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Ecosystem service analysis in marginal agricultural lands: a case study in Belize

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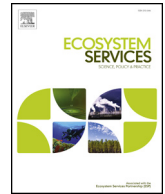
Ecosystem service analysis in marginal agricultural lands: A case study in Belize

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ABSTRACT

Globally, marginal lands, or less favored areas (LFAs), cover significant areas with large human populations, yet are relegated in policy making due to their perceived low agricultural value and a lack of information about other ecosystem services (ES) they may provide. Here we applied a simple, inclusive and qualitative ES inventory and Bayesian Belief Network modelling approach to a neo-tropical savanna LFA in Belize to assess its ES benefits, and potential trade-offs from future conversion to agriculture or a protected area. We found that consulting a broader selection of stakeholders elicited a more diverse range of ES, beyond the agricultural provisioning services considered in government planning. Further, the majority of the ES identified were accessed informally and so may be diminished under land use alternatives that formalize land tenure. We argue that, given the similar context of other LFAs, and the wider applicability of our technique, these findings have broader significance in the natural resource management and ES assessment field. Generally, we argue that simple qualitative ES analyses can efficiently provide useful planning information, and can assess how land use changes may impact local livelihoods. We argue that such methods can help improve natural resource management in LFAs and elsewhere.

1. Introduction

Increasing global food demand is driving the conversion of marginal lands to crop agriculture and grazing (Lambin and Meyfroidt, 2011; Antonelli et al., 2015). These less favored areas (LFAs) are globally significant and contain large rural, poor populations (Ruben and Pender, 2004; Barbier, 2010), yet have frequently been overlooked by natural resource management (NRM) policy makers, often due to their historically low agricultural productivity (Lipper et al., 2006). This marginalization has sometimes resulted in poor understandings of the use and function of LFAs, leading to relatively unregulated development, mismanagement, land degradation and biodiversity loss (Kuyvenhoven et al., 2004; Lipper et al., 2006).

LFAs can occur in any ecosystem and can generally be defined as social-ecological systems where productivity is severely and persistently limited by biophysical (e.g. soil fertility) and/or socioeconomic factors (e.g. market access) (Kuyvenhoven et al., 2004; Ruben and Pender, 2004). Given the high levels of poverty in LFAs, better resource management is integral not just for avoiding degradation, but also combatting poverty. Policy makers are in need of improved knowledge and methods for balancing agricultural development and environmental protection in such areas (Lipper et al., 2006).

The ecosystem services (ES) concept is increasingly employed as a means of understanding ES benefits and trade-offs from changes in land use (Power, 2010; Cordingley et al., 2016; Lazos-Chavero et al., 2016). One approach to generating information on a wider range of ES beyond those commonly focused on in NRM policy (e.g. the provision of crops, timber or grazing resources), is to use the ES framework to engage a broad range of stakeholders (e.g. local users), so illuminating the wider ES benefits of a system and how these might change in future. This can include marginalized and poor groups who are more likely to rely directly on the ecosystem for their livelihood (Malinga et al., 2013; Cárcamo et al., 2014; van Oort et al., 2015). However, ES approaches have often been limited by their expense and complexity (Busch et al., 2012; Guerry et al., 2015). More lightweight ES methods have thus been called for (Peh et al., 2013). This is particularly relevant for LFAs, which by their nature are likely to have limited resources for NRM analyses.

In this study we sought to address this gap by examining the types of, and potential future changes to, ES in the case of a lowland neo-tropical savanna LFA in Belize, which is primarily under pressure for conversion to agricultural land use. We had three aims. First, we sought to explore, for the first time, the theory that LFAs may provide a wider array of ES than typically perceived in agriculture-focused NRM

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regimes. Second, we aimed to explore how future changes to land use in a LFA can impact ES flows to local stakeholders. Finally, we applied rapid, qualitative ES inventory and participatory modelling (Bayesian Belief Network; BBN) methods, with the aim of demonstrating NRM analyses applicable in LFAs and other under-resourced areas.

We investigated the range of ES benefits and potential trade-offs perceived by respondents from two key stakeholder groups: 'national' policy makers, who dominate NRM policy for the area; and 'local' ecosystem users, who utilize the area but are not generally involved in NRM policy development. For this study, we used a case study approach to explore theories about perceived ES benefits and changes in a LFA. It thus relies on qualitative findings, instead of statistical generalizations (Gerring, 2004; Yin, 2013). Our two guiding research questions were:

(1) What are the ES perceived by respondents from the two stakeholder groups?
(2) How are these ES benefits perceived to change by the different stakeholders under different land use alternatives?

