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Community mapping of ecosystem services in tropical rainforest of Ecuador

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ABSTRACT

Tropical forests provide a wide range of ecosystem services (ES), and their continuous supply depends on efficient and effective management against deforestation and forest degradation. In Ecuador, indigenous communities are highly dependent on the forest and therefore on forest ES. However, there is a lack of knowledge about their demands concerning ES. In order to better understand how local and indigenous people use the forest and to facilitate its management, this study completed a spatially explicit assessment of ES using participatory mapping in the Sumaco Biosphere Reserve (Napo province, Central-Northern Ecuador). The Biosphere Reserve is suitable as a case study because it is a protected area with high land-use and population pressure and therefore requires the development and monitoring of management plans.

First, semi-structured interviews were conducted with experts (n = 15) in order to identify the most important ES used by the communities in the study area. In a second step, members (n = 208) of 24 communities were asked to indicate on a 3-D map where they utilize the different ES (food, wood, water, tourism, hunting). The highlighted localities were digitized and then analyzed with statistical and GIS techniques. The results showed that the ES locations were not randomly distributed, but were most abundant four kilometers or less from roads. Spatial pattern analysis identified hotspots of ES provision, and the evaluation according to administrative units allowed us to identify five municipalities where demand for all assessed ES was high. In conclusion, the combination of participatory mapping of ES and GIS-based analysis can facilitate the identification of priority protection areas, provide guidance for developing specific forest management strategies, and also support monitoring systems to detect forest degradation.

1. Introduction

It is well known that tropical forests provide ecosystem services (ES) (Naidoo et al., 2008) which derive, directly or indirectly, from ecosystem functions (Costanza et al., 1997). According to the Millennium Ecosystem Assessment report (MA, 2003), the value of ES can be divided into use values and non-use values. The use values are subdivided into direct use values, indirect use values and option values. Whereas direct use values are more easily recognized by local people, other value types are less well understood by non-experts (e.g. Entenmann and Schmitt, 2013). Forest disturbances such as deforestation and degradation cause changes in the provision of ES (Foley et al., 2007). In this context, efficient and sustainable management of the forest to secure ES provision over time is necessary. There is evidence that rural communities depend heavily on the provision of ES (Butler and Oluoch-Kosura, 2006) which often include food, medicines, locally traded goods, and other services (Blaser et al., 2011). This dependence is rarely measured and therefore often ignored in national statistics, generating inappropriate management strategies that do not take into account the role of the environment in poverty reduction (MA, 2005). Lately, there has been growing interest in including ES concepts in landscape planning and forest management (Chan et al., 2011; de Groot et al., 2010; Nelson et al., 2009). Spatially explicit data on ES help to outline the distribution of ES and identify crucial

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areas (Alessa et al., 2008; Plieninger et al., 2013). They also assist in ascertaining the contribution of ES to human wellbeing (de Groot et al., 2010) by quantifying their supply and demand (Crossman et al., 2013; de Groot et al., 2010). Moreover, spatial data allow the identification of relationships between ES and landscape characteristics (e.g. land use/cover) (de Groot et al., 2010) as well as administrative units (Syrbe and Walz, 2012).

Spatially explicit data on ES generated by participatory mapping captures local knowledge on ES and integrates the perspectives and needs of local communities into scientific research programs and the development of management strategies (Brown, 2004; Bryan et al., 2010; Fagerholm et al., 2012; Klain and Chan, 2012; Ramirez-Gomez et al., 2015). In most cases, maps derived from participatory studies are of higher quality and are more relevant than those produced by authorities without local knowledge (Goodchild and Li, 2012).

In Ecuador, there are still about six million hectares of Amazon tropical rainforest (Pezo, 2015), which contain one of the highest levels of species richness on earth (Myers, 1990) and provide many ES to local communities (Izurieta et al., 2014). Most studies or initiatives have focused either on biophysical assessment or economic valuation of ES (e.g. Bendix et al., 2013; de Koning et al., 2011; Greiber and Schiele, 2011) and there is little information available on how the local communities perceive ES (Bendix et al., 2013; Bremer et al., 2014). Furthermore, despite a lot of expert-based information on ES in Ecuador, there is a lack of knowledge of the spatial distribution of ES from the perspective of local communities. Mapping ES in Ecuador could inform forest management in protected areas within the framework of Reducing emissions from deforestation and degradation in developing countries "plus" (REDD+) initiatives and other national forest management schemes (MAE, 2011). Additionally, the Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES) has strongly emphasized the need to better integrate local and indigenous knowledge into biodiversity and ES studies (Díaz et al., 2015).

In this context, the overall goal of this study was to conduct a spatially explicit assessment of ES using participatory mapping in order to better understand the demand for ES from local communities and to facilitate ES management. The study was carried out in the Sumaco Biosphere Reserve (SBR) in Ecuador, which is characterized by high land-use and population pressure on the remaining tropical forest areas. The concept of a service provisioning area is used, referring to the source of ES (locations) (Syrbe and Walz, 2012). In particular, the study aimed to:

- identify the forest ES that are most important to the communities;
- examine the spatial distribution of selected ES based on participatory mapping; and
- evaluate the spatial arrangement of ES according to hotspots and administrative units using GIS techniques.

The results are expected to demonstrate that local community knowledge provides important information on ES that can be used as a basis for local authorities to develop forest management plans and land use planning. Furthermore, we will provide recommendations on how to use the tool of participatory mapping in other areas of Ecuador.

2. Study area

2.1. Geographic location

The study area is located in the Sumaco Biosphere Reserve (SBR), province of Napo in central-northern Ecuador (Fig. 1). The SBR consists of: (a) a core zone which comprises the National Park Sumaco-Napo-Galeras, (b) a buffer zone, and (c) a transition zone. It aims to improve quality of life for local people while maintaining the conservation of natural resources (Valarezo et al., 2002).

The core zone was designated for biodiversity and genetic resources protection, water production, and landscapes conservation. The activities allowed are research, environmental education and controlled ecotourism. The buffer zone includes protected forest and State Forest Estate. The objectives of this area are to reduce pressure on the core zone and to have places to develop ecological practices; the sustainable extraction of timber and non-timber forest products, agroforestry, research, environmental education and ecotourism are allowed. In the transition zone, the sustainable use of natural resources is promoted for the benefit of the reserve's inhabitants and users (e.g. small hydropower and water supply development, agro-productive activities, tourism and research are allowed) (MAE, 2010; Valarezo et al., 2002).

2.2. Land tenure in sumaco biosphere reserve

Indigenous communities gained legal ownership of the land in their ancestral territories in the Ecuadorian Constitution of 1998. The study area has 24 communities; each one has an administrative unit with an average area of 2295 ha. Seven communities have additional territory (called "rural territory", Ortiz et al., 2012) distributed across three administrative units that are shared by two or three communities; and one administrative unit corresponds to National Park Sumaco. In total, 28 administrative units are part of the study area.

