CHOICES
The magazine of food, farm and resource issues
Fall 2004
A publication of the American Agricultural Economics Association

Carbon Sequestration, Co-Benefits, and Conservation Programs

Hongli Feng, Catherine L. Kling, and Philip W. Gassman

Capturing and storing carbon in biomass and soils in the agriculture and forest sector has gained widespread acceptance as a potential greenhouse gas mitigation strategy. Scientists increasingly understand the mechanisms by which various land-use practices can sequester carbon. Such practices include the introduction of cover crops on fallow land, the conversion of conventional tillage to conservation tillage, and the retirement of land from active production to a grass cover or trees. However, the policy design for implementing carbon sequestration activities is still being developed, and significant uncertainties remain concerning the cost effectiveness of carbon sequestration relative to other climate-change mitigation strategies.

A potentially important plus in the cost-effectiveness ledger is the fact that the storage of carbon in agricultural soils is likely to come with a number of "co-benefits." In particular, carbon sequestration is not separable from other environmental effects of a given land-use practice. For example, the introduction of cover crops or the conversion to conservation tillage from conventional tillage also reduces soil erosion, in addition to sequestering carbon. The list of potential co-benefits is large, including wildlife habitat, water quality, and landscape aesthetics.[1]

A second key feature of carbon sequestration is its nonpoint source characteristic. The amount of carbon sequestered in a field or region is costly to measure and monitor, and protocols for doing so are still being developed, making it difficult to base any policies directly on environmental performance. (See Mooney, Antle, Capalbo & Paustian, 2004, for a discussion on the costs of measuring soil carbon credits.) In the near term, carbon sequestration policies are likely to base payments on land-use practices or other easy indicators of carbon sequestering activities.

The issue of co-benefits from sequestration activity has received relatively little attention, with some important exceptions. Plantinga and Wu (2003) estimated the reductions in agricultural externalities from an afforestation program encouraging the conversion of agricultural land to forest in Wisconsin. Using existing benefit estimates, they showed that the value of reduced soil erosion and some benefits from enhanced wildlife habitat are on the same order of magnitude as the costs of the carbon sequestration policy. Matthews, O'Connor, and Plantinga (2002) also found that carbon sequestration through afforestation has significant impacts on biodiversity and that impacts can differ by region. McCarl and Schneider (2001) found reduced levels of erosion and phosphorous and nitrogen pollution from traditional cropland as carbon prices increase. Greenhalgh and Sauer (2003) and Pattanayak et al. (2002) both showed that the water quality co-benefit of carbon sequestration is very significant.

Policy Design Issues When Co-Benefits are Considered

The co-benefit aspect of carbon sequestration and its nonpoint source nature have important implications for policy design. Two policy environments

1. *There may also be "dis-benefits" including increased pesticide use with some carbon sequestering practices.*

have been discussed by economists: (a) carbon trading in a well-functioning carbon market or (b) some type of green payment program akin to the Conservation Reserve Program (CRP) or the newly initiated Conservation Security Program (CSP). Explicit consideration of the co-benefits of carbon sequestration in the agricultural and forest sector will need to be treated differently, depending on whether carbon markets are the primary driver of sequestration activities or whether a green payment policy is pursued. In the context of carbon markets, co-benefits are externalities. To achieve socially efficient trades, we need to determine who will be responsible for (or benefit from) the noncarbon effects associated with sequestration activities. On the other hand, if we place carbon sequestration in the context of agri-environmental policies and consider it as just one of the multiple benefits from conservation practices, then a different set of issues arises, including determining which benefits are most important, which management practices should be encouraged, which geographical areas should be targeted, and whether costs, benefits, or some other criteria should be used to direct the allocation of funding.

A situation in which both green payment programs and carbon markets operate simultaneously adds complications. A green payment program would need to be designed to consider interactions between its payments and potential payments from a carbon market. For instance, if recipients of green payments were also eligible to sell carbon credits in a market, then practices that yield high levels of carbon sequestration relative to other environmental benefits would be particularly attractive to land owners (all else equal), potentially resulting in inefficient land-use decisions. If not, the carbon market would act as competition for land in the green payment program, with implications for the cost of the program. The issue of coordination between these two policy approaches is already on the horizon, as some conservation programs have been sequestering carbon for many years, and nascent carbon markets are emerging (see Butt & McCarl, this issue). The CRP program, with its annual budget of $1.6 billion, has been shown to have large carbon-sequestering potential. This is so despite the fact that carbon sequestration was added only in recent signups as an environmental benefit in the evaluation of the applications to the program.

