



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

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

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31

## 32 **Assessing and mapping cultural ecosystem services at community level** 33 **in the Colombian Amazon**

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

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

### 50 **Introduction**

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

61 the ecosystem services (ES) on which the well-being of the region's local communities  
62 is contingent.

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

76 In this study, we focus specifically on cultural ecosystem services (CES), which  
77 comprise “the non-material benefits society derives from an ecosystem, as manifested  
78 through the spiritual fulfilment, cognitive development, recreational or aesthetic  
79 fulfilment described by any individual that has access to the service” (MA 2005). The  
80 CES are alternatively defined as the contribution of ecosystems to non-material benefits  
81 such as capabilities and experiences, which result from human-ecosystem relationships  
82 (Chan et al. 2011, Chan, 2012a). These are intimately linked to the satisfaction of a  
83 human's basic needs (Balvanera & Cotler, 2007; De Groot et al., 2010; MA, 2005). The  
84 importance of traditional cultural practices, which contribute to a community's social,  
85 economic and ecological sustainability (Neff, 2011; Plieninger et al. 2015) are often

86 difficult to ascertain or even measure. However, traditional cultural practices are reflected  
87 in the strategies, symbolisms and tools communities design to perform their tasks. For  
88 example, traditional knowledge reveals cultural links and interdependence between  
89 indigenous communities and nature. One example of this interdependence is the local  
90 knowledge on location and movement, which explains the spatial patterns of the  
91 ecosystems, including sequence of events, cycles and trends. These direct links with  
92 nature are essential to ensure an individual's and a group's sense of place (Posey, 1999).  
93 Another example is that traditional knowledge on biodiversity consists of a socially  
94 regulated and complex set of values, practices, technologies and innovations, which have  
95 been developed by communities through time as they learnt to live in intimate contact  
96 with their natural surroundings. Traditional agricultural practices, fishing techniques,  
97 natural medicine and hunting methods constitute direct manifestations of this knowledge,  
98 which is embedded in the communities because it is valuable in ways both tangible (e.g.,  
99 instrumental) and intangible (e.g., reinforcement of kinship worldview related to the  
100 relationship between people and nature) (Sánchez, 2003).

101         While the application of the ES framework and the assessment of CES pose  
102 several challenges, such as the representation of diverse perceptions, varied approaches  
103 and analytical techniques are available (Gould et al., 2015). For instance, Plieninger et al.  
104 (2013) focused on the spatial representation of a wide range of CES, while Norton et al.  
105 (2012) integrated quantitative and qualitative data on eight CES. Although many scholars  
106 (Norton & Noonan, 2007) are unconvinced when it comes to quantifying CES, combining  
107 it with participatory mapping and other methods that go beyond the conventional can  
108 encourage a better understanding and management of CES (Hirons et al., 2016; Ulloa  
109 2009). There is mounting evidence demonstrating their importance particularly for the  
110 rural poor and marginalized indigenous populations whose livelihoods often depend

111 heavily on the provision of ES, and hence are more vulnerable to environmental change  
112 and ecosystem degradation (Butler & Oluoch-Kosura 2006; Cummings & Read 2016;  
113 Folke et al. 2002). It is highly likely these changes will have a greater impact on their  
114 well-being as their lifestyle is more integrated to their surroundings. Furthermore, CES  
115 due to the intangible nature of the benefits they provide, have been relatively neglected  
116 by researchers and policy-makers compared to provisioning, supporting, and regulating  
117 services (Brown & Fagerholm, 2015; Cummings & Read, 2016; Hirons et al., 2016; Ives  
118 et al., 2017; Plieninger et al., 2015; Ramírez-Gómez et al., 2017). Although measuring  
119 CES poses several conceptual and methodological difficulties, it is of huge interest and  
120 importance because of the linkages between cultural values, assessment methods, and the  
121 individual and collective decision-making that influence ecosystems and human well-  
122 being (Brown & Fagerholm, 2015; Chan et al., 2012b; Hirons et al., 2016).

123         In the case of the Amazon, various studies have sought to develop methods aiming  
124 to incorporate the traditional knowledge, which is an integral part of the communities  
125 populating the region, enabling a better understanding of the territory and the cultural  
126 values that are an integral part of the community's behaviour (Botazzi et al., 2014; Briggs  
127 et al., 2013; Cámara-Leret et al. 2014; Celentano et al., 2014; Figueiredo et al., 2013;  
128 Macia et al., 2011; Silvano et al., 2008). Studies incorporating community stakeholders'  
129 knowledge have also been conducted in Africa (Chalmers & Fabricius, 2007; Fagerholm  
130 & Käyhkö, 2009; Fagerholm et al., 2012; Schnegg et al., 2014; Sileshi et al., 2009) All  
131 the aforementioned studies demonstrate that traditional knowledge should be a key  
132 component of decision-making. They also show the importance of identifying which  
133 ecological features are associated with the cultural heritage values of stakeholders in a  
134 given cultural context and how changes in these features could affect those values. For  
135 example, Oestreicher et al. (2014) discuss a study of livelihood activities and land-use

136 practices of the communities located in the Brazilian Amazon, highlighting the need to  
137 integrate both qualitative and quantitative assessments, as the most effective way of  
138 gaining a reliable perspective on the effect that changes in the ES might have on the  
139 communities dependent on them. The quantitative data provides empirical evidence on  
140 the wide range of activities in which the communities engage, while the qualitative data  
141 helps to identify the underlying reasons for the differences between the communities  
142 participating in the study, demonstrating the plurality of forces that shape household  
143 decisions (e.g., institutional, economic, demographic factors).