Throughout the study we documented the opportunities and challenges of our rapid, qualitative approach and reflected on their potential use in LFAs and NRM more generally.

2. Background

2.1. Defining less favored areas (LFAs)

LFAs can occur in a range of social-ecological systems, ranging from desert to rainforests, and so are diverse in their conception (Lipper et al., 2006). Here we outline some shared attributes that may support shared NRM knowledge across LFAs. First, they are perceived as being severely restricted in their capacity to sustain a given use, due to persistent biophysical and/or socioeconomic limitations (Lipper et al., 2006). Second, because of these perceived limitations, they are generally marginalized in NRM policy, and so are subject to relatively unregulated and informal resource use (Ruben and Pender, 2004). Third, the real and perceived economic potential of LFAs can change over time with the emergence of new technologies (e.g. affordable fertilizer), infrastructure (e.g. roads for market access) and demographic shifts (e.g. cheaper labor) (Kuyvenhoven et al., 2004). We examine how these common factors play out in our case, and in doing so build the broader significance of our study to other LFAs. In particular we seek to explore the difference between the value of LFAs perceived by those who dominate NRM policy, and the value perceived by local users.

2.2. Belizean neotropical savannas as LFAs

Tropical savannas provide good examples of LFAs and the surrounding NRM dilemma. They are globally significant, yet in their natural state often have limited agricultural potential due to seasonal climatic pressures and soil limitations (Furley, 1999; Furley, 2016). Technical advances over the last few decades (mainly focused around improving soil drainage and nutrients) (Guimarães et al., 2004) have increased pressure to convert natural savannas into areas for intensive agriculture (Rada, 2013), and yet they appear to remain marginalized in national NRM policies. This seems to lead to a lack of balance in decision making, where a recommendation for agricultural development may not account for trade-offs against other ES, such as other provisioning, regulating and cultural services that savanna lands may provide (for example Kaur, 2006).

This process has already been seen in Brazil's extensive nutrient-limited *cerrado* savannas, where only 2.2% is under legal protection, and since 1970 over half of the savanna (880,000 km^2) has been converted to crop and livestock agriculture (Klink and Machado, 2004). While this has increased crop and livestock production in the short

term, the absence of strong and balanced NRM has also created widespread disturbance to the natural vegetation and wildlife, created imbalances in the local carbon and nutrient cycles, and led to a general degradation of regulating soil and water services (Spehar and Souza, 1995; Ribeiro et al., 2012).

The lowland neotropical savannas in Belize provide a contemporary focus for our study. Savanna lands account for approximately ten per cent of the land area in the country (Cameron et al., 2012). They have generally been assessed to have limited agricultural potential (King et al., 1993) and rich biodiversity (Hicks et al., 2011), with mainly poor populations in surrounding areas (Government of Belize, 2002, 2010). They have received only limited recognition in national environmental policies (Belize Forest Department, 2015). These areas have only been considered in the context of national land use policies and assessments dominated by agriculture, forestry and housing (King and Baillie, 1992; King et al., 1992; King et al., 1993; Government of Belize, 2016). Generally in Belize, stakeholder consultation and participation in land planning has been very limited (UNEP, 2011). Given the importance of agriculture to the national economy (Statistical Institute of Belize, 2015) and the need to house a growing population, a focus on areas suitable for farming and housing may be warranted. It does however serve to illustrate how other potential ES from Belizean savannas, and the views of savanna users, may be marginalized in national policy making (Pantin et al., 2004; UNEP, 2011). In this unregulated context, many of the most fertile savanna areas have already been converted to crop and livestock agriculture (Bridgewater et al., 2012).

3. Methods

3.1. Study area

We selected one of the least disturbed, continuous areas of lowland savanna remaining in Belize, at the northern fringe of the neotropical savanna ecosystem, the uses and ES of which had not previously been studied. The area covers approximately 116 km^2, straddling Belize and Orange Walk Districts in northern Belize, and includes an extensive mosaic of savanna and wetland (Fig. 1), reflecting variations in topography and soil types (King and Baillie, 1992).

The area has been assessed as nutrient poor with low agricultural potential (King and Baillie, 1992; Donoghue et al., Manuscript in preparation). National assessments suggest that the western side of the area is mainly suitable for pine plantations, while the eastern portion may be suited for natural, low-intensity grazing pasture and cashew tree plantations (King and Baillie, 1992). Bridgewater et al. (2012) conclude that, given the limited agricultural potential of such areas, they could be designated as protected areas.

