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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