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

156         Providing a comprehensive assessment of the benefits gained from CES, as  
157 perceived by those benefiting from their use in a rural context, is still work in progress as  
158 the shortcomings identified and discussed demonstrate. Nevertheless, as this type of study  
159 remains under-researched and poorly integrated into existing ecosystem services

160 assessments (Ives et al., 2017), the method described constitutes a step forward in their  
161 full integration to the ecosystem services discourse.

## 162 **Methods**

### 163 *Study area*

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

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

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

### 197 ***Study Design***

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

206           As the study is part of the research efforts that fall under the 'Attaining Sustainable  
207 Services from Ecosystems through Trade-off Scenarios' (ASSETS) project, the strong

208 relationships between the Colombian project partner and the local communities involved,  
209 which have been built over several years, helped to facilitate all the meetings that were  
210 held. Furthermore, the partner's extensive experience on the socio-economic and  
211 ecological aspects of the area proved particularly helpful in the design of the  
212 questionnaire used and the way the interviews were organized.

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

217         As providing a quantitative evaluation of CES is particularly difficult given the  
218 subjective nature of the non-material benefits society derives from them (Chan et al.,  
219 2012a, 2012b), it is important to build a framework, which will account for this  
220 subjectivity and simultaneously help in their valuation.

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

232 All the indicators constitute unitless ranking indices ranging from 0 to 100, with  
233 0 being the lowest and 100 the highest. For a particular SPU, each of the indicators is  
234 ranked through consensus or compromise amongst the participants.

### 235 *Data Collection*

236 The type of data providing a reasonable assessment of the benefits people derive from  
237 CES is fairly diverse. It is still work in progress as the research community continues its  
238 efforts on developing a set of useful, practical guidelines to capture them (Brown & Reed,  
239 2012; Ives et al., 2017; Plieninger et al., 2013; Ramírez-Gómez et al., 2017).

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

251 In preparation for the meetings, several questions (Appendix A) were used to  
252 facilitate the quantification of the CES identified. To help the participants, the definition  
253 of the CES categories were agreed by all at the start of the meetings. The description used  
254 the schemes from two sources: the Colombian Ministry of Agriculture (Table 2) and the  
255 scheme listed in the Millenium Ecosystem Assesment (MEA, 2005). The definitions of

256 the categories listed in MEA (2005) were adapted as described in Table 3 to ensure the  
257 information captured reflected the intended meaning as stated by the participants.

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

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

269         Once all the SPU had been clearly identified, the participants ranked each location  
270 with regards to its importance, types and frequency of use. The sense of identity, as  
271 perceived by the different participants, in relation to each SPU was discussed and  
272 consensus was reached on the values that should be assigned to the numeric indicators  
273 described earlier, which were used to rank them. Important influences in the formation of  
274 a sense of identity with regards to nature are the visual and aesthetic aspect of a place,  
275 experiencing nature in individual and community contexts, activities inescapably  
276 intertwined with the environment (e.g. fishing), often including interactions with certain  
277 species (Russell et al., 2013). All of these aspects are important to a sense of identity and  
278 provide insights into the substitutability of the CES under consideration. They also helped  
279 to determine the potential for sharing between the communities. In the final stage of the

280 discussion, the moderators attempted to assess the length of time the CES has been valued  
281 as such by the communities. This type of information helps provide arguments in favour  
282 of the efforts that ought to be made to ensure they are preserved.

### 283 *Data Analysis*

#### 284 *Principal Component and KMO-Bartlett Analyses*

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

293 The analysis is complemented with a Bartlett's test of sphericity and an estimation  
294 of the Kaiser-Meyer-Olkin (KMO) index (Table 5), a prior step often used to assess the  
295 suitability of the data for factor analysis (Williams, et al., 2010). It compares correlation  
296 coefficients with partial correlation coefficients providing evidence on the significance  
297 of the existing relation between the CES factors identified (Kim & Mueller, 1978). It was  
298 used to clarify further which were the most statistically significant CES indicators. Both  
299 analyses were performed using functions in the stats and psych packages available in R v  
300 3.2.5

#### 301 *Multiple Correspondence and correlation analyses*

302 Multiple Correspondence Analysis (MCA) was used to analyse the categorical data; this  
303 is equivalent to performing PCA on quantitative data (Sánchez, 2015). MCA is a

304 multivariate method tool enabling the analysis of systematic patterns of variations in  
305 categorical data. It provides features that represent in graph form the results of the  
306 analysis. It was used to detect and represent any underlying structure in the CES  
307 perceptions. The active variables were presence/absence of perception of an individual  
308 service and the type of ecosystem SPU was included as a supplementary variable. The  
309 analysis was performed using functions in the ade4, FactoMineR, and homals packages  
310 available in R 3.2.5.

### 311 *Spatial Analysis using diversity, intensity and richness measures*

312 Through the data collected in the PRA exercises, six annotated maps showing a total of  
313 58 cultural ecosystem service providing units (SPU) were generated, in which the SPUs  
314 act as the spatial representation of the CES. The SPUs for each service were grouped in  
315 two community clusters and 11 individual communities. These maps were scanned and  
316 geo-referenced to MAGNA-SIRGAS/Colombia Bogota Zone as spatial reference system.  
317 The information was digitized into vector layers using ESRI's ArcGIS 10.0.