Limited field observations of the regional fauna (Meerman and Vasquez, 2000; Walker and Walker, 2000; Meerman and Cladbaugh, 2013) suggest that the area provides habitat for a range of fauna, including savanna specialists such as the white-tailed deer *Odocoileus virginianus* and the endangered yellow-headed parrot *Amazona oratrix*. Generally, the distinctiveness of lowland savannas within the broader neotropical savanna biome is characterized by a high level of species endemism and this implies a high conservation value (Goodwin et al., 2013).

Crooked Tree Village (population ~1100 in 2010) (Statistical Institute of Belize, 2012) is the nearest community to the savanna. It is predominantly made up Belizean Creole people, one of the many culturally distinct groups in Belize (Shomann, 2011). Unlike some other areas, the resident population of Crooked Tree has remained relatively stable in recent decades, and consequently many villagers appear to have a good knowledge of their local land and its capabilities. The village borders the eastern side of the study area and is surrounded by the Crooked Tree Wildlife Sanctuary (CTWS), a privately managed protected area of wetland. Residents have access to the savanna study area via a raised, unsealed causeway which enables passage through the
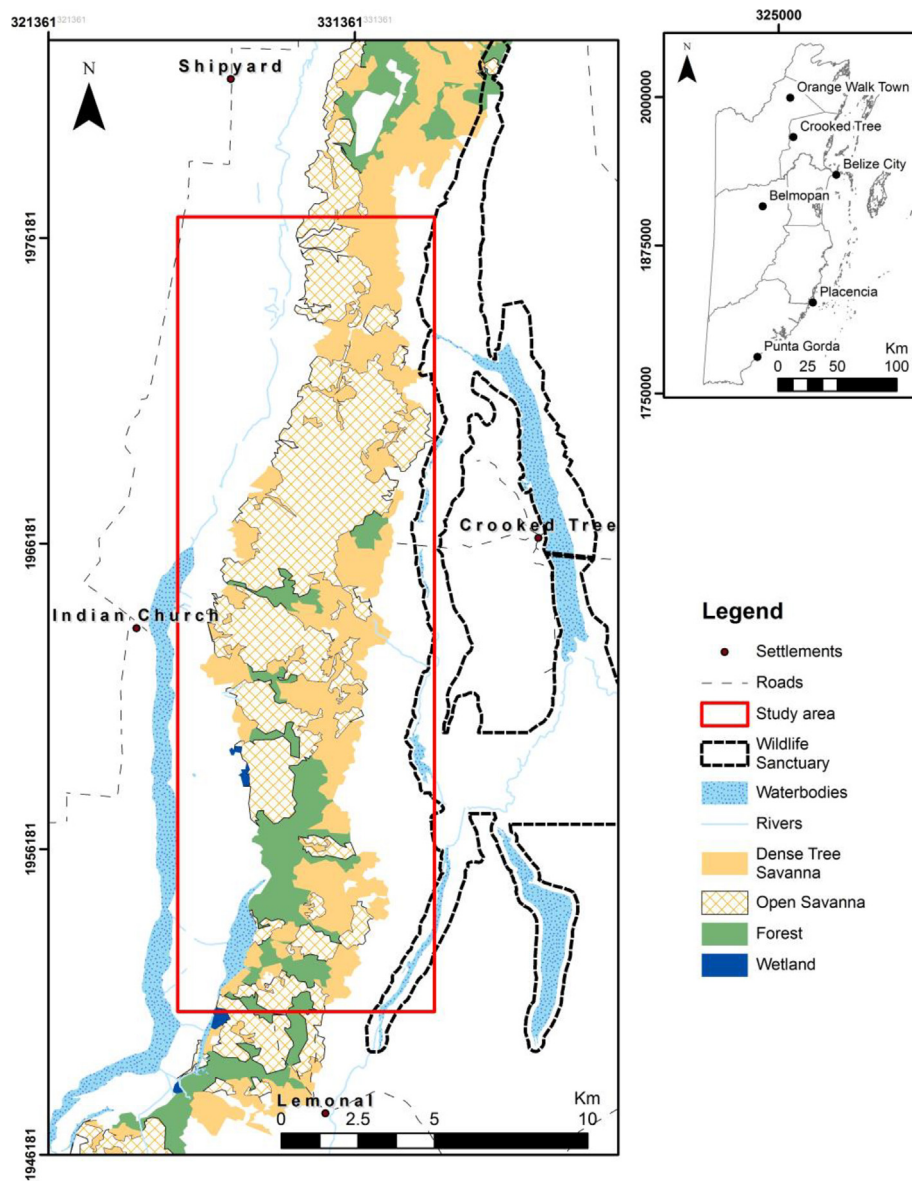
Fig. 1. Map of savanna in study area. Savanna mapping from Cameron et al. (2012).

