U.S. Agricultural and Forest Carbon Sequestration Over Time: An Economic Exploration

Heng-Chi Lee and Bruce A. McCarl[1]

---

[1] H. Lee is in Department of Economics, University of Western Ontario, London, Ontario, Canada. B.A. McCarl is in Department of Agricultural Economics, Texas A&M University, College Station, TX 77843-2124.

The majority of U.S. greenhouse gas emissions (GHGE) come from energy use with electricity generation and petroleum usage each generating about 40% of the total. Thus a large emission cut would require either a large cut in energy use, reducing dependence on fossil fuel sources, development of new technologies, which could be time consuming, or development of some form of offset.

Agriculture and forestry may be able to provide low-cost, near term GHGE reduction strategies, buying time for technological development. Specifically, known management manipulations may be employed to enhance sequestration by removing carbon from the atmosphere and storing it in trees or soils (1).

When considering agricultural and forest carbon sequestration, one needs to recognize that the capacity to sequester is limited and that an ecological equilibrium will be approached effectively saturating the ecosystems ability to hold carbon (2). In addition, while agricultural and forestry carbon sequestration activities increase ecosystem carbon storage, such activities, if discontinued, result in the return of the sequestered carbon to the atmosphere and a rapid approach to a lower carbon equilibrium. Thus, the permanence of sequestered carbon and the need for possible maintenance of non accumulating stocks must be considered.

Previous studies examining the role of agricultural and forest sector carbon sequestration have generally ignored permanence characteristics (3, 4, 5, 6, and 7). Such analyses likely overestimate the long run mitigation potential of agricultural and forestry sequestration programs. This study examines the dynamic role of agricultural and forestry carbon sequestration activities considering permanence related issues.

MODELING

To examine the dynamic role of agriculture and forest carbon sequestration we used modeling. Specifically we expanded an existing intertemporal, price-endogenous, spatial equilibrium, forest and agricultural sector model (8) to include a full set of GHG management alternatives (9,10). The model (FASOMGHG) depicts land transfers between the U.S. agricultural and forest sectors and portrays a multi-period. The results yield a simulation of prices, production, management, and consumption under the scenario depicted in the model data.

FASOMGHG considers the level and potential alteration of nitrous oxide (N_2O), methane (CH_4), and carbon dioxide (CO_2) emissions from agricultural activities. In addition, the possibility of enhancing carbon sequestration through tillage change, land use change namely conversion of croplands to grasslands or forests and conversion of grasslands to forests, and avoided deforestation is also depicted. Likewise, additional costs associated with mitigation activities are included. Furthermore, permanence concerns and the approach to a new equilibrium for sequestration is incorporated.

MODEL EXPERIMENTATION

To examine the dynamic portfolio of agriculture and forestry GHG offsets, FASOMGHG is used to simulate the strategies chosen for carbon equivalent (CE) prices ranging from \$0 to \$100 per. The CE price is applied to CO_2, CH_4, and N_2O emissions/offsets converted to CE using the 100 year Global Warming Potential (GWP). Offset estimates are computed on a total U.S. basis relative to responses under a business as usual (BAU)-zero carbon price scenario and are thus only those additionally stimulated by carbon prices plus account for all domestic leakage..

RESULTS

Figures 1 to 3 present the accumulated GHG mitigation credits from the model chosen portfolio including forest sequestration, agricultural soil sequestration, powerplant feedstock biofuel offsets, and non-CO_2 strategies.

At low prices (below \$25 with \$10 portrayed in Figure 1) and in the near term, the carbon stock on agricultural soil grows rapidly initially and is the dominant strategy. However the offset quantity later diminishes and becomes stable with a new equilibrium setting in after 30 years. Carbon stocks in the forest grow over time at low prices and non-CO_2 strategies continually grow throughout the whole time period. Biofuel is not a factor as it is too expensive.

When the prices are higher ($50 to $100 per tonne), the forest carbon stock increases first then diminishes and becomes stable; the agricultural soil carbon stock is much less important especially in the later decades; non-CO_2 mitigation credit grows over time but is not a very large player. Powerplant feedstock biofuel potential grows dramatically (ethanol is not used) over time and becomes the dominant strategy in the later decades.

Our results show that the agricultural and forest sectors offer substantial potential to mitigate GHG emissions, offsetting 3.5 to 39 percent of U.S. projected GHG emissions by 2010 for a CE price ranging from $10 to $100. The optimal mitigation portfolio to achieve such offsets changes dynamically depending on price and time. Carbon sequestration is the primary mitigation strategy implemented in the early decades and at low prices (below $25 per ton) but then stabilizes and even becomes a source after 20 to 40 years. Agricultural soil carbon sequestration is the strategy employed at low carbon prices ($10 and below) and forest carbon sequestration is dominant at prices in the $25 range. On the other hand, power plant feedstock biofuel activities become more important in the longer run or at higher prices

This study incorporates the permanence and approach to an equilibrium characteristics of agricultural soil carbon sequestration. In a joint mitigation implementation program, FASOMGHG results generally show that after 30 years of sequestration programs, the net emissions increase from cropland compared with the BAU scenario.

