the actual touristic visits (PUDs) coincide with infrastructure – roads and trails guide recreationists. Yet, in the forested area, hikers, birdwatchers and botanists seem to leave the official tracks – an effect that could also derive from the inaccurate georeferencing of Flickr (see Hauff, 2013).

This can inform development measures and enhanced infrastructure such as toilet facilities, an extension of hiking trails and signage as well as strategic placement of vistas or parking spaces along the main touristic features.

- **How can we combine multiple dimensions of CES supply features, capacity and flow for informed regional economic development?**

Using this tiered knowledge co-production strategy, we can create information on ES in a genuinely bottom-up manner, providing coastal communities with the environmental information they need for regional planning and economic growth. A stakeholder-led method, which includes a stakeholder steering committee, enables the creation of useful information and maps that address stakeholder demands (Azzopardi et al., 2023; Jacobs et al., 2016; Tengberg et al., 2012).

The community's appreciation for CES guides where and how to proceed in establishing long-term investments that contribute to the territory's socioeconomic growth. The score obtained through a participative approach, such as the one described, indicates the use and non-use value of various ecosystems (Azzopardi et al., 2023). The results of applying the proposed integrated methodology provide recommendations for future areas of development and economic development in the territory. The island of La Réunion is well-known for its diverse ecosystems, which support the territorial production organisation. The geo-referential participative method provides clear indicators of which types of ecosystems various stakeholders are willing to invest resources in as the primary source of CES. The importance of marine habitats, coastal ecosystems, and rocky land uses aligns with the island's primary economic development plans, which underlie the production apparatus on ocean import–export.

Although the low score provided to urban regions is inherently negative, it is an important conclusion to examine. This is because urban areas are perceived as regions where the community largely offers non-recreational services, and the island's ecological implications preclude urban development with the addition of cultural ecosystem services. While expansion in situations similar to Saint Philippe might assist in adding additional places for cultural ecosystem services, in this case, decision-makers must engage in a game of redevelopment and land-use modification to support culture and community recreation for ecotourism compatible forms.

The orchestration of these methods together presents a novel approach to use knowledge-co-creation in a tiered methodology. This allows to generate information on ES in a truly bottom-up manner, giving coastal communities the environmental information they require for regional planning and economic development. Hereby, a stakeholder-led process, involving a stakeholder steering committee, allows to create meaningful information and maps answering stakeholder needs.

- **Stakeholder engagement through a co-creation process in the first evaluation of CES on Réunion Island**

Knowledge co-creation is gaining popularity as an ultimate form of a participatory process. Some scholars, however, have argued that participatory approaches around knowledge co-creation could have often been adopted as a fashionable research methodology. Co-creation approaches are often considered easy to organise, inexpensive and used "without any prior consideration of whether it really is the most suitable research technique for achieving the cognitive goals of the research" (Acocella, 2012, p. 1126). Our work shows that a co-creation process requires much consideration, thoughtful planning and sufficient time to motivate and engage participation without stakeholder overload. Adjusting the work and outputs based on stakeholder and co-researchers requires flexibility, known as "creative fuzziness" in the research design phase (Sanders and Stappers, 2008), including a constant divergence and convergence of the discursive arena, with flexibility to renegotiating purposes and additional steps (Labib et al., 2023).

