Perceptions of ecosystem services provided by tropical forests to local populations in Cameroon

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A B S T R A C T

In Central Africa, local populations are deeply dependent on tropical forests, which provide numerous ecosystem services (ES). For the first time in Central Africa, we assessed the perceptions of ES provided by tropical forests to local populations, considering three land allocation types: a protected area, a Forest Stewardship Council (FSC)-certified logging concession, and three community forests. We conducted a questionnaire survey with 225 forest stakeholders in southeastern Cameroon, combining an open-ended question and 16 directed questions to evaluate the perceptions of ES significance and abundance, respectively. The ES most frequently reported as significant were provisioning (93% of respondents) and cultural & amenity services (68%), whereas regulating services were less mentioned (16%). Bushmeat provision was the only ES perceived as highly significant but not very abundant. There were slight variations of perceptions among forest land allocation types and respondents, suggesting a relative homogeneity in ES abundance. For further integrative ES assessment, we suggest quantifying ES with complementary ecological and economic approaches, such as meat provision, recreation, tourism, timber provision, spiritual experience, firewood provision, water quality regulation, and inspiration for culture. We also give three concrete recommendations for forest management, the most urgent being to provide sources of protein alternative to bushmeat.

1. Introduction

Ecosystem services (ES) are the contributions of ecosystems to human well-being (Burkhard et al., 2012). They classically include provisioning, regulating, and cultural services (de Groot et al., 2010a). ES constitute a conceptual tool that integrates human-nature relationships (Turner and Daily, 2008) and contributes to the implementation of concrete policies and practices for the sustainable use of all ecosystems.

In order to guide decision makers towards ecological sustainability, economic efficiency, and social justice, any complete ES assessment should use an integrated approach that combines relevant methods (Costanza, 2000; Farley, 2012; Millennium Ecosystem Assessment, 2005). Integrated valuations combine ecological, economic, and social approaches (Burkhard et al., 2010; Felipe-Lucia et al., 2015; Jacobs et al., 2016). Ecological approaches measure the ecological functions or ecosystem biophysical properties (Boeraeve et al., 2015; de Groot et al., 2002); economic approaches give values to ES in monetary terms (Wilson and Carpenter, 1999); and social approaches focus on the values that society attributes to each ES (Martín-López et al., 2012). Current ES assessments mainly focus on the ecological and/or economic approaches (Satz et al., 2013), whereas social approaches are rarely implemented (Kremen and Ostfeld, 2005; Boeraeve et al., 2015). However, social approaches are fundamental to better understand complex social-ecological systems (Orenstein and Groner, 2014). To ensure optimal provision of ES on which humans rely (Rosenberg and McLeod, 2005), it is essential to integrate all stakeholders' perceptions in sustainable management strategies and decisions (Braat and de Groot, 2012; Castro et al., 2011; Collins et al., 2010). The decision making process should incorporate the societies' perceptions in order to: (i) legitimize strategies and decisions, meeting multiple stakeholders' interests (Martín-López et al., 2012; Menzel and Teng, 2009); (ii) anticipate likely reactions, behavior, and compliance of key stakeholders to new regulations and measures (Gelcich et al., 2009; Gelcich and O'Keeffe, 2016; Hicks and Cinner, 2014); and (iii) identify agreement areas (Hicks et al., 2013).
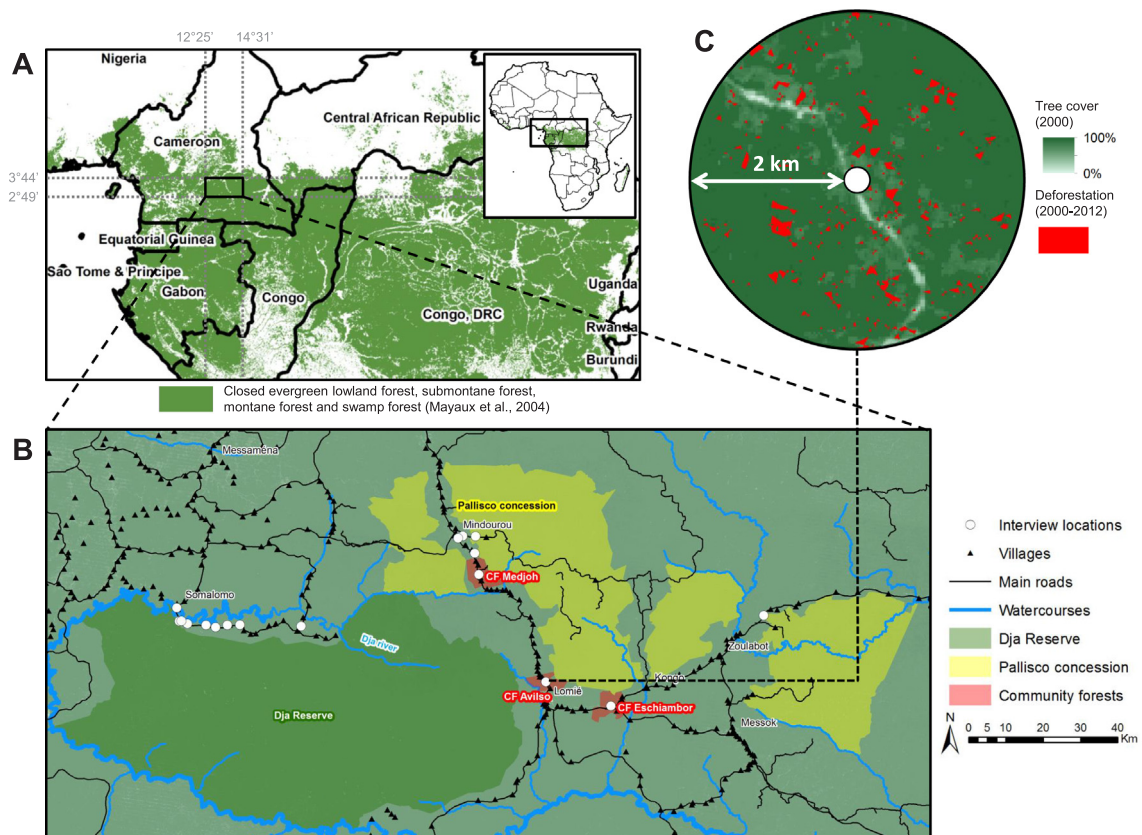
Fig. 1. Location of the study area in Central Africa (A). Sampling locations of interviews in the study area (white dots), associated with the three land allocation types (a protected area, a FSC-certified logging concession, and three community forests) (B). Example of a sampling location in a community forest, with 4% of deforested areas between 2000 and 2012 (red polygons; Hansen et al., 2013) in a radius of 2 km (C).

