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Achieving sustainable development in rural areas in Colombia: Future scenarios for biodiversity conservation under land use change

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ABSTRACT

Agricultural expansion is a complex land use change phenomenon with deep environmental and socio-economic consequences, especially across tropical countries where most of this expansion is occurring. Here we use scenario and network analysis combined with sustainability assessment to understand the drivers of landscape change and their effects on sustainable development in Colombia's rural areas, using the Central Magdalena region as a case study, and ultimately informing strategies to reconcile agricultural expansion with biodiversity conservation and rural development. Using this approach we investigated three environmental and agricultural policy scenarios: the Business as Usual scenario, enforcing a stronger regulatory framework, and adopting incentives. Our analysis show that the Business as Usual scenario is not supported by stakeholders and negatively affects most sustainability objectives with the predominant agricultural sectors in the region (cattle ranching and oil palm) not improving social inequality, and threatening biodiversity, natural resources, and food security. Both alternative scenarios improve overall sustainability, including biodiversity. Therefore to reconcile agricultural expansion, biodiversity and sustainable development, it is important to adopt a stronger regulatory and enforcement framework at different administrative levels, as well as incentive schemes focusing on small holders. Our study also shows that history cannot be ignored when thinking about the future and sustainability especially in areas with legacies of strong inequalities caused by armed conflict. Finally, we suggest that combining scenario analysis, network analysis, and sustainability assessment is a useful methodology for studying land use changes holistically, exploring complex systems at different scales, and informing locally-relevant strategies and recommendations, ultimately enabling science to be proactive.

1. Introduction

With an increasing human population and consumption reconciling agricultural expansion with biodiversity conservation and sustainable development is an ever increasing challenge, especially in the tropics where most of this expansion is occurring (Foley et al., 2005; Gibbs et al., 2010; Tscharntke et al., 2012). Increasing agriculture is a complex land use change phenomenon, being a key driver of both environmental and socio-economic change: it increases food production and stimulates economic development, but it comes at a high environmental cost, particularly in areas with weak and dysfunctional governance such as the tropics (Foley et al., 2011, 2005; Gibbs et al., 2010). Agricultural expansion leads to habitat loss and fragmentation, which in turn are the main causes of biodiversity decline worldwide (Fahrig, 2003; Green et al., 2005). It also accounts for one-third of global greenhouse gas emissions, thus contributing to climate change and is the largest user of fresh water (Foley et al., 2005; Rockström et al., 2009); while its intensive use of oil synthesised fertilisers (+700% in the last 40 years) has altered global nutrients cycles and impacted water quality, ecosystems, and fisheries (Rockström et al., 2009; Tilman et al., 2001). Since agriculture is expanding, both biodiversity conservation and sustainable development will ultimately depend on understanding the different forces (socio-political and economic) acting in these systems and on strategies to achieve integrated landscape management where environmental and socio-economic objectives can be met in the same region (Gardner et al., 2009; Grau et al., 2013; Harvey et al., 2008; Perfecto and Vandermeer, 2008).

Historically traditional shifting agriculture, illegal crops, and extensive cattle ranching, have been the main drivers of deforestation and habitat conversion in South America, including Colombia

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(Etter et al., 2006b; Grau and Aide 2008). However new land uses are now causing landscape conversion, driven by export-oriented industrial agricultural policies and strong market conditions (Grau and Aide 2008; Pacheco 2012). This is primarily related to the expansion of soybean cultivation in Brazil, Argentina, Paraguay and Bolivia, as well as the expansion of oil palm in Colombia, and to lesser extent, in Ecuador and Peru (Pacheco, 2012). The expansion of oil palm has led to the conversion of natural ecosystems, landscape homogenisation, pollution, biodiversity loss, and carbon emissions both across the tropics and in Colombia (Castiblanco et al., 2013; Danielsen et al., 2009; Fitzherbert et al., 2008; Pacheco, 2012; Savilaakso et al., 2014; Turner et al., 2011; Wicke et al., 2011). While the sector can contribute to countries' economic growth and income generation, it can also exacerbate problems associated with social inequalities and concentrate land ownership by favouring industry owners (Castiblanco et al., 2015; McCarthy, 2010; Mingorance, 2006; Vermeulen and Cotula, 2010).

In Colombia extensive cattle ranches still occupy as much as 70% of the agricultural land (Etter et al., 2006a; McAlpine et al., 2009). However oil palm cultivation has been expanding since the 1970s supported by the National government with tax exemptions, subsidised credits, and mandatory consumption through biodiesel blends (Castiblanco et al., 2013), turning the country in the 4th largest oil palm producer worldwide. Such land use changes can impact sustainability in multiple ways; hence it is challenging to design strategies to ensure both biodiversity conservation and socio-economic development across regions where complex land use transitions are occurring.

