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

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ABSTRACT
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 (SPUs) 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 which have for the local communities involved in the study and may assist in the management of the indigenous territory.

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, 2015; Navarrete et al. 2016), and uncontrolled and unplanned urban growth (Ferraz et al. 2008; Fundación Alisos 2011; Angarita-Baéz 2016). 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 and supporting and cultural services. In this manner, and by carefully evaluating social-ecological systems, it will be possible to preserve or improve ES whilst at the same time increasing human well-being (MEA, 2005; Carpenter et al. 2009; De Groot et al. 2010; 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 (Tallis et al. 2008; Bennett et al. 2009; Raudsepp-Hearne et al. 2010; Dearing et al. 2012; Poppy et al. 2014). 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’ (ME 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, 2012a). These are intimately linked to the satisfaction of a human’s basic needs (MEA 2005; Balvanera and Cotler 2007; De Groot et al. 2010). The importance of traditional cultural practices, which contribute to a community’s social, economic and ecological sustainability (Neff 2011; Plieninger et al. 2015) is often difficult to ascertain or even measure. However, traditional cultural practices are reflected in the strategies, symbols 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).

Whilst 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, whilst Norton et al. (2012) integrated quantitative and qualitative data on eight CES. Although many scholars (Norton and 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 (Ulloa 2009; Hirons et al. 2016). There is mounting evidence demonstrating their importance 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 (Folke et al. 2002; Butler and Oluocho-Kosura 2006; Cummings and Read 2016). 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 and Fagerholm 2015; Plieninger et al. 2015; Cummings and Read 2016; Hirons et al. 2016; Ives et al. 2017; 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 (Chan et al. 2012b; Brown and Fagerholm 2015; 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 (Silvano et al. 2008; Macia et al. 2011; Briggs et al. 2013; Figueiredo et al. 2013; Bottazzi et al. 2014; Câmara-Leret et al. 2014; Celentano et al. 2014). Studies incorporating community stakeholders’ knowledge have also been conducted in Africa (Chalmers and Fabricius 2007; Fagerholm and Käyhkö 2009; Sileshi et al. 2009; Fagerholm et al. 2012; Schnegg et al. 2014) All the aforementioned studies demonstrate that traditional knowledge should be a key component of decision-making. They also show the importance of identifying in 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 provide empirical evidence on the wide range of activities in which the communities engage, whilst the qualitative data help 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 were combined with a set of social landscape metrics (Brown and Reed 2012), estimated following the method described in
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 that 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 as follows: 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 (DANE 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 (DANE 2009; Ramirez-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 (Carrizosa 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 (Carrizosa Umaña 1989; De H.E.E.D.S. 2007; Dias 2009; Figueiredo et al. 2013; Hurd et al. 2016). 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 socioeconomic 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 socioeconomic 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 (SPUs) according to Luck et al. (2003) and Syrbe and Walz (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 SPUs identified were examined in relation to the following six numeric indicators: accessibility, substitutability, similarity, pleasurable (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 particular SPUs, 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 and Reed 2012; Plieninger et al. 2013; Ives et al. 2017; Ramirez-Gómez et al. 2017).

In this case, the elicitation follows a deliberative paradigm, to encourage the sharing of information amongst group members and the building of a shared understanding amongst participants (Frame 1991). 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).

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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    | 212        | 46,897    |
| Curare-Los Ingleses| Curare            | 263        | 237,643   |
| Comeyafú           | Tanimuca          | 520        | 19,023    |
| 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         | 20,351    |
Many communities value the protection of certain locations due to their historic importance. Ecosystems are a rich source of inspiration in art, folklore, national symbols, architecture and education. Many communities endow both ecosystems and their components with spiritual value. Community members tend to spend their leisure time in certain locations, which are considered inhabited by the creators of the surrounding land and where the necessary permits being issued by spiritual beings through specific rituals of cleansing, purification and harmonization.

**Definition**

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. Overall, the communities depend on the different elements the surrounding forest offers. As there has been little intervention in the region, there are areas, which are considered necessary permits being issued by spiritual beings through specific rituals of cleansing, purification and harmonization.

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

| Type            | Definition                                                                 | Topographic Location                  | Example of CES identified in La Pedrera |
|-----------------|---------------------------------------------------------------------------|---------------------------------------|----------------------------------------|
| Prohibited      | Areas where activities such as hunting, fishing, foraging, logging and 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, cemeteries, paths and hills | Putumayo river, Sucumbios Garden, lakes, mountains, virgen forest |
| 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. | Farms, stables, allotments to grow household produce or medicinal plants | Farms, stables, allotments to grow household produce or medicinal plants |
| Communal        | Locations which a community, village or social group have assigned to conduct conservation and productive activities, renovation rituals, festivities or cleansing rituals. | Peaceful locations where it is possible to enjoy nice views of the forest and the running of clear water courses, maybe see animal species | Peaceful locations where it is possible to enjoy nice views of the forest and the running of clear water courses, maybe see animal species |

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 was 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 Millennium Ecosystem Assessment (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 with the CES identified was 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, that is, SPUs, 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 SPUs visited to benefit from a cultural service.

