Chapter 6: Summary of Findings and Implications for Policy

Strategies that have been proposed to mitigate global climate change typically focus on reducing energy-related emissions of greenhouse gases (including carbon dioxide) into the atmosphere. But atmospheric concentrations of greenhouse gases (GHG) can also be reduced by withdrawing carbon from the atmosphere and storing—or sequestering—it in soils and biomass. In examining the economics of sequestering additional carbon in the U.S. farm sector through changes in agricultural land use and management practices, this study focused on two questions:

- How much of the estimated "technical potential" for carbon sequestration is economically feasible?
- How cost effective are alternative incentive structures that might be used to encourage carbon sequestering activities?

To address these questions, we adapted ERS's U.S. Agricultural Sector Model to include financial incentives to agricultural producers for additional carbon sequestered as a result of changes in land use (e.g., converting cropland to grassland or forest) or cropland management practices (e.g., using conservation tillage or alternative crop rotations). We analyzed how land use and management practices change as financial incentives vary in four policy-relevant dimensions:

- **Asset or rental basis—**Comparing "asset" payments that implicitly assume carbon is permanently sequestered with "rental" payments for carbon storage over a specified period of time,
- **Level—**Comparing payments ranging from $10 to $125 per ton of carbon permanently sequestered,
- **Symmetric or one-sided—**Comparing a scenario in which producers are paid for carbon sequestered with a scenario in which producers are paid for carbon sequestered and charged for carbon emitted, and
- **Type—**Comparing scenarios in which carbon payments are augmented with a cost-share subsidy for converting cropland or pasture to forest or converting cropland to grassland.

In brief, we find that the asset or rental basis and the level of incentive payments are critical in determining how much carbon is sequestered, how it is sequestered, how long it is sequestered, where it is sequestered, and at what cost it is sequestered. But even at the highest level of incentive payments considered, less than two-thirds of the technical potential for carbon sequestration is economically feasible. Further, incentive systems in which producers are paid for carbon sequestered and charged for carbon emitted are much more cost effective than systems without charges for emissions. However, adding a cost-share subsidy for changes in land use does not substantially improve cost effectiveness relative to a system based on payments per ton of carbon sequestered.

Asset or Rental Basis of Incentive Payments

The effect of changes in land use or land-management practices on atmospheric concentrations of GHGs depends on the length of time for which carbon is sequestered. Cropland converted from conventional tillage to conservation tillage is estimated to sequester additional carbon for a period of 20-30 years until a new carbon equilibrium is reached. The additional carbon will remain stored in the soil or biomass as long as the land remains in conservation tillage, but most of it will be quickly released into the atmosphere if the land goes back into conventional tillage. Similarly, cropland converted to forest will sequester additional carbon for 20-70 years, depending on timber growth rates and harvest decisions, but most of the additional carbon may be released if/when the timber is harvested.

A unit of carbon sequestration in soil or biomass is equivalent to a unit of GHG emissions reduction if (and only if) the carbon remains sequestered permanently. This requires maintaining the carbon-sequestering activity permanently—either with a one-time permanent commitment or with a series of contracts extending through time.

Early research on the economics of carbon sequestration assumed that agricultural producers who received incentives to switch to carbon-sequestering land uses or management practices would maintain those practices permanently after the new carbon equilibrium was reached (and the incentive payments ceased). If producers switched out of the sequestering activities after payments ceased, however, the additional carbon would be released. Traditional research on agricultural carbon sequestration, which was based on this assumption, would then overestimate the amount of additional carbon sequestered, and incentive programs based on this assumption would overpay producers for the amount of additional carbon actually sequestered.

More recent research considers a system in which producers receive proportionally smaller "rental" payments to store additional carbon for a finite contract period. Payments cease at the end of the contract period, on the assumption that the sequestering activity then will be discontinued (and the additional carbon released). If producers continue the sequestering activity after the contract ends, however, the additional carbon remains stored in the soil or biomass. Research based on this assumption would then underestimate the amount of additional carbon sequestered, and incentive programs based on this assumption would underpay producers for the amount of additional carbon actually sequestered. If rental contracts are renewed indefinitely, payments will equal those provided under the "asset payment" system. Unlike with the asset payment system, however, permanent sequestration will be assured under a series of indefinitely renewed rental contracts.

