Resource and Energy Economics 31 (2009) 299–319

Contents lists available at ScienceDirect

Resource and Energy Economics

journal homepage: www.elsevier.com/locate/ree

The opportunity cost of land use and the global potential for greenhouse gas mitigation in agriculture and forestry

Alla Golub [a], Thomas Hertel [a,*], Huey-Lin Lee [b], Steven Rose [c], Brent Sohngen [d]

[a] Center for Global Trade Analysis (GTAP), Purdue University, United States
[b] Department of Economics, National Chengchi University, Taiwan
[c] Electric Power Research Institute (EPRI), United States
[d] The Ohio State University, United States

A R T I C L E I N F O

Article history:
Received 2 May 2007
Received in revised form 29 September 2008
Accepted 29 April 2009
Available online 12 May 2009

JEL classification:
C68
Q15
Q54

Keywords:
Climate change
Land use change
Non-CO_2 greenhouse gas
Marginal abatement cost
Computable general equilibrium
Forest carbon sequestration

A B S T R A C T

This paper analyses the role of global land management alternatives in determining potential greenhouse gas mitigation by land-based activities in agriculture and forestry. Land-based activities are responsible for over a third of global greenhouse gas emissions, yet the economics of land-use decisions have not been explicitly modeled in global mitigation studies. In this paper, we develop a new, general equilibrium framework which effectively captures the opportunity costs of land-use decisions in agriculture and forestry, thereby allowing us to analyse competition for heterogeneous land types across and within sectors, as well as input substitution between land and other factors of production. When land-using sectors are confronted with a tax on greenhouse gas emissions, we find significant changes in the global pattern of comparative advantage across sectors, regions, and land types. Globally, we find that forest carbon sequestration is the dominant strategy for GHG emissions mitigation, while agricultural-related mitigation comes predominantly from reduced methane emissions in the ruminant livestock sector, followed by fertilizer and methane emissions from paddy rice. Regionally, agricultural mitigation is a larger share of total land-use emissions abatement in the USA and China, compared to the rest of the world, and, within agriculture, disproportionately from reductions in fertilizer-related emissions. The results also show how analyses that only consider regional mitigation, may bias mitigation potential by ignoring global market interactions. For example, USA-specific analyses likely over-

* Corresponding author.
E-mail addresses: golub@purdue.edu (A. Golub), hertel@purdue.edu (T. Hertel), hlee@nccu.edu.tw (H.-L. Lee), srose@epri.com (S. Rose), sohngen.1@osu.edu (B. Sohngen).

doi:10.1016/j.reseneeco.2009.04.007

estimate the potential for abatement in agriculture. Finally, we note that this general equilibrium framework provides the research community with a practical methodology for explicit modeling of global land competition and land-based mitigation in comprehensive assessments of greenhouse gas mitigation options.

1. Introduction

Changes in land use and land cover represent an important driver of net greenhouse gas (GHG) emissions. It has been estimated that roughly a third of the total emissions of carbon into the atmosphere since 1850 has resulted from land use change (and the remainder from fossil-fuel emissions) (Houghton, 2003). For example, in the 1990s, 6.4 billion tonnes of carbon alone per year was emitted to the atmosphere from industrial activities and approximately 2.2 billion per year was emitted from tropical deforestation.[1] In addition, agricultural land related activities are estimated to be responsible for approximately 50% of global methane emissions (CH_4) and 75% of global nitrous oxide (N_2O) emissions, for a net contribution from non-carbon dioxide (non-CO_2) GHGs of approximately 14% of all anthropogenic greenhouse gas emissions (USEPA, 2006a). Because of this potentially important role in the climate change debate, the policymaking community is assessing how agriculture and forestry may enter into future climate policies. These come into play, either as domestic actions (e.g., emission offsets within a cap-and-trade system), or via mechanisms for achieving international commitments for emissions reductions (e.g., the Clean Development Mechanism). In this paper, we develop a new framework for assessing the mitigation potential of land-based emissions that explicitly models the economics of land-use change and management decisions. This framework could be readily combined with existing GHG mitigation studies of industrial and fossil fuel-based GHG emissions.

A number of estimates have been made of the cost of abating greenhouse gas emissions for specific land use change and land management technologies (Richards and Stokes, 2004; USEPA, 2006b, Chapter 5). Recent studies also suggest that land-based mitigation could be cost-effective and assume a sizable share of overall mitigation responsibility in optimal abatement (Sohngen and Mendelsohn, 2003) and stabilization policies (Rose et al., 2008a). However, to date, global economic modeling of land has not been able to fully account for the opportunity costs of land-use and land-based mitigation strategies, nor the heterogeneous and dynamic environmental and economic conditions of land, which have been shown to be important (e.g., Li et al., 2006; Sohngen et al., 2009).

Despite the clear links between the agricultural and forestry sectors through land and other factor markets and international trade, existing studies do not explicitly model the reallocation of inputs (both primary factors and intermediates) within and across these and other sectors and regions in response to climate policies. National and international agricultural and forest climate policies have the potential to redefine the opportunity costs of international land-use in ways that either complement or counteract the attainment of climate change mitigation goals. This paper develops an analytical framework to capture and evaluate these potentially important relationships.

Global economic modeling of land-use is not new. There are global agricultural models (e.g., Darwin et al., 1995, 1996; Ianchovichina et al., 2001; Rosegrant et al., 2001), and global forestry models (e.g., Sohngen and Sedjo, 2006), and some that endogenously model land competition between

[1] This number was recently revised down to 1.6 BTCE/yr for gross emissions from 1990s tropical deforestation and other land-use change activities, with a range of 0.5 to 2.7 BTCE/yr due to downward revision of estimated tropical deforestation (IPCC, 2007; Houghton, 2008). Throughout this paper, greenhouse gas emissions are measured in metric tons of carbon equivalent, where 1 metric tone = 1000 kg, and one metric tone of carbon (C) equals approximately 3.67 metric tons of carbon dioxide (CO_2). Non-carbon dioxide greenhouse gases have been converted to carbon equivalent units using the 100-year global warming potentials currently used for emissions inventories under the United Nations Framework Convention on Climate Change (i.e., the IPCC's Second Assessment Report, IPCC, 1996). Metric tons of carbon equivalent are written as "TCE", million metric tons are written as "MMTCE", and billion metric tons are written as "BTCE."