Engaging citizens and stakeholders in research through knowledge

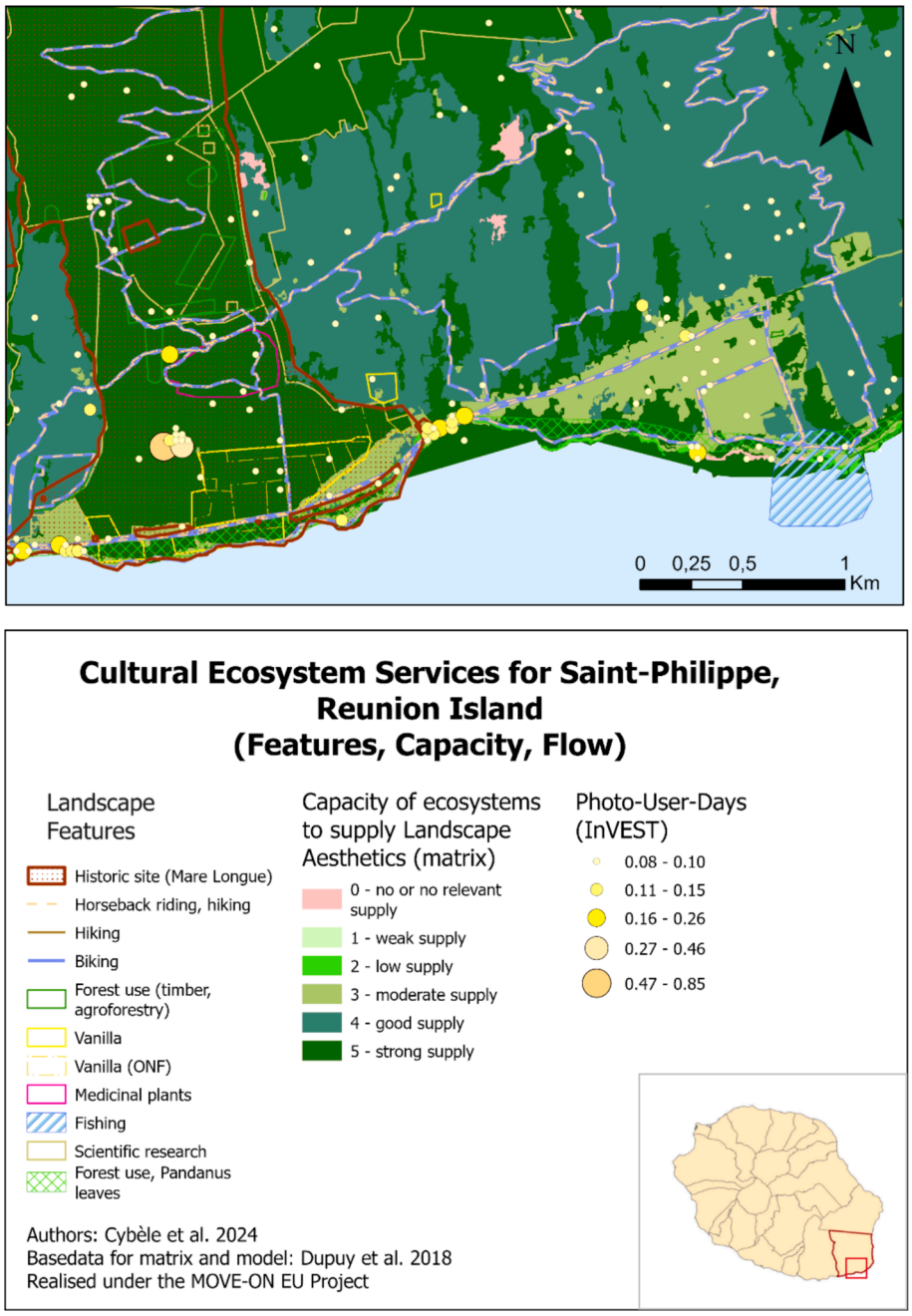

Fig. 5. Compilation from PGIS, Capacity matrix and InVEST modelling of cultural ES in the commune of Saint-Philippe, Réunion Island.

co-creation has proven fruitful in Saint-Philippe, Reunion Island. Yet, it faced particular time challenges. First, time acts as a cause for the inclusion/exclusion of stakeholders due to the availability of numerous and often perceived lengthy meetings (Wendt and Köhrsen, 2022). In our study, we observed a decreasing participation in the "steering committee" and throughout the process by citizens and actors from the public, but also a disproportionately low participation of women and young people (<30 %). Most stakeholders came from a professional context and were experts in their field. Second, participatory processes are known to be extremely time-consuming and sustainability issues (including environmental/ES governance) affect multiple realms (such as environmental planning and protection, education, agriculture or energy supply) simultaneously (Wendt and Köhrsen, 2022). Hence, our local study required expertise from different fields. At the same time, participatory processes are often pressure-laden, producing results in a very short time whilst avoiding stakeholder overload. Reed (2008) suggests embedding stakeholder participation in existing, institutionalised formats to facilitate processes where goals are negotiated and outcomes are necessarily uncertain. Therefore, basing this work on the existing sentinel community in Saint Philippe, and stretching our study over a three-year period allowed for continuity – a fact that stakeholders valued very much. The tiered aspect provided relief in this sense, as it supplied the information requested by stakeholders (e.g. information on the actual flow of CES) combined with participatory capacity-building activities on the concept of ES (e.g. seminar, expert matrix workshop) and their importance for the different sectors. Embedding participatory co-creation processes in these activities ensured awareness raising and capacity building amongst important local actors and that the obtained knowledge will stay in the community after project termination.