318 Subsequently, the locations identified by the 69 participants were joined with the  
319 layer showing the 400 land cover units (LC) recorded for the lower Caquetá River region.  
320 Using the Points in Polygon function available in the QGIS 2.10.1 analysis tools for  
321 vector files, the CES map (a point shapefile) was intersected with the land cover map (a  
322 polygon shapefile). The resulting map includes the absolute number of perceived cultural  
323 services per land unit. QGIS 2.10.1 was used for the spatial analysis, Excel 2007 and R v  
324 3.2.5 2016.04.14 for the statistical analysis. In addition, a mapping of aggregated patterns  
325 of CES was conducted following Plieninger et al. (2013), calculating the intensity,  
326 richness and diversity of cultural services; as it provides the means to capture spatial  
327 information on social landscape values, and its subsequent integration into a geographic  
328 information system and (Brown & Reed, 2012; Fagerholm et al., (2012).

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

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

## 345 **Results**

### 346 *Identification of the most important ecosystem services*

347 During the participatory discussions, we identified 13 SPU (Table 4) and seven categories  
348 of CES related to Aesthetics, Education, Cultural Heritage, Inspiration, Recreation, Sense  
349 of Place and Spiritual. We found that Education and Recreation are the two most  
350 prevalent CES categories in the region, conversely Aesthetics and Cultural Heritage  
351 appear to be the least widespread CES categories across both land cover types and  
352 *resguardos* (Figure 2, Figure 4 and Figure 5b). Participants might perceive less

353 provisioning of Aesthetics and Cultural Heritage CES as they may become intertwined  
354 with other CES or ES in certain places (Schneegg et al., 2014). Alternatively, there might  
355 be overlap between services types, as people cannot easily distinguish between them  
356 (Plieninger et al., 2013). It demonstrates the challenges related with the attempts of  
357 combining traditional and scientific knowledge (Mantyka-Pringle, et al., 2017) showing  
358 the importance of both types of knowledge and the need for studies enabling researchers  
359 to build bridges between them.

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

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

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

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

### 389 ***Diversity, Intensity and Richness***

390 Figure 6 also shows the location of the CES is evenly distributed between land and water  
391 indicating once more the importance of the river Caquetá. This confirms the results from  
392 the diversity, intensity and richness measurements (Figure 7). Of all the land cover types  
393 recorded in the region, there are three associated with moderate CES diversity (Figure  
394 7a); namely, the “dense forest on firm highland”, “dense shrubland on firm land” and  
395 “river”. The most diverse is the “dense forest”, closely followed by “river”. With regards  
396 to intensity (Figure 7b), “dense forest on firm highland” has the highest value, providing  
397 considerably more CES to local community members than other land cover types. In  
398 contrast, “dense forest subject to flooding” and “fragmented forest with pastures and  
399 crops” show the lowest intensity. Finally, in terms of CES richness (Figure 7b), both  
400 “dense forest on firm highland” and “dense shrubland on firm land” present the highest  
401 richness (roughly seven CES/land unit). They are closely followed by “river”, which

402 corroborates the importance of the river Caquetá. On the other hand, “dense forest subject  
403 to flooding” and “fragmented forest with pastures and crops” display the lowest richness  
404 (approximately 15 CES/land unit for both).

## 405 **Discussion**

### 406 *Existing CES of the Amazonian indigenous population*

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

414 Differences appear between the distributions of the CES enjoyed by each  
415 community. The number of educational CES is highest for all communities except  
416 Angostura, while inspirational and recreational CES are the second and third most  
417 frequently enjoyed by the communities of Bocas del Mirití, Borikada, Camaritagua and  
418 Yucuna. In the case of Madroño, recreation and education are the most numerous CES.  
419 The relevance of Education across all communities can be explained considering the  
420 importance that elder members associate to the task of passing their traditions to younger  
421 generations (Berkes, 2009; Martin et al., 2010). As the topics taught cover a wide  
422 spectrum (rituals, ceremonies, hunting/fishing techniques) most of the places mentioned  
423 were serving a dual role. For example, a place can provide recreation and at the same time  
424 be used for educational purposes, as it is the place where youngsters are taken to learn the  
425 skills of the trade, e.g. what they need to know to become a successful local guide. The

426 little interest in Aesthetics and Cultural Heritage might be caused by miscommunication  
427 given that the moderators had trouble explaining the western perspective of these two  
428 types of CES (Fagerholm & Käyhkö, 2009; Raymond et al., 2010; Soini & Birkeland,  
429 2014; Valdivia et al., 2010). This highlights the importance of ‘cultural translation’ to  
430 ensure survey materials have the same meaning in both cultures, furthermore it  
431 corroborates the importance of integrating both, scientific and traditional knowledge as  
432 ascertained in other studies (Cummings & Reed, 2016; Mantyka-Pringle et al., 2017).

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

#### 443 ***Contributions to community-based management and institutions***

444 Concerns on resources availability in La Pedrera have led to the formulation and  
445 implementation of management plans, which regulate the sustainable use of the land and  
446 resources amongst indigenous communities (Chaparro, 2007; Ramírez, González &  
447 Chavarría, 2015). This study demonstrates the richness and diversity of CES, information  
448 that up to now, at least to our knowledge, is not part of these plans. It is possible to record  
449 the prevalence of some CES, which means this gap in current plans should be addressed  
450 soon. The cultural significance of the Caquetá river should be brought to the notice of the

451 government, as it might help push forward measures to control the current practices which  
452 are having a detrimental effect on the proper functioning of this ecosystem. Specific  
453 threats such as river pollution from upstream gold mining, overfishing, and changes in  
454 river seasonality due to climate change have been described in other studies (Castello et  
455 al., 2011; Hurd et al., 2016; Pérez-Rincón, 2014; Portocarrero-Aya & Cowx, 2015;  
456 Ramírez-Gómez et al., 2015), thus strengthening the argument for improving the current  
457 environmental management plans implemented in the region.

