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Assessing and mapping cultural ecosystem services at community level in the Colombian Amazon

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Assessing and mapping cultural ecosystem services at community level in the Colombian Amazon

Understanding the significance that cultural ecosystem services (CES) have for traditional communities will provide useful input to the design of more appropriate regional or territorial plans for the area in which they are located. We conducted semi-structured surveys in 11 indigenous communities within the corregimiento La Pedrera, of the Colombian Amazon. We analysed the CES established in the region through a study of their preferences in relation to the service providing units (SPU) identified, using the Shannon diversity index method as an indicator of "diversity of use". More CES were identified in communities with a larger population; Education and Recreation were the two most prevalent CES categories in the study area. Our findings also highlight the cultural importance of bodies of water, which were strongly linked with Spiritual and Sense of Place CES. Furthermore, the integration of qualitative and quantitative assessments enables a better understanding of the importance CES have for the local communities involved in the study and may assist in the management of the indigenous territory.

Keywords: culture, ecosystem services, indigenous communities, community based management, tropical forest, water

Introduction

The diverse and heterogeneous nature of the Amazon, partly resulting from its plural ethnicities, is currently confronting many challenges, including high extraction and exploitation of its natural resources (e.g., timber and mineral resources), changes in land use (e.g., conversion of forests into monoculture), pervasive habitat degradation, hunting and overfishing (Portocarrero-Aya & Cowx, 2016; Navarrete et al., 2016), and uncontrolled and unplanned urban growth (Angarita-Báez, 2016; Ferraz et al., 2008; Fundación Alisos, 2011). These problems are threatening the environmental sustainability of the region and the well-being of the Amazonian tribes, which have settled there since times immemorial (Balvanera et al., 2012). This alone should be a sufficient argument to drive the search for methods that provide a more complete quantification of the ecosystem services (ES) on which the well-being of the region's local communities is contingent.

As the demand for ES continues to grow, accentuating the current environmental and social challenges, it is important to design new approaches for their management across all ES types, namely provisioning, regulating, supporting and cultural services. In this manner, and by carefully evaluating social-ecological systems, it will be possible to preserve or improve ES while at the same time increasing human well-being (Carpenter et al., 2009; De Groot et al., 2010; MA, 2005; Navarrete et al. 2016). Furthermore, their management needs to be strengthened and trade-offs between the provision of different services need to be considered, as enhancing livelihoods in the short-term by exploiting the environment unsustainably may undermine the long-term provision of essential ES and affect the well-being of future generations (Bennett et al. 2009; Dearing et al. 2012; Poppy et al. 2014; Raudsepp-Hearne et al. 2010; Tallis et al. 2008). ES research can provide information to resource managers to better understand the trade-offs and long-term impacts of different types of natural resource use (Raymond et al., 2013).

In this study, we focus specifically on cultural ecosystem services (CES), which comprise "the non-material benefits society derives from an ecosystem, as manifested through the spiritual fulfilment, cognitive development, recreational or aesthetic fulfilment described by any individual that has access to the service" (MA 2005). The CES are alternatively defined as the contribution of ecosystems to non-material benefits such as capabilities and experiences, which result from human-ecosystem relationships (Chan et al. 2011, Chan, 2012a). These are intimately linked to the satisfaction of a human's basic needs (Balvanera & Cotler, 2007; De Groot et al., 2010; MA, 2005). The importance of traditional cultural practices, which contribute to a community's social, economic and ecological sustainability (Neff, 2011; Plieninger et al. 2015) are often difficult to ascertain or even measure. However, traditional cultural practices are reflected in the strategies, symbolisms and tools communities design to perform their tasks. For example, traditional knowledge reveals cultural links and interdependence between indigenous communities and nature. One example of this interdependence is the local knowledge on location and movement, which explains the spatial patterns of the ecosystems, including sequence of events, cycles and trends. These direct links with nature are essential to ensure an individual's and a group's sense of place (Posey, 1999). Another example is that traditional knowledge on biodiversity consists of a socially regulated and complex set of values, practices, technologies and innovations, which have been developed by communities through time as they learnt to live in intimate contact with their natural surroundings. Traditional agricultural practices, fishing techniques, natural medicine and hunting methods constitute direct manifestations of this knowledge, which is embedded in the communities because it is valuable in ways both tangible (e.g., instrumental) and intangible (e.g., reinforcement of kinship worldview related to the relationship between people and nature) (Sánchez, 2003).

While the application of the ES framework and the assessment of CES pose several challenges, such as the representation of diverse perceptions, varied approaches and analytical techniques are available (Gould et al., 2015). For instance, Plieninger et al. (2013) focused on the spatial representation of a wide range of CES, while Norton et al. (2012) integrated quantitative and qualitative data on eight CES. Although many scholars (Norton & Noonan, 2007) are unconvinced when it comes to quantifying CES, combining it with participatory mapping and other methods that go beyond the conventional can encourage a better understanding and management of CES (Hirons et al., 2016; Ulloa 2009). There is mounting evidence demonstrating their importace particularly for the rural poor and marginalized indigenous populations whose livelihoods often depend heavily on the provision of ES, and hence are more vulnerable to environmental change and ecosystem degradation (Butler & Oluoch-Kosura 2006; Cummings & Read 2016; Folke et al. 2002). It is highly likely these changes will have a greater impact on their well-being as their lifestyle is more integrated to their surroundings. Furthermore, CES due to the intangible nature of the benefits they provide, have been relatively neglected by researchers and policy-makers compared to provisioning, supporting, and regulating services (Brown & Fagerholm, 2015; Cummings & Read, 2016; Hirons et al., 2016; Ives et al., 2017; Plieninger et al., 2015; Ramírez-Gómez et al., 2017). Although measuring CES poses several conceptual and methodological difficulties, it is of huge interest and importance because of the linkages between cultural values, assessment methods, and the individual and collective decision-making that influence ecosystems and human well-being (Brown & Fagerholm, 2015; Chan et al., 2012b; Hirons et al., 2016).

In the case of the Amazon, various studies have sought to develop methods aiming to incorporate the traditional knowledge, which is an integral part of the communities populating the region, enabling a better understanding of the territory and the cultural values that are an integral part of the community's behaviour (Botazzi et al., 2014; Briggs et al., 2013; Cámara-Leret et al. 2014; Celentano et al., 2014; Figueiredo et al., 2013; Macia et al., 2011; Silvano et al., 2008). Studies incorporating community stakeholders' knowledge have also been conducted in Africa (Chalmers & Fabricius, 2007; Fagerholm & Käyhkö, 2009; Fagerholm et al., 2012; Schnegg et al., 2014; Sileshi et al., 2009) All the aforementioned studies demonstrate that traditional knowledge should be a key component of decision-making. They also show the importance of identifying which ecological features are associated with the cultural heritage values of stakeholders in a given cultural context and how changes in these features could affect those values. For example, Oestreicher et al. (2014) discuss a study of livelihood activities and land-use practices of the communities located in the Brazilian Amazon, highlighting the need to integrate both qualitative and quantitative assessments, as the most effective way of gaining a reliable perspective on the effect that changes in the ES might have on the communities dependent on them. The quantitative data provides empirical evidence on the wide range of activities in which the communities engage, while the qualitative data helps to identify the underlying reasons for the differences between the communities participating in the study, demonstrating the plurality of forces that shape household decisions (e.g., institutional, economic, demographic factors).