The territory of the indigenous communities who live within the SBR is located in the buffer and transition zones and the communities have the legal title through regular land tenure laws. Communal and individual titles may exist in the area. Yet, further clarification of land tenure in SBR for both communal and individual titles is required (GAD-PHS, 2014; Valarezo et al., 2002). Although communities may hold titles to communal land, these lands are not necessarily used collectively. Every family has a "farm" where they harvest wood to support their households (Romero et al., 2011). Communal forest land use is organized internally within the local community (USAID, 2008). Since 2010, a community may confer at its general assembly the ability to request and receive a logging license to a community member who uses the land.

2.3. Description of population in the study area

The study area comprises the Hatun Sumaco parish[1] and the Kichwa[2] People of the Rukullakta (KPR)[3]. Each community that is part of the Hatun Sumaco and KPR is represented by a council consisting of a president, vice president, treasurer, secretary and ordinary members. Additionally, Hatun Sumaco has a parish government consisting of five members elected by popular vote, whereas KPR has a council with a similar structure at the community level, which represents the entire organization. The main economic activities in the study area are agriculture, fishing, hunting, gathering of non-timber products, and logging (Lehmann et al., 2010). Given that the livestock production model has not improved the economic situation in the area and has had very serious impacts on the ecosystem, ecotourism has recently become a strategy for economic development (Valarezo et al., 2002).

KPR has 17 Kichwa communities with 5266 inhabitants and an area of about 42,000 ha (Ortiz et al., 2012). In areas where most

[1] Parish is a political division by territory of low rank (third level).
[2] Kichwa is a Quechuan language which includes all strands of Quechua in Ecuador and Colombia.
[3] KPR is a social and private organization founded for indigenous communities.

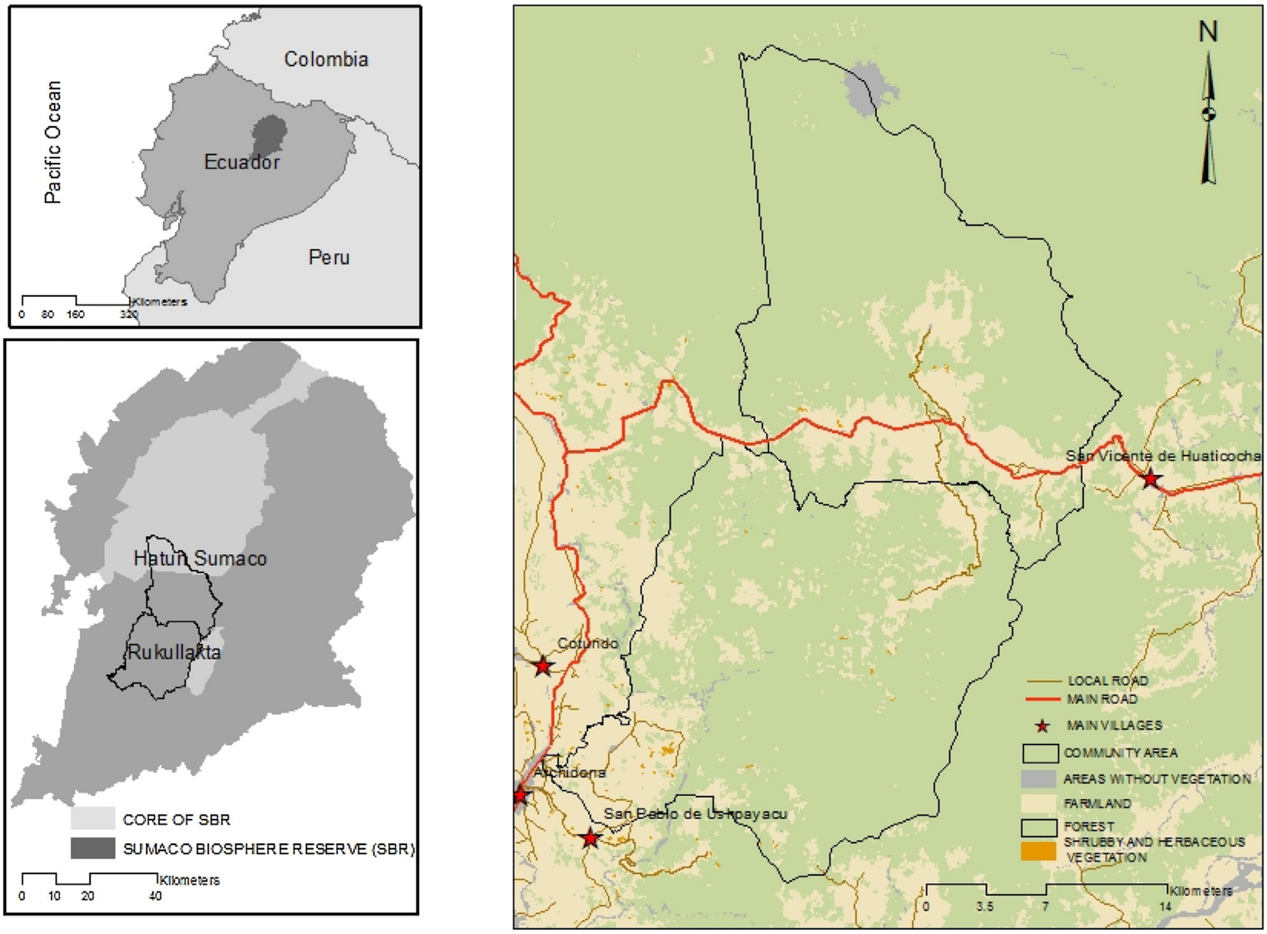

Fig. 1. Location of study area, which comprises the Hatun Sumaco parish and the Kichwa People of the Rukullakta (KPR) organization (community area). The study area is located within the buffer and transition zones of Sumaco Biosphere Reserve (SBR). The core zone of SBR is the National Park Sumaco-Napo-Galeras. Source: (MAE, 2012a).

of the population of Rukullakta lives (areas well accessible from the village of Archidona) human use of natural resources is high, whereas in areas with limited accessibility there is a lower level of interaction (Peralvo et al., 2013). KPR has forest areas in the Socio Bosque program (Hölcke and Shiguango, 2011). The main objective of this program is the preservation of native forests and highland Andean grasslands (páramos) through financial incentives paid to individuals, communities, and indigenous and low-income property owners (de Koning et al., 2011). The agricultural production adopted in the community is a traditional agroforestry system called "chakra",[4] through which mostly cacao, naranjilla (*Solanum quitoense*), and coffee (GIZ, 2011) are produced. Most of the inhabitants of KPR are Kichwas, however, internal migration in the country has generated mixed-ethnicity families (GAD-PHS, 2014).