#### 458 *Usefulness of this approach in marginalized regions with poor data availability*

459 The approach discussed is useful to assess CES in indigenous communities for six main  
460 reasons: (i) The combination of methods provide land use data that enables CES studies  
461 to be holistically traced to a more data-efficient and land user friendly approach  
462 (Oestreicher et al., 2014); (ii) The mapping process generates conversations between  
463 stakeholders, which ultimately can have a community empowerment effect (Hirons et al.,  
464 2016; Ramírez-Gómez et al., 2013; Ramírez-Gómez et al., 2015). For example in La  
465 Pedrera, the participants discussed what was being mapped, access to natural resources,  
466 and locations, and therefore gained more awareness about their shared values through the  
467 conversations that took place during the meetings; (iii) The participatory approach helps  
468 to legitimate traditional knowledge within a scientific and policy driven framework  
469 (Brown & Donovan, 2014; Cummings & Read, 2016; Gómez-Baggethun et al., 2013);  
470 (iv) The combination of multivariate methods supports the quantification of CES (Hirons  
471 et al., 2016; Oestricher et al., 2014; Plieninger et al., 2013). For example, the use of the  
472 measurements of diversity, intensity and richness provides the means to describe the  
473 distribution of CES across the region, facilitating the identification of the most important  
474 ones. Furthermore, the findings may be applicable in a wider context, e.g. communities  
475 located in more populated regions with a completely different cultural background, as

476 described in Plieninger et al. (2013); (v) Reaching similar conclusions through the  
477 application of different methods has the benefit of enabling validation in addition to  
478 providing a different perspective on the data recorded (Creswell, 2013); (vi) The spatial  
479 analysis is key to visualizing and achieving a better understanding of SPUs as it allows  
480 communities to effectively target the sustainable use of ES in the region (Bagstad et al.,  
481 2017; Campbell et al., 2012; Figueiredo et al., 2013; Ramírez-Gómez et al., 2017; Silvano  
482 et al., 2008).

483         The benefits of using participatory approaches to enable communities located in  
484 marginalized regions, to design and develop better practices to manage the ES on which  
485 they depend, has been corroborated by other studies (Bottazzi et al., 2014; Ives et al.,  
486 2017; Ramírez-Gómez et al., 2013). However, it is perhaps still too early to ascertain the  
487 long-term effect such approaches could have on the success, or otherwise, of  
488 governmental management plans.

#### 489 *Limitations of this study*

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

497         Furthermore, another limitation of this study is the limited inference power for the  
498 whole study area. Although the method described appears to provide useful input for  
499 environmental management planning, barriers to use (e.g. regulatory approval) are

500 necessary and probably difficult to achieve (Brown & Donovan, 2014, Hirons et al.,  
501 2016).

502         While it has been possible to identify the CES, the results generated are not  
503 providing an accurate measure of the spiritual or aesthetic fulfilment as perceived by  
504 those benefiting from their use. In order to enable this type of assessment, more extensive  
505 data collection and analysis is needed, in addition to better communication and  
506 understanding between the researchers and the communities involved. These limitations  
507 might be overcome with more time and resources for data collection (e.g., involvement  
508 of cultural interpreters) to address the challenges linked to cross-cultural research (Chan  
509 et al., 2012b; Gilmore et al., 2013; Gómez-Baggethun et al., 2013; Ramírez-Gómez et al.,  
510 2017). Additionally, it would be advantageous to recognize that spiritual fulfilment is a  
511 particularly sensitive issue for some indigenous communities, rarely discussed outside  
512 their own spatial and temporal context, which often includes preventative measures  
513 regarding disclosure to outsiders. We must accept that even though it would be useful to  
514 measure spiritual fulfilment when informing environmental management plans, it might  
515 not always be possible to do so. In those cases, a better understanding of the communities'  
516 viewpoint must be brought to bear, including their interdependence with those CES that  
517 are quantifiable.

518         The indefinite spatial properties of the “service providing units” (SPU) of CES  
519 represent additional challenges. As most of them are related to specific landscape  
520 attributes, the sites were pre-identified according to LC units. However, certain cultural  
521 services such as inspiration are not intuitively associated with any particular landscape  
522 attribute (Plieninger et al., 2013), which may have biased the results. Nevertheless, as the  
523 links between culture, values, nature, well-being and politics are much more complex  
524 than most articulations of ES concede (Ives et al., 2016), the method described shows a

525 way of given them presence for their integration with other relevant ES, and build a model  
526 to simulate policy scenarios, highlighting trade-offs across the full spectrum of ES  
527 applicable to the region. It also gives a “voice” to the rural communities who have the  
528 highest risk of losing the benefits derived from the intangible services we have attempted  
529 to capture.

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

536         At present, lack of data to verify the results is an ongoing limitation in all studies  
537 of this nature (Jacobs et al., 2015; Maes et al., 2013; Raymond et al., 2014; Ramírez-  
538 Gómez et al. 2017; Tengberg et al., 2012). Even though there are multiple sources of  
539 uncertainty associated with any type of ES assessment (e.g. data scarcity, functional  
540 knowledge gaps, social trade-offs, normative and value-laden arguments) as discussed in  
541 Jacobs et al. (2013), it is necessary to continue investigating even without a guarantee of  
542 reaching a consensus, as this enables progress in complex situations (e.g., lack of data,  
543 knowledge or “hard” proof) (Jacobs et al., 2015). In the particular case of CES, in spite  
544 of the rapid advancement in developing non-monetary techniques for the assessment of  
545 their social value, further research is needed to evaluate their underpinning paradigms  
546 (Cummings & Read, 2016; Raymond et al., 2014). For this reason, as this type of studies  
547 are rare and poorly integrated into existing ecosystem services assessments (Ives et al.,  
548 2017), the method described constitutes a useful way to begin bridging the gap in this  
549 research field.