Each ES assessment should be initiated with a social approach to consider the perceptions of local stakeholders (Cuni-Sanchez et al., 2016); furthermore, social methodologies to assess ES are currently disparate (Felipe-Lucia et al., 2015; Menzel and Teng, 2009) and standard approaches need to be developed. Santos-Martín et al. (2017) reviewed seven methods that are frequently used in ES literature, dealing with different data types adapted to several valuation purposes: preference assessment (e.g., Martín-López et al., 2012), time use method (e.g., García-Llorente et al., 2016), photo-elicitation surveys (e.g., García-Llorente et al., 2012), narrative methods (e.g., Kovács et al., 2015), participatory mapping (e.g., Plieninger et al., 2013), scenario planning (e.g., Bohensky et al., 2006), and deliberative methods (e.g., Karjalainen et al., 2013). Despite an ongoing debate on ES and nature's contributions to people (NCP) concepts, raised by Díaz et al. (2018), we adopted the ES framework while integrating social approaches in assessments, and emphasize the importance of doing so.

Central Africa is home to approximately 113 million people, with more than 23 million living in Cameroon (Abernethy et al., 2016). Central African forests provide a diversity of provisioning, regulating, and cultural ES, offering wood and means of subsistence to 60 million people living either inside or in the vicinity of forests (de Wasseige et al., 2015), particularly through hunting and gathering non-timber forest products (NTFP). These forests also constitute large carbon stocks that influence global climate (Pan et al., 2011), and host an important part of the world's terrestrial biodiversity (Mallon et al., 2015). Human populations also attribute a variety of socio-cultural values to Central African forests (Vermeulen, 2000). Although deforestation rates are still relatively low in Central Africa in comparison to other tropical regions (Achard et al., 2014), these forests will face multiple human pressures in the near future (Malhi et al., 2014). Environmental changes could soon be observed due to increasing human populations, demand for

economic growth, global climate change, overexploitation, and weak governance (Abernethy et al., 2016).

Local-scale assessments of multiple ES provided by Central African tropical forests are urgent and crucial, but none have been made yet (Wangai et al., 2016). These complex social-ecological systems are influenced by several groups of stakeholders with contrasting interests and uses of resources (Gillet et al., 2016; Janssen et al., 2007), and constitute a high-priority stake considering their contribution to human life quality in a high-poverty context. For the maintenance of future ES flows and sustainability objectives for forest land management, assessment of both ES significance and abundance is required. It is also essential to comprehend how the stakeholders' perceptions of ES are shaped by their surrounding environment (Hartter et al., 2014; Quintas-Soriano et al., 2016) such as forest land allocation and deforestation, and by socio-demographic characteristics (Carpenter et al., 2006; Zhang et al., 2016) to properly align forest land planning strategies (protection, production, or community management) with stakeholders' needs and uses in a sustainable manner.

The main objective of this study was to assess the perceptions of ES provided by tropical forests to local populations in southeastern Cameroon. We specifically aimed to: (i) assess the significance and abundance of ES; and (ii) identify any differences in the perceptions of ES abundance among three forest land allocation types (a protected area, a logging concession, and community forests), among areas with different deforestation rates in previous years, and among respondents with distinct socio-demographic characteristics (gender, age, ethnicity, and main occupation). Hereafter, we define the "perceptions" of ecosystem services as the cognition of usefulness and interests of the forest for its contributions to the well-being of local human populations (Attneave, 1962). We consider "land allocation types" as resulting from a planning and zoning process identifying explicit geographical areas

with allowed practices (Oyono et al., 2014).

We hypothesize that ES abundance varies among contrasting forest land allocation types, considering the differences in access to forest resources and user rights for local populations. Using a social approach with novel data in a data-deficient region, our study provides insights on the importance and perceived supply of ES, and the ability of contrasting forest land allocation types to provide abundant ES to local populations. It also contributes significantly in the understanding of the socio-demographic characteristics shaping the ES perceptions of forest stakeholders in rural areas of a developing country in Central Africa.

2. Material and methods

2.1. Study area

The study area was located in southeastern Cameroon, between latitude 2°49′N to 3°44′N and longitude 12°25′E to 14°31′E (Fig. 1). The annual rainfall is around 1640 mm with two distinct rainy seasons (August to November, and March to June), the mean annual temperature is 23.1 °C (Hijmans et al., 2005). Forests are assigned to Moist Central Africa (Fayolle et al., 2014) and were originally described as a transition type between lowland evergreen and semi-evergreen forests (Letouzey, 1985). In this area, local populations mainly comprise Bantu people, whereas the Baka Pygmy people constitute another smaller ethnolinguistic group. The Baka are considered as the Indigenous population, who were present in the forest even before the arrival of Bantu people (Winterbottom, 1992). Among the Bantu, three ethnolinguistic groups are considered native to the study area: Badjoué, Nzimé, and Ndjem. These are all part of the Makaa-Ndjem ethnolinguistic group, corresponding to the coded Zone A80 in the Guthrie classification of languages (Guthrie, 1948). They pursue similar production systems: shifting cultivation, hunting, fishing, and gathering of forest products (Vermeulen, 2000). We define "local populations" as rural communities depending on the forests for their daily activities (Bantu and Baka Pygmy populations), and "forest stakeholders" as all members of the forestry sector (comprising local populations as well as managers, workers, or officials).

According to the World Resources Institute (2012), the classified area of the National Forest Estate (NFE) represented 37% (17.5 million hectares) of Cameroon in 2011. We worked in specific locations (Fig. 1) associated with the three major land allocation types of Cameroonian tropical forests: (i) protected areas (42% of the NFE); (ii) logging concessions divided in forest management units (FMUs, 40% of the NFE); and (iii) community forests (6% of the NFE), representing in total 88% of the NFE. These forest land allocation types are also largely represented in Central Africa, at the regional scale. Estimated area, mean forest cover, deforestation rate, and the legal and illegal activities in each land allocation type are mentioned in the Supplementary Information (Appendix A).

