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Evaluating sustainability options in an agricultural frontier of the Amazon using multi-criteria analysis

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ABSTRACT

Agricultural expansion and deforestation in the Brazilian Amazon are driven by a complex interaction between economic and demographic drivers and institutional constraints. Land use policies such as Conservation Units and the Forest Code law should conserve biodiversity and other environmental aspects while, on the other hand, increasing commodity prices of beef and soy, driven by world markets provokes economic growth and expansion of the agricultural area. We carried out an impact assessment in eleven municipalities within an agricultural frontier along the road BR-163 that runs in the Brazilian Amazon states of Mato-Grosso and Pará. The impact assessment, covered a period between 2008 and 2020, showed that the autonomous development in the study area results in a strong increase in the performance of economic indicators but a reduction in environmental and some social indicators. The studied conservation policies are able to reduce negative environmental impacts to some extent, while hardly affecting economic and social indicators. The multi-criteria analysis (MCA) showed a trade-off relation between the economic and environmental dimension in such a way that the effect was much stronger in the high commodity price scenario than in the low price scenario. The policy implications of the MCA results are discussed in light of the institutional capacity of the Brazilian States under study, to implement effective conservation policies.

Introduction

Land use changes in the agricultural frontier in the Brazilian Amazon are driven by a complex interaction between economic and demographic growth, and by political and institutional constraints that increase deforestation and agricultural expansion (see Macedo et al., 2012). Land use policies in Brazil that concern the north of the State of Mato Grosso and the southeast of the State of Pará are centred on agricultural development and coexist with conservation policies. Although originally created to address biodiversity and cultural heritage, aspects of climate change are very indirectly inserted in conservation policies, such as the creation of Conservation Units and indigenous territories. Such policies favour the preservation of the forest and its role as carbon sink and a reservoir of water within the hydrologic cycle of the continent (e.g., Fearnside et al., 2009; Marengo, 2006; Nobre and Nobre, 2002).

Between 2010 and 2012, there was a strong controversy over the possible reform of Brazil's Forest Code (Código Florestal). Derived from a legislation created in the 1930s, and reformulated in 1965, the Forest Code suffered some minor modifications in the past two decades. Until recently, the code required private landowners not to use (i.e., set aside) 80% of forest in the rainforest biome of the Amazon region on their property and 35% of the Cerrado biome (the "80/20" rule). Championed by the Brazilian agribusiness lobby, the proposed new law, which replaces the previous one, would open some areas of environmental protection to farmers by loosening restrictions on the clearing of hilltop and riverbank areas. The change in the legal framework, which triggered a strong debate in the Brazilian National Congress in 2011, would also provide amnesty to small-scale farmers who illegally cut down forested areas prior to the cut-off date of July 22, 2008, and give states greater control over designating Permanent Areas of Preservation. Proponents of the reform argue it would help small farmers stay in business and stimulate domestic food production, but many environmentalists view the proposal as a step backwards in the country's fight to protect the Amazon rainforest.

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The impacts of economic and demographic development in the context of conservation policies can be studied using simulation models, but institutional constrains are much more difficult to tackle (see McNeill et al. (this volume) for a critical discussion). For example, the ineffective presence of the State institutions, associated with corruption of institutional personnel and the economic context that favours the expansion of the agricultural frontier, results in a close correlation between deforestation and regional economic growth. In other words, strong economic growth leads to much larger deforestation than enforced by the present "80/20 rule" of the Forest Code law. To deal with this institutional context, we understand the actual governance scheme as rather loose and vulnerable to prevailing political interests which are associated with the economic forces in the region. In such a context, the ability of institutions to carry out monitoring programs, enforce law and control policy objectives is assumed to be limited.

In the impact assessment presented in this paper, we define 'strong' and 'weak' governance as the capacity or lack of capacity, respectively of institutions to effectively play their role in protecting forest areas under the two conservation policies: the protection of areas established as Conservation Units, and those protected under the Forest Code law. Weak or strong governance is thus managed as the deviation of the policy's original intention to protect forests, given a scale of 0–100% to policy intention. In this setting we assessed the impacts of 'weak' and 'strong' governance for the "80/20%" Forest Code rule and protection of Conservation Units, as well as for the mandate of the new Forest Code rule, which would imply in a significant reduction of protected forest areas.

In many cases, impact assessments usually do not consider environmental, economic, social and institutional aspects in an integrated way (Kates et al., 2001; Robinson, 2004; Reid et al., 2005; Wood and Lenné, 2005; Kates and Dasgupta, 2007). In a joint European and southern countries project (LUPIS – Land Use Policies and Sustainable Development in Developing Countries) a methodological framework was developed for sustainability assessment (see Reidsma et al., 2011). This framework is meant to be generic and flexible, so that it can be applied across a range of issues and countries. Jointly, this framework was adopted for the case study in Brazil, for which a land use simulation model LUSMAPA (see Verburg et al., this volume) was developed. Using LUSMAPA (Land Use Simulator Mato Grosso-Pará), we developed and carried out a simulation study on deforestation rates and agricultural development up to 2020.