This paper presents an assessment of subjective well-being linked to a range of CES perceived by the indigenous communities living in the Colombian Amazon. The services identified were valued using a number of indicators discussed and agreed with those involved in the study (researchers and community members). The data recorded was combined with a set of social landscape metrics (Brown & Reed, 2012), estimated following the method described in (Plieninger et al., 2013). It has the potential to widen the scope of the discussion to address the full range of values affecting the sustainability of the region, as it provides the means to link the CES valued with other relevant ES, and build a model to simulate policy scenarios, highlighting trade-offs across the full spectrum of ES applicable to the region (ASSETS, 2012), thereby helping to inform public decision-making. The pragmatic approach developed should ensure key cultural aspects of the local communities are given due consideration in the political discourse.

Providing a comprehensive assessment of the benefits gained from CES, as perceived by those benefiting from their use in a rural context, is still work in progress as the shortcomings identified and discussed demonstrate. Nevertheless, as this type of study remains under-researched and poorly integrated into existing ecosystem services assessments (Ives et al., 2017), the method described constitutes a step forward in their full integration to the ecosystem services discourse.

Methods

Study area

The Colombian Amazon is a meeting point of three distinct geologic formations: the Andes, an extensive sedimentary plain and the Guiana Highlands. The chemical composition of the soil is characterized as poor and easily subject to erosion. The main rivers (listed in a North-South direction) are: Vichada, Guaviare, Vaupés, Apaporis, Caquetá, Putumayo and Amazonas. The main biome in the region is the tropical rainforest (*Institute of Hydrological, Meteorological and Environmental Studies*-IDEAM, 2010). Other land cover types are aquatic ecosystems, native savannas, secondary vegetation and urban zones, which jointly comprise 6.1% of the territory (Fundación Alisos, 2011). Its indigenous population belongs to 22 ethnic groups, which constitutes 24.72% of the total number of ethnic groups known in Colombia (Departamento Administrativo Nacional de Estadística, 2005).

The communities involved in this study are all settled in the *corregimiento* (a rural administrative unit) of La Pedrera. It is situated in the Lower Caquetá River Basin, a tributary of the Amazon River, in the Amazonas Department, Colombia (Figure 1). The *corregimiento* has a total area of 394,994 ha. It has experienced a continuous population growth over the past two decades: the 1985 census reported 1631 inhabitants and the 2005 census, 3267 residents. Official projections estimated that by 2017 the population may stand at 5269 inhabitants (Departamento Administrativo Nacional de Estadística, 2009; Ramírez-Gómez et al., 2015).

The majority of the population settled in the region during the 20th century for different reasons, mainly associated with a colonial, conflict-driven migratory movement. This type of influx tends to be linked with a high level of deforestation which usually triggers further migration as people need to look further afield for their resources (Fundación Alisos, 2011). Additional impacts noticeable in the Lower Caquetá River Basin have been caused by evangelization processes and the prohibition of indigenous practices (Umaña, 1989), exploitation of rubber, planting of illegal crops and the expanded marketing efforts along the border with Brazil resulting in illegal logging practices and the overexploitation of large fish (De H.E.E.D.S., 2007; Dias, 2009; Figueiredo et al., 2013, Hurd et al. 2016; Umaña, 1989). The *corregimiento* of La Pedrera includes the territories of 13 indigenous communities (excluding those located in La Pedrera town). This research involved 11 of them (Table 1). To facilitate data collection, the communities were classified in groups on the basis of geographic proximity and socio-economic profile (Table 1).

Study Design

The approach followed is a pragmatic paradigm for non-monetary valuation, which integrates elements of deliberative and instrumental paradigms as described in Raymond et al. (2014). An instrumental non-monetary valuation of CES following the method described in Plieninger et al. (2013) is used to assess patterns of services. A deliberative process of value elicitation is used to extract and give form to the communities' traditional knowledge of the landscape. This is achieved through a combination of mapping and semi-structured interviews with subsequent integration in a geographical information system (GIS) (Fagerholm et al., 2012; Palomo et al., 2013; Ramírez-Gómez et al., 2015).

As the study is part of the research efforts that fall under the 'Attaining Sustainable Services from Ecosystems through Trade-off Scenarios' (ASSETS) project, the strong relationships between the Colombian project partner and the local communities involved, which have been built over several years, helped to facilitate all the meetings that were held. Furthermore, the partner's extensive experience on the socio-economic and ecological aspects of the area proved particularly helpful in the design of the questionnaire used and the way the interviews were organized.

The interviews were structured to facilitate the identification of the CES that are an integral part of the communities' way of life. In addition to the location of the site, the information recorded for each of the services identified includes types of use, time of use, proximity and restriction of access.

As providing a quantitative evaluation of CES is particularly difficult given the subjective nature of the non-material benefits society derives from them (Chan et al., 2012a, 2012b), it is important to build a framework, which will account for this subjectivity and simultaneously help in their valuation.

The framework used in this study is based on the identification of service providing units (SPU) according to Luck et al. (2003) and Syrbe & Waltz (2012); the locations identified are classified by level of importance, for instance those that are prohibited, enchanted or communal (Table 2). The classification schemes enabled the research team to ground the information supplied by the participants during the group meetings. They were particularly useful during the analysis once it was integrated with the cartographic data. The different SPU identified were examined in relation to the following six numeric indicators: accessibility, substitutability, similarity, pleasurability (whether the place was used because of its pleasing nature), beauty (aesthetics), and memories (remembrance). By doing so, it was possible to establish the collective motivations of participants in visiting certain locations in order to benefit from the CES.

All the indicators constitute unitless ranking indices ranging from 0 to 100, with 0 being the lowest and 100 the highest. For a particular SPU, each of the indicators is ranked through consensus or compromise amongst the participants.

Data Collection

The type of data providing a reasonable assessment of the benefits people derive from CES is fairly diverse. It is still work in progress as the research community continues its efforts on developing a set of useful, practical guidelines to capture them (Brown & Reed, 2012; Ives et al., 2017; Plieninger et al., 2013; Ramírez-Gómez et al., 2017).

In this case, the elicitation follows a deliberative paradigm, to encourage the sharing of information among group members and the building of a shared understanding among participants (Frame & O'Connor, 2011). To this end, semi-structured group interviews were designed following the participatory rural appraisal (PRA) developed by Chambers (1994), in which a group of people are interviewed at the same time and questions and answers between the researcher and the participants are emphasized. In this case, the importance of recording the ranges and spatial distribution of CES through direct communication with the stakeholders (community members) enjoying them is stressed. To ensure the final valuation was as inclusive and representative of the population as possible, it was important to involve members playing different roles in the community (e.g. village leaders, hunters, housewives).

In preparation for the meetings, several questions (Appendix A) were used to facilitate the quantification of the CES identified. To help the participants, the definition of the CES categories were agreed by all at the start of the meetings. The description used the schemes from two sources: the Colombian Ministry of Agriculture (Table 2) and the scheme listed in the Millenium Ecosystem Assestment (MEA, 2005). The definitions of the categories listed in MEA (2005) were adapted as described in Table 3 to ensure the information captured reflected the intended meaning as stated by the participants.

The meetings took place over a period of 30 days between May and June 2014. Information on the perceptions associated to the CES identified, were obtained from those residents who had made use of them for a period of 10 years or more. In total, 69 community members, of which 29 were men and 40 were women, took part voluntarily in these meetings.

At the start of each meeting, the participants were asked which sites, i.e. SPU, were important to their well-being. Each of them was located on a map provided by the researchers for this purpose. The maps used were developed by the communities with the help of the Colombian partner in a preceding collaborative exercise. As the participants were familiar with them, it facilitated the location of the SPU visited to benefit from a cultural service.

