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Analysing plausible futures from past patterns of land change in West Burkina Faso

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ABSTRACT

In a context of fast land changes due to human activity, the old "Malthus vs. Boserup" debate about human pressure on natural resources is more than ever a prevalent subject. We illustrate this debate with an example based on the Tuy Province in West Burkina Faso, which has known an important development these last fifteen years, as mainly observable in the major regression of its natural vegetation.

The objective of this article is to question the possible future scenarios of this region, by using a spatial model to understand past land change mechanisms and prospect plausible future ways of development. In particular, the spatial model describes the vegetation clearance processes identified during field campaigns, which we used to draw prospective scenarios and assess their possible effect on natural vegetation evolution.

The processing of remote sensing images helped us reveal that one quarter of the total study area was cleared during the last fourteen years. Surveys carried out in the field enabled the identification of the three main processes responsible for these changes: farm size expansion, creation of new farms due to family nuclearization and migrant settlement. The model was then built to reproduce these three processes, and was validated by comparison with the land use classification of remote sensing images. Our model was also used to explore past clearance mechanisms: we found that 90% of the clearance was shared equally between farm size expansion and nuclearization processes, the settlement of migrants being responsible for less than 10% of the clearance. Model outputs also showed a shift in the clearance schemes compared to ancient practices: land characteristics are no longer considered when land is cleared and now clearance also occurs in neighbouring villages with available lands. These results suggest that the region has finally evolved similarly to a Malthusian rationale, even if the past dynamics resulted from a complex combination of factors.

Finally, we analysed several prospective scenarios to assess the impacts of i) different population evolutions (normal demographic growth, emigrations and demographic regulation), ii) the implementation of protected areas in each village, iii) an intensification of farming systems. Two possible solutions for reducing natural vegetation clearance in the region are discussed: Emigration to other regions or a demographic regulation accompanied with an intensification of agricultural systems. However, the question remains whether such changes can be accomplished rapidly enough to abate the pressing natural vegetation decrease threat and to maintain an acceptable livelihood in the region.

1. Introduction

The last fifty years have seen a large acceleration of land-cover changes, with estimates of global cropland expansion of more than 154 million hectares between 1985 and 2005 (Ramankutty et al., 2002; Foley et al., 2011) at the expense of natural vegetation. At the beginning of this century, as much as 50% of ice-free areas had already been transformed from natural vegetation to human land use, with agriculture covering 12% of Earth's ice-free land, and pasture 26% (Vitousek et al., 1997; Turner et al., 2007; Haberl et al., 2007; Foley et al., 2011). A more recent study estimated that 2.3 million km^2 of forest land were lost between 2000 and 2012 and 0.8 million km^2 of new forests were gained (Hansen et al., 2013). Most of the land changes result from anthropogenic causes, due to the expansion of cropland and

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pasture lands (Lambin and Meyfroidt, 2011; Tilman et al., 2001; Goldewijk, 2001; Green et al., 2005; Ramankutty et al., 2008). These conversions raise major concerns about loss of biodiversity and extinction of many vegetable and animal species, increase of carbon dioxide concentration in the atmosphere, soil erosion, climate disruption and weakening of poor communities and households that depend on forests (Djoudi et al., 2015; Vitousek et al., 1997).

Among the important theories inspired by human-induced transformation of the natural environment, probably the most famous proposed was by Malthus (Malthus, 1989). He postulated that exploitation of the natural environment is proportional to demographic growth, implying that populations cannot exceed a threshold that depends on available natural resources. On the contrary, Boserup (1965) argued that population growth leads to an optimization of natural resources exploitation, along with a boost in technical innovation. For example, population increase in low density areas where traditional practice is slash-and-burn has led to intensified cropping systems (with more investment in labour or capital per unit surface area). Intensification enabled populations to grow with reduced damages on natural resources. The shift from a Malthusian rationale to a Boserupian one is called the “agrarian transition” (Jouve, 2006).

More recently, several authors showed that such approaches linking demography and innovation were not sufficient to explain land changes (Angelsen and Kaimowitz, 1999; Leach and Fairhead, 2000; Lambin et al., 2001; Cochet, 2004). These are triggered by a complex combination of natural, economic, political, institutional, technological, cultural and demographic factors (Lambin et al., 2001). In the context of globalization where interconnections between places and people are exacerbated, causal relationship patterns induced by the combination of factors are often amplified, hence the observed surge in cropland expansion and forest conversion (Lambin and Meyfroidt, 2011; Lambin et al., 2001). With land change acceleration, the question of agrarian transition, or the capacity of populations to react and adapt to their changing environment, is crucial. Understanding past mechanisms and combinations of factors that have led to the current land configuration is paramount in order to draw and assess future evolution trends (Stephenne and Lambin, 2001; Licker et al., 2010) that diverge from a Malthusian scenario.