Long-term effects of the work become visible in the uptake of ES assessments in various local governmental and administrative

authorities, e.g. requesting a refined assessment of urban and *peri*-urban areas and the need for a more detailed agricultural ES map. This information will flow into the updated Land Use Planning Plan. Based on the strong interest of authorities in an island-wide ES assessment, a capacity matrix assessment at island scale was initiated, paired with an ES capacity building component.

4.1. Uncertainties linked to the tiered approach and why it is worth overcoming them

Bringing together different methods to assess CES poses challenges. Similarly to any participatory process, the quality of PGIS results depends on the representativeness of participants in the mapping – a broad representation of different societal groups is needed for truly inclusive outcomes. Secondly, PGIS methods have been mostly applied at local scales and integration of results into larger-scale decision-making has been elusive. As a result, PGIS results need triangulation by other methodologies, such as biophysical and socio-ecological GIS analyses (Cox et al., 2014). Likewise, the challenges of expert-based matrix method applications have been broadly discussed (Hou et al., 2013, Campagne and Roche, 2017; 2018). Shortcomings in the use of social media to quantify recreational CES were presented by Wood et al. (2013), including biases related to demanding sportive activities and underrepresenting visitors who travel shorter distances from home. The InVEST recreation module only allows users to retract uploaded Photos up to 2017, excluding latest recreational activities. Yet, the field of geotagged and crowdsourced data for CES assessment, such as geotagged tweets, shows great advancement (Langemeyer et al., (2023) – but often at the cost of simplicity of use compared to the InVEST modules.

Here, a tiered approach (Grêt-Regamey et al., 2017) can outweigh the challenges presented. Through triangulation of methods, the weaknesses of each method can be levelled. One methodological and operational advantage of this study is the involvement of multiple types of stakeholders and the creation of awareness and fostering of social learning related to ecosystem services (Santos-Martín et al., 2018). Further, complementing mapping methods and triangulation allows to present a nuanced, holistic picture of CES supply, including where, when, by whom and how CES are supplied and actually used.

5. Conclusion

Our study presents a tiered participatory approach towards identifying cultural ecosystem services and better integrating them into policy- and decision-making at municipal and territorial scales. Using knowledge co-creation stood in the centre of the study, co-defining the needs of municipal stakeholders of Saint-Philippe, Réunion Island, and shaping the research aims. During a three-year period, activities took place to capture the different aspects of CES features, supply capacity, and flow, thus the use of CES, using focus groups, PGIS, matrix approaches and ES modelling. The flexible participatory process led to the creation of the first ES maps of Réunion Island and led to strong awareness-raising about ecosystem services and the human dependence on functioning ecosystems.

Such tiered approaches using co-creation for CES present an interplay between established (and tested) and evolving (and testing) modes of socio-cultural orchestration, providing stakeholders with the tools and information they need for effective land use planning and enhanced regional economic development.

CRediT authorship contribution statement

Cathleen Cybèle: Writing – review & editing, Writing – original draft, Visualization, Resources, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Jarumi Kato-Huerta:** Writing – review & editing, Writing – original draft, Methodology, Formal analysis. **Miriam Montero-Hidalgo:** Writing – original draft, Methodology, Investigation. **Benjamin Burkhard:** Project administration, Conceptualization. **Rekha Grimoire:** Data curation. **Francesco Sica:** Writing – review & editing. **Ina Sieber:** Conceptialisation, Methodology, Data curation and analysis, Modelling, Investigation, Visualization, Writing - original draft, Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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Annex

Table 1: Sociodemographic aspects of the expert panel.

Habitats of expertise	Age	38	38	40	47	36	55	27	39	30	38
	Gender	W	W	M	M	M	W	M	M	M	M
	marine			X	x				X		
	aquatic				x				X		
	agriculture		x	X						X	
	forest	X	X	X	X			X			
	urban			X		x					
Type of expertise	Decision making			X		X			x		X
	Planning	X	X		X		X	X	X	x	
	Environmental specialist	X	X	x					X		
	Economic sector										

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Further reading

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