Hatun Sumaco parish was created in 2011. It has seven indigenous communities with about 2902 inhabitants, and an area of about 39,000 ha (GAD-PHS, 2014); the population density is therefore much lower than in KPR. The land use consists of different types of cropland (mainly naranjilla and guayusa (*Ilex guayusa*)), grassland, forest areas under the Socio Bosque program, reserve area, water bodies, and populated areas (GAD-PHS, 2014). The majority of the communities in Hatun Sumaco have naranjilla crops which are considered the main income source of the families; these crops are farmed on land parcels where the primary and secondary forests are cleared (GAD-PHS, 2014). The chakra system is therefore less present than in KPR.

[4] "Chakra" includes timber, exotic fruits, medicinal plants, edible species, species used for making handicrafts, as well as ornamental and other objects (GIZ, 2011).

3. Methods

This study combines qualitative social science methods such as expert and community interviews and participatory mapping of ES, with quantitative spatial analyses (Fig. 2). There are several techniques used in ES mapping (Plieninger et al., 2013), such as: (a) delineating sites on the map using pencils or markers, (b) locating special sites and landscape values on the map with color-coded adhesive sticker dots (Brown, 2004), and (c) pre-identifying and numbering special sites on the map and annotating them in a questionnaire. This study uses option (b), since option (a) *"may imply digitization efforts and has high variability in terms of participant responses"* (Brown, 2004; Plieninger et al., 2013) and option (c) does not permit visualization of the results of the individual responses on the map at the moment of the interview which may bias the results (Plieninger et al., 2013).

3.1. Expert interviews

Semi-structured expert interviews were conducted in order to prepare for the community interviews (see below). The aim of the expert interviews was to identify the most important forest ES with a direct use value for the communities in the study area and to fine-tune the social-demographic stratification of the community

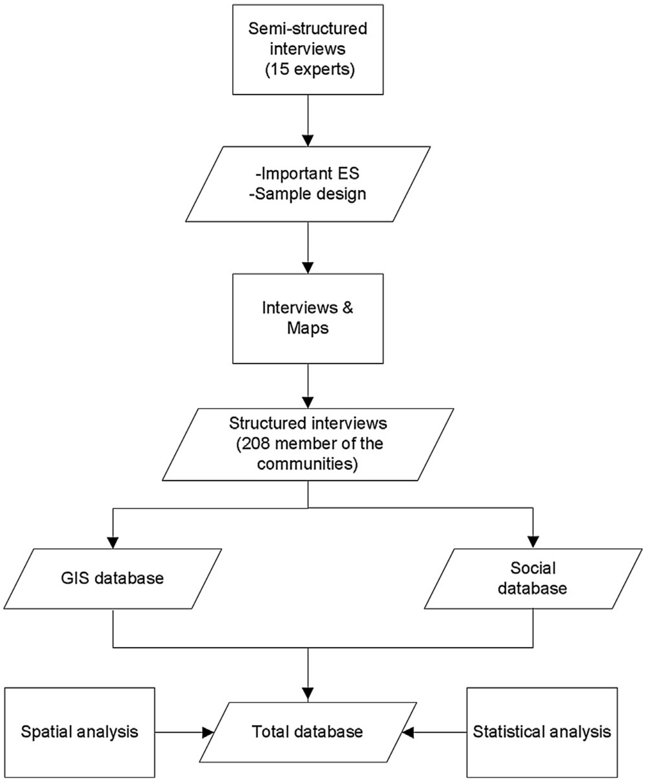

Fig. 2. Summary of the methodology used in the study. For further explanation see text.

Table 1
List of experts interviewed.

Type of organization	Organization	Number of experts interviewed
Governmental Organization (GO)	Ministry of Environment	4
	Ministry of Public Health	1
	Provincial Government of Napo	1
	GIZ	1
Non-Governmental Organization (NGO)	Rainforest Alliance	2
	CONDESAN	1
Consultant (C)	Independent	2
Indigenous Organization (IO)	Quixos Organization	1
University (U)	Universidad Estatal Amazónica (UEA)	2

CONDESAN: Consortium for Sustainable Development of the Andean Ecoregion (acronym in Spanish).
GIZ: German Corporation for International Cooperation (acronym in German).

sample. For this purpose, an introduction presenting concepts of forest degradation and ES was included (Appendix A). The preparatory expert interviews were required because a preliminary survey showed that it was necessary to have a structured interview to facilitate communication with community members.

The semi-structured interviews were carried out with 15 hand-picked experts, the smallest acceptable sample size in qualitative research (Bertaux, 1981; Guest et al., 2006; Mason, 2010; Rubin and Babbie, 2010). Experts were considered suited for the purpose of the study if they were involved in an organization that works with natural resources and communities in the study area, such as non-governmental organizations (NGOs), universities and government organizations (Table 1). First, an NGO expert was contacted who then facilitated access to key experts in other institutions. The interviews were carried out by telephone in Spanish between December 2014 and January 2015 and were recorded; they had an average duration of 20 min. The expert interviews identified five important ES, which were used in the participatory mapping exercise (more details in Results). In order to exemplify the results, various statements are cited in italics. The interview numbers are in brackets, for abbreviations see Table 1.

3.2. Community interviews

Two hundred and eight face-to-face, structured interviews were performed with members of 24 local communities; this sample size is similar to other ES mapping studies (Plieninger et al., 2013). Questions addressed socio-demographic aspects (age, gender, community, activity/occupation and years of living in the study area) and the location of the five types of ES in the study area (Appendix B). On average, about nine people were interviewed from each community, taking into account equal representation of gender and age classes (see Results). This sampling design was informed by expert interviews, as 70% of the experts believed that age (U2: "*I think you should have two groups*. . .*.the young and adults, the young will give you a different perspective because they are more connected to technology*") and gender (U1: "*the group of women is key* . . .. *one of the reasons is that men increasingly focus on economic activities while women still see the forest as a cultural heritage*") should be considered.

The interviews were conducted by the first author of this study with the help of a translator in Spanish and Kichwa language and had an average duration of ten minutes. The interviews included a traditional map (paper, A0 format, at 1:105,000 scale) and an oblique 3-D map (wood, A0 format, at 1:105,000 scale) in order to collect information about the location of the five important ES; the maps showed the most important land cover and landscape features making it possible for the interviewees to orient themselves. The administrative units were not used, which made it possible to map ES outside of these boundaries. The interviewees had to identify the location of ES on the map one by one; for each ES, he/she was asked to place a square sticker – color-coded according to ES – on up to three sites. Measurement of community demand for tourism was based on the desired amount and potential use of this ES by the communities (Villamagna et al., 2013; Wolff et al., 2015). For the other ES, measurement of demand was based on the level of direct use or consumption (Burkhard et al., 2012; Wolff et al., 2015).

The squares (area = 25 mm^2) were also fixed to a legend showing each identified ES (e.g. the presence of edible plants and fruits was marked with the color green). Based on test interviews, the questions (Appendix B) were formulated in such a way that they could be easily understood by the interviewees who were not familiar with the ES concepts (e.g. Question 2: "Where do you often hunt?"). The interviews did not include the different uses that the communities have for the ES; for example, water can be used as drinking water and/or for irrigation. Generally, the local people did not talk openly about the sale of wood because they recognized that the majority of them practice this activity illegally (they do not have the permission required by the authorities). Therefore, "Question 3" about wood focused on domestic uses.

