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Overview of Agricultural and Forestry GHG Offsets on the US Landscape

Brian C. Murray

The articles in this issue by Reilly and Alig et al. have focused primarily on the potential impacts of climate change in the agriculture and forest sectors, respectively. However, as discussed in the introductory article by Sohngen and McCarl, agriculture and forestry could also play a role in actions to mitigate greenhouse gases (GHGs) and forestall the threat of climate change. This article provides a brief overview of the types of agricultural and forestry activities that could be undertaken to sequester or reduce GHG emissions as well as their technical and economic potential to offset emissions from other sectors of the economy. The co-effects of these mitigation actions on other (nonclimate) environmental outcomes are discussed in the article by Feng, Kling, and Gassman.

How Much GHG can be Mitigated in Agriculture and Forestry, and at What Price?

US agriculture and forestry operate on an extensive land base; thus, the biophysical potential for GHG mitigation in these sectors is quite large. Under current conditions, US agricultural soils and forests sequester about 700 million tonnes (metric tons) of CO_2 equivalent per year (EPA, 2004), over 90% of which is from forest carbon sequestration. Although this amount alone offsets about one tenth of national GHG emissions, various actions can be taken to enhance sequestration above these baseline levels. Estimates of the biophysical carbon sequestration potential from changing management practices on the nation's cropland alone range from 300 to 550 million tonnes of CO_2 equivalent per year (Paustian et al., 2001). That is equal to the amount of CO_2 emitted annually by about 25–45 million cars. There is also ample potential to enhance carbon sequestration through afforestation, which can store up to 5–10 tonnes CO_2 per acre per year over a timber rotation (20–50 years in the most productive forests of the Southern and Pacific Northwestern U.S.). Given the amount of land available for conversion from agriculture to forest, this could amount to tens or hundreds of millions of tonnes CO_2 of additional annual carbon sequestration. Moreover, long-term storage of carbon in harvested wood products is possible for several decades at least, though not all accounting frameworks would necessary include this as a creditable form of sequestration (e.g., Kyoto).

As a major emitter of CH_4 and N_2O, approximately 470 million tonnes CO_2 equivalent per year (EPA, 2004) or 7% of the total of all GHG emissions, substantial opportunity may exist to reduce these gases through changes in crop and livestock management if the economic incentives are strong enough.

Agricultural producers operate in competitive markets, often global in scale; the practices they currently employ are likely to be fairly efficient in producing as much saleable output as possible for a given level of inputs. Therefore, changes in agricultural land use and forest practices may involve opportunity costs in the form of higher production costs, lower or more variable yields, lower quality products, or some combination of the above. Farmers, then, may need some sort of economic inducement in order to engage in alternative practices that lower GHG emissions or sequester carbon. However, even if farmers are not directly paid to mitigate GHGs, they may do so as an economic response to GHG constraints put on other sectors of the economy, which could drive up prices of

What Activities in Agriculture and Forestry Can Help Reduce GHG Concentrations?

Agricultural and forestry activities can reduce and avoid the atmospheric buildup of GHGs, such as carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O), in three basic ways: *sequestration, emissions reduction,* and *fossil fuel substitution*.

- **Sequestration**. CO_2 can be removed from the atmosphere and sequestered in soils, biomass, and harvested products, which can act as carbon sinks. Carbon sequestered in soils and biomass can be protected and preserved to avoid CO_2 releases to the atmosphere (i.e., remain sequestered instead of emitted).
- **Emissions reduction.** Agricultural CH_4 and N_2O emissions can be directly reduced by modifying livestock management and fertilizer applications. Emissions of CO_2 can be avoided indirectly by reducing the use of energy-intensive inputs in agriculture.
- **Fossil fuel substitution.** Net CO_2 concentrations can be lowered by using biofuels produced in the agricultural sector instead of fossil fuels to produce electricity. When biofuels are used, CO_2 is essentially recycled in the atmosphere, as carbon is sequestered in biomass throughout its growth stage and released during energy production. In contrast, fossil fuel combustion releases energy that would otherwise be stored permanently below ground in coal, gas, and petroleum deposits.

A list of specific GHG mitigation activities and the GHGs they most directly affect is provided in Table 1.

energy and energy-intensive goods (such as fertilizers) and thereby indirectly reduce input usage and corresponding emissions.