Once all the SPU had been clearly identified, the participants ranked each location with regards to its importance, types and frequency of use.The sense of identity, as perceived by the different participants, in relation to each SPU was discussed and consensus was reached on the values that should be assigned to the numeric indicators described earlier, which were used to rank them. Important influences in the formation of a sense of identity with regards to nature are the visual and aesthetic aspect of a place, experiencing nature in individual and community contexts, activities inescapably intertwined with the environment (e.g. fishing), often including interactions with certain species (Russell et al., 2013). All of these aspects are important to a sense of identity and provide insights into the substitutability of the CES under consideration. They also helped to determine the potential for sharing between the communities. In the final stage of the discussion, the moderators attempted to assess the length of time the CES has been valued as such by the communities. This type of information helps provide arguments in favour of the efforts that ought to be made to ensure they are preserved.

Data Analysis

Principal Component and KMO-Bartlett Analyses

Principal Component Analysis (PCA) was used to analyse the numeric indicators recorded for the different CES identified by the participants**,** namely accessibility, substitutability, similarity, pleasurability, aesthetic beauty, and remembrance. The aim of this step was to determine the most common indicators driving the community members in search of a location providing a service. This information gives insight into community preferences and can be useful for more effective sustainable and environmental management and conservation (Bottazzi et al., 2014; Figueiredo et al., 2013; Plieninger et al., 2015; Silvano et al., 2008).

The analysis is complemented with a Bartlett's test of sphericity and an estimation of the Kaiser-Meyer-Olkin (KMO) index (Table 5), a prior step often used to assess the suitability of the data for factor analysis (Williams, et al., 2010). It compares correlation coefficients with partial correlation coefficients providing evidence on the significance of the existing relation between the CES factors identified (Kim & Mueller, 1978). It was used to clarify further which were the most statistically significant CES indicators. Both analyses were performed using functions in the stats and psych packages available in R v 3.2.5

Multiple Correspondence and correlation analyses

Multiple Correspondence Analysis (MCA) was used to analyse the categorical data; this is equivalent to performing PCA on quantitative data (Sánchez, 2015). MCA is a multivariate method tool enabling the analysis of systematic patterns of variations in categorical data. It provides features that represent in graph form the results of the analysis. It was used to detect and represent any underlying structure in the CES perceptions. The active variables were presence/absence of perception of an individual service and the type of ecosystem SPU was included as a supplementary variable. The analysis was performed using functions in the ade4, FactoMineR, and homals packages available in R 3.2.5.

Spatial Analysis using diversity, intensity and richness measures

Through the data collected in the PRA exercises, six annotated maps showing a total of 58 cultural ecosystem service providing units (SPU) were generated, in which the SPUs act as the spatial representation of the CES. The SPUs for each service were grouped in two community clusters and 11 individual communities. These maps were scanned and geo-referenced to MAGNA-SIRGAS/Colombia Bogota Zone as spatial reference system. The information was digitized into vector layers using ESRI's ArcGIS 10.0.

Subsequently, the locations identified by the 69 participants were joined with the layer showing the 400 land cover units (LC) recorded for the lower Caquetá River region. Using the Points in Polygon function available in the QGIS 2.10.1 analysis tools for vector files, the CES map (a point shapefile) was intersected with the land cover map (a polygon shapefile). The resulting map includes the absolute number of perceived cultural services per land unit. QGIS 2.10.1 was used for the spatial analysis, Excel 2007 and R v 3.2.5 2016.04.14 for the statistical analysis. In addition, a mapping of aggregated patterns of CES was conducted following Plieninger et al. (2013), calculating the intensity, richness and diversity of cultural services; as it provides the means to capture spatial information on social landscape values, and its subsequent integration into a geographic information system and (Brown & Reed, 2012; Fagerholm et al., (2012).

Diversity refers to the ratio of entries per land cover type, with the distribution of CES calculated by using the Shannon diversity index (H*). Intensity is the total number of service sites mentioned by the participants, whereas richness is the number of different services per land cover type.. Additionally, the number of entries for each CES per LC type was also calculated**.** All these computations were carried out in Excel after exporting the attribute table of the merged map computed in QGIS 10.2. Entries for each CES were recorded in the following LC types: (1) dense forest on firm highland, (2) dense forest subject to flooding, (3) fragmented forest with pastures and crops, (4) dense shrubland on firm land, (5) mosaic of pastures, crops, and natural areas, (6) rivers (50 meters wide), and (7) secondary vegetation.

Initially, the *resguardo*, community, land cover type and frequency of CES landscape use by the participants were quantified in absolute numbers and in relative proportion. Subsequently, the absolute and relative number of the identified cultural indicators of all participants (n = 69) and the total number of entries (n = 98), as well as the number of associated CES types for each land cover type and landscape feature were listed (Plieninger et al., 2013).

Results

Identification of the most important ecosystem services

During the participatory discussions, we identified 13 SPU (Table 4) and seven categories of CES related to Aesthetics, Education, Cultural Heritage, Inspiration, Recreation, Sense of Place and Spiritual. We found that Education and Recreation are the two most prevalent CES categories in the region, conversely Aesthetics and Cultural Heritage appear to be the least widespread CES categories across both land cover types and *resguardos* (Figure 2, Figure 4 and Figure 5b). Participants might perceive less provisioning of Aesthetics and Cultural Heritage CES as they may become intertwined with other CES or ES in certain places (Schnegg et al., 2014). Alternatively, there might be overlap between services types, as people cannot easily distinguish between them (Plieninger et al., 2013). It demonstrates the challenges related with the attempts of combining traditional and scientific knowledge (Mantyka-Pringle, et al., 2017) showing the importance of both types of knowledge and the need for studies enabling researchers to build bridges between them.

In addition to suggesting Education and Recreation are the most prevalent CES, Figure 3 also shows “dense forest on firm highland” and “rivers” are the two LC types with the largest number of SPUs, and hence the most visited to benefit from different CES. In the case of “dense forest on firm highland”, Education, Inspiration, Recreation, and Spiritual CES all account for more than five SPUs each; meanwhile, Education, Recreation, and Sense of Place are associated with at least five SPUs each in the “rivers” LC. These data indicate that participants obtain varied non-material benefits from these two LC types. Figure 4 (Table 6), shows Education has the most uniform distribution across the different *resguardos*, while the distribution of other CES is not as consistent (e.g., Inspiration or Cultural Heritage).

The results of the KMO analysis and PCA are included in Table 5. The KMO coefficients are all approximately 0.5, which means the data is suitable for factor analysis (Williams et al., 2010) and show that aesthetics and remembrance are the most significant, followed by accessibility and pleasurability.The PCA results show that 4 of the 6 CES categories are necessary to explain 94% of the variance in the data. Therefore, the locations visited to enjoy CES are all highly valued, at least in relation to the indicators recorded.

Figure 5a shows that water jets, streams, and brooks (SPU) offer the greatest number of CES of all landscape features, which demonstrate the particular value the communities place on them. Furthermore, these bodies of water are sources of important activities needed by the communities such as fishing and transport. Figure 5a also suggests the locations are used for more than one purpose.

The MCA map (Figure 6, Table 6), show the CES are well distributed across the communities; i.e. within the categories covered, all communities managed to identify a location in which they benefited from at least one CES. The clusters in Figure 6 indicate that each community tends to enjoy the benefits in specific locations, which differ among the communities. This seems to suggest that if one community were to lose access to a particular service, it is not clear if its members would be willing to travel further away to enjoy it.