CTWS for nine months per year (it is frequently submerged during the wet season).

The number of households below the poverty line in Belize District (which contains the study area) increased from 18% to 20% between 2002 and 2009, with a higher proportion of poverty in rural areas such as Crooked Tree (Government of Belize, 2002, 2010). Generally, livelihood strategies in the village were observed to be diversified. In addition to resource extraction and ecotourism on the savanna and neighboring areas, many Crooked Tree residents commute to Belize City and Orange Walk for casual or permanent work in the services sector.

Official authorities that regulate and manage resources in the study area are divided between several government agencies, and these regulations are poorly enforced (UNEP, 2011). An assessment in the CTWS concludes that the study area is under an 'informal' NRM regime negotiated among local users, the Belize Audubon Society (the organization managing the neighboring CTWS), and distant government authorities (Belize Audubon Society, 2009). Land tenure within the study area appears contested: the study area was mainly perceived locally as common land, while national land titling records indicate that large portions of the savanna are privately owned (though unused) by

landholders who are not residents in the area. These national and local stakeholder groups appear to interact on the management of the study area mainly in an informal manner (See 'Section 3.6' for definitions of informality and resource access).

3.2. Stakeholders and sample selection

Our study sought to explore how perceived ES from an LFA can vary between two particular groups: those who support, or are close to, a national, primarily agriculture-focused NRM regime; and those who directly use the LFA. We thus identified two key stakeholder groups for our study: 'local' users; and 'national' policy makers or government land managers. Local users were defined as those residing in Crooked Tree Village. National stakeholders were not resident in the area and were drawn from areas of government, academia or civil society that influence the study area (see Appendix). While this categorization does not include all stakeholders (e.g. absentee land owners; global savanna experts), we view that it does capture the perspectives of the main stakeholders involved in the management and/use of the study area, and enables a useful comparison for our research.

Data were collected from 32 respondents (24 local and 8 national

Table 1
Summary of future land use scenarios.

Scenario		Description
1	Status quo	Continued use of the system under the status quo for ten years
2	Conservation	The study area is declared a protected area to exclude extractive uses
3	Improved pasture	Conversion of the area to enclosed pastures with improved fodder (e.g. high nutrient grasses)
4	Intensive agriculture	Large-scale conversion of the study area to intensive crop agriculture

stakeholders) through questionnaires and semi-structured interviews. While this is only a small sample, we view that it is sufficient to support findings relevant to our study area, and to other LFAs: our study does not use a statistical approach, but instead uses a case study to examine theoretically if LFAs (given their common attributes) can provide a wider range of ES than those suggested in formal NRM regimes typical of such areas, and to see how future trade-offs can affect different stakeholders (Gerring, 2004; Yin, 2013).

Data were collected for two types of analyses (described further below): an ES inventory, which used data from all respondents (32 in total); and rapid, participatory Bayesian Belief Network (BBN) modelling of expected changes to ES under future land use scenarios, which was conducted with an even number of local and national stakeholders (16 respondents in total). Respondents were recruited through purposive chain-sampling aimed at ensuring a breadth of respondents in gender (21 male, 11 female), age and occupation (See Appendix). To ensure that we captured the full array of ES perceived by stakeholders, we sought theoretical data saturation for both stakeholder groups (Guest, 2006). Data saturation appeared to be reached within the 24 local interviews, with no new ES being reported after the 13th local interview. Data saturation was not apparent for the national interviews, thus only limited conclusions on the diversity of ES perceived by the national respondents were obtained (see Section 4). The sample for the BBN modelling did not seek saturation, instead, it focused on a theoretical illustration of how perceptions of change can differ between local and non-local stakeholders.

3.3. Inductive, qualitative identification of ecosystem services

With the aim of demonstrating a simple and inclusive ES assessment useful to other researchers and land managers in LFA contexts, we obtained qualitative descriptions of ES and their perceived directional change (i.e. increase, no change or decrease) under future alternative land uses. This differs from other more complicated and costly analyses which aim to quantify, value and/or map ES (Bagstad et al., 2013). In the same vein as van Oort et al. (2015), we adopted an inductive approach to understanding perceived ES benefits and changes. As recommended by Lal et al. (2003) and Malinga et al. (2013), we identified relevant ES through investigating the breadth of human interactions with the ecosystem, rather than having the set of ES predetermined by data availability or the views of a few (expert) stakeholders.