Several recent studies have examined the size of incentives necessary to generate GHG mitigation in the agriculture and forest sectors. Ongoing work by various researchers uses a model of the US forest and agricultural sectors (FASOMGHG) to estimate responses to a price incentive for GHG mitigation across these sectors. Results for the United States from one study using FASOMGHG (Lee, McCarl, Gillig, & Murray, in press) show the response from GHG price incentives ranging from $5 to $80 per tonne of CO_2 offered for all GHG mitigation options within the sectors (Figure 1). Some specific results include:

- Agricultural soil carbon sequestration and forest management are fairly low-cost options, each producing more than 100 million tonnes of CO_2 eq. mitigation per year at a GHG price of $5/tonne.

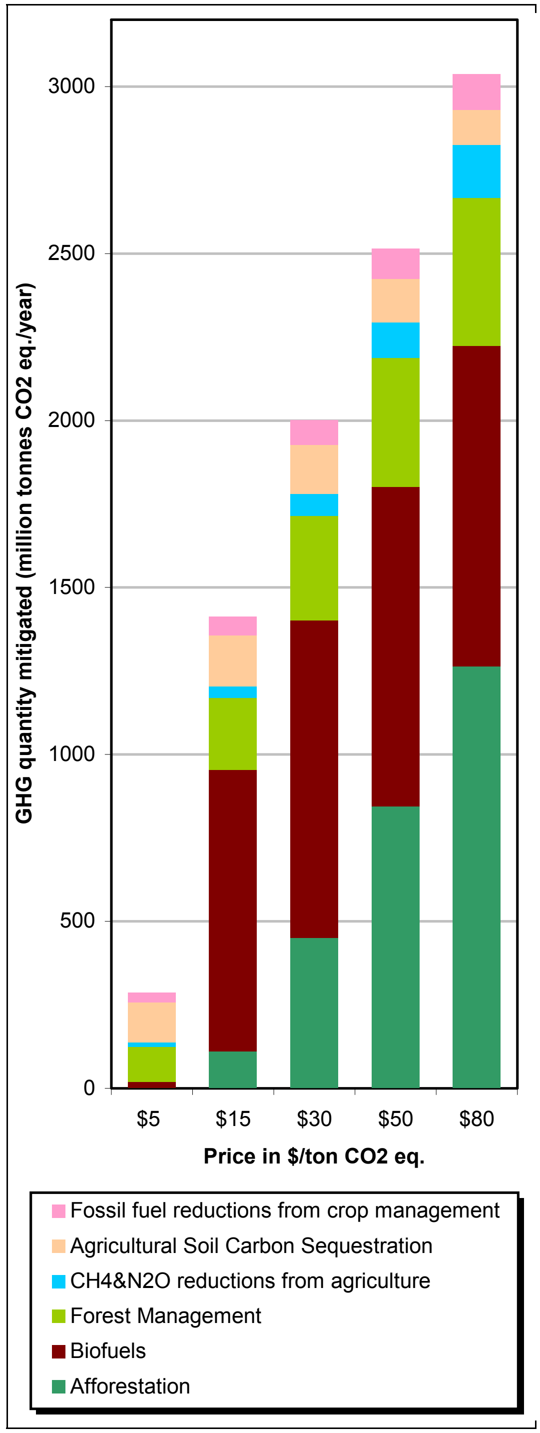

Figure 1. GHG mitigation by activity: US agriculture and forestry.
Note. Data from Lee et al (in press).

- Afforestation and biofuels become the dominant mitigation options at GHG prices above $15–30/tonne.[1]

Table 1. Key mitigation strategies in agriculture and forestry.

Mitigation strategy	Strategy nature	Greenhouse gas affected CO_2	CH_4	N_2O
Afforestation	Sequestration	X		
Rotation length	Sequestration	X		
Timberland management	Sequestration	X		
Deforestation (avoided)	Sequestration	X		
Biofuel production	Fossil fuel substitution	X	X	X
Crop mix alteration	Emission reduction, sequestration	X		X
Rice acreage reduction	Emission reduction		X	
Crop fertilizer rate reduction	Emission reduction	X		X
Other crop input alteration	Emission reduction	X		
Crop tillage alteration	Sequestration	X		
Grassland conversion	Sequestration	X		
Irrigated /dry land conversion	Emission reduction	X		X
Livestock management	Emission reduction		X	
Livestock herd size alteration	Emission reduction		X	X
Livestock system change	Emission reduction		X	X
Liquid manure management	Emission reduction		X	X

- Mitigation of CH_4 and N_2O from agriculture has a fairly small but steady scope for mitigation.