Table 1. Total acres and annual change for some environmental indicators as a result of land retirement in the UMRB.

Policy scenarios	Carbon sequestration (tons)	Erosion reduction (tons)	N Runoff reduction (pounds)	Acres enrolled (acres)
Actual CRP	1,054,000	15,293,000	4,654,000	3,122,000
Targeting carbon	4,141,000	4,699,000	6,365,000	3,926,000
Targeting erosion	988,000	43,744,000	9,399,000	3,972,000

Co-benefits in the Upper Mississippi River Basin (UMRB)

Given the present existence of green payment programs (e.g., the CRP as well as the new CSP), the remainder of this paper explores the co-benefits of carbon sequestration in the context of subsidy policies. The example developed here compares carbon sequestration, erosion reduction, and nutrient reduction benefits across several different methods that could be used to implement the CRP program in the Upper Mississippi River Basin (UMRB). Similar methodologies are used in Kurkalova, Kling, and Zhao (2004), although that study explores the adoption of conservation tillage in the region.

The UMRB covers 189,000 square miles in seven states in the central United States and is a highly fertile agricultural region, with 67% of the area being either cropland or pasture land. The potential for significant co-benefits from carbon sequestration in the region is large, given that it contains more than 1,200 stream segments and lakes that appear on the US Environmental Protection Agency's listing of impaired waterways. The region contained 3,363,000 acres of CRP in 1997 with a total annual payment of about $277,500,000 (estimated with the rental payment information of the 18th signup of the CRP). Average CRP rental rates in Iowa and Illinois are above $120/acre, whereas Missouri and Wisconsin have the lowest rental rates with an average of about $60/acre. The average rental rate in Minnesota, $86/acre, falls in the middle.

To estimate the environmental benefits of converting land to CRP, we use the Environmental Policy Integrated Climate (EPIC) model version 3060.[2] EPIC simulations were run for each point in the Natural Resource Inventory database in the

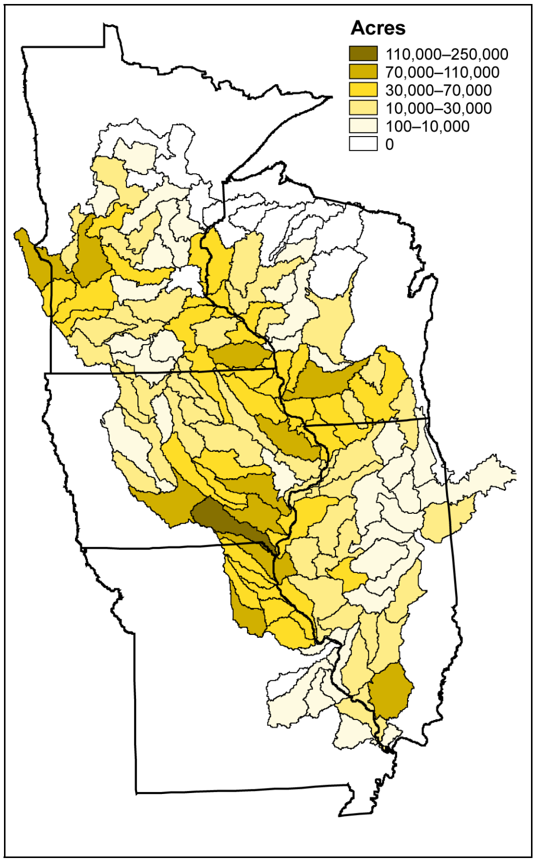

Figure 1. Area selected—the actual CRP program.

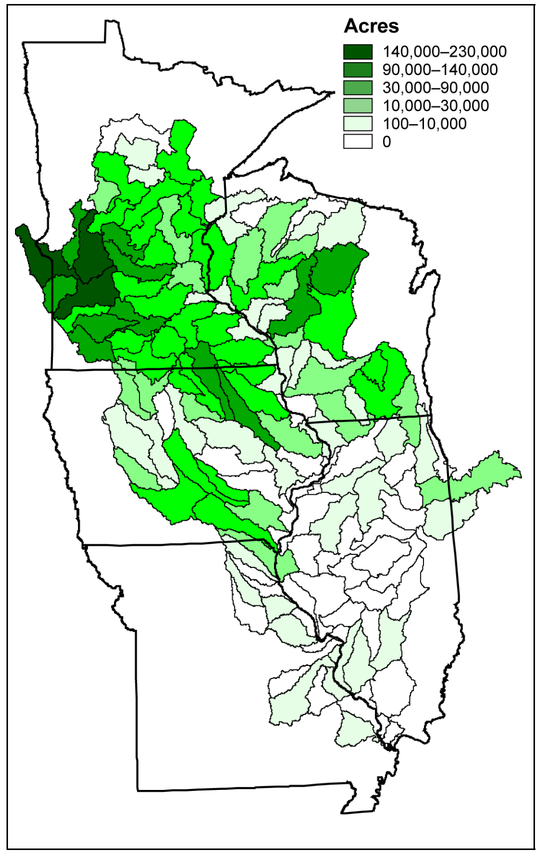

Figure 2. Area selected—target carbon.