3.4. Ecosystem services inventory

A range of ES inventory approaches have been trialed ranging from the global to the local (UK National Ecosystem Assessment, 2011). We employed a two-part method: first, we used the respondent interviews with local and national stakeholders to identify their 'ecosystem goods and services' (Costanza et al., 1997), and then, based on existing literature on similar ecosystems, we conceptualized the ES that provide such goods and services.

3.5. Bayesian belief networks

To investigate perceptions of qualitative changes in ES under different future land use scenarios, the study employed a rapid consultative modelling process using BBNs (Cain et al., 2003). A range of approaches to participatory environmental modelling exist (Basco-Carrera et al., 2017). BBNs are dynamic influence diagrams where changes in the state of independent variables can be causally linked to changes in the state of dependent variables (See Appendix). BBNs can reflect uncertainty through conditional probability tables (CPTs) for each dependent variable, which map how likely a particular state of the dependent variable is, given a change in the state of a particular independent variable. Variables, states and probabilities can originate from diverse data sources ranging from direct measurement to stakeholder opinions. BBN software can also provide a simple and flexible tool for representing complex systems in an intuitive and accessible diagrammatic form. They have been used in NRM analyses to model the possible influence of 'interventions' (e.g. future land use regimes) on 'objectives' (e.g. ES benefits), and intermediate variables (e.g. ecosystem components) (Haines-Young, 2011).

We chose to use BBNs due to: their simple, graphical approach that is understandable to non-experts (Henriksen et al., 2007); their ability to support rapid qualitative modelling (Cain et al., 2003); their ability to provide useful results in low-information situations (Landuyt et al., 2013); and their usefulness in assessing ES (Haines-Young, 2011).

We employed a simplified version of the comprehensive participatory methodology from Cain et al. (2003). Two semi-structured interviews were conducted with each participant. First to design then to validate each stakeholder's view of current and future ES provided by the study area, and how they expected the ES to change (increase, decrease or no change) after a 10 year period under four future land use scenarios (Table 1) (see Appendix). There were two main changes to the method proposed by Cain et al. (2003). First, we did not include group consultations with the aim of agreeing a single 'master' BBN of the system, and instead used individual BBNs to understand and compare the views from separate stakeholders. Second, to keep the method simple, and following similar examples (Castelletti and Soncini-Sessa, 2007; Coutts, 2013), we did not include probabilistic information on the likelihood of a change in a variable. Instead we represented all relationships deterministically through binary coding of the CPT (i.e. where a participant viewed that an independent variable was likely to change the state of a dependent variable, this change was given a probability of 100%, with all other possible states for that relationship having 0% probability). While this means that uncertainty is not represented in the BBNs it does serve to illustrate qualitative differences in what different stakeholders thought was 'most likely'.

The four land use scenarios (Table 1) were selected from the wider range of scenarios suggested by respondents during the interviews. The selected scenarios were chosen to cover the spectrum of alternative uses suggested at the policy level for this LFA (see Section 2). Results of the individual modelling were summarized in 'agreement tables' where stakeholder views could be compared – akin to contrasting performance matrices in multi-stakeholder multi-criteria analyses (Stirling and Mayer, 2001; Haines-Young, 2011).

3.6. Classification of ecosystem services

To investigate the differences between the perceptions of different stakeholders, ES were classified under two typologies: ES type (i.e. regulating, cultural and provisioning), with supporting services excluded to avoid double counting (MEA, 2005); and how local stakeholders generally accessed the ES (i.e. 'public goods', 'formal' or 'informal'). Factors influencing resource access are multi-dimensional and complex (Lakerveld et al., 2015). We focus our analysis of access on the notion of environmental 'endowments' set out by Leach et al. (1999) and elaborated in Fisher et al. (2014). Endowments refer only to the

Table 2
Inventory of respondent perceptions of ES currently provided by study area.