The results shown in Figure 1 are within the range of those found in other recent studies of mitigation potential in US agriculture and forestry. The USDA Economic Research Service recently completed a report (Lewandrowski et al., 2004) that found carbon sequestration potential in US agriculture to be up to 600 million tonnes of CO_2 per year at a cost of up to $35/tonne. Those numbers are lower than the totals in Figure 1, but the USDA study evaluated afforestation and agricultural soil management only, not forest management, biofuels, or non-CO_2 gas mitigation. The USDA's afforestation and agricultural soil carbon estimates are within the price-quantity range for those activities shown in Figure 1. A review of forest carbon sequestration studies over the last 10–15 years (Richards & Stokes, 2004) found a wide range of estimates of economic potential in the United States, ranging from 100 to 2,800 million tonnes CO_2 eq. per year of carbon sequestration at costs ranging from $1/tonne to $40/tonne.

These results suggest that US agriculture and forestry together have a rather sizeable potential to mitigate the buildup of greenhouse gases. The highest estimates, in the range of 3 billion tonnes of CO_2 eq. per year, would offset approximately 40% of all US GHG emissions—an amount larger than the GHG contribution of all motor vehicles in the United States. However, such a large potential can only be realized at very high incentive levels ($50–80/tonne CO_2 eq.). In contrast, GHG trades in the European Union are now being realized at prices of approximately $10/tonne CO_2 eq. and at much lower prices in informal markets emerging in the United States (see Butt & McCarl, this issue).

Agricultural and Forestry as GHG "Offsets"

The notion of agriculture and forestry activities serving as an offset to emissions in other sectors of the economy is rooted in the policy and institutional environment surrounding climate change mitigation. Most efforts to mitigate GHGs focus

1. *In this model simulation, biofuel potential is capped at just under one gigaton CO_2 equivalent per year, because of underlying assumptions about biofuel use capacity constraints in the US electricity generation sector. Without such a capacity constraint, biofuel potential would substantially outpace the other mitigation options at the higher prices evaluated.*

heavily on the CO_2 emissions from the energy, transportation, and industrial sectors, where a vast majority of developed countries' emissions originate. In the United States, for instance, CO_2 emissions from these sectors comprise about 80% of gross aggregate US GHG emissions (EPA, 2004). Much of the remaining GHG balance, however, can be attributable to agriculture and forestry activity, so there remains a substantial scope for US agriculture and forestry to offset the emissions from these other sectors.The institutions that have formed to implement GHG mitigation policy internationally and domestically in the United States have taken a mixed-bag approach to the role of the agriculture and forest sector in mitigation efforts. The Kyoto Protocol of the UN Framework Convention on Climate Change includes agriculture sector GHG emissions of CO_2, CH_4, and N_2O as part of each country's compliance commitment, but carbon sinks from agricultural soils and forestry activities have a more limited role, at least in the initial commitment period of 2008–2012. Of course, the United States has decided not to abide by the Kyoto Protocol commitments at this time, so the Kyoto provisions have fairly limited relevance for US domestic policy on the role of agriculture and forestry in GHG mitigation. However, the US Senate recently considered an alternative to Kyoto—the Climate Stewardship Act (S.139), introduced by Senators John McCain and Joseph Lieberman—which proposed binding GHG limits for some sectors of the US economy. The McCain-Lieberman bill was defeated in the Senate, but by a narrow enough margin (53–45) that follow-up proposals are now being considered. Under McCain-Lieberman, agricultural emissions were not to be capped, but mitigation projects in agriculture and forestry (and any other sector not covered in the cap) could be used to develop credits that are tradable to offset emissions in sectors covered by the caps (e.g., electric utilities, transportation, and manufacturing).

The following section and the article in this issue by Butt and McCarl provide more detail on project-based approaches to GHG offsets.