The southern, western and eastern regions of Burkina Faso are currently facing issues of natural resource depletion due to anthropogenic pressure. During these last thirty years, there was an average annual increase of cropland at the expense of woodland between 0.96 and 1.3% in these regions (Ouédraogo, 2006; Paré et al., 2008; Ouedraogo et al., 2010). The authors agree that the changes are due to the demographic increase, exacerbated by important migrations (Gray, 2005; Reenberg et al., 2003; Tallet 2007; Ouedraogo et al., 2010; Etongo et al., 2015). Severe droughts in the 1970s have indeed pushed the populations of northern Burkina Faso to southern regions where the land to be cleared was still abundant and the climate more favourable to crops. But other factors also contributed to the degradation of natural resources, among which, the introduction of new agricultural tools (e.g. chemical inputs, mechanization, Pingali et al., 1987), government policies, changes in food habits and access to new markets (Paré et al., 2008; Ouedraogo et al., 2010; Caillault et al., 2012; Hansen and Reenberg, 1998). These factors are well identified but the quantification of their impacts remains elusive, although a good understanding of the ongoing processes and their respective impacts on the depletion of natural vegetation remains a prerequisite when proposing corrective measures. Current studies only propose courses of action to stop the dynamics in progress but without a real evaluation of the impacts of these actions.

In the present study, based in the Tuy province, in the cotton region of West Burkina Faso, we estimate the weight of the factors that have triggered past dynamics, as well as assess the impacts of different proposals for action. First, we identify and describe land change mechanisms of the last 15 years in this province. These mechanisms in turn suggest plausible futures of the populations in the study area, the threats they face and the choices available to them. The recent and future trends are investigated using remote sensing images, field survey and spatial dynamics modelling. Backward and forward land change projection scenarios generated by the model can then be assessed according to the previous theories. The study area was chosen for the significant trends which are characteristic of cotton cropping regions of West Africa: an important population growth and the introduction of new cropping practices. The main land change was an expansion of croplands at the expense of natural vegetation. Today, the province is going through a pivotal period, as it is currently facing natural resource depletion, and is bound to experience critical occupancy issues with a predicted doubling of the population within the next thirty years (Tallet, 2007). Soil impoverishment due to fallow shortening has huge consequences on smallholder farmers who must resort to more fertilizers and chemicals to compensate for yield decrease. The farmers are also impacted by natural vegetation decline, as they depend on woodlands for timber, fuel, wild foods, medicinal herbs and ecosystem services like soil recovery or water management (Djoudi et al., 2015). The increasing number of conflicts over resource access, reviving buried ethnical tensions, is an alarming indicator of this critical situation (Diallo and Vall, 2010; Audouin and Gautier, 2017; Gonin and Gautier, 2016). A recent study showed that such changes in the Sahel were responsible for a dramatic impoverishment of biodiversity (Walther, 2016). This highlights the urgent need for measuring these mutations in order to anticipate their consequences and limit their impact. This article aims at describing the evolution of the zone since year 2000, in the light of this particular history.

After describing the data used for the study and the spatial dynamics model structure, we quantify land changes over the past 14 years and identify driving factors that are integrated in the spatial model. The contribution of each factor to the observed trends can thus be quantified and different hypotheses of past clearance patterns tested. We also simulate prospective scenarios according to different predictions of population growth where possible solutions to reduce future overexploitation of natural resources can be assessed. Among them, the intensification of farming systems is tested as a way to sustainably contain cropland expansion trends. Finally, the discussion part replaces the backward and forward projections in the Malthus vs Boserup debate to assess different possible paths of the agrarian transition.

2. Material and method

2.1. Study area

Tuy is a province of 5600 km^2 and is an old zone of agricultural colonization of Burkina Faso. About 50% of the area was cropped domain in 2014 and 16% was dedicated to protected areas (Fig. 1). With a Sudanian climate and soils mainly ferruginous, the natural vegetation is woodlands, composed of bushes and trees. In 2012, around 80% of the farms were less than 10 ha in size with some draft animals, 15% were agro-pastoralists with up to 30 ha and a cattle herd. The lasts 5% were livestock farmers with less than 6.5 ha, a herd of 10–50 heads (Marre-Cast and Vall, 2013; Vall et al., 2017). The dominant crops are cotton, maize and sorghum, the proportions of which vary within each farm depending on its type.

A brief overview of the history of the zone is necessary to understand the evolutions that occurred over the past 14 years. During the colonization period, the main cropping systems included fallows of more than ten years. Those entirely manual systems were based on cereals associations (sorghum, millet, black-eyed pea, peanuts…). The region witnessed its first notable transformations after gaining independence in 1960. An important campaign for cotton promotion began, when farmers benefited from chemical and new seed subsidies, and the first ploughs were introduced. The cotton crop was rapidly adopted in the 1970s, causing major changes in farming systems. The