Energy Economics 46 (2014) 548–554

Contents lists available at ScienceDirect

Energy Economics

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

Integrated assessment modeling of climate change adaptation in forestry and pasture land use: A review

Steven K. Rose *

Energy and Environmental Analysis Research Group, Electric Power Research Institute, 2000 L Street NW, Suite 805, Washington, DC 20036, USA

ARTICLE INFO

Article history:
Received 26 May 2013
Received in revised form 18 September 2014
Accepted 20 September 2014
Available online 28 September 2014

JEL classification:
Q23
Q24
Q54
Q56
Q12
E17

Keywords:
Climate change
Adaptation
Land use
Forestry
Pasture
Livestock

ABSTRACT

Climate change is likely to affect commercial forest and pasture land use and production activities. As such, behavioral responses that adapt to the new and evolving climatic conditions are also likely. Integrated Assessment Models (IAMs) have an important role to play. IAMs are a unique class of models that integrate global biophysical and economic systems in order to explore issues with potentially significant interactions and feedbacks between the two systems, such as potential future impacts from climate change. Climate risks to forestry, pasture, and livestock are potential risks that need to be understood and weighed. Those risks are defined by both the nature of climate change as well as society's adaptive capacity. This paper reviews and characterizes climate change adaptation modeling of forestry and pasture land use by IAMs, as well as economic modeling. The paper discusses what needs to be modeled or considered, what we have learned from the literature available, and issues and opportunities for future research. The literature is sparse, and in an early stage, but has already yielded insights regarding adaptation's potential for reducing risks, and possibly generating societal benefits. Empirical modeling will be important going forward to identify adaptation options and provide an observation based grounding for IAM modeling. Relevant empirical modeling to date is limited but highlights that there are many potential facets to adaptation related to these sectors that need to be considered by IAMs in some form. Data deficiencies will also need to be overcome and IAM model development advanced. This paper is part of a research initiative, and special issue of this journal, to improve adaptation modeling in climate impacts research.

1. Introduction

Integrated assessment models (IAMs) are a unique class of models that integrate global biophysical and economic systems in order to explore issues with potentially significant interactions and feedbacks between the two systems. IAMs have generated a rich literature related to potential future GHG emissions, climate change, and climate change mitigation (e.g., IPCC, 2000; Weyant et al., 2006; Fisher et al., 2007; Clarke et al., 2014). Integrated assessment (IA) modeling of climate change impacts is an important research area because IAMs are novel in their ability to directly and consistently evaluate global trade-offs over time between climate change management costs and benefits, and mitigation and adaptation investments.

IAMs have begun assessing potential climate change impacts and adaptation responses, but the literature thus far is limited. There is an IAM literature on potential aggregate monetary climate change damages (e.g., see Tol, 2008, meta analysis), as well as economically optimal GHG emission pathways (e.g., Manne and Richels, 1992; Nordhaus, 2008). Climate damage representations in this literature are highly aggregated and stylized. Adaptation responses, if any, are internalized in the underlying research results used to calibrate IAM damage functions or stylized (e.g., Anthoff and Tol, 2008). There is also a sparser IAM literature on select specific potential climate damages (e.g., Reilly et al., 2007, 2012; Sands and Edmonds, 2005), which has estimated some potential adaptation responses to different climates. Specific IAM analysis of potential climate impacts and adaptation in forestry and pasture land using activities is extremely scarce (Reilly et al., 2007). This dearth of analysis is due in large part to data limitations, but also to limitations in current IA modeling, especially with respect to forest management and dynamics. IA modeling has historically concentrated on energy systems and their climate change consequences. IA land use modeling with climate change is a more modern model development area, with agriculture modeling more advanced than that for managed forest lands (e.g., Rose et al, 2012). Explicit climate impacts and adaptation analyses on land-using activities by IAMs have concentrated on crop sector impacts.

Modeling climate change adaptation in forestry and pasture land use, like adaptation modeling for many sectors, consists of two modeling stages: estimation of the future biophysical implications of climate change (e.g., changes in growth and disturbance regimes), and modeling of economic responses to the biophysical changes.

* Tel.: +1 202 293 6183.
E-mail address: srose@epri.com.

http://dx.doi.org/10.1016/j.eneco.2014.09.018

There are to date very few IA modeling studies of livestock or forestry sector climate impacts and adaptation. Adaptation is a behavioral, or economic response to changes in climatic conditions. Most economic studies have been carried out with sectoral partial equilibrium models, primarily with respect to forestry (Table 1).

One IA study has however simultaneously evaluated climate change impacts across land-using sectors—forestry, livestock, & crop production (Reilly et al., 2007). Reilly et al. (2007) employ an IAM with a structured economy-wide general equilibrium economic model within that allows them to estimate potential climate adaptation behavior related to forestry and pasture land use within and between sectors. Sectoral economic models have a narrower economic scope, but richer behavioral structure and ability to explore more detailed adaptation possibilities (Perez-Garcia et al., 2002; Sohngen et al., 2001). Empirical models focus on the past and provide the numerical foundation for structured economic models by statistically estimating specific behavioral responses to climate change from observations (Mu and McCarl, 2011; Seo and Mendelsohn, 2008a, 2008b). Empirical models can identify and characterize actual adaptation responses that can inform decision-making about potential future responses. Structural models capture overarching fundamental features and processes of a system and parameterize relationships with empirical estimates in order to evaluate changes in structure to alternative conditions, such as potential future climate change.