3.3. Data analysis

3.3.1. Interview analysis

The semi-structured expert interviews were transcribed and analyzed in MAXQDA, (VERBI GmbH; version 10). Initially, the interviews were coded with open codes. Open coding is unrestricted coding of the data. It is done line by line, or even word by word. The aim is to identify concepts, which may initially be provisional (Strauss, 1987). Later, an axial code was created, which involved intense analysis of one category at a time (Strauss, 1987). The data was sorted into 14 major ES categories (e.g. water, education, tourism, scenic beauty and others) according to the Millennium Ecosystem Assessment (MA, 2003). A similar procedure, using the categories age and gender, was employed to summarize the responses according to the sample design.

3.3.2. ES mapping analysis

The maps created with each individual community member were scanned and georeferenced to digitize the locations of the ES recorded with point features using QGIS software. In total, 967 ES locations were digitized. An Excel database was generated with the social-demographic data gathered during the interviews. Afterwards, the Excel and GIS databases were joined. Excel 2007 (Microsoft; version 2007) and RStudio (RStudio, Inc.; version 0.98.1073) were used for statistical analyses and ArcGIS (ESRI; version 10) was used for spatial analyses.

3.3.2.1. Statistical analysis.
It was expected that the distance between each ES location and the roads and main villages respectively could explain some of the variation in the spatial distribution of the ES. The proximate distances between ES location and roads and between ES location and main villages were calculated as the straight-line distance. Later, descriptive statistics were applied to obtain a general distribution of ES in the study area.

3.3.2.2. Spatial analysis.
A continuous surface representing the density of ES locations based on kernel was calculated; thus identifying hotspots.[5] Kernel density mapping generated a circular area of a certain bandwidth or search radius around an indicator (Alessa et al., 2008; Van Der Veen and Logtmeijer, 2005). A search radius parameter of 2000 m was used, according to the mapping scale (1:200,000) and an estimated respondent error of 100–200 m (size of the stickers); and testing threshold distances (Alessa et al., 2008; Brown, 2004). The output cell-size parameter was determined from the approximate scale of the survey maps and set to 100 m. The grouping of the density values was defined using the "natural breaks" classification and it was assigned a value index for better visualization of the results, where the high density values have "nine" on the value index and decrease until "one" for the low density values. The "natural breaks" classification method identifies "breakpoints" between classes using Jenks' optimization algorithm. The algorithm minimizes the value differences between data for maximum homogenization within the same class and emphasizes the dispersion between intervals (Jenks, 1963).

Finally, spatial indices such as intensity and richness were calculated based on the administrative units. These units are meaningful because they facilitate the generation of management and policy recommendations in each community. In this case, intensity is the total number of ES locations identified by all interviewees per administrative unit; richness is the number of different ES per land administrative unit (Plieninger et al., 2013). The groupings of the spatial indices were also defined by classification of the natural breaks.

4. Results

4.1. Important forest ES in the study area

The experts were asked about the most important forest ES with a direct use value for the communities in the study area. In total, they mentioned 62 forest ES, which were grouped into 14 major ES categories. Each expert mentioned an average of four ES. The four ES most often mentioned were food, wood, tourism, and water (Fig. 3).

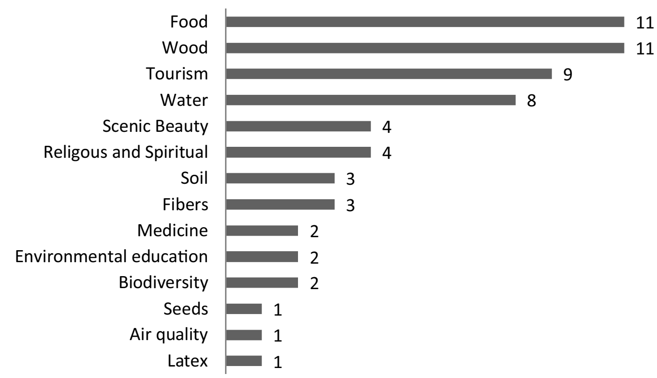

Fig. 3. Important forest ES mentioned by the experts (n = 15) summarized by 14 major ES categories. The numbers indicate the number of statements in each category. One expert could make several statements within and across categories.

Food was the most frequently mentioned ES and for the community interviews it was subdivided into gathering of plants and fruits and hunting. Most of the experts' statements relating to food focused on: edible plants contained in forests that are important for the diet and sustenance of the communities (U1: "*garabato de yuyo which is a wild fern that gives a special flavor to the traditional dishes*"); fruits (GO1: "*chonta fruit*" which comes from a palm); and animals (U1: "*guanta*" (*Agouti paca*)). However, a few experts mentioned that those communities located close to the cities prefer to buy food at the market.

Wood and tourism were the second and third most frequently mentioned ES. Wood is a traditional forest ES, which has different uses such as providing a source of economic support for the communities as well as the construction of houses and wooden boxes for the transportation of naranjilla and others; This is exemplified in statements from U1: *"the wood and toquilla straw are used to build houses"* and NGO2: *"the forest gives shelter if you manage to sell a tree"*. Regarding tourism, the scenic beauty of the study area has generated some tourism initiatives and the communities have an interest in extending this ES in the area (GO2: *Ïf you ask the local people what they would like to work on in the future, many identify tourism*").

Finally, water was the fourth most frequently mentioned ES, mainly referring to the role of forest in providing protection of water sources. This is reflected in the following statements: *"maintenance of water sources"* [GO3] and *"forest protects these areas* (watershed) *where livestock should not be present"* [U2].

4.2. Demographic characteristics of the local interviewees and demand for ES

Women made up 48% of the sampled population and 52% were men. Twenty-six percent of the interviewees were under 27 years old, while 50% were between 27 and 53 years and 24% above 53. The most common activity/occupation in the communities was farming (73%), followed by housewives (11%), and high school students (7%); nine percent were school teachers, public employees, carpenters, or had some other occupation. Additionally, of those involved in farming, 44% were women and 56% were men. Forty-eight percent of the interviewees had lived in the study area for between 20

[5] A hotspot is the intensity of an incident in space (Van Der Veen and Logtmeijer, 2005).

Table 2
Demand for five ES according to land cover.

Land cover	Area (ha)	Number of ES locations
Forest	151,994	676
Areas without vegetation	2110	5
Farmland	43,023	283
Shrubby and herbaceous vegetation	277	3

and 37 years, while 28% had lived there less than 19 years, and 24% for over 37 years.[6]

Fifty-nine percent of the local interviewees located all five ES on the map. In total, 967 locations of ES provisioning sites were mapped. Each person usually mapped one position per ES. Tourism (222), followed by gathering of plants and fruits (206), wood (205), and water (203) were the ES most frequently located on the map by the interviewees, whereas fewer locations were identified for hunting (131).