A model analysis was done on the consequences of ignoring the fact that agricultural sequestration gains only persist until a new equilibrium is reached. Namely we assumed that the gains from changing tillage management continued adding carbon at the same rate for 100 years. Clearly neglecting sequestration limits overestimates the role of cropland sequestration.

CONCLUSIONS

Permanence and approach to a carbon equilibrium with gains ceasing are important characteristics of agricultural and forestry related sequestration strategies. In a dynamic setting are agricultural and forestry sequestration strategies can be counted upon to develop carbon increments for about 30 years after which they stabilize. In spite of that they may play an important role in providing more time to find long-run solutions such as new technologies to halt the increasing ambient greenhouse gas concentration as discussed in (11). Biofuels and non-CO2 strategies exhibit long run sustainability but biofuels only take a role at carbon prices above $50 per ton.

REFERENCES AND NOTES

1. McCarl, B.A., and U.A. Schneider. "Curbing Greenhouse Gases: Agriculture's Role." *Choices* (First Quarter 1999):9-12.

2. West, T.O., and W.M. Post. "Soil Organic Carbon Sequestration Rates as Influenced by Tillage and Crop Rotation: A Global Data Analysis." *Soil Sci. Soc. Amer. J.* 66(November 2002):1930-46.

3. McCarl, B.A., and U.A. Schneider. "Agriculture's Role in a Greenhouse Gas Emission Mitigation World: An Economic Perspective." *Review of Agricultural Economics* 22(spring/summer 2000):134-59.

4. McCarl, B.A., and U.A. Schneider. "The Cost of Greenhouse Gas Mitigation in U.S. Agriculture and Forestry." *Science* 294, 21(2001):2481-82.

5. Antle, J.M., S.M. Capalbo, S. Mooney, E.T. Elliott, and K.H. Paustian. 2001. "Economic Analysis of Agricultural Soil Carbon Sequestration: An Integrated Assessment Approach" *Journal of Agricultural and Resource Economics,* 26(2):344–367.

6. Noble, I., and R.J. Scholes. "Sinks and the Kyoto Protocol." *Climate Policy* 1, 1(January 2001):5-25.

7. Schuman, G.E., H.H. Janzen, and J.E. Herrick. "Soil Carbon Dynamics and Potential Carbon Sequestration by Rangelands." *Environ. Pollut.* 116(2002):391-96.

8. Adams, D.M., R.J. Alig, J.M. Callaway, B.A. McCarl, and S.M. Winnett. "The Forest and Agricultural Sector Optimization Model (FASOM): Model Structure and Policy Applications." United States Department of Agriculture Forest Service Research Paper PNW-495, Pacific Northwest Research Station, Portland, Oregon, 1996.

9. Schneider, U.A. "Agricultural Sector Analysis on Greenhouse Gas Emission Mitigation in the U.S.", PhD-Dissertation, Department of Agricultural Economics, Texas A&M University, December 2000.

10. Lee, H. "The Dynamic Role for Carbon sequestration by the U.S. Agricultural and Forest Sectors in Greenhouse Gas Emission Mitigation." PhD Thesis, Department of Agricultural Economics, Texas A&M University, 2002.

11. Marland, G., B. A. McCarl, and U.A. Schneider. 2001. Soil Carbon: Policy and Economics. *Climatic Change,* 51: 101-117.

