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Analysis

Taking account of governance: Implications for land-use dynamics, food prices, and trade patterns

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ABSTRACT

Deforestation, mainly caused by unsustainable agricultural expansion, results in a loss of biodiversity and an increase in greenhouse gas emissions, as well as impinges on local livelihoods. Countries' governance performance, particularly with respect to property rights security, exerts significant impacts on land-use patterns by affecting agricultural yield-related technological investment and cropland expansion. This study aims to incorporate governance factors into a recursive agro-economic dynamic model to simulate governance impacts on land-use patterns at the global scale. Due to the difficulties of including governance indicators directly into numerical models, we use lending interest rates as discount rates to reflect risk-accounting factors associated with different governance scenarios. In addition to a reference scenario, three scenarios with high, low and mixed divergent discount rates are formed to represent weak, strong and fragmented governance. We find that weak governance leads to slower yield growth, increased cropland expansion and associated deforestation, mainly in Latin America, Sub-Saharan Africa, South Asia and Southeast Asia. This is associated with increasing food prices, particularly in Sub-Saharan Africa and Southeast Asia. By contrast, strong governance performance provides a stable political and economic situation which may bring down deforestation rates, stimulate investment in agricultural technologies, and induce fairly strong decreases in food prices.

1. Introduction

Forests contain large carbon stocks, storing 20 to 100 times more carbon per unit area than agricultural land (Upadhyay et al., 2005). It is estimated that 247 Gt carbon were stored in over 2.5 billion ha of forest in the early 2000s in Asia, Latin America and Sub-Saharan Africa (Saatchi et al., 2011). In addition, tropical forests preserve a high level of biodiversity, retaining 75% of the primary vegetation (Myers et al., 2000), which helps enhance the resilience of such ecosystems to external shocks (Fischer et al., 2006). However, in the last two decades, about 290 million ha of forest have been lost due to anthropogenic land conversion (FAO 2010). The expansion of agricultural land, including cropland and pastureland, is the major driver of deforestation (Eliasch, 2008). Between 1980 and 2000 more than 83% of new cropland was established on former forest area, especially in Latin America, Sub-Saharan Africa and Southeast Asia (Gibbs et al., 2010). The greatest expansion of pastureland, by about 42 million ha, occurred in Latin America (Gibbs et al., 2010). In a global study of tropical forests, conversion to agricultural land accounted for around 56% of total forest change (Barbier et al., 2005). Around 60% of deforestation in Africa was due to the conversion of forests to small-scale agriculture, whereas conversion to large-scale agriculture occurred mainly in Latin America and Asia (Barbier et al., 2005). Deforestation and forest degradation contributed to 12–20% of global anthropogenic carbon emissions in the last two decades (van der Werf et al., 2009).

Various drivers of agricultural land expansion such as increasing food demand due to population growth, trade liberalization, and other direct forces of deforestation such as commercial logging and firewood consumption have been studied in the literature (Rowe et al., 1992; Capistrano, 1994; Cropper and Griffiths, 1994; DeFries et al., 2010, Hosonuma et al., 2012, Schmitz et al., 2012). It has been suggested that underlying factors need to be distinguished from direct and intermediate causes to better understand the process of deforestation (Angelsen and Kaimowitz, 1999), and among such underlying factors, institutions and macroeconomic factors are fundamental to forest conservation (Geist and Lambin, 2002; Barbier et al., 2005; Galinato and Galinato, 2013).

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Institutions are humanly devised constraints that regularize human actions (North, 1990), and thus they affect human land-use behavior. Bromley (2006) emphasizes that institutions are represented in the form of public policies, property rights and norms. Property rights are the control of benefit streams generated from resources (Bromley, 2006). They include state property rights, private property rights, common property rights and open access (Bromley, 2006). In the case of land use, property rights often refer to land tenure or ownership. They create incentives which affect the agents' calculation of costs and benefits of their land-use patterns, which in turn affect their choice of land-use activities (Angelsen and Kaimowitz, 1999). Insecure property rights can therefore signal high costs for technological investment due to high risks, and lead to unregulated and undesired deforestation with the purpose of creating new agricultural land (Angelsen, 1999; Bohn and Deacon, 2000; Culas, 2007; Araujo et al., 2009; Yu and Farrell, 2013). Due to the risks and uncertainties resulting from insecure land ownership, the discount rates for calculating present value of land use in the future are higher than they would be under secure property rights (Araujo et al., 2009). The effect of discount rates on resource depletion depends on the substitution between capital and other inputs. High discount rates not only depreciate the future value of a resource stock leading to the depletion of the resource, but reduce the capital investment incentives for resource extraction which would defer depletion. In the case of deforestation, high discount rates provide disincentives for capital investment in agricultural production and encourage cropland expansion which encroaches forests, since a lack of investment in crop yields has to be compensated by additional cropland expansion (Deacon, 1994; Deacon, 1999; Bohn and Deacon, 2000; Culas, 2007; Araujo et al., 2009).

