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Permanence of agricultural afforestation for carbon sequestration under stylized carbon markets in the U.S.

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ABSTRACT

This paper examines the permanence of agricultural land afforestation under stylized carbon markets at the regional level in the US. Attention is focused on Southern and Midwest regions which historically have experienced a relatively large amount of land-use change between the agriculture and forest sectors. The Forest and Agriculture Sector Optimization Model–Greenhouse Gases model is used to examine responses between sectors as part of the regional afforestation policy analysis. Main findings suggest that most of afforested area in the Midwest regions remains unharvested by mid-21th century but a significant percentage of afforested area in the Southern regions shifts back to agricultural uses by this time. We also simulated a policy where carbon sequestration credits paid for afforestation are reduced 40% relative to other mitigation actions. A permanence value reduction for afforestation further promotes the harvesting of afforested stands in the Southern regions. Also, it has an impact not only on grassland pasture but also on high productive cropland. Results of this analysis are robust to lower permanence value reduction rates for higher carbon prices and can serve as upper bound of impacts for lower carbon prices.

1. Introduction

Afforestation of agricultural land has significant capacity to sequester carbon under potential carbon pricing programs (Alig et al., 2010a Enkvist et al., 2007; Johnson et al., 2009). Moreover, it has been suggested that including the forest and agriculture sectors in a carbon trading system creates incentives to both control land use emissions and increase land use sinks (Reilly and Asadoorian, 2007). However, despite the potential for significant offsets of emitted carbon through afforestation, a number of unknowns related to sequestered carbon integrity, and in particular the issue of permanence of forest-based sequestration, make it difficult to determine the longevity of carbon sequestered through afforestation efforts on agriculture land.[1]

One concern is that afforested acres will revert to previous land uses over long timeframes or if market conditions change. Reversion to previous land use would cause at least some sequestered carbon to be lost back to the atmosphere. Harvesting of afforested stands to take advantage of increasing timber value is one way that sequestered carbon might be emitted (i.e., not meeting permanence considerations).[2] Despite this concern, there is at least some evidence that operators afforesting acres as part of government-assistance conservation programs tend to keep land in forest uses (Alig et al., 1980). The harvest option has generally received little attention in the terrestrial GHG mitigation literature. In previous studies examining projected GHG offsets in the agriculture sector, harvesting of afforested acres was not considered Enkvist et al. (2007); Murray et al. (2004) or was only considered implicitly (Lewandrowski et al., 2004[3]; Lee et al., 2007). This affects the expected values to the landowner from afforestation (because landowners do not have the possibility to harvest trees when they become commercially viable) and does not allow for examination of how harvesting behavior affects the permanence of afforested acres. Others have quantified the volume of carbon sequestered in afforested stands with and without harvesting activities (Birdsey, 1996), but have not projected the magnitude of harvests on afforested stands. The current study fills that broad gap both by considering the harvest option conceptually and by estimating the magnitude of associated impacts.

Buffers (additional carbon sequestered over and above compensated amounts) are suggested in response to concerns over the permanence

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[1] With respect to terrestrial carbon pools, sequestration occurs when plants extract CO_2 from the atmosphere and store C in biomass and soils. Emissions occur when C in soils and biomass is oxidized and returned to the atmosphere as CO_2. By international convention, C stocks and changes in C stocks (either as C sequestration or CO_2 emissions) are reported in CO_2 equivalents where 1 mt C = 3.67 mt CO_2.

[2] Aside from the anthropogenic factors there are many natural factors that could cause carbon release from trees into the atmosphere, such as forest fire and tree diseases.

[3] The Lewandrowski et al. (2004) study paid landowners the rental rate of carbon sequestered over a 15 year period and also factored in the landowner decision to enroll the value of 15 year-old standing timber. This framework is consistent with allowing landowners to harvest after 15 years.

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for forest carbon projects (Gorte and Ramseur, 2008). Such a buffer is typically implemented as requiring more carbon in the program that one receives credit for. That is, the total carbon in the forest program is discounted to serve as an insurance buffer. The discounts can be as high as 50% depending on how risky the project is (Gorte and Ramseur, 2008) and on the length of timber rotations, whether reforestation takes place, and whether credits for fuel offsets are applied (Kim et al., 2008). Yemshanov et al. (2012) estimate non-permanence conversion factors[4] with values ranging between 1 and 25 for different afforestation programs in Ontario, Canada. The authors find that these values depend on the reduction rate, future price expectations for temporary carbon offsets, geographic location, harvest rotation length, and plantation type. Others suggested a long term conservation easement or permanent timberland set aside programs (Sohngen and Brown, 2008 and Nepal et al., 2013) or a long enough commitment period (e.g., 100 years commitment period required by Climate Action Reserve (CAR, 2010)), to ensure permanence of forestry carbon offset program including afforestation.