This paper reviews and characterizes climate change adaptation modeling of forestry and pasture land use by IAMs, and economic models, and discusses the importance of and opportunities for empirical modeling. The paper discusses what needs to be modeled, or at least considered, what we have learned from the literature available, and issues and opportunities going forward. Subsequent sections are organized as follows. Sections 2 and 3 describes types of potential climate change impacts for forest and pasture land use and production, and the potential adaptation options in response to climate change. Section 4 discusses key impacts and adaptation insights to date from the currently limited literature. Section 5 discusses issues and opportunities for advancing forest and pasture land use impacts and adaptation modeling and understanding overall, and in particular for empirical modeling. Section 6 concludes.

This paper is part of a research initiative to improve adaptation modeling in climate impacts research. The initiative is designed to evaluate current empirical and modeling work, define research gaps, identify needs for empirical research, and identify opportunities for incorporating empirical adaptation knowledge into modeling.

Before continuing, a brief comment regarding the scope of this paper is appropriate. This paper discusses IA and economic modeling of climate change adaptation related to commercially managed forest and pasture lands and their economic production, including grasslands, rangelands and livestock products, and commercial forests and wood products. The geographic scope is global, consistent with integrated assessment models. Non-commercial and unmanaged lands and their societal goods and services are beyond the scope of this paper. Thus ecosystem services, informal extraction and markets, recreational value, and non-market values (option, existence, and esthetics values) are not considered, nor are adaptation on these non-commercial lands—in natural processes or via public policy.

2. Climate change impacts

Climate change can affect pasture and forest related commercial products indirectly, via land impacts, or directly. For instance, livestock production can be indirectly affected by climate change impacts on pasture productivity, plant community structure, and forage nutritional quality. Research to date suggests that mild warming will increase pasture productivity in humid temperate regions and decrease productivity in arid and semiarid regions. Changes in precipitation are also considered a key determinant of future rangeland productivity and plant species—both highly correlated with precipitation. Climate change can also directly affect livestock animal productivity, fertility, and mortality. Thermal stress can reduce conception rates and productivity, and even result in mortality. In addition, climate variability may affect productivity, with projected increases in variability suggesting the potential for additional losses, possibly greater than those associated with average changes in climate (Porter et al., 2014; Scholes et al., 2014; Walthall et al., 2012; Easterling et al., 2007).

A variety of climate change impacts are relevant to forest-related products and the forests from which they are derived. Climate change can alter growth rates and growing seasons, thereby affecting biomass and timber supplies. Climate change can also affect forest tree species composition, disturbance regimes (e.g., pests, fires, disease, wind damage), as well as forest access, forest roads & facilities, and non-timber forest product productivity. Research to date suggests that warmer temperatures and increases in atmospheric carbon dioxide concentrations will increase tree growth rates, and facilitate poleward migration of commercially productive species. However, there is the potential for climate related forest dieback, but primarily in remote forests. Increases in direct tree damage are possible with elevated fire and insect risk, as well as wind, ice, and snow damage. There is also the potential for changes in forestland access, roads, and facilities (Easterling et al., 2007; Scholes et al., 2014).

3. Adaptation options

Pasture and forestry related production and land-use could adapt to some climate change risks. Adaptation could take the form of autonomous private-sector responses to climate change stimuli. Autonomous adaptation responses are endogenous reactions to changing current and expected production conditions. Potential autonomous responses are bounded by current response capacity, which is defined by things like available technology, resources, and substitutes. Autonomous responses are distinct from non-autonomous

Table 1
Adaptation studies of forestry and pasture land use.

Study	Type	Behavioral model	Forestry adaptation	Pasture land use adaptation
Reilly et al. (2007)	Structured–Integrated Assessment	Economy-wide general equilibrium	Production levels, input substitution, consumption levels, land-use change, trade, economy-wide resource re-allocation	Production levels, input substitution, land-use change, consumption levels, trade, economy-wide resource re-allocation
Sohngen et al. (2001)	Structured–Economic sectoral	Forestry sector partial equilibrium (with intertemporal optimization)	Production levels, consumption levels, land-use change, trade, species selection, management intensity, rotation modification, location choice (biome level)	n/a
Perez-Garcia et al. (2002)	Structured–Economic sectoral	Forestry sector partial equilibrium	Production levels, consumption levels, trade	n/a
Mu and McCarl (2011)	Empirical	Econometric	n/a	Land use change, livestock stocking rates
Seo and Mendelsohn (2008a)	Empirical	Econometric	n/a	Agricultural farm type selection
Seo and Mendelsohn (2008b)	Empirical	Econometric	n/a	Livestock species selection, livestock population