(i) The protected area studied was the Dja Biosphere Reserve, which is the largest protected area in the country and aims to conserve biodiversity according to a management plan approved by the Forestry Administration. It is a "Man and Biosphere Reserve" since 1981, listed as a UNESCO World Heritage site since 1987, and is defined as the IV-category of IUCN protected areas. The reserve comprises a core area of nearly 526,000 hectares in which agricultural, gathering and hunting activities are prohibited. In the buffer zone (not yet precisely delimited), local populations can pursue non-industrial sustainable activities such as wood collection, NTFP gathering, and slash-and-burn agriculture (Appendix A). According to the Conservation Service and local guides, between 15 and 100 tourists annually visit the northern part of the reserve where this research was conducted. Tourists are interested in discovering local Baka traditions and major wildlife species such as forest buffalo (*Syncerus caffer nanus*), chimpanzee (*Pan*

troglodytes), giant pangolin (*Manis gigantea*), elephant (*Loxodonta cyclotis*), mantled guereza (*Colobus guereza*), leopard (*Panthera pardus*), or western lowland gorilla (*Gorilla gorilla gorilla*). This area is also included in the Dja Biosphere Regional REDD+ Project, which aims to reduce deforestation and forest degradation on 1.2 million hectares of forests in and around the protected area. Previous awareness campaigns for wildlife conservation were conducted under the European "ECOFAC" program.

(ii) The logging concession studied was certified by the Forest Stewardship Council (FSC) in 2008, and has been managed by the Pallisco company (http://www.pallisco-cifm.com) since 2004. The company develops forest management plans for their concession areas with a 30-year planning approved by the Forestry Administration (Cellule Aménagement Pallisco and Nature+, 2015). The main timber species selectively logged are sapelli (*Entandrophragma cylindricum*), tali (*Erythrophleum suaveolens*), okan (*Cylicodiscus gabunensis*), and ayous (*Triplochiton scleroxylon*). Nearly 341,000 hectares of the Pallisco logging concession are FSC-certified, with FSC standards applied to ensure economic effectiveness and viability of forest management; ecological integrity of the forests (i.e., reduced-impact logging, protection against pollution, protection of wildlife); and social equity. The social program includes a supply of complete security equipment, health care, accommodation, social security cover, and training for workers. The bordering rural populations are also supported through the Area Fee distributed to local councils, communication and education, creation of a consultation framework, and social realizations such as housing improvement, construction of water wells, boreholes, and classrooms or donation of school supplies. There is no tourist activity in the logging concession. Local populations benefit from user rights for NTFP and deadwood collection in 98% of the concession area, and hunting activities are authorized for self-consumption, with traditional selective techniques, and only for non-protected species (see details in Appendix A).

(iii) The three community forests (CF) that we studied – Medjoh (4964 ha), Avilso (3433 ha), and Eschiambor (5069 ha) – are located between the protected area and the logging concession. The CF were created in the country after the 1994 Cameroonian Forestry Law with the objective of improving rural livelihoods by increasing monetary revenues, village infrastructures, forest self-management empowerment, and rural employment (Ezzine de Blas et al., 2011). CF are dedicated to exclusive use by village communities (i.e., for timber harvesting, hunting, NTFP gathering, deadwood collection, or agriculture). They are managed with a simple management plan written and implemented by the community itself, after the approval and under the control of the Forestry Administration.

2.2. Sampling strategy

We interviewed a total of 225 respondents, distributed into three groups of 75 forest stakeholders, with each group being interviewed about one of the three land allocation types. We used stratified sampling to divide each group of 75 respondents among several sampling locations, with a total of 23 locations for the 225 respondents. In each sampling location, respondents were selected randomly and the number of selected respondents was proportional to the total population of the location. The 23 different locations were situated inside or beside (up to 4.1 km) one of the three land allocation types: (i) nine villages in the buffer zone of the protected area; (ii) four villages bordering the logging concession, the workers' camp, and the headquarters of the company; and (iii) eight villages located inside the three community forests (Fig. 1). These locations covered more than 50% of all possible survey locations.

The total sample size of 225 was based on an estimation of the minimal number of respondents needed (*n*) to reach a statistical

accuracy of 5% (*d*) for estimating the proportion of positive answers (*p*) concerning each ES perception, calculated with the following formula: $n = 4p \, (1 - p)/d^2$ (Dagnelie, 2011). Based on the answers provided by the first 20 respondents interviewed (*p*), we estimated the total sample size needed (*n*) to reach the statistical accuracy of 5% (*d*) for estimating the proportion of positive answers for each individual ES perception. We used the minimum value obtained to define our real sample size of 225 respondents. Based on the final dataset of individual ES perceptions (*p*), we confirmed that the sample size of 225 respondents (*n*) was sufficient to reach a statistical accuracy of 5% (*d*).

2.3. Questionnaire survey

In order to evaluate the ES perceptions of forest stakeholders, we used a questionnaire survey conducted face to face with the 225 respondents. The questionnaire survey was conducted on a voluntary basis after the investigator explained the aim of the study with a systematic statement. Respondents gave their free, prior, and informed verbal consent for participation. Our methodology followed the recommendations of Bird (2009). Three groups of 75 respondents each were attributed to three distinct land allocation types. All questions were asked explicitly with respect to the forest land allocation type attributed to the respondent. Respondents were well aware of the limits of each forest land allocation type and these limits are clearly and physically materialized with painted trees and well-maintained paths. The questionnaire survey was divided into two sections to collect information about two distinct types of ES perceptions (Table 1): First, a general, open-ended question was asked to identify the spontaneous perceptions of ES significance: "What are the usefulness and interests of this forest for local populations?" Second, 16 directed questions allowed evaluation of the perceptions of ES abundance for 16 particular

ES. Respondents were encouraged to justify their answers with a short explanation. The 16 ES were grouped into provisioning ES, regulating ES, and cultural & amenity ES according to the standard classification of The Economics of Ecosystems and Biodiversity (de Groot et al., 2010b). The 16 questions were asked in random order to avoid any influence among provisioning, regulating, and cultural & amenity ES perceptions. Selection of the 16 ES included in the directed questions was based on a combination of different lists of ES provided by tropical forests (Brandon, 2014; de Groot et al., 2002; Fenton, 2012). The term "ecosystem services" was not explicitly used during the survey, but rather the concrete benefits that people directly get from forests were mentioned (Orenstein and Groner, 2014). The questionnaire was tested with 10 local experts (scientists and officials) before conducting the survey.

