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Agriculture, forestry, and other land-use emissions in Latin America

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A B S T R A C T

Nearly 40% of greenhouse gas (GHG) emissions in Latin America were from agriculture, forestry, and other land use (AFOLU) in 2008, more than double the global fraction of AFOLU emissions. In this article, we investigate the future trajectory of AFOLU GHG emissions in Latin America, with and without efforts to mitigate, using a multi-model comparison approach. We find significant uncertainty in future emissions with and without climate policy. This uncertainty is due to differences in a variety of assumptions including (1) the role of bioenergy, (2) where and how bioenergy is produced, (3) the availability of afforestation options in climate mitigation policy, and (4) N_2O and CH_4 emission intensity. With climate policy, these differences in assumptions can lead to significant variance in mitigation potential, with three models indicating reductions in AFOLU GHG emissions and one model indicating modest increases in AFOLU GHG emissions.

1. Introduction

Globally, 42.6 $PgCO_2e$ of greenhouse gas (GHG) emissions were emitted in 2008; 81% of these emissions were from energy combustion and industrial processes (Fig. S1; EC, 2011).[1] Latin America accounted for a mere 7% of global GHG emissions. However, nearly 40% of GHG emissions in Latin America (Fig. S2) were from agriculture, forestry, and other land use (AFOLU) in 2008, more than double the global fraction of AFOLU emissions. From 2005 to 2008, AFOLU emissions in Latin America declined dramatically due to a reduction in AFOLU CO_2 emissions in Brazil (Fig. S3) as a result of stringent policies to reduce deforestation. An open question remains as to whether these declines will continue or if emissions will begin to rise again.

In this article, we investigate the future trajectory of AFOLU GHG emissions in Latin America, with and without efforts to mitigate, using a multi-model comparison approach. This work builds on the work of Rose et al. (2012), which examines mitigation potential at a global level in a multi-model framework, and on the work of Smith et al. (2014a), which compiles bottom-up estimates of mitigation potential. While many recent papers examine the role of land in mitigation regimes, they have focused their attention on land transitions (e.g., Popp et al., 2014), bioenergy (e.g., Calvin et al., 2013; Rose et al., 2014), or trade-offs between different land policy schemes (e.g., Calvin et al., 2014; Reilly et al., 2012; Wise et al., 2009) at the global level. This paper expands on these efforts by examining the emission consequences and mitigation potential of land transitions in a particular region (Latin America).

Section 2 discusses the models and scenarios included in this article. Section 3 examines the AFOLU GHG emissions in Latin America absent any climate mitigation efforts. Section 4 discusses potential mitigation options and how they influence emissions under climate policy in Latin America. Section 5 provides some discussion, concluding remarks, and areas for future research.

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[1] The numbers quoted in this paragraph and in Figs. S1–S3 are from the EDGAR data set (EC, 2011). There is significant uncertainty in historical emissions, particularly of AFOLU CO_2. For more information on emissions uncertainty, see Blanco et al. (2014).

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2. Methodology

This article utilizes the models and scenarios developed for the CLIMACAP–LAMP project[2] to assess AFOLU GHG emissions in Latin America. For more information on the project and its scenarios, we refer the reader to the introductory article of this special issue (van der Zwaan et al., 2016). In this section, we describe the models and scenarios included in this study.

2.1. Models

Several approaches to modeling AFOLU in economic and integrated assessment models exist. Some models exclude the sector entirely, either explicitly or implicitly assuming that AFOLU GHG emissions are zero. Some models include AFOLU by parameterizing functions (e.g., bioenergy supply curves and AFOLU GHG marginal abatement cost curves) to other offline models or studies. These models often include limited feedbacks. For example, an expansion in bioenergy consumption in these models may not change GHG emissions, if both elements are included through separate, non-interacting functions, or if bioenergy is assumed to be sustainably grown and therefore carbon-free. A third type of model includes a structural representation of the agriculture and land sector, ensuring consistency between production, consumption, and emissions. In this article, we focus our analysis on the second and third types of models (see Table 1). The model descriptions included in this paper are focused on the treatment of AFOLU and AFOLU GHGs. For more information on these models, we refer to the reader to publications developed by their respective modeling teams: ADAGE (Ross, 2009); EPPA (Paltsev et al., 2005); GCAM (Calvin et al., 2011) and TIAM-WORLD (Loulou, 2008; Loulou and Labriet, 2008).