550 **Conclusion**

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

560 Qualitative methods can be used as an initial step to determine the cultural value  
561 and social preferences in terms of ES. The data generated can be used in a preparatory  
562 stage, before proceeding to gather the information necessary for the quantification of the  
563 services identified. This study provides the communities with a tool to ensure their  
564 tradition and knowledge are evaluated at an equal footing with the interests of other  
565 external groups, given that: (1) It provides the means to identify the existing CES of the  
566 Amazonian indigenous population that live in La Pedrera. (2) It includes a spatial  
567 representation of the CES as SPUs; valuable information that ought to be part of any  
568 environmental plan to ensure they are given due consideration in the organization of the  
569 indigenous territory identified in La Pedrera. Bearing in mind there will be other criteria,  
570 such as their effect on provisioning, regulating, supporting services, which also need to  
571 be taken into consideration. (3) It provides outputs, which can be used in studies aiming  
572 to determine how enhancement of human well-being can be coupled with upkeep or  
573 improvement of CES, for example, if an area of high spiritual value (e.g. an ancestral  
574 forest) is identified for the protection of an endangered species and a plan is designed to

575 restrict all human access for this purpose, the results would highlight the need for  
576 designing less drastic measures (i.e. no access).

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

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

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780 [ticle&id=362:siona-la-gente-del-rio-de-la-cana-brava&catid=19:atlas-etnico-de-](http://observatorioetnicocecoin.org.co/cecoin/index.php?option=com_content&view=article&id=362:siona-la-gente-del-rio-de-la-cana-brava&catid=19:atlas-etnico-de-colombia&Itemid=67)  
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905

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

<b>Resguardo</b>	<b>Communities</b>				<b>Population</b>	<b>Area (ha)</b>
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

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

<b>Type</b>	<b>Definition</b>	<b>Topographic Location</b>
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

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

<b>CES</b>	<b>Definition</b>	<b>Example of CES identified in La Pedrera</b>
<b>Aesthetic</b>	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

<b>CES</b>	<b>Definition</b>	<b>Example of CES identified in La Pedrera</b>
<b>Cultural heritage</b>	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.
<b>Education</b>	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.
<b>Inspiration</b>	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
<b>Recreation (ecotourism)</b>	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.
<b>Sense of Place</b>	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
<b>Spiritual</b>	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.

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

SPU	Definition of landscape features
Cananguchal	Vegetation formations with a homogenous composition and structure where the Canangucho palm ( <i>Mauritia flexuosa</i> ) 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 ( <i>Cecropiaceae</i> ). 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

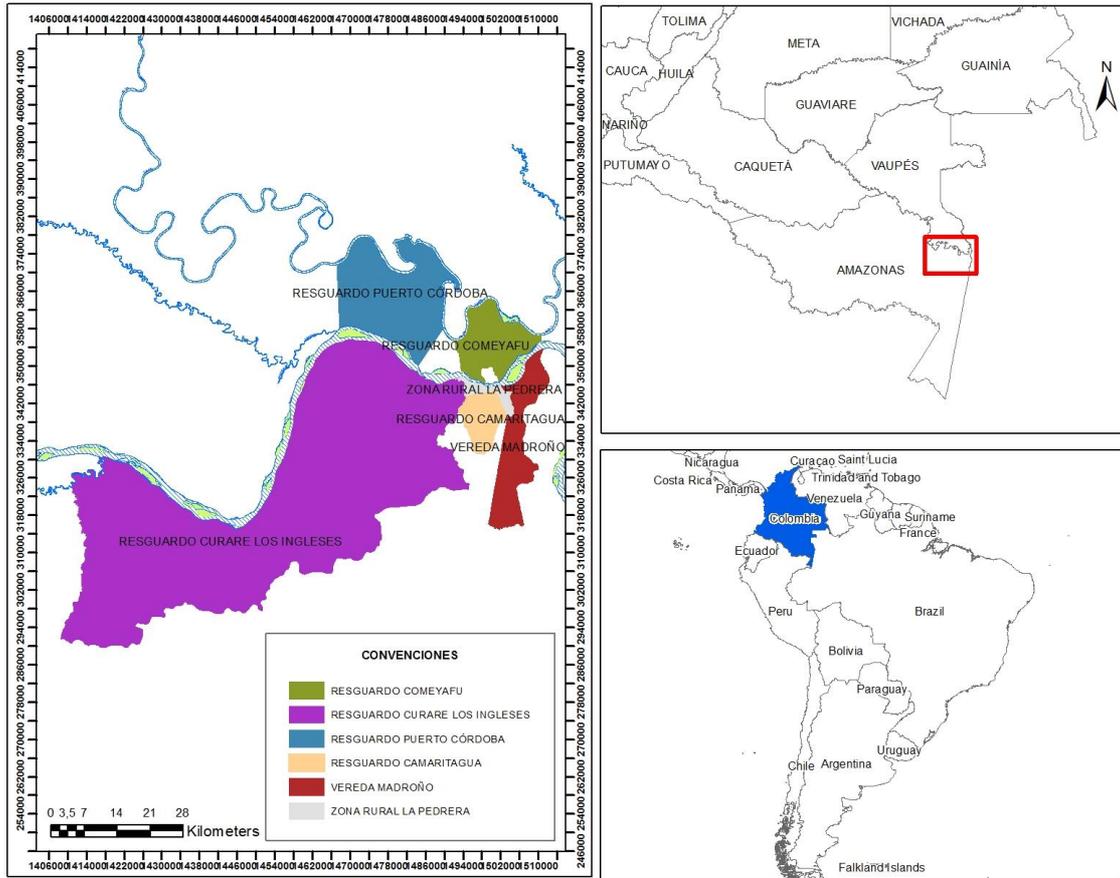
SPU	Definition of landscape features
Playa de río (beach)	A beach is a deposit of unconsolidated sediments that vary between sand and gravel, in the Caqueta river it is common to see them when the level of the river descends, in addition, it is known that some species of turtles disobar in them.
Curare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