The questionnaire survey was carried out by the same investigator between March and May 2016. Questions and answers were in French for 210 respondents (one of the two national official languages of Cameroon, the other being English) and with the assistance of a translator in the Baka language for 15 respondents. The investigator was trained to conduct and deliver the questionnaire to avoid any differences in data collection, as recommended by Collins (2003). Individual surveys lasted between 15 and 45 minutes. The investigator took notes and did not use any recorder. If our methodology was scaled up with more respondents and several investigators, use of audio recording instead of note-taking would have been recommended to avoid any bias between investigators, as well as a unique translator if possible.

2.4. Data analysis

The answers obtained from the two sections of the questionnaire survey (one open-ended question and 16 directed questions) were

Table 1
Classification questions asked to the 225 respondents and the two-section questionnaire survey used for the evaluation of ecosystem services (ES) perceptions. (A) The first section of the questionnaire was a general open-ended question for the evaluation of ES significance, and (B) the second section comprised 16 directed questions for evaluating the perceptions of ES abundance, corresponding to a set of 16 ES provided by tropical forests and grouped into: provisioning ES (n = 6), regulating ES (n = 5), and cultural & amenity ES (n = 5). The service "Vegetal NTFP" gathers the provision of all vegetal non-timber forest products coming from the forest (wild fruits, leaves, tubers, mushrooms, raw materials, etc.), except traditional medicine which has been evaluated separately.

Classification questions:		
	Gender?	
	Age?	
	Ethnicity?	
	Main occupation?	

A) Open-ended question (perceptions of ES significance):		
	"What are the usefulness and interests of this forest for local populations?"	

B) Directed questions (perceptions of ES abundance):		
Categories of ES	**Ecosystem services**	**Questions ("Yes/No? Please explain…")**
Provisioning ES (n = 6)	Meat (hunting)	"Is there a lot of meat coming from hunting in this forest?"
	Fish (fishing)	"Is there a lot of fish coming from fishing in this forest?"
	Vegetal NTFP	"Are there a lot of vegetal non-timber forest products coming from gathering in this forest?"
	Traditional medicine	"Is there a lot of traditional medicine coming from this forest?"
	Timber	"Do local populations find a lot of timber coming from this forest?"
	Firewood	"Do local populations find a lot of firewood coming from this forest?"
Regulating ES (n = 5)	Climate regulation	"Does this forest influence the climate? If all of this forest is cut, would the climate and seasons be different?"
	Water quality regulation	"Is the water quality better in the rivers of this forest than outside?"
	Air quality regulation	"Is the air quality better in this forest than outside?"
	Soil formation and regeneration	"Is the soil fertility better in this forest than outside for slash-and-burn practices?"
	Natural hazard mitigation	"Does this forest protect the population against disturbances, as storms, floods or diseases?"
Cultural & amenity ES (n = 5)	Cultural heritage and identity	"Is this forest part of the heritage of local populations? Does it have a symbolic value?"
	Inspiration for culture	"Is it possible to see many plants, trees, animals, and insects in this forest?"
	Spiritual experience	"Are there a lot of rituals and traditions in this forest?"
	Recreation	"Do local populations sometimes go inside this forest to relax and stroll without working?"
	Tourism	"Are there a lot of tourists coming in this forest and paying something to come?"

considered as two independent datasets coded in binary values. They were office-coded from the week after the last questionnaire conducted (Bird, 2009). A list of all forest ES identified in the open-ended answers (first section of the questionnaire, perceptions of ES significance) was compiled. The open-ended answer of each respondent was then coded as a list of binary values: we attributed the value "1" to each ES identified in the answer of the respondent, and the value "0" to each ES not identified. Answers to the 16 directed questions (second section of the questionnaire, perceptions of ES abundance) were also coded as 16 binary values: "0" values were attributed to ES perceived as "not provided" or "less provided than before", and "1" values were attributed to ES perceived as "clearly provided".

The most frequently reported ES provided by forests to local populations were identified using both answer datasets (R package "ggplot2", Wickam, 2009). In each of the two datasets, we calculated the proportions of respondents identifying each ES individually, and identifying at least one ES out of the three ES categories (provisioning, regulating, and cultural & amenity ES).

In order to identify the effect of spatial and socio-demographic variables as potential determinants of the perceptions of ES abundance, we used 16 logistic regressions modelling the probability of positive answers for each individual ES (second section of the questionnaire) as a function of the six following variables: (i) the land allocation type considered in the answers (spatial qualitative variable), (ii) the deforestation rate between 2000 and 2012 around the sampling locations (spatial quantitative variable), (iii) gender (socio-demographic qualitative variable), (iv) age (socio-demographic quantitative variable), (v) ethnicity (socio-demographic qualitative variable), and (vi) the main occupation of each respondent (socio-demographic qualitative variable). *P*-values were adjusted with the Benjamini and Hochberg (1995) method to account for multiple comparisons, controlling the false discovery rate. For each significant qualitative variable explaining the perception of a service, we computed confidence intervals on the differences among the means of levels of the variable with Tukey's 'Honest Significant Differences' method (level of significance: $P < 0.05$), based on an analysis of variance model. For each significant quantitative variable (deforestation rate and age of respondents) explaining the perception of a service, we confirmed their significance in shaping the ES perceptions with Pearson's correlation tests.

The deforestation rate (Fig. 1C) used in the previous analysis was calculated in a circle of radius 2 km centered on each sampling location, using the 30-meters spatial resolution data of net tree cover loss between 2000 and 2012 (Hansen et al., 2013). The calculated deforestation rates around the sampling locations were used to quantify the impacts of the direct surrounding environment of the respondents on their perceptions of ES, more than the deforestation in overall land allocation types. We chose a radius of 2 km for calculating the deforestation rates in order to avoid overlaps of calculated deforestation between adjacent sampling locations, and based on the mean distance of 2.2 km to access the collection sites of NTFPs from the center of the largest village in the study area (Gillet et al., 2016). Mertens and Lambin (1997) also observed that more than 80% of all deforestation occurred at a distance less than 2.5 km from main roads in southern Cameroon.