Diversity, Intensity and Richness

Figure 6 also shows the location of the CES is evenly distributed between land and water indicating once more the importance of the river Caquetá. This confirms the results from the diversity, intensity and richness measurements (Figure 7). Of all the land cover types recorded in the region, there are three associated with moderate CES diversity (Figure 7a); namely, the “dense forest on firm highland”, “dense shrubland on firm land” and “river”. The most diverse is the “dense forest”, closely followed by “river”. With regards to intensity (Figure 7b), “dense forest on firm highland” has the highest value, providing considerably more CES to local community members than other land cover types. In contrast, “dense forest subject to flooding” and “fragmented forest with pastures and crops” show the lowest intensity. Finally, in terms of CES richness (Figure 7b), both “dense forest on firm highland” and “dense shrubland on firm land” present the highest richness (roughly seven CES/land unit). They are closely followed by “river”, which corroborates the importance of the river Caquetá. On the other hand, “dense forest subject to flooding” and “fragmented forest with pastures and crops” display the lowest richness (approximately 15 CES/land unit for both).

Discussion

Existing CES of the Amazonian indigenous population

The results generated demonstrate the abundant non-material and cultural benefits the indigenous communities of the Colombian Amazon obtain from the region. All communities use locations for all the categories of CES covered in the MEA scheme which demonstrates how their lives are strongly integrated with their natural surroundings (Figure 5b); similar results are described by Boillat & Berkes (2013) who acknowledge the importance of indigenous knowledge and the need of finding new ways to observe, discuss, and interpret this information.

Differences appear between the distributions of the CES enjoyed by each community. The number of educational CES is highest for all communities except Angostura, while inspirational and recreational CES are the second and third most frequently enjoyed by the communities of Bocas del Mirití, Borikada, Camaritagua and Yucuna. In the case of Madroño, recreation and education are the most numerous CES. The relevance of Education across all communities can be explained considering the importance that elder members associate to the task of passing their traditions to younger generations (Berkes, 2009; Martin et al., 2010). As the topics taught cover a wide spectrum (rituals, ceremonies, hunting/fishing techniques) most of the places mentioned were serving a dual role. For example, a place can provide recreation and at the same time be used for educational purposes, as it is the place where youngsters are taken to learn the skills of the trade, e.g. what they need to know to become a successful local guide. The little interest in Aesthetics and Cultural Heritage might be caused by miscommunication given that the moderators had trouble explaining the western perspective of these two types of CES (Fagerholm & Käyhkö, 2009; Raymond et al., 2010; Soini & Birkeland, 2014; Valdivia et al., 2010). This highlights the importance of 'cultural translation' to ensure survey materials have the same meaning in both cultures, furthermore it corroborates the importance of integrating both, scientific and traditional knowledge as ascertained in other studies (Cummings & Reed, 2016; Mantyka-Pringle et al., 2017).

Figure 4 shows how the presence of each CES type is distributed across the five *resguardos* involved in the study. Comeyafú as a territorial group has the highest number of CES when compared to the others, while Madroño has the lowest number. There are two reasons for this: in the first place, Comeyafú is the *resguardo* with the highest population whilst Madroño has the smallest one. In the second place, mostly non-indigenous inhabitants, foreigners looking for opportunities, populate the latter. Hence their take on CES (traditions and sense of place) is likely to be very different from that of the indigenous tribes. The correlation between population size and the number of services enjoyed is also evident in similar studies conducted in other communities (Plieninger et al., 2013; Ramírez-Gomez et al., 2017, Sallis et al., 2006;).

Contributions to community-based management and institutions

Concerns on resources availability in La Pedrera have led to the formulation and implementation of management plans, which regulate the sustainable use of the land and resources amongst indigenous communities (Chaparro, 2007; Ramírez, González & Chavarría, 2015). This study demonstrates the richness and diversity of CES, information that up to now, at least to our knowledge, is not part of these plans. It is possible to record the prevalence of some CES, which means this gap in current plans should be addressed soon. The cultural significance of the Caquetá river should be brought to the notice of the government, as it might help push forward measures to control the current practices which are having a detrimental effect on the proper functioning of this ecosystem. Specific threats such as river pollution from upstream gold mining, overfishing, and changes in river seasonality due to climate change have been described in other studies (Castello et al., 2011; Hurd et al., 2016; Pérez-Rincón, 2014; Portocarrero-Aya & Cowx, 2015; Ramírez-Gómez et al., 2015), thus strengthening the argument for improving the current environmental management plans implemented in the region.

Usefulness of this approach in marginalized regions with poor data availability

The approach discussed is useful to assess CES in indigenous communities for six main reasons: (i) The combination of methods provide land use data that enables CES studies to be holistically traced to a more data-efficient and land user friendly approach (Oestreicher et al., 2014); (ii) The mapping process generates conversations between stakeholders, which ultimately can have a community empowerment effect (Hirons et al., 2016; Ramírez-Gómez et al., 2013; Ramírez-Gómez et al., 2015). For example in La Pedrera, the participants discussed what was being mapped, access to natural resources, and locations, and therefore gained more awareness about their shared values through the conversations that took place during the meetings; (iii) The participatory approach helps to legitimate traditional knowledge within a scientific and policy driven framework (Brown & Donavan, 2014; Cummings & Read, 2016; Gómez-Baggethun et al., 2013); (iv) The combination of multivariate methods supports the quantification of CES (Hirons et al., 2016; Oestricher et al., 2014; Plieninger et al., 2013). For example, the use of the measurements of diversity, intensity and richness provides the means to describe the distribution of CES across the region, facilitating the identification of the most important ones. Furthermore, the findings may be applicable in a wider context, e.g. communities located in more populated regions with a completely different cultural background, as described in Plieninger et al. (2013); (v) Reaching similar conclusions through the application of different methods has the benefit of enabling validation in addition to providing a different perspective on the data recorded (Creswell, 2013); (vi) The spatial analysis is key to visualizing and achieving a better understanding of SPUs as it allows communities to effectively target the sustainable use of ES in the region (Bagstad et al., 2017; Campbell et al., 2012; Figueiredo et al., 2013; Ramírez-Gómez et al., 2017; Silvano et al., 2008).

The benefits of using participatory approaches to enable communities located in marginalized regions, to design and develop better practices to manage the ES on which they depend, has been corroborated by other studies (Bottazzi et al., 2014; Ives et al., 2017; Ramírez-Gómez et al., 2013). However, it is perhaps still too early to ascertain the long-term effect such approaches could have on the success, or otherwise, of governmental management plans.

Limitations of this study

One constraint of this study is that we focussed on those CES that can be repeatedly mapped in the same geographic locations. However, many CES are not static in time or space. For example, animals may provide CES (e.g. education, inspiration and spirituality) but cannot be mapped because they move. Thus, our study has only captured a subset of the CES that people obtain from their local landscapes; this must be borne in mind, particularly when attempting to include the results in the decision making efforts associated with local and regional management plans affecting these communities.

Furthermore, another limitation of this study is the limited inference power for the whole study area. Although the method described appears to provide useful input for environmental management planning, barriers to use (e.g. regulatory approval) are necessary and probably difficult to achieve (Brown & Donovan, 2014, Hirons et al., 2016).

While it has been possible to identify the CES, the results generated are not providing an accurate measure of the spiritual or aesthetic fulfilment as perceived by those benefiting from their use. In order to enable this type of assessment, more extensive data collection and analysis is needed, in addition to better communication and understanding between the researchers and the communities involved. These limitations might be overcome with more time and resources for data collection (e.g., involvement of cultural interpreters) to address the challenges linked to cross-cultural research (Chan et al., 2012b; Gilmore et al., 2013; Gómez-Baggethun et al., 2013; Ramírez-Gómez et al., 2017). Additionally, it would be advantageous to recognize that spiritual fulfilment is a particularly sensitive issue for some indigenous communities, rarely discussed outside their own spatial and temporal context, which often includes preventative measures regarding disclosure to outsiders. We must accept that even though it would be useful to measure spiritual fulfilment when informing environmental management plans, it might not always be possible to do so. In those cases, a better understanding of the communities' viewpoint must be brought to bear, including their interdependence with those CES that are quantifiable.