4.3. Spatial distribution of ES locations

The minimum distance between an ES location and the main villages (Fig. 5) was approximately 1 km, while the maximum distance was 15 km. Also, the results highlighted that the recorded locations of ES increase by a distance of 8 km from a main village. The measurements of distance between the ES locations and the nearest main road (Fig. 4) showed that most of the ES were recorded within a distance of less than 4 km from the roads.

Seventy percent of the ES locations mapped were located within areas of forest cover and the rest were mainly in farmland (Table 2). The ES with the most locations located within the forest were "tourism" (166) followed by "gathering of plants and fruits" (156) and "wood" (139). In farmland (including crops and traditional agroforestry systems), the leader was "water" (89) followed by "wood"(64) and "tourism"(53). Additionally, about 7% of the ES locations were recorded in the core area (Fig. 1) with "tourism" (21), "gathering of plants and fruits" (15) and "hunting" (14) being recorded in more locations.

4.4. Spatial arrangement of ES

The density maps of the recorded ES locations (Fig. 5) showed that there was one "major hotspot" that was shared by all the ES, while the minor hotspots did not show any common pattern of distribution amongst the different types of ES. The "major hotspot" is located in the central part of the study area, specifically in three administrative units of KPR. The social data highlight that the major hotspot resulted from the ES registered by two communities from Hatun Sumaco, and eleven from KPR. The majority of the hotspots were located in forests (compare Fig. 1), with the exception of water, for which one hotspot was registered in farmland ("2"), and tourism, for which one hotspot ("4") was located in an area with forest and farmland cover.

Additionally, spatial indices were calculated using the administrative units of the study area (Fig. 6). The highest intensities of ES locations were recorded in five administrative units (between 62 and 109 locations), two of which belong to the Hatun Sumaco parish and three to KPR. Most of the units had a richness of five; from the units which had a richness of less than one, three were located in KPR and one in Hatum Sumaco parish. It is noteworthy that the size of the administrative unit is not a determining factor in the number of ES locations (intensity); for example, in the north of the study zone the biggest polygon (19.000 m^2) has an intensity value of between 8 and 23, whereas in the center of the area there is polygon with an area of 5000 m^2 that has an intensity value of between 62 and 109.

5. Discussion

5.1. Important forest ES the demand for these from local communities

The local people in the study area are highly dependent on the forest because it contributes to livelihoods and cultural traditions (Izurieta et al., 2014). The interviewed experts identified four important ES provided directly by the forest for the community. In the following, the results from the expert interviews are discussed in view of the results from the community interviews.

5.1.1. Food

The experts generally believed that the communities are highly dependent on the forest to obtain plants, fruits and animals for their daily diet, a statement supported by Valarezo et al. (2002). However, some experts mentioned that the communities located near to the cities prefer to buy food at the market. This view is also reflected in the results of the community interviews which revealed that the number of mapped ES locations increases with the distance from the main villages. This is due to the fact that the forest cover around the main villages is already degraded or deforested (Izurieta et al., 2014) and due to the presence of village markets.

More locations were registered for the gathering of plants and fruits than for hunting. There may be several reasons for this: a) forest disturbance and degradation has led to the reduction of numbers and species of animals (e.g. deer, mountain tapir spider monkey and others) (Valarezo et al., 2002); b) the creation and upgrade of roads (MAE, 2012b) has improved access to the markets; c) Art. 3 of the law for the preservation of reserved areas prohibits hunting in a Reserve; d) damage to the forest has forced local people to walk longer distances to hunt; e) the fact that hunting is an illegal activity may have discouraged respondents from recording hunting locations; and f) in general, the focus on economic and productive development has led to a decrease in ancient practices such as hunting (Salgado, 2012) as also observed by Ramirez-Gomez et al., 2015 in the region.

Some similarities are found between Ecuadorian and Brazilian Amazon communities. The interviewed communities consistently registered more locations for the use of plants and fruits, water, wood and tourism than for hunting (e.g. Bernard et al., 2011). Also, hunting practices typically occur within a radius of 8 km from an access point (roads or rivers). This has also been observed for Brazilian communities (Peres and Nascimento, 2006; Peres and Lake, 2003). Despite the fact that fewer locations were registered for hunting than for the other ES in the area, when practiced excessively it can nevertheless cause forest degradation (Simula, 2009). For example, a forest affected by hunting has less availability of key species (seed dispersers) that help the regeneration of large-seeded plants (Harrison, 2011; Peres, 2001).

Finally, plants and fruits is an ES that needs to be managed in the zone because the observed high demand in the area can cause forest degradation due to excessive harvesting (Arnold and Perez, 2001; Simula, 2009).

5.1.2. Tourism

New practices such as tourism are becoming important in the study area (Valarezo et al., 2002). The interviewed experts stated that tourism is an opportunity to promote sustainable forest management. The members of the communities registered this

[6] The five-number summary (sample minimum, lower quartile, median, upper quartile, sample maximum) was used to define intervals in the data presented.