2.2. ADAGE

The Applied Dynamic Analysis of the Global Economy (ADAGE) model is a multi-region, multi-sector dynamic computable general equilibrium (CGE) model (Ross, 2009). The version of ADAGE used for the current study is a recursive dynamic version focused on the agricultural sector. It includes disaggregation of individual major agricultural crops and bioenergy feedstocks as well as incorporation of land as a factor of production with tracking of land cover and land use in terms of physical area (Beach et al., 2011). Land cover categories included are cropland, pasture, managed forests, unmanaged forests, natural grassland, and other land. Land conversion is modeled using a nested constant elasticity of substitution (CES) function and explicitly incorporates costs of land conversion as well as land supply elasticities. Marginal conversion costs are assumed to be equal to the difference in value between land types while land supply elasticities are based on historically observed rates of land conversion. The key database used in this study is the Global Trade Analysis Project (GTAP) data base version 7.1 (Narayanan and Walmsley, 2008) which comprises 57 sectors and 112 regions, corresponding to the global economy in 2004. Because there are no explicit sectors for biofuels and their respective feedstock crops and by-products in the GTAP database, we incorporated these sectors by splitting the relevant existing sectors. The final database includes disaggregated sectors such as corn, soybeans, rapeseed-mustard, palm-kernel, sugarcane, and sugar beets; biofuels categories such as corn ethanol, wheat ethanol, sugarcane ethanol, sugar beet ethanol, soy biodiesel, rapeseed biodiesel, palm oil biodiesel, and major by-products of biofuels production such as dried distillers' grains with solubles (DDGS) and oilseed meals. The modified GTAP data base was aggregated to 8 regions and 36 sectors and updated to the model baseline year 2010 using secondary data on energy, biofuels, agriculture, and livestock sectors from secondary data sources including the Food and Agricultural Organization (FAO), International Energy Agency (IEA), U.S. Department of Agriculture (USDA), Energy Information Administration (EIA), U.S. Department of Energy (DOE), and others. GHG emissions from all sources are included in ADAGE, along with opportunities for GHG mitigation.

CO_2 emissions from fuel use are tied directly to the quantity of each category of fossil fuel combusted. Options for fuel substitution in production and household energy consumption are controlled by the model's CES nesting structure and substitution elasticities. Non-CO_2 emissions enter the production function as an input. Sector-specific abatement cost curves are implemented through elasticities of substitution between each GHG and all other inputs calibrated based on marginal abatement cost curves (EPA, 2006, 2013). Emissions from land use change are calculated by multiplying the area of land conversion by the difference in carbon sequestration (above and below ground vegetative carbon and soil carbon) provided by the two land types multiplied by IPCC default emissions factors for land use change (IPCC, 2006). As a result, changes in carbon stock occur immediately following a land conversion. ADAGE calculates projected global and regional economic production, energy use, agriculture activity, biofuel production, land use change and greenhouse gas emissions from all sources from 2010 to 2050 at 5-year time steps. Latin America is represented within the current ADAGE model by Brazil and an aggregated region of all other countries in Latin America.

2.3. EPPA

EPPA is a multi-region, multi-sector recursive-dynamic CGE model of the global economy (Paltsev et al., 2005). Latin America is represented in EPPA by Mexico, Brazil, and an aggregated region of all the other countries in Latin America. The model calculates emissions of greenhouse gases (CO_2, CH_4, N_2O, HFCs, PFCs and SF_6) and other pollutants, and also represents abatement and mitigation policies, including gas-specific control measures (Hyman et al., 2003). The agriculture activities in the model are crops, livestock and forestry, plus regional specific biofuels crops. Land use categories are cropland, pasture, managed forest, natural forest and natural grass. Natural vegetation is incorporated explicitly considering their "non-use" value in the utility function. EPPA considers competition among land use categories by considering that farmers can transform one land category to others if they are able to cover explicitly the costs of conversion. This approach implies that intensively managed land can be "produced" from less intensively or unmanaged land, and also that farmland can be abandoned. The conversion of natural vegetation in EPPA is limited by the observed land supply response in the last two decades (Melillo et al., 2009). It mimics the increasing costs associated to larger deforestation in a single period and the additional institutional costs, as environmental legislation and consumer pressures to conservationism. Land use changes in EPPA operates on a per country level, but it is connected with the Terrestrial Ecosystem Model - TEM (Felzer et al., 2004) to distribute EPPA's land-use predictions by 0.5° grid cell level based on climate, soil and economic information.

2.4. GCAM

GCAM is a global integrated assessment model, coupling representations of the economy, energy system, agriculture and land use system, and climate system. The model operates in five-year time steps from 1990 to 2100. GCAM disaggregates Latin America into seven regions (Argentina, Brazil, Colombia, Mexico, Central America and the Caribbean, Northern South America, and Southern South America). The agriculture and land use component of GCAM further disaggregates these

[2] The Integrated Climate Modelling and Capacity Building Project in Latin America (CLIMACAP) is a European Commission funded effort focused on analyzing the effects of mitigation strategies in key Latin American Countries. The Latin American Modeling Project (LAMP) is a similar effort funded by the U.S. Environmental Protection Agency and the U.S. Agency for International Development. The projects are collaborating to develop a multi-model comparison project focused on mitigation in Latin America. More information on the projects is available at: https://tntcat.iiasa.ac.at/CLIMACAP-LAMPDB/.