The objective of this paper is to examine permanence issues of agricultural land afforestation under stylized carbon markets at the regional level in the US. We first quantify changes in projected afforestation levels and projected harvested afforestation hectares (hereinafter ha) under carbon pricing relative to a base case with no carbon price. We focus our attention on the Southern and Midwest regions which, historically, have experienced a relatively large amount of land-use change between the agriculture and forest sectors (Alig et al., 2010b). We then consider a simulated policy that reduces the value of carbon credits applied to carbon offsets from afforestation of agricultural land into our model. In particular, we explore changes in afforestation levels, harvested afforestation area, land use changes within the agriculture sector (pasture, conventional cropland, and energy crop) as well as land use movement between the agriculture and the forest sectors when afforestation carbon offsets are depreciated by 40% and when they are fully credited. To capture interactions between the agriculture and forest sectors, we employ the Forest and Agriculture Sector Optimization Model–Greenhouse Gases (FASOM–GHG), which projects changes in land uses involving forestry and agriculture and has an extensive carbon accounting system for the US private forest and agricultural sectors including final products and disposal.

The paper is organized as follows. In the next section we describe our policy simulation model and the methods used to examine alternative afforestation programs. Results are presented in the third section. We first present results for the base (no carbon price) and for the stylized national carbon market program. Then, we present changes due to carbon offsets reduction from agricultural afforestation. We describe changes in afforestation levels, harvest rates of afforestation stands, and land use. A sensitivity analysis for our main results closes the third section. The fourth section discusses the policy implications of our findings including changes in Greenhouse Gases (GHG) stored in both sectors due to the policy measures, and the fifth section concludes.

2. Simulation analysis

2.1. Model description

FASOM–GHG is a linked model of the agriculture and forest sectors that uses an inter-temporal dynamic optimization approach to simulate markets for numerous agriculture and forest products (Adams et al., 1996; Lee et al., 2007). Because the model is linked across sectors, the agriculture and forest sectors can interact in the provision of substitutable products (e.g., biomass feedstock) and the use of lands that could produce either agriculture or forest products. Production, consumption, and export and import quantities in both sectors are endogenously determined in FASOM–GHG so as management strategy adoption, land use allocation between sectors, and resource use, among other variables. Commodity and factor prices are endogenous, determined by the supply and demand relationships in all markets included within the model. In addition to land conversion between the two sectors, FASOM–GHG also exogenously includes the conversion of land from the agriculture and forest sectors to developed land use.

FASOM–GHG includes all states in the contiguous U.S, broken into 11 market regions.[5] Afforestation of agriculture land is feasible in 8 regions (afforestation in the Great Plains, western Texas, and the western portion of the Pacific Northwest is currently not considered). Once tree planting occurs (either after timber harvest or after land conversion) timber harvest decisions are made based on market conditions and assumed minimum harvest ages. Minimum harvest age differs across regions. FASOM assumes longer timber rotations in the North, Midwest, and Pacific Northwest regions (about 40 to 50 years) compared with shorter timber rotations in the Southern regions (about 20 to 30 years). For carbon accounting associated with afforestation, FASOM–GHG adopts the FORCARB approach (Birdsey et al., 2000), which projects carbon budgets for privately owned forests in the US. The four major types of carbon pools included in FORCARB are trees, understory vegetation, forest floor, and soil. Other GHG accounting follows from Schneider (2000) and McCarl and Schneider (2001).

FASOM–GHG accounts for and tracks a variety of agriculture and forestry resource conditions and management actions. In addition to traditional agriculture and forest products, selected agricultural and forestry commodities can be used as feedstocks for bioenergy production processes in FASOM–GHG, possibly affecting fossil fuel usage and associated GHG emissions after accounting for emissions during hauling and processing of bioenergy feedstocks (referred to here as offset fossil fuel emissions). For example, CO2 emissions from energy use can be reduced through renewable fuels, such as switchgrass and short-rotation tree species, which can be grown and used instead of fossil fuels to generate electricity or transportation fuels. Detailed description of GHG accounts by sector is found in Appendix A. FASOM–GHG is run here for the timeframe 2010 to 2080 represented in 5-year time periods with a discount rate set to 4%. A condensed mathematical description of the FASOM–GHG structure is available in Latta et al. (2011) and complete documentation is available in Beach et al. (2010).

2.2. Simulating baseline and stylized national carbon market program

Within FASOM–GHG, a variety of practices and land use changes are available for agriculture and forestry producers to supply GHG offsets to a simulated carbon market. In standard FASOM–GHG runs, all significant mitigation activities are available to their respective sectors and those activities are adopted as appropriate given optimal economic behavior. Landowners receive carbon payments for offsets but are penalized for carbon released to the atmosphere. There are no assumed contract lengths and management actions and land use changes can occur at any time based on market conditions. Our initial run included a zero carbon price (base) and two standard FASOM–GHG carbon pricing runs at $30 and $50/ton CO2e (hereinafter the unmodified scenarios), as presented in Fig. 1. We used a minimum $30/ton price based on results from Alig et al. (2010a), who found that little afforestation is projected for prices lower than $30/ton CO2e. We also simulated a scenario with $50/ton to investigate effects of a higher CO_2 price.

In our second step, we compared each of the two carbon-price runs with the base to quantify the longevity of afforested stands and, consequently, impacts on land use allocation within the agricultural sector. In particular, we looked at changes in afforestation levels, harvested

[4] By converting carbon sequestration costs to a permanent offset equivalent. The authors define a non-permanence conversion factor as "*factor by which permanent offset credit prices would need to exceed the temporary offset price for the latter to be of interest to potential buyers who are interested in offset credits*"

[5] See Beach et al. (2010) for more details on region descriptions