Description	Final ecosystem service	Ecosystem goods	Final ES category[*]	Access[**]	Respondent type[***]
Oak (*Quercus* spp.) harvested for charcoal production	Oak provision	Oak fuelwood	P	I	B
Harvesting palmetto (*Acoelorraphe wrightii*) stems	Palmetto provision	Palmetto stems	P	I	B
Pine (*Pinus caribaea*) logging for sale	Commercial pine provision	Pine timber	P	I	B
Unenclosed cattle grazing in dry season	Unenclosed cattle habitat provision	Stock feed and shelter	P	I	B
Collecting dead pine (*Pinus caribaea*) for fuelwood	Personal pine provision	Dry pine fuelwood	P	I	B
Sand extraction for construction (small scale)	Sand provision	Sand	P	I	B
The savanna provides a buffer between other human populations, which is perceived to reduce crime	Human traffic regulation	Security	R	P	B
Hunting of white-tailed deer(*Odocoileus virginianus*) passing between gallery forest and savanna	Game species provision	Animal products	P	I	B
Occasional birding tourists on the savanna	Tourism cultural setting	Birdwatching	C	I	B
Medicines/fruits harvested within the study area	Medicine/fruit provision	Medicinal herbs and fruits	P	I	L
Recreational camping, mainly in the dry season	Recreation cultural setting	Recreational camping	C	I	L
A cultural attachment to the historical use of the savanna	Cultural setting for identity	Heritage supporting identity	C	I	L
Vegetation on the savanna sequesters carbon	Climate regulation	Stable climate	R	P	N
Vegetation on savanna regulate surface runoff	Flood regulation	Less variable flood peaks	R	P	N
Vegetation and soils on savanna filter nutrients, pollutants and regulate acidity of water flows	Water quality regulation	Clean water supporting downstream ecosystems	R	P	N
Vegetation on savanna regulates erosion during flood season	Erosion regulation	Topsoil integrity	R	P	N
Catching live fauna	Provision of live fauna	Live animals	P	I	N

* P = Provisioning; C = Cultural; S = Supporting; R = Regulating.

** F = Formal; I = Informal; P = Public good.

*** L = Local respondents only; N = National respondents only; B = Both local and national respondents.

capacity to access a resource (e.g. due to proximity to a resource), whether legal or not. The 'legitimate' right to use these resources is treated separately as resource 'entitlement', and is not considered here (at least not because of the subjectivity of assessing the legitimacy of resource access where land tenure is contested). To distinguish between different types of endowments, we first assessed whether an ES was 'public' (non-rival and/or non-excludable) or 'private' (rival and/or excludable) (Fisher et al., 2009), and secondly, for private ES, whether access was formal (i.e. covered by legal statute) or informal (i.e. not enshrined in legal statute) (FAO, 2002) (see Table A4). While the resulting three designations of public, informal or formal are a major simplification, we believe it provides an effective indicator of how benefits are generally being accessed by local stakeholders.

4. Results

4.1. Research question 1: ES perceived by stakeholders

Respondents identified 17 existing services (Table 2) currently provided by the study area, and a further two services that could be provided under certain future land use scenarios (Table 3). These indicate a diversity of ecosystem benefits extending well beyond

Table 3
Inventory of respondent perceptions of future ES provided by study area under different scenarios.

Description	Final ecosystem service	Ecosystem goods	Final ES category[*]	Access[**]	Respondent type[***]
Crop production	Crop provision	Fruit/ vegetables	P	F	B
Ranching cattle production	Enclosed cattle habitat provision	Stock feed and shelter	P	F	B

* P = Provisioning.

** F = Formal.

*** B = Both local and national respondents.

agricultural provisioning services. The majority of the ES conceptualizations are common in the ES literature (see MEA, 2005). Requiring further explanation is the distinction between enclosed and unenclosed habitat for cattle, which are accessed in different ways: the former utilizes formalized land parcels, while the latter is based on informal grazing of a common resource.

Regarding how perceived ES varied between the two stakeholder groups, our conclusions are limited due to an apparent lack of theoretical data saturation in the national stakeholder group. However a number of findings are clear. First, both national and local respondents reported mostly provisioning ES. Second, regulating services were not prominent amongst local respondents, with only one regulating service reported by this group; in contrast, national stakeholders identified a series of regulating services. Third, cultural services were reported frequently by local respondents, but not by our limited sample of national respondents. Fourth, all of the current ES benefits perceived by both groups of respondents were accessed informally or as public goods.

4.2. Research question 2: perceived changes to ES benefits under future land uses

Below and in Table 4 we provide a written summary of the main results of the BBN modelling. Summarized and full agreement tables are in the Appendix (Tables A6 and A7).

For the 10-year status quo scenario, there was wide disagreement within and between the stakeholder groups on how provisioning services (e.g. game and timber provision) would be impacted. There were also mixed views at the national level on changes in regulating services. The only clear areas of agreement between national and local stakeholders were that the cultural services would be maintained. Overall there was only agreement that services would stay the same or decline under the status quo scenario – no increases to ES benefits were perceived under this scenario.

For the future land use scenarios (conservation, improved pasture and intensive agriculture), all ES benefits identified were provisioning or cultural services. All were accessed informally with the exception of the two new formal potential future ES (crop and enclosed cattle habitat provision). For most ES, there was a lack of agreement between

Table 4
Nature of disagreements on change in ES within and between stakeholder groups.