The indefinite spatial properties of the "service providing units" (SPU) of CES represent additional challenges. As most of them are related to specific landscape attributes, the sites were pre-identified according to LC units. However, certain cultural services such as inspiration are not intuitively associated with any particular landscape attribute (Plieninger et al., 2013), which may have biased the results. Nevertheless, as the links between culture, values, nature, well-being and politics are much more complex than most articulations of ES concede (Ives et al., 2016), the method described shows a way of given them presence for their integration with other relevant ES, and build a model to simulate policy scenarios, highlighting trade-offs across the full spectrum of ES applicable to the region. It also gives a "voice" to the rural communities who have the highest risk of loosing the benefits derived from the intangible services we have attempted to capture.

The neglect of ecosystem disservices could be problematic as the optimisation of specific ES may simultaneously exacerbate associated disservices. Given the absence of an accepted typology for ecosystem disservices (Shackleton et al., 2016) and the difficulty of clarifying the meaning of the services identified in the study with the people involved, a future improvement on the current method would be to build such a typology in the context of rural communities in the Amazon.

At present, lack of data to verify the results is an ongoing limitation in all studies of this nature (Jacobs et al., 2015; Maes et al., 2013; Raymond et al., 2014; Ramírez-Gómez et al. 2017; Tengberg et al., 2012). Even though there are multiple sources of uncertainty associated with any type of ES assessment (e.g. data scarcity, functional knowledge gaps, social trade-offs, normative and value-laden arguments) as discussed in Jacobs et al. (2013), it is necessary to continue investigating even without a guarantee of reaching a consensus, as this enables progress in complex situations (e.g., lack of data, knowledge or "hard" proof) (Jacobs et al., 2015). In the particular case of CES, in spite of the rapid advancement in developing non-monetary techniques for the assessment of their social value, further research is needed to evaluate their underpinning paradigms (Cummings & Read, 2016; Raymond et al., 2014). For this reason, as this type of studies are rare and poorly integrated into existing ecosystem services assessments (Ives et al., 2017), the method described constitutes a useful way to begin bridging the gap in this research field.

Conclusion

As populations and the demand for multiple ecosystem services increase, there is a growing need to integrate both local and scientific knowledge about ecosystem services in a way that is accessible to decision-makers at all levels. We have shown it is possible to identify the benefits people derive from the CES they have access to. The approach can be useful for helping indigenous communities visualize which areas are important to them from a cultural perspective, opening a feasible path to integrate it with the information gathered about other types of ES, particularly in those approaches that take a holistic view on management (Hirons et al. 2016; Villa et al., 2014; Ramírez-Gómez et al., 2015; Ramírez-Gómez et al. 2017).

Qualitative methods can be used as an initial step to determine the cultural value and social preferences in terms of ES. The data generated can be used in a preparatory stage, before proceeding to gather the information necessary for the quantification of the services identified. This study provides the communities with a tool to ensure their tradition and knowledge are evaluated at an equal footing with the interests of other external groups, given that: (1) It provides the means to identify the existing CES of the Amazonian indigenous population that live in La Pedrera. (2) It includes a spatial representation of the CES as SPUs; valuable information that ought to be part of any environmental plan to ensure they are given due consideration in the organization of the indigenous territory identified in La Pedrera. Bearing in mind there will be other criteria, such as their effect on provisioning, regulating, supporting services, which also need to be taken into consideration. (3) It provides outputs, which can be used in studies aiming to determine how enhancement of human well-being can be coupled with upkeep or improvement of CES, for example, if an area of high spiritual value (e.g. an ancestral forest) is identified for the protection of an endangered species and a plan is designed to restrict all human access for this purpose, the results would highlight the need for designing less drastic measures (i.e. no access).

Although there is a scarcity of written evidence enabling us to corroborate the results obtained by estimating the CES diversity index, its usefulness in assessing the CES enjoyed in another region (as discussed in Pleinenger et al., 2013), the consensus reached by the participants during the meetings carried out in this study, and the qualitative and quantitative data that was collected and analysed, provide a high level of confidence in its potential use as indicator for the purposes described.

Spatially explicit information on cultural ecosystem services, which incorporates the differentiated perceptions of local populations, provides a rich basis for the development of sustainable land management strategies. These could realign the agendas of biodiversity conservation and cultural heritage preservation, which currently direct the management strategy of the Amazon (Harmon, 2007; Hermoso et al. 2016).

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Table 1. Indigenous communities involved in the study grouped by their *resguardo*

Resguardo	**Communities**				**Population**	**Area (ha)**
Puerto Córdoba	Puerto Córdoba	Loma Linda	Bocas del Mirití		212	46897
Curare-Los Ingleses	Curare		Borikada		263	237643
Comeyafú	Tanimuca	Yucuna	Angostura	Bacurí	520	19023
Camaritagua	Camaritagua				64	8456
Vereda Madroño	Constituted mainly by "non-indigenous inhabitants" (arriving 25-30 years ago attracted by the gold fever in the municipality of Taraira. They settled in the region, forming families (frequently with indigenous women)				56	20351

Table 2. Classification scheme for locations that have an importance for the Siona Indigenous communities (Ministerio de Cultura, 2014)

Type	**Definition**	**Topographic Location**
Prohibited	Areas where activities such a hunting, fishing, foraging, logging, cultivation are not allowed. The regulations are set because these places are considered to be inhabited by the creators	Chorros, lakes, lagoons, streams, mountains, salados, places of origin, cementaries, paths and hills
Enchanted	Locations recognized by the indigenous culture as areas which cannot be entered without the necessary permits being issued by spiritual beings through specific rituals of cleansing, purification and harmonization.	Putumayo river, Sucumbios Garden, lakes, lagoons, mountains, virgin forest
Communal	Locations which a community, village or social group have assigned to conduct conservation and productive activities, renovation rituals, festivities or cleansing rituals	Farms, stables, allotments to grow household produce or medicinal plants

Table 3. Definition of CES categories as agreed in meetings with the communities (adapted from MEA 2005 scheme)

CES	**Definition**	**Example of CES identified in La Pedrera**
Aesthetic	People perceive the aesthetic value of a place considering different aspects of the ecosystems. This is reflected in their support for preserving the national parks, the care taken to select the place to build their dwellings or in the routes designed to enjoy the natural beauties of the area.	Peaceful locations where it is possible to enjoy nice views of the forest and the running of clear water courses, maybe see animal species

CES	Definition	Example of CES identified in La Pedrera
Cultural heritage	Many communities value the protection of certain locations due to their historic importance (cultural landscapes) or due to the existence of species that hold cultural importance. The diversity of ecosystems is considered an important factor, which contributes to the diversity of cultures.	As there has been little intervention in the region, there are areas, which are considered cultural icons, such as the Yupatí Hill or lakes that hold a diverse number of aquatic species.
Education	The ecosystems, their components and processes constitute the main knowledge, which many communities aim to transmit to future generations through education, both formally and informally. Furthermore, the ecosystems themselves influence the knowledge systems developed by different cultures.	Overall, the communities depend on the different elements the surrounding forest offers. For this reason, any activity taking place in the forest is closely linked to the acquisition of the knowledge needed to survive, such as hunting and fishing practices, or the best places to visit to profit from them.
Inspiration	Ecosystems are a rich source of inspiration in art, folklore, national symbols, architecture and marketing	The locations linked with seasonal changes in the crops trigger the initiation of rituals to demonstrate their gratitude for the benefits they will derive
Recreation (ecotourism)	Community members tend to spend their leisure time in certain locations, which are selected because they constitute landscapes of natural or cultivated beauty.	Locations associated with peacefulness or which people tend to visit to enjoy time with their families.
Sense of Place	The concept of sense of place in relation to an ecosystem is closely linked with characteristics that make a location unique, in addition to promoting strong feelings of belonging in the people that visit them.	All the locations of importance in the region, such as the Yupatí Hill were labeled as providing this unique feeling
Spiritual	Many communities endow both ecosystems and their components with spiritual value.	The prohibited locations are examples of locations providing this CES. It can be negative (affecting the health of the visitor) or positive when they have been adequately “blessed” by the community member who has the authority to do so.