3. Results and discussion

3.1. Characteristics of respondents

Despite our random sampling, more men (78% of respondents) were interviewed because women were less willing to participate when asked to. Indeed, as in many traditional African societies, household heads are usually men, which potentially affects the willingness for women to express their opinion (Dave et al., 2016). However, the sex ratio of respondents was similar among the three land allocation types. Respondents were between 15 and 79 years old, the mean age was 43.

Respondents were divided into six ethnolinguistic groups: Badjoué (43% of respondents), Nzimé (18%), Ndjem (3%), Baka Pygmy (7%), non-local Cameroonians (25%), and foreigners (4%, corresponding to students and expatriates working in the logging concession). The main occupations of the respondents were: farmers (37% of respondents), salaried (29%), mixed occupation (19%, comprising respondents who acknowledged having more than one occupation), students (6%), officials (4%), fishermen (1%), hunters (1%), and others (3%, comprising merchants, tour guides, and taxi men). The characteristics of the 225 respondents match the socio-economic surveys conducted by the logging concession (Cellule Aménagement Pallisco and Nature+, 2015), and the respondents can be considered as representative of local communities and forest stakeholders in the study area. Additional details about the sampled population are provided in the Supplementary Information (Appendix B).

3.2. Perceptions of ES significance and abundance

We compiled a list of 17 ES mentioned in the open-ended answers (first section of the questionnaire, perceptions of ES significance). Only three differences were observed with the list of 16 ES used in the directed questions (second section of the questionnaire, perceptions of ES abundance): firewood and timber were combined as "wood", and two supplementary cultural ES were identified (education and housing). When analyzing the ES reported most frequently, spontaneous (ES significance) and directed perceptions (ES abundance) showed different results (Fig. 2).

Perceptions of ES significance mainly comprised provisioning (93.3% of respondents) and cultural & amenity (68.0%) ES (spontaneous perceptions, Fig. 2A). In contrast, regulating services were much less frequently mentioned (16.0%), and were almost exclusively mentioned in the protected area (33.3% of respondents from the protected area, 10.7% from the logging concession, and 4.0% from the community forests). This result highlights the influence of past awareness campaigns on spontaneous ES perceptions, as also shown by other authors (e.g., Hartter and Goldman (2011) in Uganda). This supports the possible appropriation of future conservation programs by local populations based on environmental education (Caballero-Serrano et al., 2017), raising awareness of the benefits and provision of ES (Bryan et al., 2010), and explanation of the law (Vermeulen et al., 2009). In the protected area, 93.3% of respondents identified at least one cultural & amenity ES, compared to 57.3% in the community forests and 53.3% in the logging concession. The most frequently perceived ES were: vegetal non-timber forest products provision (83.6% of all respondents), meat provision (59.6%), cultural heritage (50.2%), fish provision (36.0%), wood provision (34.7%), and traditional medicine provision (30.2%).

Provisioning services were also the most frequently perceived ES in other studies such as Hartter (2010) in Uganda, Zhang et al. (2016) in Nigeria, or Dave et al. (2016) in Madagascar. The perceptions of provisioning services from the forest were also analyzed by Sassen and Jum (2007) in central Cameroon, who showed high dependency of farmers on the forest for their livelihoods. In a subsistence economy based on the primary sector, particularly in developing countries, provisioning services are considered as the most important (Iftekhar and Takama, 2007), associated with more tangible and identifiable value (Rodríguez et al., 2006), and being fundamental for the livelihoods of local populations (Fagerholm et al., 2012). Therefore, provisioning ES are also more frequently assessed than other categories (e.g., Guerbois and Fritz (2017) in Zimbabwe). But, our results also show that forest stakeholders were aware of the abundant supply of all regulating ES when explicitly questioned about them using directed questions.

All respondents identified the abundance of at least one provisioning and one regulating ES, and in most cases (99.6%), at least one cultural & amenity ES as well (directed perceptions, Fig. 2B). The abundant ES most frequently identified from the 16 directed questions were: provision of traditional medicine (97.3% of all respondents),
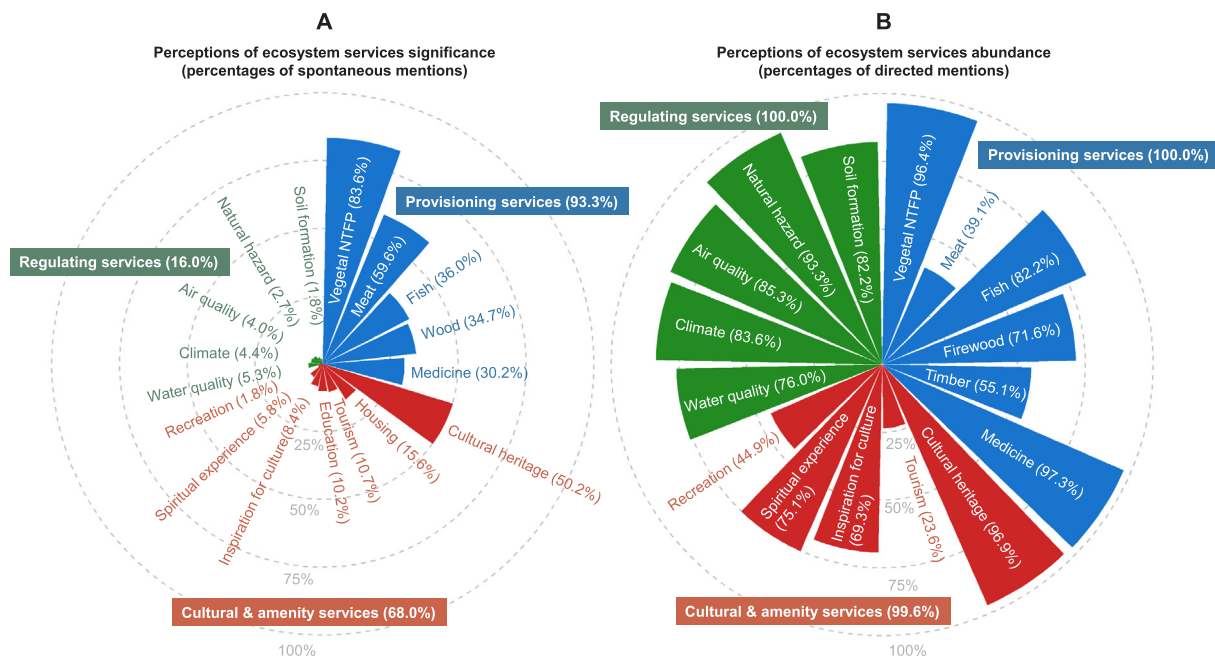
Fig. 2. Percentages of 17 spontaneous (A, ES significance) and 16 directed (B, ES abundance) perceptions of forest ecosystem services from interviewing 225 forest stakeholders. Percentages for each individual ES show the proportion of all respondents mentioning these ES. Percentages in boxes are the proportions of respondents mentioning at least one ES in each of the three ES categories. Three differences have to be noticed in the list of spontaneous perceptions (A) in comparison with the list of directed perceptions (B): firewood and timber were combined as "wood", and two supplementary cultural & amenity ES were identified (education and housing).