Ecosystem services	Nature of stakeholder disagreement
Environmental setting for recreation	Disagreement within both groups on how formalization would change informal recreational access to the area
Environmental setting for tourism	Same as above
Game species provisioning	Local disagreement on both the sustainability of current game hunting, and how formalization would change access
Palmetto provisioning	Disagreement within both stakeholder groups on the sustainability of current palmetto extraction
Pine provisioning for sale	Same as above
Pine provisioning for use	Disagreement within both stakeholder groups on the sustainability of current pine extraction
Provision of live fauna	Disagreement between stakeholder groups on sustainability of activity
Unenclosed cattle habitat provision	Disagreement within both stakeholder groups on both the sustainability of current practice, and the ability to prevent the practice under land formalization

national and local stakeholders about the direction of ES change. For example, in the conservation scenario a local respondent believed conservation would increase supply of game species and pine lumber, whilst a national stakeholder thought they would reduce. For the two agricultural development scenarios (improved pasture and intensive agriculture) an expected increase in formal provisioning was traded off against a perceived decrease in game species and flood regulation for the pasture scenario. Under the intensive agriculture scenario the present benefits of regulating water quality and providing recreational opportunities were anticipated to be reduced.

Interestingly, all of the disagreements about future changes to the ecosystem benefits, whether within a stakeholder group or between the two groups, were based on either: (1) differing perspectives about the sustainability of a land use; or (2) on how access to an ES benefit might change if land management and tenure was formalized.

5. Discussion

With regard to the first research question on the ES perceived by respondents from the two stakeholder groups, our key findings were: (1) including broader participation of local and national stakeholders led to the identification of a more detailed and diverse range of ES, beyond the agricultural ES that currently dominate national land use planning policy; and (2) informal provisioning services were the most commonly reported ES by both stakeholder groups.

For the second research question (on how these ES benefits may change in the future) our main findings were: (1) under the status quo, only cultural ecosystem services (principally supporting ecotourism) were thought likely to increase, while there was wide disagreement on provisioning services (e.g. pine, palmetto, game); and (2) under all future scenarios of land use change (conservation, improved pasture and intensive agriculture), stakeholders predicted other ES to decline or could not agree on the direction of change (apart from the formal agricultural provisioning ES, which were expected to increase).

Below we discuss four arising issues of relevance for the study area, other similar LFAs, and ES assessments generally.

5.1. Diverse ecosystem services from an LFA

Our study provides further evidence that LFAs are undervalued in national NRM regimes (Lipper et al., 2006), and suggests that simple ES analyses can help to better understand the benefits of LFAs. Our inclusive approach generated a more balanced representation of ES in the study LFA, including informal ES beyond the agricultural provisioning services dominating national land use planning in Belize. This is in agreement with other studies which have found that participatory approaches can provide in-depth understandings of social-ecological systems (Malinga et al., 2013; Ramirez-Gomez et al., 2015; Lazos-Chavero et al., 2016). We suggest that this phenomenon is characteristic of LFAs, because of a lack of information on ES, and informal 'hidden' resource use.

ES from LFAs are likely to vary depending on the social-ecological

context, and the range of stakeholders engaged. For example, in southern Belize, communities near similar savannas are predominantly Mayan and tend to have different uses and perceptions of their land compared to Creole populations (such as the population of Crooked Tree) (Shomann, 2011). Similarly, Bridgewater et al. (2012) were focused on conservation, and suggested the value of Belizean savannas as buffer zones for protected areas. The perceived value of an LFA will also likely change over time, with changes to infrastructure, technology and markets (Kuyvenhoven et al., 2004).

5.2. Informal ES, trade-offs and poverty in LFAs

Our study has illustrated how shifts towards land uses that formalize land tenure can negatively affect informal resource access. In contrast to the dominant national narrative that agricultural development would improve livelihoods in the area, many of the (local and national) stakeholders perceived that a range of current ES benefits would in fact decline due to the formalization of land access implied under future scenarios, and the subsequent restriction of access. For example, in the interviews respondents repeatedly articulated that provisioning of game, pine and palm resources, which are all harvested mainly for direct subsistence by the poorer families in the village, would be adversely affected by a shift to cropping or enclosed grazing.