The difficulty in choosing between the two assumptions/payment systems is that we do not know how many producers would actually continue carbon-sequestering activities after incentive payments cease. Continuation would depend on a combination of farm, producer, and market conditions. We analyze both systems to estimate a range of possible outcomes.

Lastly, adoption of agricultural activities that sequester carbon will add to the stock of carbon in soil or biomass for decades, but only until a new carbon equilibrium is reached. Permanent maintenance of the sequestering activities will store the added carbon permanently. But even permanent terrestrial sequestration can only serve as a "bridge" until new (low- or no-carbon) energy technologies are developed and adopted. Carbon sequestration in soil and biomass cannot offset increasing emissions of GHGs indefinitely.

Level of Incentive Payments

The amount of carbon that can feasibly be sequestered through changes in agricultural land use or management practices depends not only on the asset or rental basis of incentive payments but also on the level of incentive payments. We evaluated a range of incentive levels corresponding to payments of $10 to $125 per ton of permanent carbon sequestration.

We used two alternative payment systems to estimate how much carbon would be sequestered under 15-year contracts for a range of incentive levels. Under the asset payment system, producers receive the full $10 to $125 per ton over the 15-year contract period (on the assumption that they will continue the sequestering activities after the contract ends and the additional carbon will be permanently sequestered). Under the rental payment system, producers receive a share of the value of permanent sequestration in exchange for 15 years of storage of additional carbon (on the assumption that to discontinue the sequestering activities after the contract ends, they will require additional payments). At a 5-percent discount rate, the corresponding rental payments amount to $4 to $44 per ton of carbon over the contract period.

In the absence of incentive payments, about 4 MMT of additional carbon are currently sequestered in agricultural soils in the United States each year. With incentive payments corresponding to $10 per ton of permanent carbon sequestration, results suggest that producers would change land-use and land-management practices to the extent that an additional 0.4 MMT would be sequestered under the rental payment system per year and an additional 10 MMT would be sequestered under the asset payment system. Within this range, the actual amount of additional sequestration would depend on the extent to which producers continue carbon-sequestering activities after incentive payments cease. Similarly, results suggest that additional sequestration would range from 72 to 160 MMT with incentive payments corresponding to $125 per ton of permanent carbon sequestration. Permanent sequestration at these levels would offset 4 to 8 percent of gross U.S. GHG emissions in 2001.

Total program payments during the contract period range from $95 million to $2 billion per year under the asset payment system, for net increases in carbon sequestration ranging from 10 to 160 MMT per year. If producers discontinue carbon-sequestering land uses and management practices after the 15-year contract period ends, the program will have generated carbon sequestration worth only one-third of its payments—because most of the carbon will be released when the activities are terminated, and we estimate that 15 years of carbon storage has only one third the emissions-mitigating value of permanent carbon sequestration. At the $125-payment level, the overpayment would be approximately $1.3 billion. By contrast, the rental payment system pays only for the time carbon remains sequestered. If producers discontinue carbon-sequestering activities after contracts end, no overpayment will have been made. Likewise, if producers continue to renew their contracts and maintain their carbon-sequestering activities, the rental system will incur the same total cost as the asset payment system but will have ensured permanent sequestration.

The level of incentive payments also affects the type and geographic distribution of changes in land use and management practices because different sequestering activities become economically feasible at different incentive levels. At low levels of incentive payments (corresponding to less than $25 per ton of permanent carbon under the rental payment system), we estimate that increased use of conservation tillage would be the dominant source of additional sequestration. This effect reflects the fact that returns from conservation tillage systems are already close to returns from conventional tillage systems in many areas. At higher incentive payment levels, afforestation becomes the dominant source of additional carbon sequestration in agriculture. Land is drawn first from pasture. As incentives increase, an increasing share of afforested land is drawn from cropland (which is generally more productive than pasture). Only at incentive levels of $125 per ton with the asset payment system is a small amount of cropland converted to grassland (assuming no additional incentive, such as Conservation Reserve Program payments). This pattern of adoption is consistent with earlier economic studies using a variety of models and data sources (e.g., Antle et al., 2001, and McCarl and Schneider, 2001).