region (more than 40,000 points in total) for ten years, the duration for most CRP contracts. Carbon sequestration is measured as the annual average of the total accumulated carbon (i.e., the difference of the total soil carbon pool at the beginning and the end of the simulation period). Other environmental benefits (reduction of water erosion and nitrogen runoff) are the average of the annual measurement, where CRP land is compared to intensive farming practices typical for the region. For the whole UMRB, the annual average carbon-sequestration rate for land converted to CRP is 0.487 tons/acre. The first row of Table 1 provides an estimate of three environmental benefits that result from the existing CRP program.

We next examine how sensitive these environmental results are to different ways of implementing the policy. Specifically, we consider how much carbon would have been sequestered by the CRP had the program been implemented primarily as (a) a carbon sequestration policy or (b) an erosion reduction policy. Information on rental rates is used to analyze two different scenarios with different targeting strategies, such that parcels with the highest targeted benefit are chosen until the program funding (the total expenditure for the actual CRP program) is exhausted.

Two results are evident in Table 1. First, if the CRP had been targeted at carbon specifically (row 2), then considerably more carbon would have been sequestered relative to the actual CRP (row 1). More reduction in nitrogen runoff would also have been achieved, although the erosion reduction benefit would have fallen relative to the existing program. Second, if the CRP had been targeted at erosion specifically (row 3), then significantly more erosion and runoff benefit would have been achieved, while carbon sequestration levels would have declined slightly. Different regions benefit from the program depending on which policies are used to implement the program. Figure 1 indicates

2. *Additional information concerning EPIC can be found in Gassman, et al. (2004). Details concerning model assumptions and data can be found in Feng, Kurkalova, Kling, and Gassman (2004).*

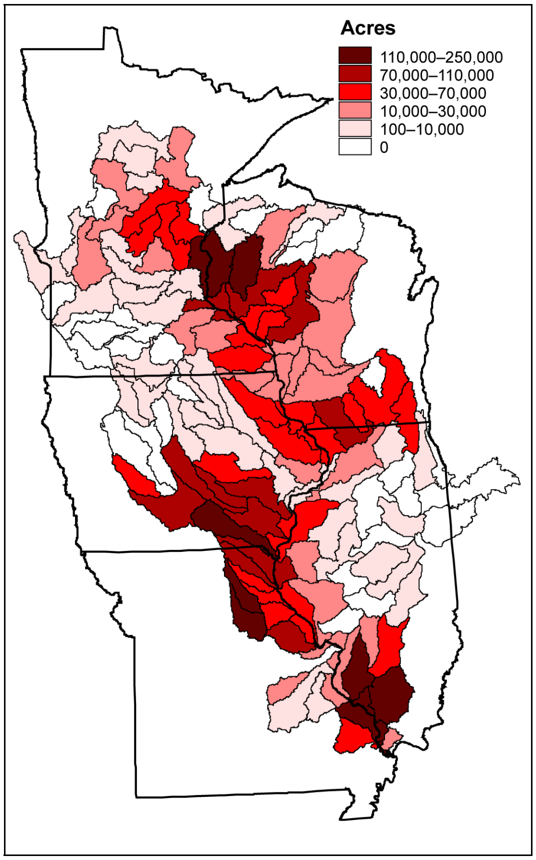

Figure 3. Area selected—target erosion.

that the actual CRP acres are about evenly spread around the region. When carbon is targeted, selected land concentrates in southern Minnesota, eastern Wisconsin, and parts of Iowa (Figure 2); when erosion is targeted, selected land concentrates along the Mississippi river (Figure 3).

To gain more perspective on the total amount of carbon sequestered, suppose there is a carbon market with various prices. At a carbon price of $10/ton—a relatively low value used in the literature—the value of the carbon sequestered by the actual CRP is about $10 million. This is far less than the actual program costs in the region, implying that at this price the carbon market would not be able to induce the land-use practice change the actual CRP program induced. On the other hand, if the carbon price were over $100/ton, the value of the carbon sequestered by the actual CRP would be about a third of the program's costs. However, if parcels with the best carbon potential participate in the market, as theory would predict, then the total value would be above $300 million, which exceeds the program's costs. In this case, the carbon market could replace the actual CRP in the sense of obtaining the same level of carbon sequestration. However, other environmental benefits might be reduced. This perspective illustrates the complication of policy design for carbon sequestration when both green payment programs and carbon markets coexist.