Table 4. Description of Service Providing Units (SPU) with defining landscape features (Angarita-Báez, 2016)

SPU	Definition of landscape features
Cananguchal	Vegetation formations with a homogenous composition and structure where the Canangucho palm (*Mauritia flexuosa*) is highly predominant. It grows on hydro-morphological soils with poor drainage, which are generally classified as flood plains (Triana Gómez, 1998).
Cerro Yupatí (Yupatí Hill)	Approximately 340m in height and part of the La Pedrera geological formation. Located between the Comeyafú and Angostura communities.
Chorros (Water Jets)	Rapids that appear throughout the length of the river Caquetá triggered by the presence of large rock formations that affect the speed of the water flow. In many cases, it restricts the exchange of goods taking place between the communities, as the river is the main route for transport.
Islas (Islands)	Areas located in flood plains with a tree cover of moderate height, predominantly Yarumo (*Cecropiaceae*). The nutrients supplied during the periodic flooding of the river make the soils in the area highly fertile (Alarcón-Nieto & Palacios, 2005)
Lagos (Lakes)	Bodies of water that become larger with the increase of the river Caquetá's flow. The lakes created because of the river's meandering behavior are known in the region as "Black waters", due to the sediment and biomass found in the lake floor in various degrees of decomposition
Puerto Caimán	Conservation area created to help preserve the different fauna inhabiting the area. Hunting is not allowed.
Caños (Brooks) y Quebradas (Streams)	Small to medium watercourses distributed throughout the Amazon jungle that can change from a virtually dry river bed to a raging torrent in a matter of hours during a heavy downpour. Their water level is linked to the floods in the Caquetá river
Salados (Saltlicks)	Areas located in the middle of the rain forest characterized by short vegetation with a dominance of marshes rich in black soil, the water flowing from them is dark, has a high content of salts with a particularly bitter taste. Regularly visited by different species of animals (Molina González, 2010).
Sabana	Savanna-like enclaves with short trees and open canopy, and shrubby vegetation, surrounded by closed canopy (tall forest)
Caqueta River	The Caqueta River rises in the Colombian Massif and carries an enormous amount of suspended material and nutrients to the long course, making its waters appear as white. It is the main provider of transport and fish in this area of the Amazon

SPU	Definition of landscape features
Playa de río (beach)	A beach is a deposit of unconsolidated sediments that vary between sand and gravel, in the Caqueta river it is common to see them when the level of the river descends, in addition, it is known that some species of turtles disobar in them.
Curare	Sacred site that is currently inhabited by the community thanks to a spiritual permit granted to the inhabitants of the area

Table 5. Principal Component Analysis (PCA) on six indicators. PCA Cumulative Variance was complemented with KMO-relative coefficients

Rotated components matrix				**Variance coefficients**	
Indicators	**PCA Analysis**				**KMO**
	1	2	3	Cumulative variance	Coefficients
Accessibility	0.801	0.472	-0.081	50.341	0.488
Substitutability	-0.151	-0.012	0.936	73.113	0.378
Similarity	0.509	-0.078	0.707	87.328	0.447
Pleasurability	0.331	0.796	0.076	94.693	0.485
Aesthetic Beauty	-0.145	0.820	-0.119	99.325	0.598
Remembrance	-0.825	0.073	-0.074	100.000	0.558
Rotation Method: Varimax Normalization using Kaiser					

Table 6. Legend for symbols in MCA map (See Figure 4 and Figure 6)

Resguardo/Vereda	**Code_R**	**Community**	**Code_comm**	**CES type**	**Code_CES type**
Camaritagua	Camr	Camaritagua	Cam	Aesthetics	Aes
Comeyafú	Cmy	Angostura	Ang	Educational	Edu
		Bacurí	Bac	Heritage cultural	Her
		Tanimuca	Tan	Inspirational	Ins
		Yucuna	Yuc	Recreational	Recr
Curare-Los Ingleses	Cr_LI	Borikada	Brk	Sense_of_Place	SoP
		Curare	Cr	Spiritual	Spt
Puerto Córdoba	P_C	Bocas del Mirití	B_d_M	**U_P_TYPE**	
		Lomalinda	LmL	Land	
		Puerto Córdoba	P_Co	Water	
Vereda Madroño	V_M	Madroño	Mdr	U_P	

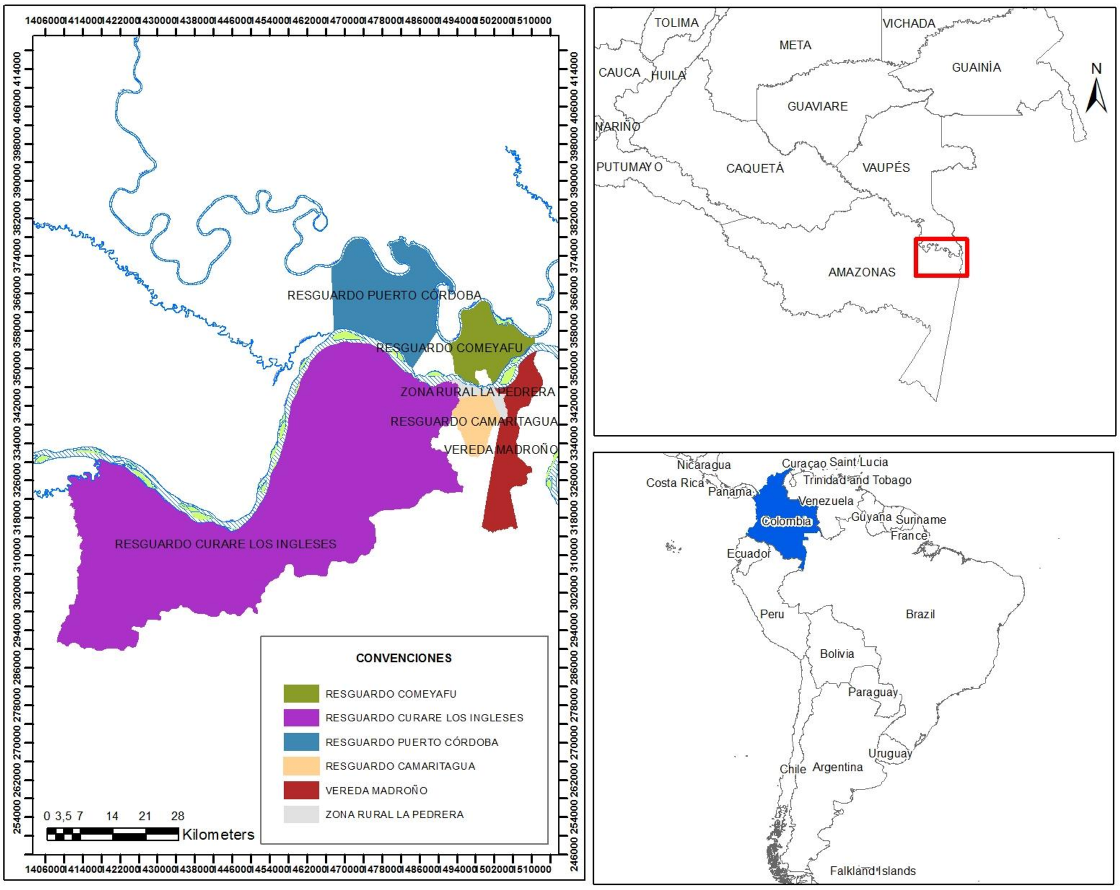


Figure 1. Geographic distribution of the *resguardos* within the La Pedrera *corregimiento* along the Lower Caquetá River region in the Amazonas Department in Colombia (Lat: -1.25, Long: -69.6 (1° 15′ 0″ S, 69° 36′ 0″ W)). Underlying cartography Conservation International - Colombia. ArcGis.