Project GHG Accounting Issues

In the context of GHG mitigation policy, a *project* refers to a purposeful activity in a specific location and sector to reduce GHGs below some baseline level in order to demonstrate a net emissions reduction. In principle, a project's mitigation quantity can be used to offset emissions in a capped sector. Project-based offsets introduce several important phenomena that would need to be incorporated into the project GHG accounting system in order to maintain the integrity of the trade between an emission unit allowed by one party (the buyer of the offset) and an emission unit reduced by another party (the project developer or seller of the offset). There is currently an effort underway by the World Resources Institute (WRI) and World Business Council on Sustainable Development (WBCSD) to develop consensus standards for project-level accounting across sectors and countries to enable more accurate comparisons across GHG projects. Key project accounting issues are discussed below.

Additionality and Project Baselines

The net GHG benefit of a mitigation project is the additional GHG emission reductions (sequestration) that occur relative to emissions (sequestration) levels in the project's absence. This is the concept of *additionality.* To determine additionality, project managers need to establish a project *baseline*, which is an estimate of the emissions or sequestration that would occur under business as usual. Setting an accurate project baseline can be difficult, because it involves quantifying a hypothetical outcome, rather than the world as it exists with the project. A number of analyses and GHG mitigation programs have focused on the complexity of setting a baseline case to estimate GHG mitigation benefits (e.g., WRI/WBCSD, 2003).

"Permanence" and the Risk of Sequestration Reversal

The accumulated carbon from forestry and agricultural sequestration practices can be re-released back to the atmosphere through either natural or intentional disturbances, such as fires, management changes, or logging. The climate benefits of carbon sequestration activities are therefore potentially reversible. One way to deal with this problem is to design project contracts that assign liability for carbon reversal if it occurs. However, a project may last for a finite time period, in which case the threat of reversal occurs after the project ends. One way to address this problem is to set up the transaction as a carbon lease or rental contract for a set period of time—say, five years (Marland, Fruit, & Sedjo, 2001). At the end of the lease, the credit expires and the buyer needs to replace the carbon with another set of verifiable sequestration (or emission reduction) units. Yet another way is to discount the amount of offset credit given in the first place to account for the possibility of future reversal.

Leakage

Project-based mitigation approaches run the risk that some of the direct GHG benefits of these efforts will be undercut by leakage of emissions outside the boundaries of the project. For instance, a tree-planting project in one place may displace tree planting that would have occurred elsewhere, a so-called "investment crowding" effect. Or, the adoption of zero-tillage in some locations may cause other producers to intensify their cultivation practices elsewhere (also called "slippage"). Therefore, it may be important to recognize the potential for leakage in agriculture and forestry projects and to develop methods to target or design projects to minimize leakage, monitor leakage after projects are implemented, quantify the magnitude of leakage when it exists, and take leakage into consideration when estimating net GHG benefits of activities.

Transaction Costs

In addition to the direct production costs from adopting changes in management practices, there are also costs associated with actually getting the mitigation project up, running, and operational. These transaction costs include those for

- initial project planning;
- measuring, monitoring, and verifying the project's GHG effects;
- market brokering and assembly; and
- insuring risks.

These transaction costs may be paid by the offset buyer, seller, or both, but in any case, they impose real costs that diminish the net value of the offsets generated. Transaction costs tend to have a large fixed-cost component to them and are therefore more burdensome for small projects than for large ones.

Table 2. Activity portfolio at different cost levels and time frames.

	Near term	Long term
Low cost	Agricultural soil carbon management Forest management	Reduction of non-CO_2 emissions from changes in crop and livestock practices
High cost	Afforestation Biofuels	Biofuels

Conclusions

Due to the effects of land use on the carbon cycle and the dominance of agriculture and forests as a land use in the United States, the scope for agriculture and forestry practices on GHG flows can be substantial. A number of actions within the sectors can be taken. Table 2 identifies candidate activities within the sectors at high and low prices and in the near term and long term. Some activities, such as changes in crop tillage practices and forest management, can be accomplished at a fairly low opportunity cost and in the near term. However, sequestration options tend to have a saturating effect over time as the new (postpractice) equilibrium for soil or biomass carbon is reached and may even experience reversal if harvesting or natural disturbances intervene. Therefore, emission reduction or fossil fuel substitution projects, such as biofuels, may have a more permanent impact on mitigation efforts in the long run.

For More Information

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Brian C. Murray is director of the Environmental and Natural Resource Economics Program, Research Triangle Institute International, Raleigh, NC.