Conclusions

Given that carbon sequestration cannot be separated from many important co-benefits, policies focused on increasing carbon storage in agriculture and forest lands need to consider carefully the consequences of carbon sequestration programs on multiple environmental benefits. To demonstrate the importance of this point, this article presents results from an analysis of a large and potentially rich source of carbon sequestration as well as co-benefits—the Upper Mississippi River Basin. Our results suggest that had the CRP been designed to achieve the greatest carbon for the budget allocated, the land parcels chosen for inclusion would be significantly different from either the actual CRP or a different kind of program that targets soil erosion instead.

Numerous design challenges remain for conservation policies to elicit socially optimal levels of carbon sequestration, nutrient loads, soil erosion, biodiversity, and other landscape amenities. In addition to considering co-benefits, interactions among incentives from competing conservation programs (e.g., the CRP and the CSP) and the introduction of carbon markets will also present challenges to policy design. Finally, we note that the results presented here are based on field-level simulations for a large region and that there is ongoing development of EPIC, other environmental models, and economic models of costs. As the models evolve, the results of analyses such as the one undertaken here may change as well.

For More Information

Feng, H., Kurkalova, L.A., Kling, C.L., & Gassman, P.W. (2004). *Environmental conservation in agriculture: Land retirement versus changing practices on working land* (04-WP 365). Ames, IA: Iowa State University Center for Agricultural and Rural Development. Available on the

World Wide Web: http://www.card.iastate.edu/publications/DBS/PDFFiles/04wp365.pdf.

Gassman, P.W., Williams, J.R., Benson, V.R., Izaurralde, R.C., Hauck, L.M., Jones, C.A., Altwood, J.D., Kiniry, J.R., & Flowers, J.D. (2004). *Historical development and applications of the EPIC and APEX models* (ASAE paper no. 042097). PSt. Joseph, MI: American Society of Agricultural Engineers. Available on the World Wide Web: http://asae.frymulti.com.

Greenhalgh, S., & Sauer, A. (2003). *Awakening the dead zone: An investment for agriculture, water quality, and climate change*. Washington, DC: World Resources Institute. Available on the World Wide Web: http://pubs.wri.org/pubs_description.cfm?PubID=3803.

Kurkalova, K., Kling, C., & Zhao, J. (2004). Multiple benefits of carbon-friendly agricultural practices: Empirical assessment of conservation tillage. Environmental Management, *33*(4), 519-527.

Matthews, S., O'Connor, R., & Plantinga, A.J. (2002). Quantifying the impacts on biodiversity of policies for carbon sequestration in forests. *Ecological Economics*, *40*(1), 71-87.

McCarl, B.A., & Schneider, U.A. (2001). Greenhouse gas mitigation in U.S. agriculture and forestry. *Science*, *294*(5551), 2481-82.

Mooney, S., Antle, J.M., Capalbo, S.M., & Paustian, K. (2004). Influence of project scale on the costs of measuring soil C sequestration. *Environmental Management*, *33*(S1), S252-S263.

Pattanayak, S.K., Sommer, A., Murray, B.C., Bondelid, T., McCarl, B.A., & Gillig, D. (2002). *Water quality co-benefits of greenhouse gas reduction incentives in U.S. agriculture* (final report). Washington, DC: Environmental Protection Agency. Available on the World Wide Web: http://foragforum.rti.org/documents/Pattanayak-paper.pdf.

Plantinga, A.J., & Wu, J. (2003). Co-benefits from carbon sequestration in forests: Evaluating reductions in agricultural externalities from an afforestation policy in Wisconsin. *Land Economics*, *79*(1), 74-85.

Catherine L. Kling is professor of economics in the Department of Economics at Iowa State University and head of the Resource and Environmental Policy Division at the Center for Agricultural and Rural Development (CARD), Iowa State University. Hongli Feng and Phillip W. Gassman are assistant scientists at CARD, Iowa State University. *We appreciate the significant and careful computational assistance of Todd Campbell and editorial suggestions of Brent Sohngen and an anonymous reviewer. All errors and lack of clarity are our responsibility. For more information on the carbon sequestration work on the Upper Mississippi River Basin discussed herein, see our web site http://www.card.iastate.edu/environment/carbon/.*