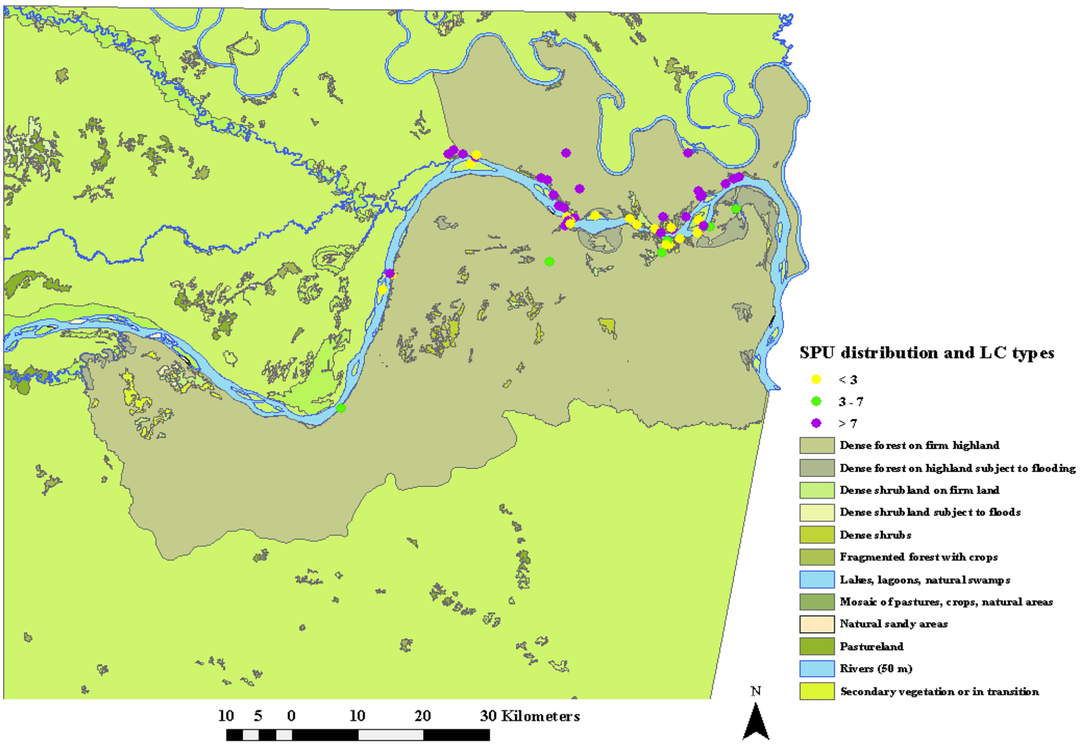


Figure 2. Geographic distribution of Service Providing Units (SPU) in Land Cover Map. ArcGis.

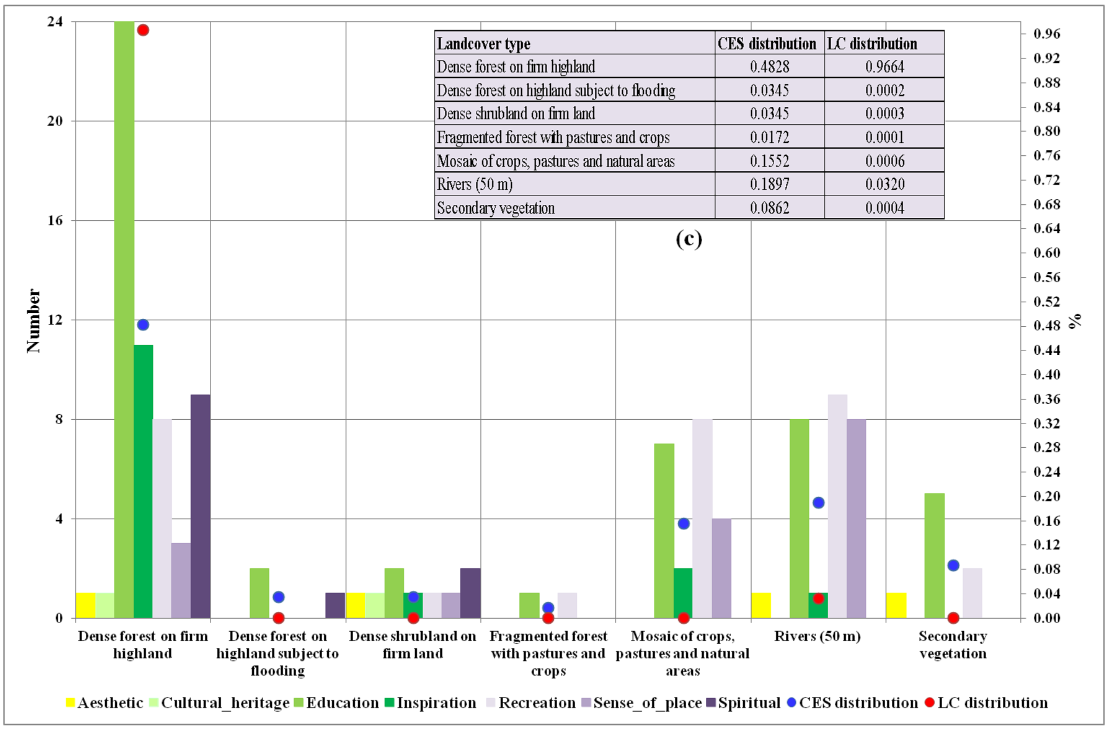


Figure 3. Distribution of Service Providing Units (SPU) across LC types and CES categories (MEA-2005). (a) CES distribution across LC (X-axis: LC types, Y-axis:

number of CES). (b) Distribution of CES types identified within each "resguardo" (X-axis CES types, Y-axis Number SPU). (c) Distribution of CES across LC types, distribution of LC type coverage in region . Symbology (Table 5)

