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Addressing climate change cause and effect on land cover and land use in South Asia

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ABSTRACT

This paper evaluates the role of trade liberalization and agricultural intensification in mitigating climate change cause and effects on land use and emissions using a computable general equilibrium model. Our results indicate that cropland expansion triggered by climate-induced crop productivity changes results in deforestation and increases emissions in South Asia and globally. Global full trade liberalization on all goods is the optimum policy for South Asia despite significant global deforestation, but for the world, unilateral partial trade liberalization on all goods is a more appropriate policy while ensuring a considerable emissions reduction for South Asia. These results indicate that mitigation responses to climate change are location specific and no one trade policy is suitable at the regional and global levels. Lastly, agricultural intensification by improving productivity growth is the best strategy in land-based emissions mitigation, thereby avoiding the transformation of forest and pasture lands for agricultural cultivation both at regional and global levels.

1. Introduction

Climate change and rising population exacerbate the competition for land resources. A primary form of land conversion is the expansion of cropland and pasture from forestry, mostly to fulfill the growing demand for food. The future is expected to see a continuation of this transformation which is also driven by the impacts of climate change on agriculture. Although land-use affects climate change with greenhouse gas (GHG) emissions triggered by deforestation, climate change will also affect future land cover and land use with climate-induced negative impacts on agricultural productivity. Thus a key challenge for sustainability is how to feed a massive population while preserving forest ecosystems and their services, particularly in developing countries.

While the Intergovernmental Panel on Climate Change (IPCC, 2014) notes that, around 24% of all GHG emissions are produced from the land-use sector, Vermeulen et al. (2012) explain that 6–18% of GHG emissions are due to land-cover and land-use change (LCLUC). This has led to the recognition that global climate change mitigation is incomplete in the absence of a land-use induced emissions reduction policy (Scherr et al., 2009). Among the land-use strategies, agricultural intensification[1] rather than cropland expansion has been identified as the best strategy allowing global demand for food to be supplied mostly from existing agricultural land (Byerlee et al., 2014; Firbank et al., 2008). This enables the preservation of the world's remaining forests and limits the losses of biodiversity and GHG emissions induced by deforestation. This is based on the theory that technological change improves the productivity of existing agricultural land so that it saves the conversion of forest ecosystems into agricultural lands (Stevenson et al., 2013). However, the empirical literature suggests that the role of agricultural intensification in minimizing cropland expansion and deforestation is not identical at local, regional, and global levels. For example, a net saving of land at the global scale may be a result of cropland expansion at the local level (Byerlee et al., 2014) which affects local deforestation and increases LCLUC induced emissions.

The literature has also identified trade policy reforms as having a substantial role in determining the pattern of land use (Golub and Hertel, 2008; Niklitschek, 2007), allowing changes in LCLUC-induced emissions. In fact, global markets are thought to serve as an adjustment mechanism in response to the adverse impacts of climate change on agricultural production, thus altering the global patterns of consumption and production (Tobey et al., 1992). These changes lead to land-use changes in different regions, and thus LCLUC-induced emissions. On the other hand, agricultural output and input prices as well as transportation costs are among the key determinants of the trade-deforestation nexus (Robalino and Herrera, 2010). When trade liberalization occurs, local agricultural prices increase, leading to cropland expansion and increased local deforestation for land use in agriculture, resulting in an increase in LCLUC-induced emissions. Countries with higher

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[1] This can be technically defined as an increase in agricultural output per unit of input (FAO, 2008).

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comparative advantage in producing agricultural and timber goods are the ones that are most affected with increases in trade (Robalino and Herrera, 2010). In this study, we hypothesize that trade liberalization and agricultural intensification can serve as mechanisms for mitigating LCLUC-induced emissions while simultaneously offsetting the adverse impacts of climate-induced crop productivity changes on agricultural production.

The effects of agricultural intensification and trade liberalization on land use, GHG mitigation or deforestation have been extensively analysed as separate investigations in the recent literature (e.g., see Faria and Almeida, 2016; Byerlee, 2014; Meyfroidt et al., 2013; Stevenson et al., 2013; Villoria, 2013; Lambin and Meyfroidt, 2011; Burney, 2010; Robalino and Herrera, 2010; Golub and Hertel, 2008) but they have been undertaken as separate studies. However, to the best of our knowledge, no previous study has integrated and analysed these two issues within a single framework. The paper addresses the following key research questions. First, what are the impacts of climate-induced change scenarios on land-use changes and LCLUC-induced emissions? Second, what forms (unilateral, regional, global) of trade liberalization policies (partial or full; agricultural and non-agricultural) are effective in mitigating LCLUC-induced emissions and deforestation caused by climate change? Third, what are the impacts of agricultural intensification on LCLUC-induced emissions? Fourth, is there any optimum trade policy option for mitigating the impacts of climate change on LCLUC and emissions? Fifth, what is the potential impact of technological change as a mechanism to reduce LCLUC-induced CO_2 emissions and deforestation on agricultural crops? This paper is the first attempt to consider these various dimenisons to provide a comprehensive analysis based on empirical evidence from a computable general equilibrium (CGE) model of land use, using South Asia as a case study.