Scenario analysis combined with sustainability assessment can be a great tool for strategy development and for providing future recommendations because it is a way of investigating future pathways as well as the consequences of different policies within complex systems (Alcamo and Henrichs 2008; Spangenberg 2007; Tzanopoulos et al., 2011). To guide sustainable development, assessment of future scenarios should include all dimensions of sustainability, i.e. environmental, social, and economic aspects, as well as the relations between them (Pope et al., 2004; Reidsma et al., 2011). Strategy development also requires understanding of the drivers of change acting on a system and their impact, which can be achieved with Network Analysis (Wasserman and Faust, 1994).

Here we deploy scenario and network analysis combined with sustainability assessment to understand the drivers of change and their effects on sustainability under different environmental and agricultural policy scenarios in the Magdalena region of Colombia, ultimately informing strategies to achieve biodiversity conservation while fostering sustainable development across an agricultural area. This is particularly timely in the country considering it aims to achieve a sustainable and green growth (DNP, 2014) and it is undertaking a peace process, which will open new investment and development opportunities. Finally, our study will demonstrate how combining scenario analysis, network analysis and sustainability assessment is a useful methodology to understand systems in which multiple drivers interact at different scales affecting different aspects of sustainability, to study complex phenomena such as land use changes in a holistic way, and to inform locally-relevant strategies and recommendations.

2. Material and methods

2.1. Study site

The study took place in the Middle Magdalena region of Colombia, which covers the central area of the inter-Andean Magdalena River valley, in the Department of Santander and in the municipalities of Sabana de Torres and Puerto Wilches, extending over 3000 km^2 (Fig. 1). The region is part of the rainforest biome; it is naturally characterised by humid tropical forests and wetlands and has a tropical climate with mean annual temperature of 27 °C and bimodal rainfall of 2100–2600 mm annually (IDEAM et al., 2007). It hosts endangered and endemic species and it is considered an important genetic corridor as well as an important site for migratory bird species (Hernández-Camacho et al., 1992).

However, the majority of its natural ecosystem has been converted into cattle ranches and oil palm plantations while the remaining natural habitats are threatened by further agricultural conversion (Castiblanco et al., 2013; Etter et al., 2006b). Extensive and low productivity cattle ranching and increasing oil palm plantations are the dominant land uses in the region, which has the second largest amount of suitable land for oil-palm conversion in the country (Etter et al., 2006a; Molano 2009; Castiblanco et al., 2013). Other economic activities are gold mining and oil extraction (Molano, 2009).

The economic and social context has been characterised by violence, uneven development, and lack of government presence and institutions, which led to a coercive context of powerful elites, unofficial authorities, and poor participation (Molano, 2009). Poverty is still widespread with all municipalities except Barrancabermeja displaying unmet basic needs indexes greater than 60% (PDPMM-CINEP, 2007). Peace arrived in the region less than ten years ago but land inequality and power imbalance persist, making sustainable rural development challenging to achieve (Molano, 2009).

2.2. Data collection and analysis

We used an integrated methodology that combines scenario analysis and sustainability assessment (Pope et al., 2004; Sheate et al., 2008; Partidário et al., 2009) with network analysis (Tzanopoulos et al., 2011) to investigate the drivers of change in the region, their effect on sustainability under different scenarios, and to define management and policy recommendations for sustainable development (Fig. 2). Scenario analysis is often used in environmental research topics such as land use and biodiversity (Berkel and Van Verburg, 2012; Sala, 2000) and combined with sustainability assessment can help policy makers to understand the impact of potential policies or management plans (Westhoek et al., 2006). Such assessments can be conducted against a baseline to verify how acceptable the impacts of a proposal would be or against a series of aspirational objectives (Pope et al., 2004). We used the latter because it focuses on positive change, instead of merely minimizing any negative effects (Pope et al., 2004).

We further integrated network analysis to understand the relationships between drivers, impacts, and sustainability, and to inform management and policy recommendations to reconcile agricultural expansion and rural development with biodiversity conservation in the region. Network analysis is based on graph theory and focuses on the causal relationships (links) among different entities (nodes) (Wasserman and Faust, 1994). It is particularly helpful to explore real world systems in which drivers do not act in isolation and may have multiple consequences, and to identify which entities are key within such systems (de Nooy and Mrvar, 2005).

The research involved a number of stages. First, we conducted a literature review on the region and on Colombian agricultural policy to understand the changes that have occurred in the area and its social, economic, and environmental issues. We then interviewed experts and stakeholders (N = 42) to understand further the drivers of change acting in the area and their impact on sustainability, to explore potential future scenarios and interviewees' views on them, and to identify important sustainability objectives. Through the interviews we also wanted to incorporate local knowledge,