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

Rotated components matrix				Variance coefficients	
Indicators	PCA Analysis			Cumulative variance	KMO Coefficients
	1	2	3		
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					

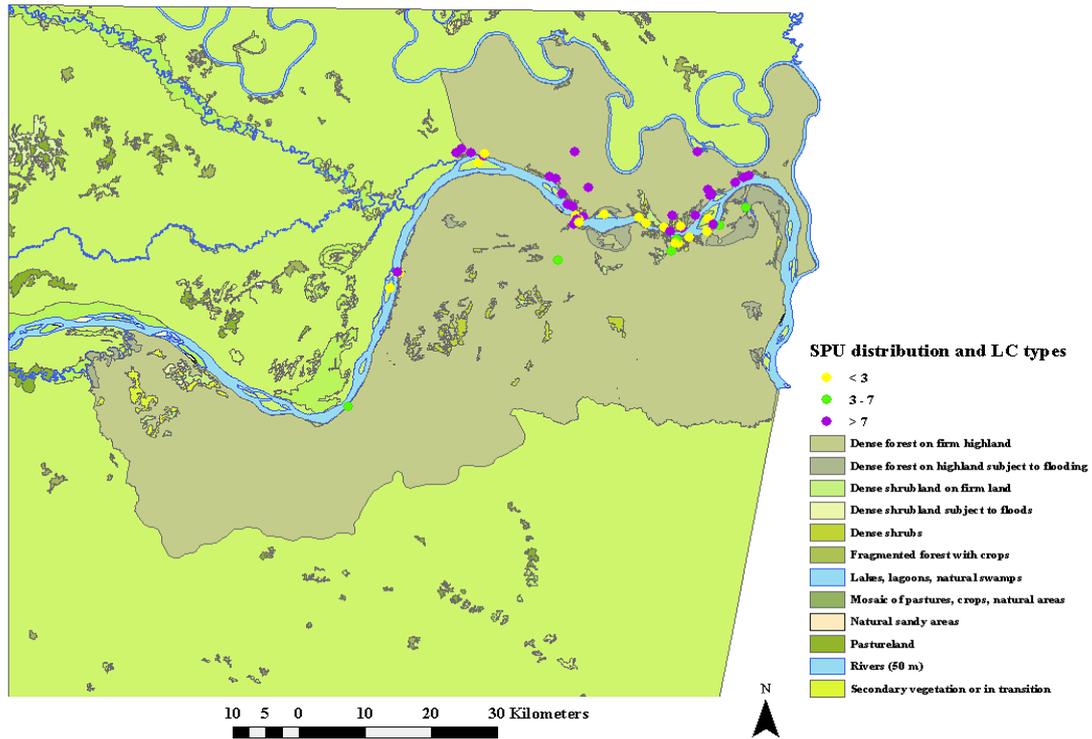
916 Table 6. Legend for symbols in MCA map (See Figure 4 and Figure 6)

Resguardo/Vereda	Code_R	Community	Code_community	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	<b>U_P_TYPE</b>	
		Lomalinda	LmL	Land	
		Puerto Córdoba	P_Co	Water	
Vereda Madroño	V_M	Madroño	Mdr	U_P	



917

918 Figure 1. Geographic distribution of the *resguardos* within the La Pedrera *corregimiento*  
 919 along the Lower Caquetá River region in the Amazonas Department in Colombia (Lat: -  
 920 1.25, Long: -69.6 (1° 15' 0" S, 69° 36' 0" W)). Underlying cartography Conservation  
 921 International - Colombia. ArcGis.