Property rights are not retained by themselves, but they are rather contingent on the performance of governance (Bhattarai and Hammig, 2001; Hagedorn, 2008; Wang et al., 2013; Yu and Farrell, 2013). Without well enforced land rights, forests fall into an open access situation which leads to forest degradation caused by a free-riding problem. Since the state is the ultimate enforcer for private and common property rights (Bromley, 2006), its performance, determined by the political and economic situation in a country, affects the effectiveness of public polices and property rights. We can therefore expect that a country with strong governance, i.e., a stable political situation combined with good government accountability, will improve forest conservation (Deacon, 1994; Bhattarai and Hammig, 2001).

Global land-use models have been used in several studies to assess the driving forces for deforestation such as demographic change, trade liberalization and economic growth (Verburg et al., 2008, Popp et al., 2010; Schmitz et al., 2012, Valin et al., 2013; Popp et al., 2014). Using global models instead of micro-level econometric models enables the analysis of such global underlying factors that determine regional land-use patterns. However, institutional factors are widely missing in global analyses so far, and their impacts have not been examined on a global basis, although the importance of policy and institutions has been extensively discussed in the theoretical literature and studied at a local level (Geist and Lambin, 2002). In this paper, governance factors are incorporated into a recursive agro-economic dynamic optimization model, the Model of Agricultural Production and its Impact on the Environment (MAgPIE) (Lotze-Campen et al., 2008; Popp et al., 2010; Popp et al., 2014), to analyze the impacts of governance on land use and its implication for development issues, such as agricultural yield growth, food prices and changes in trade. The following specific questions will be examined: (1) how does governance performance affect deforestation, GHG emissions, cropland expansion, and productivity in the crop sector?, (2) how are food prices affected by governance performance, particularly in developing countries?, and (3) what are the effects of governance on agricultural trade?

The remainder of the paper is organized as follows. Section 2 introduces the model employed for simulating impacts of governance on land use. Section 3 presents data on governance performance and discount rates, and a description of governance scenarios. Results about impacts of governance on the biophysical and social dimensions are presented in Section 4. Section 5 discusses the findings and Section 6 draws conclusions.

2. Simulation Methods

The MAgPIE model is employed to simulate governance impacts on land-use dynamics. The objective function of the model is to fulfill food, livestock and material demands at minimum costs under certain socio-economic and biophysical constraints (Lotze-Campen et al., 2008; Popp et al., 2012). The quantity of food demand is based on exogenous projections of future population and income growth. The model covers the most dominant food and feedstuffs, and livestock production types for 10 world regions (Fig. 1), the classification of which is based on the economic situation that is coincident with governance structure. Trade, increase of agricultural yields through augmenting R&D investment, and land expansion are the primary means of fulfilling food and material demand, while the major costs involved are costs of input factors, land conversion, transportation to the closest market, and R&D investment. Socio-economic constraints like trade liberalization in terms of reduction of self-sufficiency rates are prescribed at the regional level to determine inter-regional reallocation of agricultural production, while intra-regional trade is not taken into account. Biophysical constraints such as potential crop yields, carbon density and water availability, derived from the global hydrology and vegetation model LPJmL (Bondeau et al., 2007, Müller and Robertson 2014), as well as land availability (Krause et al., 2013) are prescribed at the 0.5 degree grid cell level. The LPJmL model is used only to derive consistent sub-national yield patterns for current crop varieties, carbon stocks, water withdrawals and water availability for the beginning of the simulation period. The yield increases projected by MAgPIE are not fed-back to the LPJmL model.

Based on the review of theoretical and empirical analyses in the Introduction, this paper focuses on deforestation induced by creating new cropland, and includes macroeconomic and governance factors, as they are assumed to exert an impact on yield-related agricultural technological investment as well as cropland expansion. Assuming the world is experiencing moderate trade liberalization, in order to satisfy the growing regional food demand at minimum production costs, the model can either invest in R&D (Dietrich et al., 2014) for yield-increasing technological change (TC) or in cropland expansion. The presented simulation covers the period from 1995 to 2050 at 5-year intervals with 700 simulation units based on a k-means clustering algorithm of aggregating 59,199 spatial grid cells (Dietrich et al., 2012). The optimization process is computed at the cluster level.

The annuity approach is adopted to distribute the costs of yield-related technological investment and cropland conversion costs occurring in the current time step into the future. A time horizon of 30 years has been adopted, since this is commonly practiced in agricultural investment. This study uses an annuity factor, where payments are made at the beginning of each period, since costs already occur in the first period in the model.

$$annuity_i = \frac{1-(1+r_i)^{-t}}{\frac{r_i}{1+r_i}},$$

where r_i is a discount rate for an economic world region i. Through the annuity, the value of the discount rates which depend on governance performance, affects land use choices in terms of costs related to R&D investment to increase yields and costs of conversion from forests to cropland. Using this method, the costs occurring in the current time step are equally distributed over six 5-year simulation periods (a planning horizon of 30 years), in which the costs of the first period are considered as sunk costs. The same holds true for other investments in the model such as