We argue that, as articulated by Daw et al. (2011), this formalization of land use is likely to affect the most vulnerable people who are generally more reliant on informal resources. This applies to both the significance of such informal ES benefits to their overall income, and to their limited ability to substitute other ES benefits in cases where access to informal ES benefits is lost. This links to existing theories that unless trade-offs against informal benefits are explicitly recognized, the most vulnerable may generally be worse off under formalized NRM regimes (Osborne, 2013; Dwyer, 2015). We argue that, given the level of poverty in LFAs generally and the likelihood of informal resource use in such areas (Kuyvenhoven et al., 2004), this issue may apply widely in LFAs.

5.3. Simple, qualitative ES analyses

The above findings were uncovered through a simple, rapid, qualitative approach to ES analysis. We suggest that this and similar methods may provide an efficient means for generating information in marginalized, data-poor areas (Kovács et al., 2015; Lakerveld et al., 2015; Ramirez-Gomez et al., 2015). A key methodological point to emphasize is that, while many ES methods have become complicated and costly in order to deal with perceived system complexity, there may be many practical situations where even basic qualitative information ES can be sufficient. Such rapid, pluralistic, constructivist approaches to generating knowledge for environmental decision making may be especially useful where time and resources are limited and previous information is patchy or non-existent. Examples of such methods already exist (Waters et al., 2012; van Oort et al., 2015), and we suggest the method used in this study as a particularly simple and effective

approach.

These methods may be particularly useful in LFAs, where NRM regimes may need to recognize the concerns of local users in order to build local legitimacy and a culture of self-regulation. Given the marginalization of LFAs and an associated lack of enforcement of regulations, community management can be seen as an integral approach to successful NRM in such areas. While the success of community-based NRM has been mixed (Roe et al., 2009), studies are increasingly suggesting that recognition of informal land use and associated ES is central to its success (Kamoto et al., 2013; van Oort et al., 2015). Our results show a diversity of informal values in our study area, and wide disagreement on how these services will change in the future. Better reflecting these values in NRM policy may help to improve its local legitimacy and effectiveness. This is underscored in Belize by the case of an unsuccessful community-based ecotourism NRM scheme in a nearby area which failed to account for the heterogeneity of interests and values within the community (Belsky, 1999).

Additionally, while we believe that the method used in this study was reasonably effective, we suggest that it could be further simplified. While the use of BBNs provides a potential linkage with quantitative analyses (e.g. on ES provision levels and/or economic value), the first step in implementing the ES approach is simply to identify and 're-cognize' the diversity of ES (TEEB, 2010). The usefulness of qualitative analyses for this first step is already apparent in the emerging literature on ES (Peh et al., 2013; Bakhtiari et al., 2014; Cárcamo et al., 2014) and in local NRM processes using qualitative ES approaches in practice (Waters et al., 2012). Concurring with the view of Malinga et al. (2013), we suggest that the time investment for even simple-scenario modelling may outweigh the amount and quality of new information generated from the exercise, and that effective ES analyses could rely solely on ES inventories. Further simplification would make the tools yet more applicable in underfunded NRM regimes, including many of the world's savannas and other LFAs.

6. Conclusions

More balanced and sustainable NRM is needed to achieve sustainable environmental and social outcomes in the world's LFAs, of which tropical savannas are one example. Through applying a novel and easily applicable method to the new case of a neo-tropical savanna LFA in Belize, we have demonstrated the breadth of ES values that may accrue from an LFA, and how these might change in the future.

Our findings show that, in our case, while the dominant NRM discourse in Belize is still focused on developing agricultural provisioning services such as cropping and cattle grazing (and historically, pine timber harvesting), stakeholders in fact perceive a wider range of non-agricultural provisioning, cultural and regulating services. Further, most of these are being accessed informally (potentially by poorer members of rural communities), outside of the national land tenure regime. By recognizing this breadth of ES, NRM regimes may be more able to understand and manage the consequences of trade-offs arising from land use change.

For Belizean savannas in particular, our study reinforces the need for better recognition of the full range of values and uses of the ecosystem, beyond a policy that tacitly promotes conversion to agricultural or enclosed grazing land on the grounds of economic efficiency, and risks consequential negative effects such as loss of livelihood for smallholders who can no longer access the land informally. This has implications for the development and management of savannas worldwide as pressure on land continues to increase.

The techniques developed in this study respond to a general need in many countries to assess the consequences of developing LFAs for more intensive and formal types of land use, as population pressure increases. In this context the scenario modelling method provides a simple, effective means to elucidate linkages between land use change, expected changes in access to ecosystem services and possible consequences for poverty or well-being of the local populations.

Appendix A

Supplementary data associated with this article can be found, in the online version, at https://doi.org/10.1016/j.ecoser.2018.06.002.

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