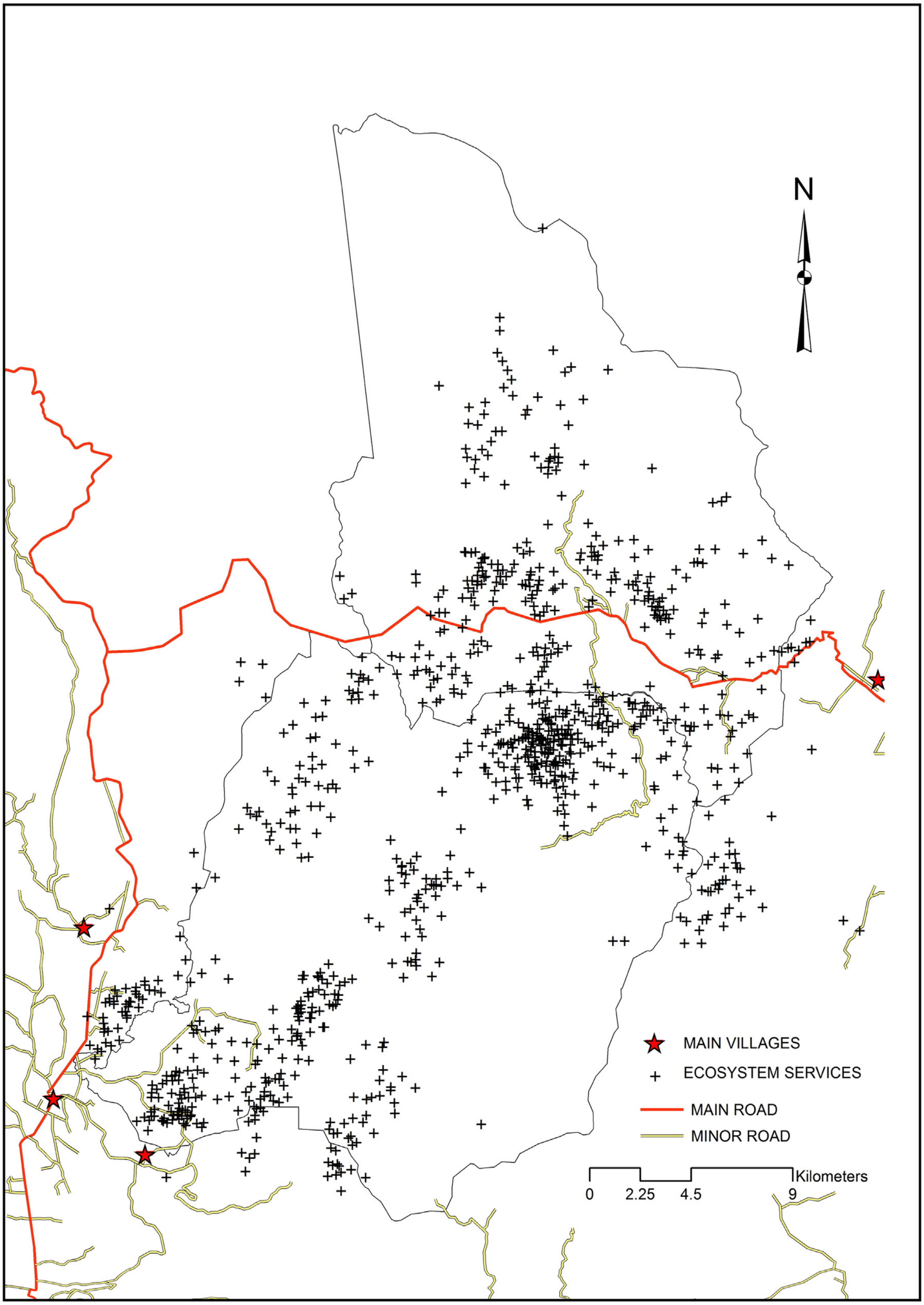

Fig. 4. Ecosystem service (ES) locations (n = 967) as indicated by local people during the participatory mapping process; five important ES were considered; for further information see text.

ES in several locations across the whole area showing the high potential for tourism development in the area. A similar behavior was observed by (Ramirez-Gomez et al., 2016) in Colombia where tourism showed the largest spatial occurrence in the study area. Despite of the potential importance of this ES there is no development agenda in the communities; for example, of the 24

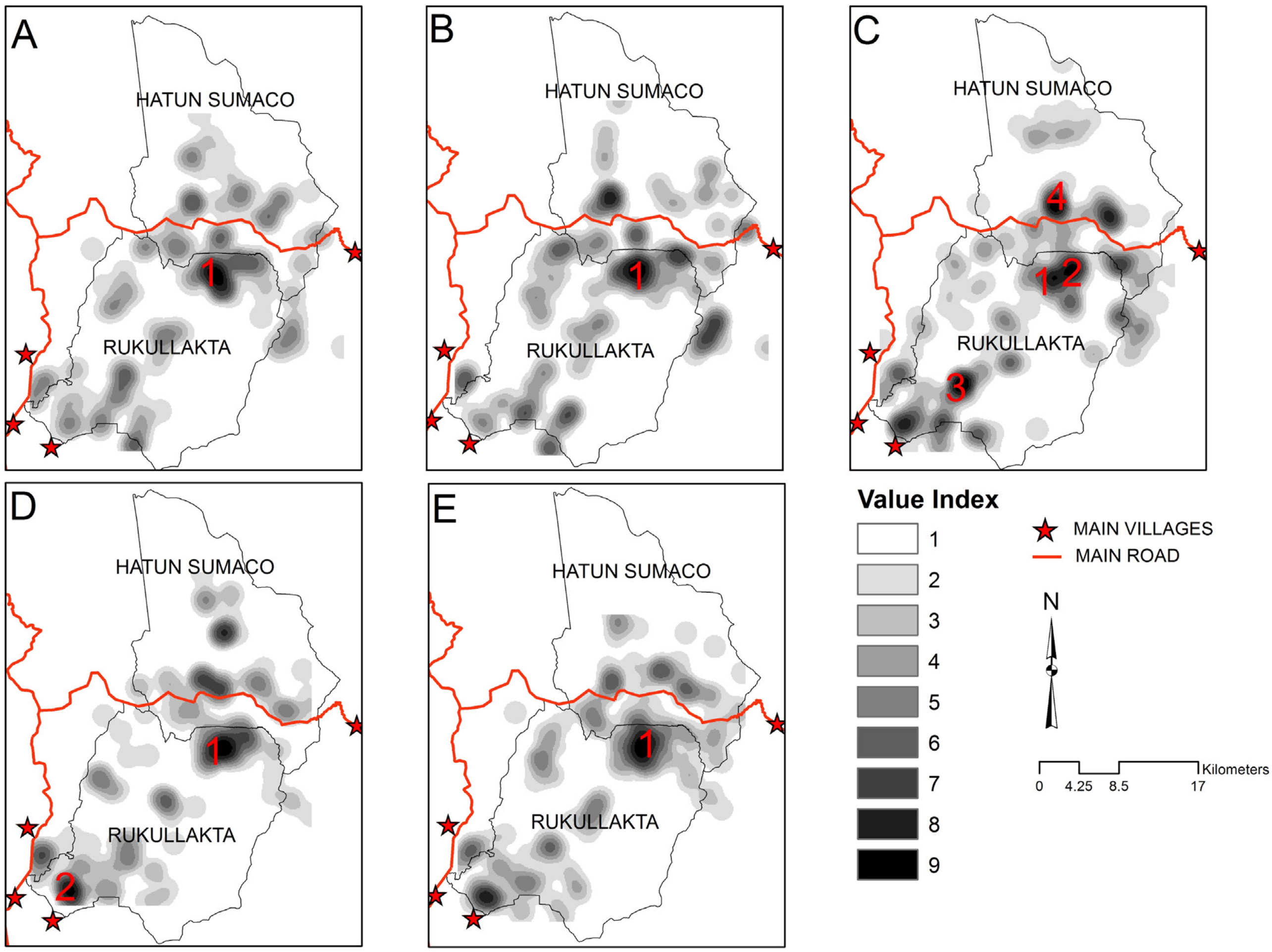

Fig. 5. Hotspot maps of individual ES; a high value index corresponds to locations where the density of ES locations was high. Plants and fruits (A), hunting (B), tourism (C), water (D) and wood (E).There was one major hotspot (marked "1") where high value indices overlapped for all ES; in addition, there were individual hotspots for each ES; for explanation see text.

communities, only Pacto Sumaco has two official tourism locations for trekking and wild flora and fauna sighting (GAD-PHS, 2014). Therefore, in the case of tourism we are analyzing the potential use and not the actual use (see Section 3.2). This could explain why the number of tourism hotspots (4) is higher than for the other ES. The potential areas of tourism overlapped to some degree with hunting areas which indicates a certain conflict potential (e.g. Kichwa community has forbidden hunting close to the tourism locations (Loaiza et al., 2016)). In this area, tourism is not currently a managed ES (Valarezo et al., 2001) which can cause forest degradation, as is the case in some developed countries (Simula, 2009).