Once all the SPUs had been clearly identified, the participants ranked each location with regard 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 regard 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 have 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 (Silvano et al. 2008; Figueiredo et al. 2013; Bottazzi et al. 2014; Plieninger et al. 2015).

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 and 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 the presence/absence of perception of an individual service, and the type of ecosystem SPUs 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 (SPUs) 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 and Reed 2012; Fagerholm et al. 2012).

Diversity refers to the ratio of entries per land cover type, with the distribution of CES calculated
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, and 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 5(b)). 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 that are the most prevalent CES, Figure 3 also shows that ‘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 that education has the most uniform distribution across the different resguardos, whilst 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 that the data are 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 four of the six 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 5(a) 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 5(a) also suggests that the locations are used for more than one purpose.

The MCA map (Figure 6, Table 6) shows that the CES are well distributed across the communities, that is, 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 amongst the communities. This seems to suggest that if one community was 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 that 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 7(a)), 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 regard to intensity (Figure 7(b)), ‘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 7(b)), both ‘dense forest on firm highland’ and ‘dense shrubland on firm land’
Table 4. Description of Service Providing Units (SPU) with defining landscape features (Angarita-Báez 2016).

| SPU                  | Definition of landscape features |
|----------------------|----------------------------------|
| Cananguchum          | 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 Yupati (Yupati Hill) | Approximately 340 m in height and part of the La Pedrastra geological formation. Located between the Coyeyafí 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 and 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 behaviour 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. |
| Carros (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. |
| Playa de río (beach) | A beach is a deposit of unconsolidated sediments that vary between sand and gravel, in the Caquetá river, it is common to see them when the level of the river descends, and in addition, it is known that some species of turtles disobl 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-rela-
tive coefficients.

| Indicators          | 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 | 94.639             | 0.485        |
| Aesthetic           | −0.145 | 0.820 | −0.119 | 99.325             | 0.598        |
| Beauty              | −0.825 | 0.073 | −0.074 | 100.000            | 0.558        |

Rotation Method: Varimax Normalization using Kaiser

Present the highest richness (roughly seven CES/land units). 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 units 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 5(b)); similar results are described by Boillat and 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, whilst 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 with 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, for example, 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 and Käyhkö 2009; Raymond et al. 2010; Valdivia et al. 2010; Soini and
This highlights the importance of 'cultural translation' to ensure that 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, whilst 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 (Sallis et al., 2021).
2006; Plieninger et al. 2013; Ramírez-Gomez et al., 2017).

**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 et al. 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 that 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; Pérez-Rincón 2014; Portocarrero-Aya and Cowx 2015; Ramírez-Gómez et al. 2015; Hurd et al. 2016), 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 provides land use data that enable 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 (Ramírez-Gómez et al. 2013, 2015; Hirons et al. 2016). 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 (Gómez-Baggethun et al. 2013; Brown & Donavan, 2014; Cummings and Read 2016); (iv) the combination of multivariate methods supports the quantification of CES (Plieninger et al. 2013; Oestricher et al., 2014; Hirons et al. 2016). 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, for example, 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 (Silvano et al. 2008; Campbell et al. 2012; Figueiredo et al. 2013; Bagstad et al. 2017; Ramírez-Gómez et al. 2017).

The benefits of using participatory approaches to enable communities located in marginalized regions, design and develop better practices to manage the ES on which they depend have been corroborated by other studies (Ramírez-Gómez et al. 2013; Bottazzi et al. 2014; Ives et al. 2017). However, it is perhaps still too early to ascertain the long-term effect such approaches that 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 and Donovan 2014; Hirons et al. 2016).

Whilst 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 are 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. 2017), the method described shows a way of giving them presence for their integration with other relevant ES and builds 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 optimization 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 (Tengberg et al. 2012; Maes et al. 2013; Raymond et al. 2014; Jacobs et al. 2015; Ramírez-Gómez et al. 2017). 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 (Raymond et al. 2014; Cummings and Read 2016). For this reason, as this type of studies is 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 that 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 in 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 (Villa et al. 2014; Ramirez-Gómez et al. 2015, 2017; Hirons et al. 2016).

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 that 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 and 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 were 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).

**Acknowledgements**

This work took place under the ‘Attaining Sustainable Services from Ecosystems using Trade-off Scenarios’ project (ASSETS; http://espa-assets.org/; NE-J002267-1), with funding from the United Kingdom’s Ecosystem Services for Poverty Alleviation program (ESPA; www.espa.ac.uk). ESPA receives its funding from the Department for International Development (DFID), the Economic and Social Research Council (ESRC) and the Natural Environment Research Council (NERC). We are grateful to La Pedrera’s Association of Indigenous Communities (AIPEA, acronym used in the Spanish denomination) and the traditional authorities for their support. We would also like to express our gratitude to the communities who participated in the study and to the anonymous reviewers for their insightful comments on an earlier draft of this paper.

**Disclosure statement**

No potential conflict of interest was reported by the authors.

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Appendix A

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