cultural heritage (96.9%), provision of vegetal non-timber forest products (96.4%), natural hazard mitigation (93.3%), air quality regulation (85.3%), climate regulation (83.6%), fish provision (82.2%), soil formation and regeneration (82.2%), water quality regulation (76.0%), spiritual experience (75.1%), firewood provision (71.6%), and inspiration for culture (69.3%).

The existing scientific literature is not unanimous concerning the interpretation of relative frequencies of perceptions on provisioning, regulating, and cultural ES. Some authors argue that rural populations perceive provisioning ES more frequently than in urban societies, due to a cognitive disconnection of human well-being from life supporting environments in cities (e.g., Casado-Arzuaga et al., 2013; Martín-López et al., 2012). Others emphasize that rural residents mention regulating and cultural ES more frequently than provisioning ES, because they possess ecological knowledge of the importance of the environment and the forests' ES (e.g., Muhamad et al., 2014). Our results showed that, depending on the method used (evaluation of spontaneous or directed perceptions), both these hypotheses could be confirmed.

Logically, perceptions of ES abundance included more frequent mentions of all individual ES than spontaneous ES significance, with the exception of meat provision. This implies that according to forest stakeholders' perceptions, meat abundance could not be sufficient to meet its high significance for local populations. However, the perceptions of meat significance and abundance must be interpreted critically and are most probably underestimated. Indeed, hunting practices are prohibited or at least regulated in the three land allocation types (see Appendix A), potentially leading to false answers of respondents wanting to conceal their knowledge of hunting practices, particularly in the protected area and the logging concession. Respondents were possibly inhibited by the fear of controls and repression by the investigator, despite being an independent researcher. Gillet et al. (2016) noticed particularly high hunting pressure in this area. Hunting practices target a wide range of animal species, of varying sizes from large mammals to very small rodents in highly defaunated areas. Commercial hunting has also been recognized as a major threat in the Dja Reserve (Betti, 2004),

and the conservation effectiveness of this protected area has been questioned. Moreover, accessible forests such as community forests are known to be strongly defaunated and could be considered as "empty forests" (Nasi et al., 2011), thus inducing major ecological consequences.

3.3. Determinants of perceptions of ES abundance

Slight variations in the perceptions of ES abundance were identified. Nevertheless, we used logistic regressions to identify their spatial or social determinants. The two spatial variables "land allocation type" and "deforestation rate" significantly influenced the perceptions of the abundance of five and two individual ES. The four socio-demographic variables had fewer impacts (Table 2): "gender," "age," "ethnicity," and "main occupation" each significantly influenced the perceptions of one individual ES. Prior to this analysis, we removed two categories of "main occupation" from the dataset as they were each only represented by two respondents ("fishermen" and "hunters"). The adjusted P-values associated with the explaining variables of 16 logistic regressions are provided in the Supplementary Information (Appendix C).

Perceptions of the five ES abundances significantly influenced by land allocation type were firewood, tourism, inspiration for culture, timber, and spiritual experience in decreasing order of significance. The protected area showed the most frequent mentions of two ES: inspiration for culture and tourism. The logging concession showed the most frequent mentions of one ES: spiritual experience (linked to the respect that local populations maintain for ancient villages mainly situated in the logging concession far from main roads and considered as sacred sites). The community forests showed the most frequent mentions of two ES: firewood and timber provision. Apart from these particular ES, perceptions of individual ES abundance did not differ among the three studied land allocation types. This implies that these forests present rather similar potentials in their ES supply, which is also explained by comparable forest covers: from 89.5% in the buffer zone of the protected area to 90.9% in the agroforestry zone of the logging concession

Table 2

Influence of explaining variables (land allocation type, deforestation rate, gender, age, ethnicity, and main occupation) on the perceptions of ecosystem services abundance, according to 16 logistic regressions, Tukey's tests for qualitative variables, and Pearson's correlation tests for quantitative variables. For significant qualitative variables in columns (land allocation type, gender, ethnicity and main occupation), we provide the proportions of positive answers obtained for the perceptions of the ES in line and the letters in parentheses summarize the similarities and differences among levels according to Tukey's tests. For quantitative variables (deforestation and age), a significant decrease in the perception of ES abundance with the increasing variable is indicated with ↓. Indication "n.s." stands for "not significant" influence of the variable in the column on ES perceptions in line.