5.1.3. Wood

According to the experts, wood exploitation is a primary ES, and this is corroborated by Bernard et al. (2011). This applies especially in the buffer and transition zones (Valarezo et al., 2002) where logging is permitted for those with a logging license. In the study area, there is a demand for certain species of timber, e.g., cedar (*Cedrela odorata*), canelo (*Nectandra* spp.), walnut (*Juglans neotropica*), and others (Valarezo et al., 2002) that are generally found in primary forest (Palacios and Jaramillo, 2001). Although most of the wood harvest is sold (GAD-PHS, 2014), the experts also emphasized its household use. This contrasts sharply with other communities in the Amazon, for example, in Maués State Forest (Brazil) where most of the residents use the wood for home construction, storage houses or boats rather than for sale. This is because the extraction of timber in Brazil is mainly carried out by companies, operating under a concession system (Bernard et al., 2011).

The local people do not generally want to talk openly about the sale of wood because they recognize that most of them practice this activity illegally. For this reason our question about wood focused on domestic uses. In this context, most of respondents registered the locations of this ES near to their farms. The hotspots for wood are in the center of the study area, close to roads, reflecting ease of transportation. The lack of control on harvesting of wood for domestic uses can affect forest ecosystem process (Cummings and Read, 2016), causing forest degradation in the long term (Simula, 2009).

5.1.4. Water

The forest cover in the study area assists water catchment and hydro generation and thereby supports provision of water for the communities, tourism, transport (lower elevation zone), aquaculture and others (Valarezo et al., 2002). The experts focused more on the quality of the water as an ES provided by the forest than on quantity because there are problems with water contamination. The rivers in the area are susceptible to contamination because local people have placed pastures and crops close to them or cut trees in the adjacent areas (GAD-PHS, 2014; Izurieta et al., 2014; MAE, 2012a; Valarezo et al., 2001). The area has several rivers and

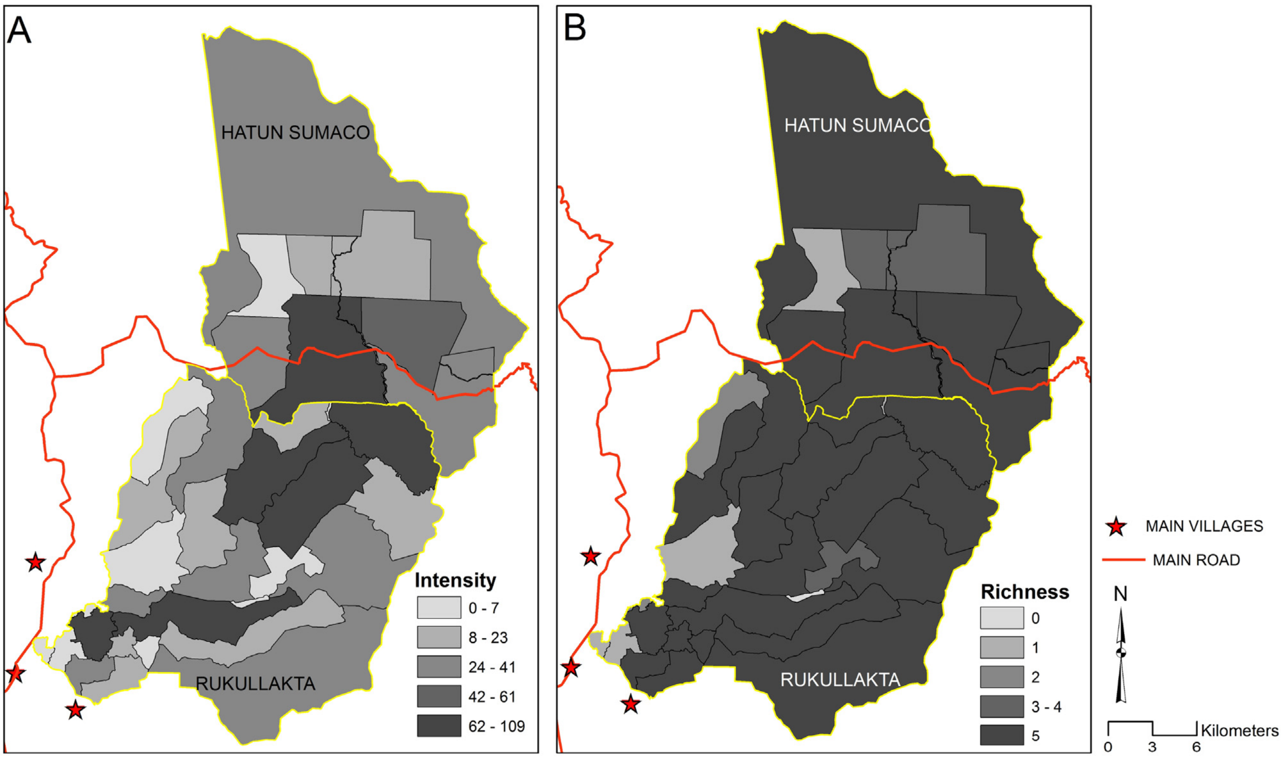

Fig. 6. Index of ES: (A) intensity (the total number of locations of ES per administrative unit) and (B) richness (the number of different ES per land administrative unit).

water sources meaning that the services are well spread across the area. However, in most cases, members of the communities identified the same places (two hotspots) where they extract the water using piped water systems without treatment; this leads to a situation where the communities are exposed to poor quality drinking water (GAD-PHS, 2014).

According to the experts, forested watersheds have better water quality than watersheds surrounded by other land uses (see also Lee et al., 2009; Paudyal et al., 2015; Tong and Chen, 2002). Additionally, highly fragmented (Lee et al., 2009) and degraded forest (Birch et al., 2014) often contributes to a decline in water quality.

5.2. Distribution and spatial arrangement of ES

Descriptive statistics for understanding the general spatial distribution of ES showed that the roads are a determining factor in the distribution of ES. This is because they facilitate the easy extraction of forest resources (Peres and Lake, 2003). A few ES locations (e.g. gathering of plants and fruits and hunting) were mapped inside the core zone where only activities such as research, environmental education, and controlled ecotourism are allowed (Valarezo et al., 2002). Because the descriptive statistics do not provide location-specific information (Brown and Fagerholm, 2015), intensity analysis (e.g. hotspots) was undertaken and spatial indices (e.g. richness, intensity) were calculated to generate information about the spatial arrangement of ES.