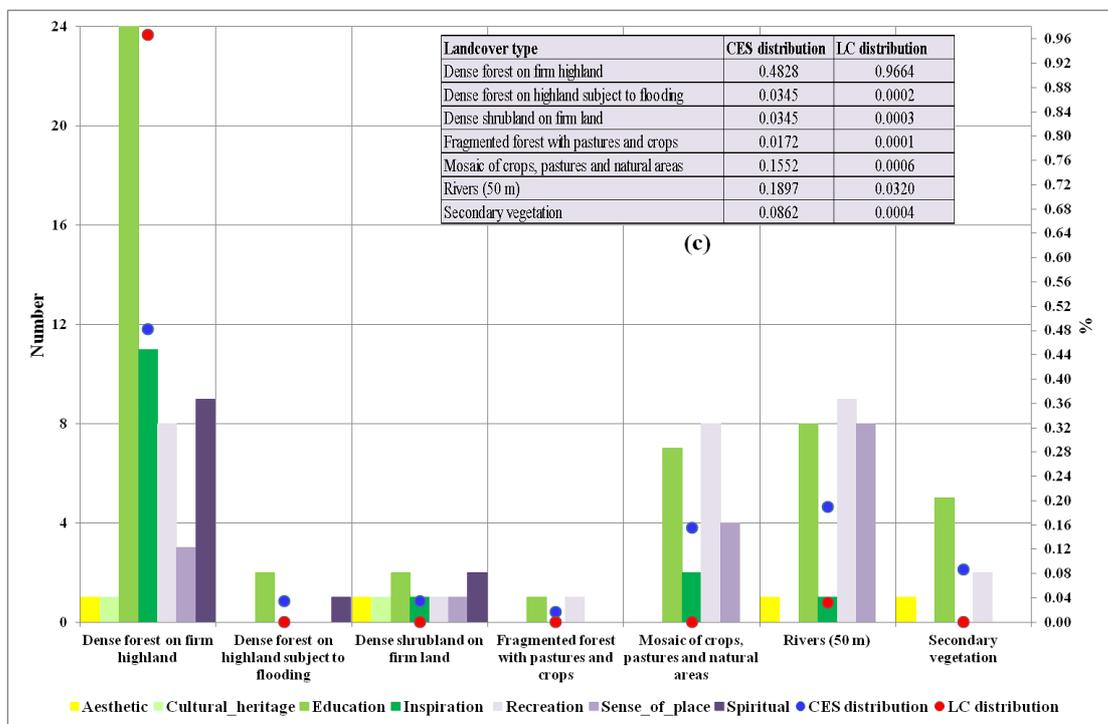


922

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

924 ArcGis.

925

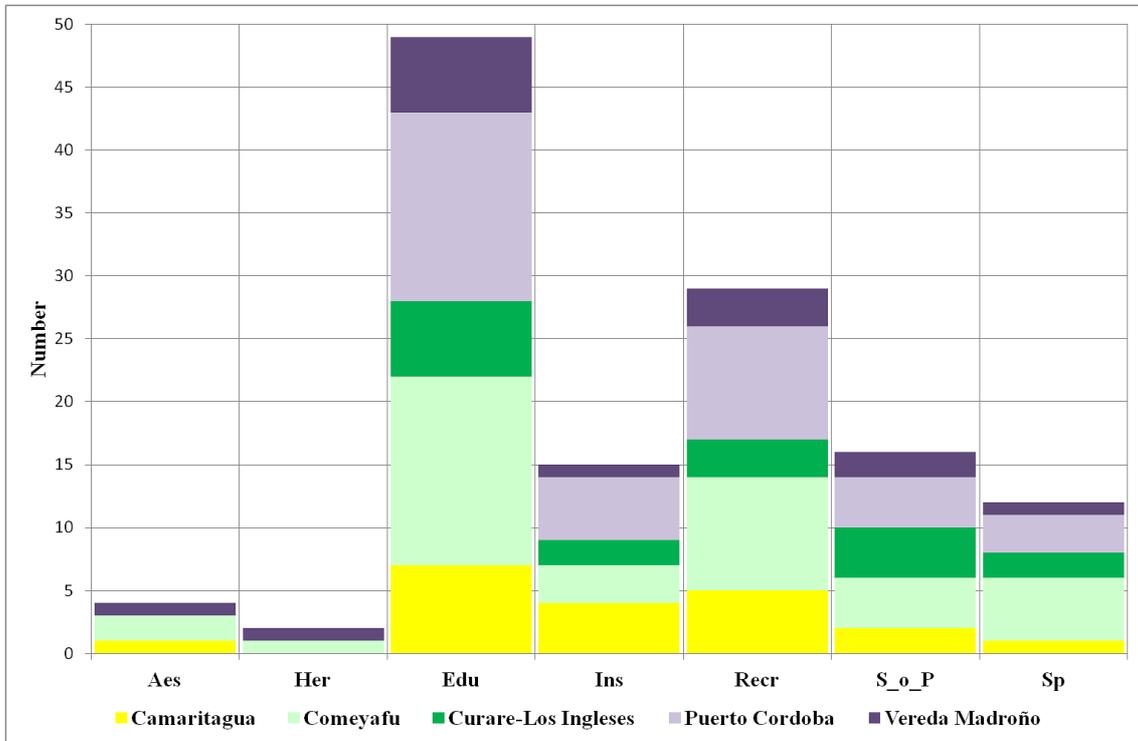


926

927 Figure 3. Distribution of Service Providing Units (SPU) across LC types and CES

928 categories (MEA-2005). (a) CES distribution across LC (X-axis: LC types, Y-axis:

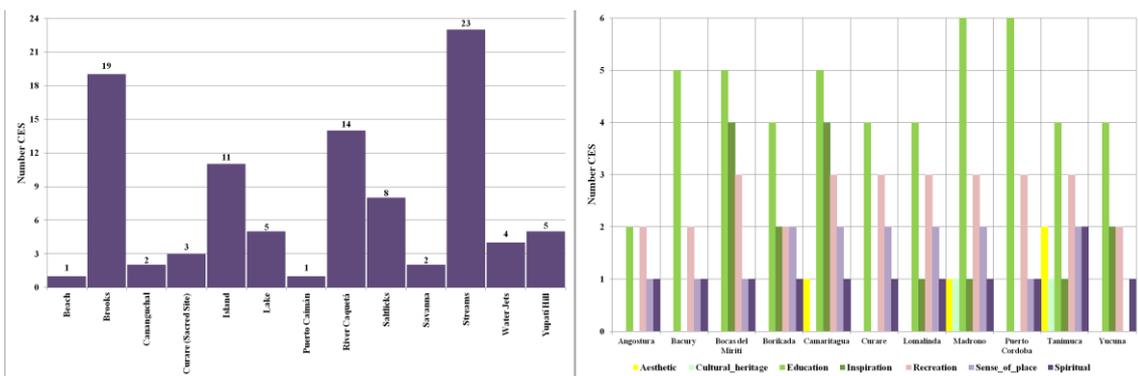
929 number of CES). (b) Distribution of CES types identified within each “resguardo” (X-  
 930 axis CES types, Y-axis Number SPU). (c ) Distribution of CES across LC types,  
 931 distribution of LC type coverage in region . Symbology (Table 5)  
 932