The developed impact assessment draws on our previous land use simulations with LUSMAPA (Verburg et al., this volume) and adds a conclusive set of indicators to measure the full array of sustainability aspects in the economic, environmental and social context. The likelihood of sustainable development rests upon policy objectives. Moreover, inherent and underlying trade-offs usually occur when dealing with sustainable development (see McNeill et al., 2012). In this respect, multi-criteria analysis and decision making have been used in a wide array of studies (e.g., Mendoza and Martins, 2006; Ananda and Herath, 2009) to deal with such issues. As Belton and Stewart (2002) pointed out, multi-criteria analysis and decision making has several properties which are very useful in natural resource management, since it takes account of multiple, conflicting criteria, structuring the management problem, providing a model that can serve as a focus for discussion, and offers a process that leads to rational, justifiable, and explainable decisions (see Mendoza and Martins, 2006). To evaluate the effects of policy objectives that contribute to sustainable development within the agricultural frontier, we developed and used a multi-criteria analysis approach.

Methodology

Study area

The Brazilian States of Mato Grosso and Pará are considered the most deforested within the Brazilian Amazon. An important share of this deforestation is concentrated along both sides of the highway BR-163 that connects Cuiabá in the State of Mato Grosso with Santarém in the State of Pará. Moreover, Mato Grosso is considered to be one of the most important soy producing states in Brazil (e.g., Rodrigues-Filho et al., 2012). The study area, which is located along BR-163, includes eleven municipalities that comprise approximately 282,415 km^2 of land and represent various stages of agricultural development. These eleven municipalities were classified into three categories, based on their level of agricultural development. These levels of consolidated agricultural areas were grouped in three study units. In Mato Grosso the municipalities *Feliz Natal*, *Marcelândia*, *Sinop* and *Sorriso* represent a consolidated agricultural area in which agriculture is well developed. In this study unit, referred to as South area, the forested area was estimated around 19,778 km^2 in 2008, of which 5089 km^2 protected in Conservation Units. Pasture, soy and other crop area in 2008 was estimated at respectively 2885 km^2, 7083 km^2 and 6539 km^2 (Verburg et al., this volume). The municipalities of *Alta Floresta*, *Guarantã do Norte* and *Novo Mundo* in Mato Grosso represent an intermediate agricultural area, and is referred to as Central area. In 2008 forested area was estimated on 10,364 km^2 (2477 km^2 in Conservation Units), pasture area on 6682 km^2, soy area on 44 km^2 and other crops area on 154 km^2. In the southern part of the state of Pará the four municipalities *Itaituba*, *Novo Progresso*, *Rurópolis* and *Trairão* represent the pioneer stage of the agricultural frontier, called North area. Here forest area in 2008 was estimated on 102,113 km^2 (57,524 km^2 in Conservation Units). The agricultural area in 2008 was divided in pasture (3376 km^2), soy (11 km^2) other crops (566 km^2), while a substantial amount of land was considered to be fallow (120,590 km^2). A detailed description of the case study can be found in Verburg et al. (this volume) and Rodrigues-Filho et al. (2012).

The LUSMAPA model in brief

The Land Use Simulator Mato Grosso-Pará (LUSMAPA) comprises three sub-models, one for each study unit (i.e., the areas North, Central and South). In each sub-model six land use types are defined: unprotected forest, the protected forest types Forest Code area and Conservation Units, pasture, soy and other crops. The latter land use type comprises both temporal crops (i.e., rice, beans, manioc, corn and cotton) and permanent crops (i.e., banana, coffee, rubber, cocoa and fruit trees). In the North area an additional land use type was defined as fallow land that is deforested but not (yet) cultivated. Land conversion in the model is driven by an external demand for beef and soy, driven by international market prices of these commodities. To meet the demand, cattle and soy will be produced in the study area, by scaling down the demand function of both commodities at national level to the study area using linear regression. In the model we assume demand and supply to be in equilibrium, resulting in an increasing production of cattle and soy when market prices rises. To meet an increasing demand in a next time step (one year) production (supply) has to be increased as well, by expanding the agricultural area and increasing agricultural productivity (cattle density and soy production per unit area), but the increase of the latter is relatively small. By deforestation pasture area will be expanded. Soy area expansion is derived from pasture conversion, other crop area conversion and (direct) deforestation to soy. The demand for other crop area is determined by the population number in each area, since we assume that these