Resource and Energy Economics 35 (2013) 148–170

Contents lists available at SciVerse ScienceDirect

Resource and Energy Economics

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

Natural carbon capture and storage (NCCS): Forests, land use and carbon accounting

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A R T I C L E I N F O

Article history:
Received 13 September 2011
Received in revised form 28 June 2012
Accepted 28 December 2012
Available online 24 January 2013

JEL classification:
Q15
Q23
Q54

Keywords:
Land allocation model
Forest vintages
Carbon sequestration
Carbon accounting
Optimal rotation
Land allocation between alternative uses
Transition/steady-state

A B S T R A C T

The use of forests as natural carbon capture and storage sinks is considered by introducing carbon sequestration benefits' accounting in a multi-vintage partial equilibrium land-use model, under different carbon price scenarios. The consequences to timber and land markets and to the profile of the carbon sequestration time path are examined in the short-run, long-run, and transition. Following IPCC, three carbon accounting methods are considered: the carbon flow, the ton-year crediting and the average storage. A full proof of long-run optimality of steady-state forest is provided. Numerical simulations are performed and results discussed illustrating the setup's potential.

1. Introduction

Forest carbon sequestration is widely recognized as both an ecological and economically viable instrument to help mitigating climate change.[1] While most of the debate on forest carbon has focused on deforestation, a recent study (Forest Carbon Index, 2009) mentions that additional forest re-growth

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[1] According to the Third Assessment Report of the Intergovernmental Panel on Climate Change (IPCC), up to 20% of excessive emissions can be captured in forests and biological sinks over the next 50 years.

0928-7655/$ – see front matter
http://dx.doi.org/10.1016/j.reseneeco.2012.12.003

and management could potentially double the amount of carbon credits obtained from avoided deforestation, which is responsible for almost 20% of total greenhouse gases (GHG) emissions. While avoiding deforestation and forest degradation stops emissions before they occur, growing forests through afforestation or reforestation helps to recapture CO_2 and store it in forests. Moreover, forests can also be managed to increase forest carbon stocks by either extending rotations or maintaining carbon sequestered in long-term storage structures [e.g. wooden furniture, wood used in construction, or harvested wood products (HWPs)].[2] In the context of the design of the international forest carbon management agreement, the recently proposed National Inventory (NI) approach by Andersson et al. (2009), based on the concept of "full carbon accounting" applied to measurable stocks, also encourages a wide range of land management activities that can contribute to terrestrial carbon sequestration, including afforestation, reforestation, adjustment in optimal rotations, as well as the storage of carbon in HWP's, among others.

In this context, besides targeting land-use intertemporal decisions, and accounting for the issue of permanence of the sequestered carbon, the design of carbon policies to preserve and extend current forested land should take into account several other factors that may affect benefits and costs of using forests as carbon sinks. Stavins and Richards (2005), in a review on this subject, have identified some of the most relevant ones, namely, forestry practices and related rates of carbon uptake over time, the opportunity cost of the land for alternative uses, harvesting and forest product sinks and changes in forest and agricultural product prices.

From a theoretical perspective the introduction of carbon sequestration benefits is already well understood in a single forest stand context *à la* Faustmann, as in Van Kooten et al. (1995), where timber and land prices are exogenous. However, to explicitly account for all the factors above mentioned, a vintage model with endogenous timber and land prices is required.[3]

The purpose of this paper is to extend prior literature on forestry economics, namely, the land allocation vintage forest model developed in Salo and Tahvonen (2002, 2003, 2004) by incorporating carbon sequestration benefits. More specifically, three different carbon accounting methods are considered and their impact evaluated: the carbon flow method (essentially a Pigouvian tax/subsidy on the carbon externality), the ton-year crediting regime, and the average storage, following the IPCC (Intergovernmental Panel on Climate Change) Special Report on Land Use, Land Use Change and Forestry. We characterize and provide a complete proof of the new optimal equilibrium conditions. Without imposing any particular terminal conditions, it is possible to evaluate and better understand the interplay between all factors and the main driving forces of the adjustments in the optimal forest age class structure, namely, forest management practices and land allocation between alternative uses.

We supplement the analytical model with numerical simulations, and a sensitivity analysis of the numerical results over a range of values for relevant parameters most likely affecting forest based carbon sequestration costs is provided. The results obtained illustrate the impact of the different incentives underlying each carbon accounting method. The balance between adjustments in management practices and land use changes varies significantly with carbon accounting and the carbon policy (here defined by the carbon price path).

The simulation exercise also provides new insights of the transition toward the long run equilibrium that cannot be studied analytically, but only numerically. Different impacts are predicted when forest age classes are explicitly modeled. In order to take advantage of increasing carbon prices not only land is reallocated between forest and alternative uses, but also harvest is adjusted inter-temporally by trading-off discounted timber revenues against discounted net carbon benefits, implying either postponing or cutting earlier in response to the incentives provided by each type of carbon accounting.

[2] See Sedjo (2006), and Joensuu Forestry Networking Week (2000), among others. For other forms of CO_2 capture and storage see Barrett (2009).

[3] The importance of considering age-structured information when studying optimal harvesting of biologically renewable populations is recently demonstrated by Tahvonen (2009). This author has contributed to the literature on optimal harvesting of biological renewable populations by solving analytically an age-structured optimal fishery model. The results show that optimal steady-states are different from those obtained in the particular case of the biomass model, proving the importance of introducing age-structured information in the problem.