Regionally, most of the increase in conservation tillage occurs in the Great Plains, Corn Belt, and Lake States. Most afforestation occurs in the Southeast, the Delta States, and Appalachia. The small amount of cropland conversion to grassland (about 100,000 acres) occurs in the Southern Plains.

Incentive levels are thus critical in determining how much carbon will be sequestered, how it will be sequestered, and where it will be sequestered. Even at the highest incentive levels we analyzed, the economic potential to sequester additional carbon in agricultural soils and biomass is much less than the technical potential as indicated by soil science and forestry studies. Estimated economic potentials are lower than estimated technical potentials because our analysis incorporates the costs and returns associated with different activities and models the choices that farmers might make under different incentive systems. We assume that producers will adopt carbon-sequestering land uses and management practices that are technically feasible only if they are also economically feasible.

For conservation tillage, soil science studies (Lal et al., 1998, and Eve et al., 2000) estimate a technical annual carbon sequestration potential of 35-107 MMT. By contrast, at incentive levels corresponding to $125 per ton of additional carbon permanently sequestered, we estimate that only about one-fourth (7-27 MMT) of this technical potential would be economically feasible. For afforestation, estimates derived from Birdsey (1996) suggest a technical potential of 91-203 MMT; we estimate that only about two-thirds of this potential (65-133 MMT) would be economically feasible at incentives corresponding to $125 per ton of carbon permanently sequestered. Technical and economic potentials diverge the most for land use change from cropland to permanent grasses: Eve et al. (2000) estimate a technical potential of 26-54 MMT, whereas we estimate that virtually none of this would be economically feasible even at the highest incentive levels considered.

Symmetry of Incentive Payments

Our reference scenario incorporates both "carrots" (in the form of incentive payments to producers for additional carbon sequestered through changes in land use and management practices) and "sticks" (in the form of payments by producers for carbon emissions from changes in activities). For comparison, we analyzed a scenario using carrots alone.

Conservation tillage is the only activity that can be reversed in our model, so the choice of tillage practice is the only choice we analyze that could generate carbon emissions. In the carrots-only scenario, net carbon sequestration through conservation tillage is lower and program costs significantly higher across all payment levels. At incentive levels corresponding to $125 per ton of carbon permanently sequestered, a carrots-only system would sequester an additional 3.5 MMT at a cost of $1.5 billion. By contrast, at equivalent incentive levels, a system with both carrots and sticks would sequester an additional 7 MMT at a cost of $300 million—twice as much carbon at one-tenth the average cost per ton.

Type of Incentive Payments

In another set of simulations, we included a 50-percent cost-share subsidy for converting cropland to forest or grassland, in addition to the incentive payments per ton of carbon sequestered. Adding a cost-share subsidy does not appear to improve substantially the cost effectiveness of the incentive system. The cost-share subsidy would increase sequestration at low carbon-payment levels but not at high payment levels, and the incremental cost for the incremental sequestration does not appear to be lower than for the simple system. Furthermore, since the cost-share applies only to land-use change activities, it distorts the mix of carbon sequestration activities away from changes in cropland management.

Limitations in the Present Analysis Leave Questions

Our findings are consistent with the hypothesis that carbon sequestration in agricultural soils and biomass is a low-cost technology for reducing the atmospheric concentration of greenhouse gases. These GHG mitigation activities can serve as a bridge from the present to a time when new (low- or no-carbon) energy technologies are developed and adopted, or, alternatively, when technologies for the capture, separation, and storage of energy-related carbon emissions in other sinks become cost effective. If future research on GHG implications of land-management activities in the agricultural sector shows, for example, that nitrous oxide emissions could increase with carbon sequestration in some activities, our results would overstate the net reduction in total GHG emissions. Also, given that afforestation appears to have the greatest potential for additional sequestration, better understanding of market linkages between agriculture and forestry over an extended period is extremely important. McCarl et al. (2003) suggest that the long-term dynamics are complicated due to the feedback effects of substantially increasing the supply of timber and, consequently, dampening timber prices.

Finally, our analysis does not incorporate the institutional costs associated with measuring, monitoring, and crediting the carbon sequestered for the different policy approaches. Though the costs are likely to vary significantly depending on the features of the program and the range of activities covered, at this point we know very little about the cost structures. Full consideration of transaction costs would likely show, in most cases, that our present estimates of cost effectiveness are higher than what would be experienced in real-world situations.