933

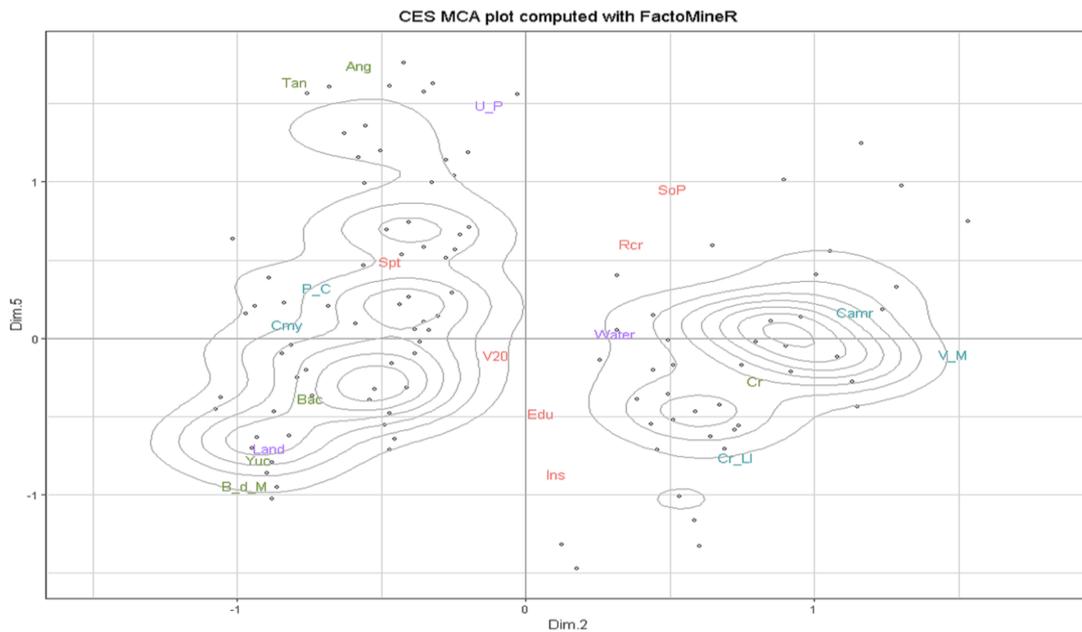
934 Figure 4. Distribution of CES categories across each *resguardo* in La Pedrera (X-  
 935 axis=CES types, Y-axis=Number of SPU), see Table 6.

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937

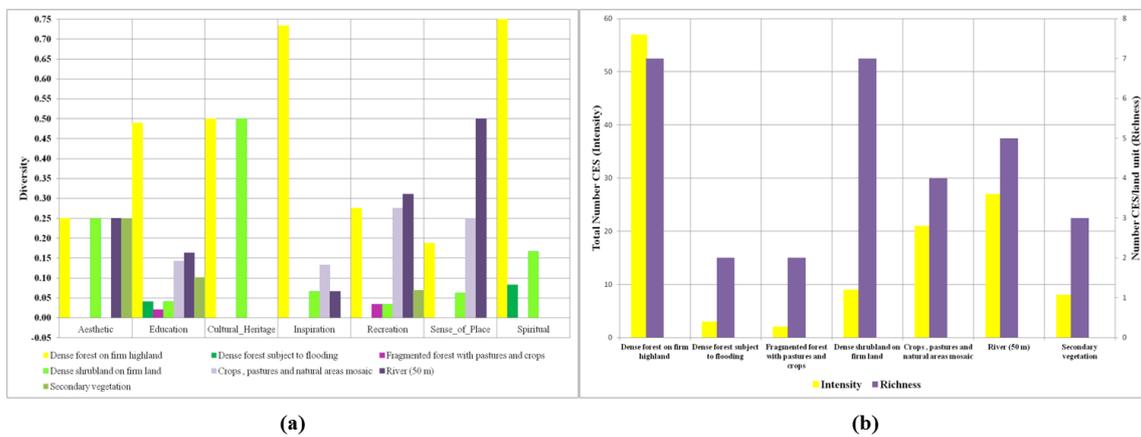
938 Figure 5. a).Distribution of CES across landscape features (SPU) The X-axis=SPU; Y-  
 939 axis=number of CES. b). Distribution of CES types across the communities (X-  
 940 axis=community; Y-axis=number of SPU) (for details on each type of feature see Table  
 941 4).



942

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

948



949

950 Figure 7. Statistical analysis computed according to method described in Plieninger et al.  
 951 (2013) for (a) CES diversity in La Pedrera (b) CES Intensity and Richness in La Pedrera.

952

953 **Appendix A**

954 Questionnaire designed for the meetings is part of the Supplementary material

955 accompanying this publication