Services	Land allocation type			Deforestation	Gender		Age	Ethnicity						Main occupation					
	Protected area	Logging concession	Community forests		Man	Woman		Badjoué	Nzimé	Ndjem	Baka	Other Cameroonian	Foreigner	Farmer	Salaried	Mixed	Official	Student	Other
Vegetal NTFP	n.s.			n.s.	n.s.		n.s.	n.s.						n.s.					
Meat (hunting)	n.s.			n.s.	n.s.		n.s.	n.s.						36% (ab)	52% (b)	16% (a)	0% (a)	69% (b)	67% (ab)
Fish (fishing)	n.s.			n.s.	n.s.		n.s.	n.s.						n.s.					
Firewood	52% (a)	61% (a)	100% (b)	↓	n.s.		n.s.	n.s.						n.s.					
Timber	53% (ab)	43% (a)	67% (b)	↓	49% (a)	74% (b)	n.s.	n.s.						n.s.					
Traditional medicine	n.s.			n.s.	n.s.		n.s.	n.s.						n.s.					
Cultural heritage and identity	n.s.			n.s.	n.s.		n.s.	n.s.						n.s.					
Tourism	64% (b)	1% (a)	5% (a)	n.s.	n.s.		n.s.	n.s.						n.s.					
Inspiration for culture	93% (c)	71% (b)	44% (a)	n.s.	n.s.		↓	n.s.						n.s.					
Spiritual experience	78% (ab)	84% (b)	63% (a)	n.s.	n.s.		n.s.	n.s.						n.s.					
Recreation	n.s.			n.s.	n.s.		n.s.	n.s.						n.s.					
Water quality regulation	n.s.			n.s.	n.s.		n.s.	88% (b)	58% (a)	50% (ab)	93% (ab)	68% (a)	60% (ab)	n.s.					
Climate regulation	n.s.			n.s.	n.s.		n.s.	n.s.						n.s.					
Air quality regulation	n.s.			n.s.	n.s.		n.s.	n.s.						n.s.					
Natural hazard mitigation	n.s.			n.s.	n.s.		n.s.	n.s.						n.s.					
Soil formation and regeneration	n.s.			n.s.	n.s.		n.s.	n.s.						n.s.					

(Appendix A). We could then expect to observe more distinct differences in the perceptions of ES abundance in comparison with other land uses, such as mining concessions or agricultural areas. The respondents from areas that experienced the highest deforestation rates between 2000 and 2012 perceived the abundance of timber and firewood less frequently (58 respondents were interviewed in areas with more than 5% of deforestation). The net deforestation rates for the period 2000–2012 in a radius of 2 km from the sampling locations were between 0.0% and 12.7% (Hansen et al., 2013), with the following means for sampling locations grouped by land allocation types: 0.5% for the protected area, 5.0% for the logging concession, and 3.1% for the community forests. The net deforestation rates estimated in close vicinity (2 km) of the respondents were independent of the net deforestation rates inside each whole land allocation type, which were: 0.0% in the protected area (core area), 0.1% in the logging concession, and 1.5% in the community forests for the same period (see Appendix A for more details). Several authors have already shown the influence of spatial variables in shaping ES perceptions, highlighting the role of the interview location (Cuni-Sanchez et al., 2016; Hartter et al., 2014), local landscape (Alassaf et al., 2014; Allendorf and Yang, 2013; Muhamad et al., 2014; Zhang et al., 2016), vicinity and access to forest resources (Castillo et al., 2005; Diaz et al., 2011; Sodhi et al., 2010), and the use (or non-use) of particular areas in the landscape (Alassaf et al., 2014; Allendorf and Yang, 2013; Muhamad et al., 2014).

Women perceived the abundance of timber more frequently than men. The cultural inspiration from the forest was less frequent for older respondents. Cultural inspiration was evaluated with a question about the richness of all species in the forest (or biodiversity), suggesting that older respondents currently perceive the existence of less species in forests than in the past. The ethnicity of the respondents significantly explained the perceptions of water quality regulation: Badjoué respondents mentioned the role of the forest in water quality regulation

more frequently than the Nzimé and non-native Cameroonian respondents. Respondents with different occupations showed distinct perceptions of the supply of bushmeat through hunting: salaried and students perceived a high abundance of meat more frequently than the officials and respondents with mixed occupations. Socio-demographic variables were only rarely observed as determinants of ES perceptions in our study in southeastern Cameroon, in contrast with other studies. For example, socioeconomic status (Alassaf et al., 2014; Allendorf and Yang, 2013; Caballero-Serrano et al., 2017; Hartter et al., 2014; Muhamad et al., 2014; Orenstein and Groner, 2014), education level (Allendorf and Yang, 2013; Sodhi et al., 2010), age (Allendorf and Yang, 2013; Martín-López et al., 2012), gender (Allendorf and Yang, 2013; Hartter, 2010; Orenstein and Groner, 2014; Rönnbäck et al., 2007; Warren-Rhodes et al., 2011), social conditioning (Zhang et al., 2016), life experience and historic relationships with the environment (Alassaf et al., 2014; Allendorf and Yang, 2013; Caballero-Serrano et al., 2017; Muhamad et al., 2014; Zhang et al., 2016) were highlighted as important determinants of ES perceptions in other contexts. The importance of certain socio-demographic variables as determinants of ES perceptions in other studies clearly shows that ES perceptions are highly dependent on the local socio-cultural context (Alassaf et al., 2014; Allendorf and Yang, 2013; Caballero-Serrano et al., 2017; Hartter et al., 2014; Muhamad et al., 2014; Orenstein and Groner, 2014), notably defined by land tenure and village territory size in Central Africa (Gillet et al., 2016, 2015).

The perceptions of the abundance of nine ES (out of 16) were not explained by any of the six spatial or socio-demographic variables (Table 2). Our hypothesis of variations in ES abundance among contrasting forest land allocation types led us to conduct a spatial stratified sampling. Although our results showed relative homogeneity of ES perceptions through the area, it is still difficult to disentangle the major effects between social and spatial determinants because of unbalanced

social sampling (see Appendix B).

3.4. Need for an integrated ES assessment

While ES have already been investigated in other regions of Africa (e.g., Byg et al., 2017; Dawson and Martin, 2015; Hartter and Goldman, 2011), our study was the first step in integrated local-scale assessment of multiple ES provided by forests in Central Africa. We used a social approach to consider the perceptions of ES significance and abundance before implementing the more frequent ecological and economic approaches (Boeraeve et al., 2015; Cuni-Sanchez et al., 2016; Kremen and Ostfeld, 2005; Martín-López et al., 2014; Satz et al., 2013; Spangenberg and Settele, 2010).

The local forest stakeholders must inevitably be integrated in ES assessments as they are daily using, managing, and changing these ecosystems (Muhamad et al., 2014). A social approach in ES assessment could not be replaced by a unique economic valuation. Indeed, monetary proxies overlook the non-material benefits provided by ecosystems (Dawson and Martin, 2015). These benefits can be the basis for interpreting the ES perceptions obtained from social approaches, such as considering the importance of spiritual experience in the logging concession in our study.