12. The work underlying this paper was supported by USEPA, USDOE, SANREM and the Texas Agricultural Experiment Station.

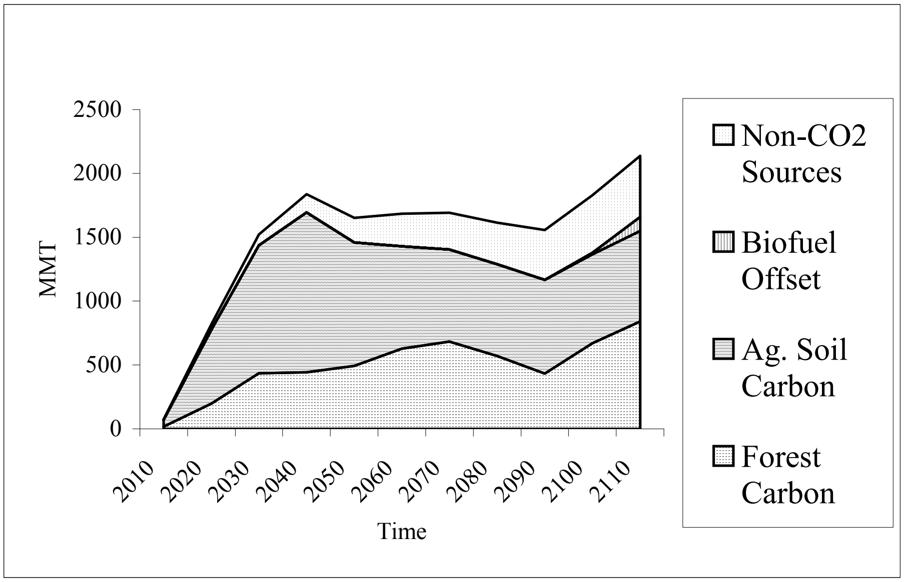

Figure 1. Cumulative mitigation contributions from major strategies at a $10 carbon equivalent price

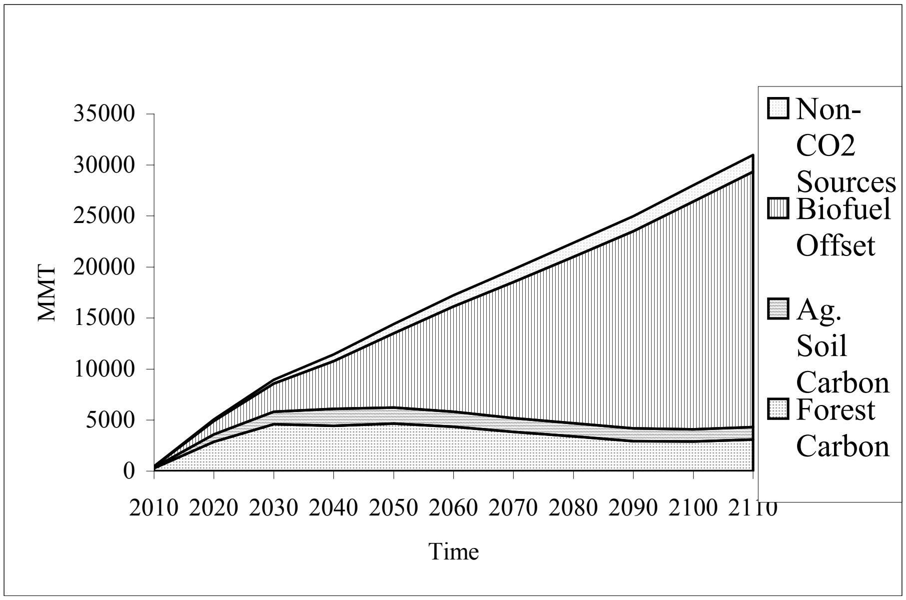

Figure 2. Cumulative mitigation contributions from major strategies at a $50 carbon equivalent price

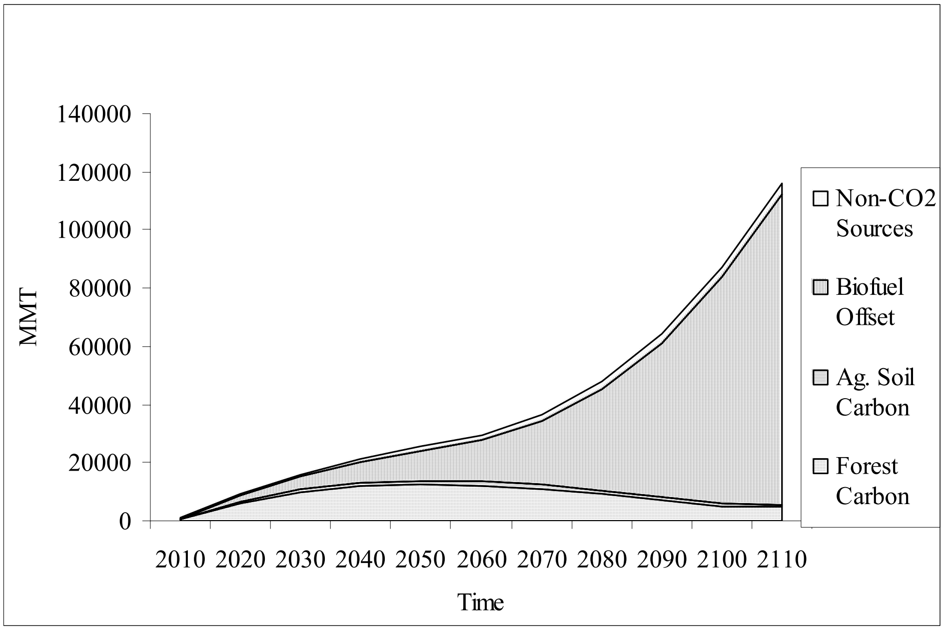

Figure 3. Cumulative mitigation contributions from major strategies at a $100 carbon equivalent price