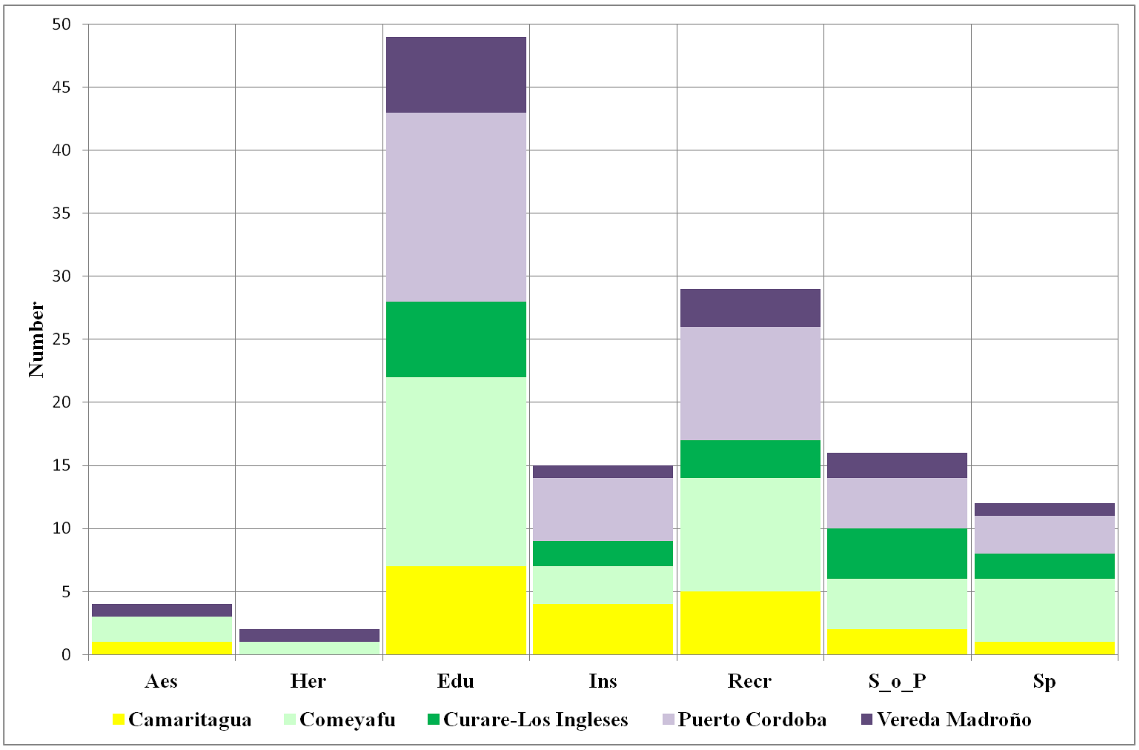


Figure 4. Distribution of CES categories across each *resguardo* in La Pedrera (X-axis=CES types, Y-axis=Number of SPU), see Table 6.

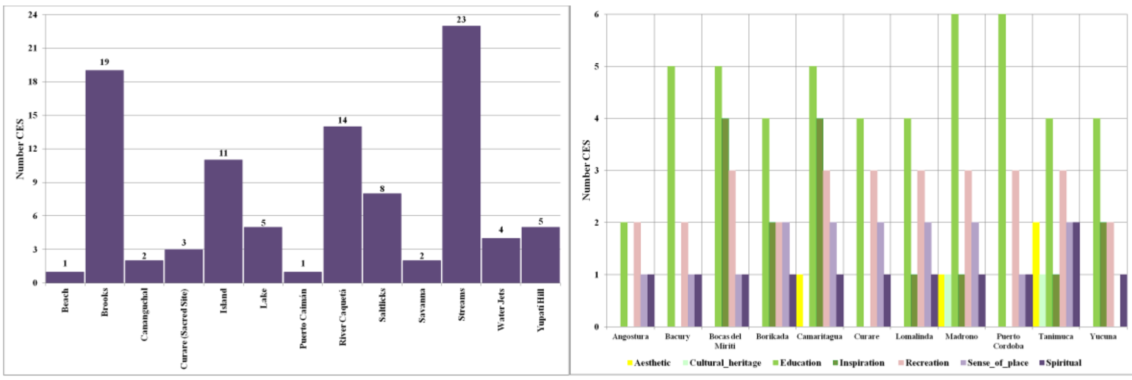


Figure 5. a).Distribution of CES across landscape features (SPU) The X-axis=SPU; Y-axis=number of CES. b). Distribution of CES types across the communities (X-axis=community; Y-axis=number of SPU) (for details on each type of feature see Table 4).

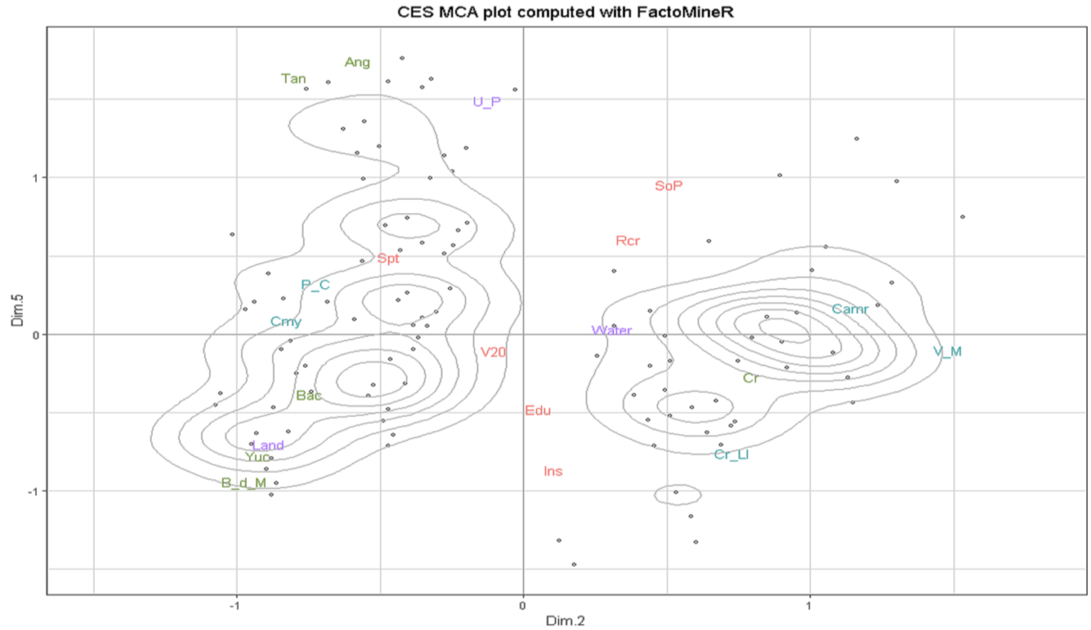
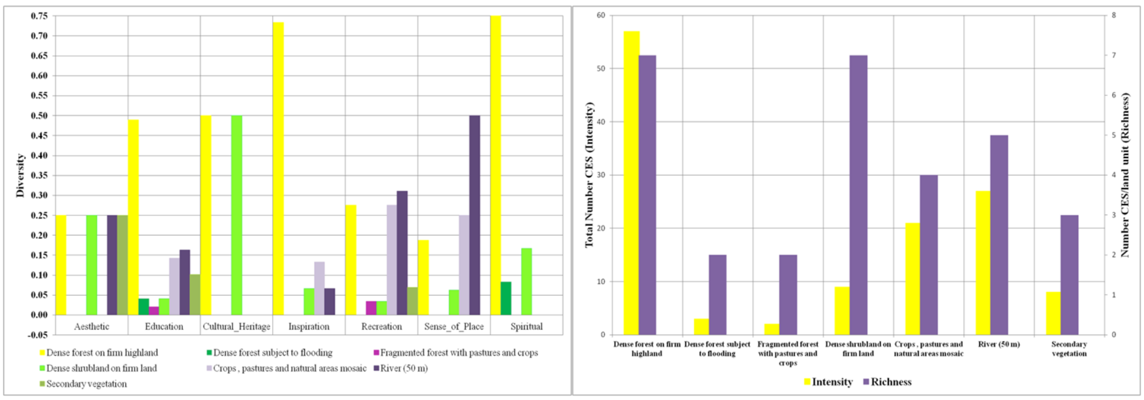


Figure 6. Multiple Correspondence Analysis (MCA) map for CES type, Community and Service Provisioning Unit (details of symbols in Table 6). The labels correspond to the communities (green), the *resguardos* (blue), presence of CES type (red), and the SPU type (purple) associated to the CES identified. Moreover, since some observations overlap, density curves were added to see those zones that were highly concentrated.



(a) (b)

Figure 7. Statistical analysis computed according to method described in Plieninger et al. (2013) for (a) CES diversity in La Pedrera (b) CES Intensity and Richness in La Pedrera.

Appendix A

Questionnaire designed for the meetings is part of the Supplementary material accompanying this publication