As a priority, we recommend gaining further insights on the unique ES for which the perceptions of abundance do not meet the ES significance, i.e., bushmeat provision. This is essential for any policy ambitions for the maintenance of ES supply and sustainable management (Geijzendorffer and Roche, 2014). We also propose to quantify the most variable (and controversial) ES in terms of perceptions of abundance such as recreation, tourism, timber provision, spiritual experience, firewood provision, meat provision, water quality regulation, and inspiration for culture (biodiversity), using complementary assessment methods. The supply of all of these ES should be quantified with detailed monitoring, integrating spatial and temporal variability, using market surveys for provisioning ES (Levang et al., 2015), social mapping for cultural ES (Fagerholm et al., 2012), and ecological measures for regulating ES (Mononen et al., 2017).

Our study could be replicated and integrated at a larger scale across Central African forests and countries. We acknowledge that no one should directly extrapolate our results to the entire Central African region or even to other communities. Although only slight variations were observed among ES perceptions in contrasting forest land allocation types, over-simplifying complex socio-ecosystems across large scales could lead to a lack of policy relevance of interpretations and decisions. Local studies of people's uses and preferences are essential for a proper understanding of social-ecological systems (Dawson and Martin, 2015). Qualitative assessments of ES provision are also required to implement sustainable management strategies and decisions (Braat and de Groot, 2012; Collins et al., 2010).

3.5. Practical implications for management

We indicate three concrete recommendations for forest management based on our results.

First, bushmeat provision appeared to be the most deficient in the perceptions of ES abundance, compared to ES significance. In Central Africa, both biodiversity conservation and human food security must be pursued through multiple compatible interventions (Friant et al., 2015; Lindsey et al., 2013). Law enforcement is indispensable to mitigate illegal poaching (Critchlow et al., 2017; Lindsey et al., 2013) but a complete ban is not conceivable for poor households heavily dependent on bushmeat as their main source of proteins (Challender and MacMillan, 2014; Foerster et al., 2012; Lindsey et al., 2013). We suggest implementing participatory repressive enforcement program in the logging concession, targeting the poaching businesses with the participation of local populations (Vermeulen et al., 2009). We also highlight the importance of distinguishing endangered species (such as great

apes) that must not be hunted, and more resilient species, such as the blue duiker (*Philantomba monticola*) or the African brush-tailed porcupine (*Atherurus africanus*), that could sustain moderate hunting pressure (Nasi et al., 2011; van Vliet and Nasi, 2008). Even if factors such as taste preference or tradition may influence human dietary choices (Ordaz-Németh et al., 2017), we also recommend providing alternative sources of proteins, for instance through local fish farming, local aviculture, or supply of butcher's meat in a small grocery equipped with a freezer. Any adequate domestic fishery or animal rearing system needs to minimize negative environmental impacts (Lindsey et al., 2013; Rentsch and Damon, 2013; Wilkie et al., 2005), and offer products at affordable prices for poor rural populations. Cultural appropriation of alternative sources of proteins could also be critical, considering the mental blocks for rearing activities in Central Africa. Use of vegetal proteins such as beans and other pulses (Ordaz-Németh et al., 2017), and edible insects (particularly caterpillars) that are highly consumed in Cameroon (Meutchieye et al., 2016) should also be considered and expanded as alternative sources of proteins.

Second, considering the perceptions of high abundance of NTFP (96.4% of respondents), this economic sector shows a high potential as an alternative livelihood for the future. In Cameroon, NTFP are an important source of food (Sassen and Jum, 2007) and income for households (Lescuyer, 2010). Domestication of NTFP species for agroforestry systems have shown potential to improve livelihoods (Ingram et al., 2012; Vermeulen and Fankap, 2001). Endamana et al. (2016) identified the following NTFP as the most important sources of cash income in Cameroon, Congo, and the Central African Republic: honey, medicinal plants, okok (*Gnetum africanum*), bush mangoes (*Irvingia* ssp.), cola nuts (*Cola* spp.), palm wine and mats (*Raphia* spp., *Elaeis guineensis*), caterpillars, mushrooms, and arrowroot (Marantaceae) leaves.

Third, knowing the current fragility of the forest sector in the region, specifically FSC-certified companies (Karsenty, 2018), we promote the new model of "Concessions 2.0" adapted to the future challenges of Central African forests (Karsenty and Vermeulen, 2016). This model suggests a shift from the classic logging concession system solely involving the state and the private sector for wood exploitation. It moves towards a new model of governance based on a multi-stakeholder platform (including local populations and local NGOs) empowered to make decisions on the management and marketing of other resources (comprising NTFP) inside the concession. Considering the differences of perceptions of ES abundance among land allocation types for wood and cultural ES, including tourism (Table 2), this model could answer various needs of local populations. Concessions 2.0 would allow associative or commercial valorization of many ES; it combines the mapping and recognition of customary territories inside and around the logging concession, sharing of timber resources and revenue, commercial exploitation of NTFP, and management of overlapping rights through inclusive governance. A better inclusion of all user rights of local populations in the management strategy of the logging concession could avoid major conflicts such as superposition of agricultural and logging activities, severe poaching, and illegal logging (Levang et al., 2015). Concessions 2.0 also constitute an opportunity to develop tourism for the benefit of local communities, with the possible support of another economic operator. To our knowledge, no logging concession in Central Africa is involved in the development of eco-tourism. Tourism ES was perceived by respondents as the least abundant, but there is an eco-tourism potential in the three forest land allocation types, which is slightly exploited only in the protected area. The practical challenges to be overcome include facilitating procedures to obtain visas at the national level, and developing visitor facilities and infrastructure (transport and accommodation) at the local level.

4. Conclusions

In this study, we integrated all ecosystem services (ES) that are

classically attributed to tropical forests in the first social assessment of ES significance and abundance for local populations in southeastern Cameroon. Our results highlighted a high significance of provisioning and cultural & amenity ES. The perceptions of the abundance of all ES met the ES significance except for bushmeat provision. We identified only slight variations in the perceptions of ES abundance, revealing relative homogeneity and similar ES perceptions among different forest land allocation types and respondents. We proposed eight ES to be quantified with complementary ecological and economic methods, and three concrete recommendations for forest management.

Acknowledgements

Appendix. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ecoser.2019.100956.

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