The hotspots results showed that the distribution of ES locations is not spatially uniform in the study area as also observed in other Amazon communities (Bernard et al., 2011; Parry et al., 2010). Several studies in the Amazon region showed the impact of population on the demand for ES (Albert et al., 2007; Ramirez-Gomez et al., 2015; Sirén and Henrik, 2007). In this case, the high population density of KPR may cause overexploitation of ES (e.g. Fagerholm et al., 2012) and may result in declining ES provision in the area (Ramirez-Gomez et al., 2015). This is indicated by the fact that interviewees in this area demanded more ES in hotspot areas and registered more hotspots (Fig. 6). On the other hand, Hatun Sumaco has a lower population density than KPR and interviewees in this area registered less demand for ES in the hotspots as well as fewer hotspots. This suggests a lower level of pressure on the stocks of ES (Ramirez-Gomez et al., 2015). The major hotspot shows that there is an overlap in demands for the five ES that can cause conflicts relating to the use of ES; for example, the removal of trees that can be used to collect food, or commercial timber production or traditional use that can impact the wildlife and people (Cummings and Read, 2016).

The spatial indices (Fig. 5) allow for comparison of ES across different administrative units within the study area (Brown and Fagerholm, 2015). Six communities show low values of richness and intensity in the study area; this may be related to the lower population density in the case of Hatun Sumaco, whereas in KPR the proximity of the communities to the main villages and their denomination as "urban areas" might have contributed to the observed low values (Ortiz et al., 2012). Additionally, most of the communities have high coexistence (richness) of ES, which is not related to the result of intensity. Considering only one measure for management may ignore important areas with high intensity values (Bryan et al., 2010). In general, the reason for high intensity of ES in some communities could be the accessibility (Fig. 6) given that they are located close to main roads. Specifically, in the case of Hatun Sumaco one community has a high demand for ES despite the fact that the population density (11 persons/km^2) is not the highest in the parish (GAD-PHS, 2014). In the case of KPR, the high intensity values associated with some territories might be explained by internal territorial planning of the organization; these areas are classified as "rural" that are used by the communities for the exploitation of natural resources (Ortiz et al., 2012).

5.3. Management recommendations

Based on our observations, we consider that the creation of management plans and an increased presence of rangers close to the roads in the SBR are necessary. The management plans should focus on regulating ES such as tourism, gathering of plants and fruits, wood and hunting (see Section 3.3), because these are the activities that can cause forest degradation if practiced excessively. In this context, the management plans and regulations should also consider the cultural values of the communities to achieve an integrated management in the area.

There are four administrative units that had high values of intensity and richness; focusing on the management of those areas allows the handling of multiple objectives at place-specific scales (Bryan et al., 2010). Three of these administrative units are part of the KPR organization that does not have political representation in the province. However, the organization does have autonomy in the form of a decentralized management at the territorial and administrative levels. In the past, the KPR organization has had numerous achievements, but the local people are now concerned because there is no coordination or communication between each community council and the general council, resulting in uncoordinated efforts (Salazar and Coquinche, 2014). The KPR recognizes the importance of the natural resources as the basis of their economic, social and political development. Finally, although one administrative unit belonging to Hatun Sumaco parish has representation in the provincial government, it does not have a clear organizational structure according to the law, and is weak in management. Also, each community works independently, resulting in differing levels of development (GAD-PHS, 2014). Therefore, it is necessary that each community in both the parish and KPR develops a management plan with the support of local district and provincial authorities; this is most urgent in the communities that have high values of intensity and major hotspots.

6. Conclusion and recommendations for further research

The mapping method used in this study has advantages such as the use of hardcopy maps and stickers that allows for its application even in remote zones where no internet is available; however, the precision of the results can be compromised because of the scale of the map (Brown and Fagerholm, 2015). Furthermore, the versatility and low cost of the method permits it to be used as a tool for monitoring ES in remote reserve areas with limited financial resources. In fact, the monitoring of ES is one of the challenges that the current participatory governance[7] of SBR intends to address (Torres et al., 2014). An important aspect is that the design of the sample, which took into account gender and age for participatory mapping, was appropriate and represented a proper sampling design. Regarding the reliability of the interviews, it was observed that since the study was carried out in an area under legal protection, the mapping may be influenced by fear of locating an ES because its practice is forbidden by law (e.g. wood extraction, hunting).

The results regarding distribution and spatial patterns of ES reported in this study used secondary data from the Ministry of Environment (e.g. roads, land cover map 2014), which is an official source of environmental data in Ecuador, and data on administrative units generated by consultants. Since the road network in the area is quickly expanding and administrative units are liable to change, it is advisable for any future studies to verify and update the secondary data to obtain more accurate results.

[7] An initiative implemented in SBR to improve the management of natural resources through dialogue between different actors (Torres et al., 2014).

This was the first community mapping exercise in Ecuador, which can act to sensitize the local communities to the ES that the forest provides (Strauss, 1987). To test this, it will be necessary to carry out other participatory studies where members of these communities provide their opinions on the results and recommendations for resource use. An aspect to be considered is that the local communities are only willing to contribute information to research for academic and political purposes if they are informed of the objectives, the results are shared with them, and the community council has previously agreed to the research activities.

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Appendix A. Semi-structured interviews – Experts

Introduction

The FAO mentions that forest degradation is a change within the forest, which negatively affects the structure or function of a forest, thus reducing the capacity to provide products and/or services.

Ecosystem services are the benefits people obtain from ecosystems. These are: provision (e.g. food, water, fiber, fuel and genetic resources), regulation (e.g. flood control, drought, air quality, erosion, climate, disease and natural disasters) and cultural services (e.g. recreational, spiritual, non-material benefits such as religious, and others) that directly affect people, and supporting services (e.g. soil formation, photosynthesis, nutrient cycling, etc.).

The value of ecosystem services can be divided into use values and non-use values. Use values are classified as direct use values, indirect use values and option values. The interviews are focused on ecosystem services with direct use value because the main characteristic of these is that they are tangible. They may be used directly for consumption (e.g. wood, hunting, medicinal and edible plants) or not (e.g. enjoyment of recreational and cultural services).

Question1.-I have some preliminary questions related to your professional position.

What are the responsibilities of your job?

Is your institution involved in initiatives to promote sustainable forest management?

Question2.-Could you mention services with direct use value offered by the forest that are important to the community?

Examples:scenic beauty, education and culture, wood, non-timber services such as food, fibers etc, and others.

Question3.-In your opinion, what are the ecosystem services most affected by forest degradation?

Question4.-In your opinion, which people should be interviewed?

It is intended to conduct interviews that include a map with Hatun Sumaco and Rukullakta organizations. What aspects do you think need to be considered to obtain a sample that captures the perceptions within the communities?

Appendix B. Structured interview – Communities

Question1.-Where do you frequently collect plants and fruits?

Question2.-Where do you often hunt?

Question3.-Where do you collect wood for domestic use?

Question4.-Where do you collect water for domestic consumption?

Question 5.-Where are the areas that you think have potential as tourist attractions?

Question 6.-How old are you?

Question 7.-What organization do you belong to?

Question 8.-What community do you belong to?

Question 9.-What is your activity/occupation?

Question 10.-How many years have you been living here?

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