We chose South Asia as a region to investigate for the following reasons. This is a region where nearly a quarter of the world's population dwells on only 3.7% of the world's total land area (Food and Agricultural Organization (FAO), 2015). Global climate change predictions indicate that South Asia will be one of the areas most affected by global warming. By 2100, temperatures are expected to rise on average by 2 °C in some parts and 4 °C in others (World Bank, 2009, 2013). With a huge cumulative population by 2050 that will exceed China's, this region is likely to accelerate the current LCLUC with significant impacts on the ecosystem (Vadrevu et al., 2015). Agriculture is not only the primary form of land use in South Asia amounting to 50% of the total area (FAO, 2015), but this region is experiencing expansion and intensification of cropland and shrinking forest and pasture lands coupled with higher population growth and poverty (Mitra and Sharma, 2010). Under a more likely climate–induced crop productivity scenario, South Asia's productivity of major crops will decline significantly, which is second only to Sub-Saharan Africa (Hertel et al., 2010). The recent IPCC Fifth Assessment Report predicts that the decline in agricultural productivity caused by climate change will result in the largest number of food-insecure people being located in South Asia (Pachauri et al., 2014).

The remainder of the paper is organized as follows. Section 2 reviews the releveant theoretical and empirical literature related to this study, with an emphasis on the economic models of land-use. Section 3 describes the modeling framework underlying the Global Trade Analysis Project (GTAP)-Agro-Ecological Zones (AEZ) model, the database used, and simulated shocks for analyses. Results of the study are presented and discussed in Section 4 while Section 5 concludes.

2. Literature review

The nature of land use in any particular location is strongly influenced by climate. In particular, the agriculture and forestry sectors are very vulnerable to climate change, which will alter the relative productivity of lands. Land use affects climate change in three ways. First, land use patterns influence GHG emissions; second, land use is important in assessing the impacts of climate change; and third, land use is necessary for the reduction of GHG emissions (Hertel et al., 2008). With approximately 80% of the crop and pasture lands expanding by replacing forests, particularly in the tropics (Gibbs et al., 2010), land-cover change has become a significant source of CO_2 emissions (Vermeulen et al., 2012). In the period 1750–2011 forestry and other land use accounted for about a third of anthropogenic CO_2 emissions, whilst they accounted for about 12% of emissions from 2000 to 2009 (IPCC, 2015).

A number of empirical studies indicate that regional agricultural production could be significantly affected by climate change, especially in the poorer regions of the world. For example, Hertel et al. (2010), Laborde (2011) and Knox et al. (2012) projected the impacts of climate change on agricultural production in various regions including South Asia and found significant declines in crop yields by the 2050s. More recently Bandara and Cai (2014) and Cai et al. (2016) have analysed the impacts of climate-induced productivity changes on food production and prices in South Asian countries and found signficant adverse effects. A decline in crop productivity has further implications for land-use changes in the sense that additional land has to be brought into production to maintain output which increases the rate of deforestation. Recent empirical studies suggest that land-based mitigation could represent a cost-effective portfolio of mitigation strategies for long-term climate stabilization (Hertel et al., 2008; Ahammad et al., 2012).

Past empirical studies have either focused on the role of trade liberalization on land use and GHG mitigation or the impacts of agricultural intensification driven by technological change on land use and GHG mitigation. Research on the role of trade liberalization has however produced mixed results. The spatial adjustment of agriculture to the productivity of land is the theoretical basis for forest transition. Thus international trade can improve these changes between land use and the productive potential of different regions (Mather and Needle, 1998). Empirical evidence shows that trade openness is a primary determinant of deforestation in some parts of the world given the possibility that international trade can generate economic incentives. For example, the potential increase in profitability associated with the production of particular crops has been an incentive (Faria and Almeida, 2016). On the other hand, incentives such as real exchange rate depreciation have led to an expansion of afforested land in some regions showing the controversy of the role of trade liberalization (Niklitschek, 2007).

Since trade liberalization leads to lower global costs of food, regions with comparative advantage in agricultural production such as Latin America and China will export more agricultural crops, causing deforestation and significant additional amounts of CO_2 emissions (Verburg et al., 2009). However, regions with a comparative disadvantage such as South Asia and North Africa, face the highest increases in imports, and thus lower their CO_2 emissions due to trade liberalization. Hence in the absence of regulations, trade liberalization leads to higher economic benefits at the expense of the environment and climate (Schmitz et al., 2012). Similar studies show that trade liberalization leads only to small land-use shifts in Europe but dramatic changes in Africa and other developing regions, resulting in more negative environmental implications (Van Meijl et al., 2006). Thus trade plays a significant role in determining the countries in which deforestation is likely to occur (Golub and Hertel, 2008). Given the spatial and commodity-wise variations, there is a need for regional and commodity-focused analysis of different types of liberalization options, as well as detailed assessments of the combined economic environment impacts before any general conclusion for the effects of trade liberalization on LCLUC can be drawn (Verburg et al., 2009).

World agriculture shows a distinct transition regarding the contribution of extensive (cropland expansion) and intensive (crop intensification) margins to total agricultural production. Before the beginning of the 20th century, production increases in agriculture had been made mainly through the extensive margin. However, this