Chapter 5: Empirical Analysis

Empirical results were obtained from running USMP under the four farm-sector incentive scenarios for carbon sequestration described in chapter 4 of this report. Tables 5.1-5.4 detail selected results for the four simulation scenarios that capture alternative designs for carbon-sequestration incentives. Results of the simulation scenarios represent changes relative to the 2010 baseline, that is, they reflect impacts beyond those that would occur in a 2010 world with no new carbon sequestration incentives.

Scenario 1: Rental Payment for Net Sequestration, No Cost-Share—*Reference Policy Scenario*

Table 5.1, scenario 1 suggests that U.S. agriculture has significant economic potential to store additional carbon—although the amounts sequestered are well below the levels estimated to be technically possible in soil science studies (see table 2.2). For permanent sequestration valued at \$10, \$25, \$50, \$75, \$100, and \$125 per mt, farmers receive rental payments of \$3.54, \$8.85, \$17.70, \$26.55, \$35.40, and \$44.25 per mt of carbon sequestered during the 15-year contract period. [Remember, if they were to sequester the carbon permanently, the present discounted value of their receipts would be the full asset value for permanent sequestration per ton.] At these carbon prices, the farm sector is estimated to sequester 0.4, 6.3, 30.3, 42.8, 54.3 and 72.0 MMT of carbon per year. At the lowest carbon price, neither of the land-use change options appears to be economically attractive: all net sequestration (i.e., 0.4 MMT) results from the expanded use of conservation tillage (fig. 5.1). At all higher payment levels, however, afforestation accounts for 86-94 percent of total sequestration.

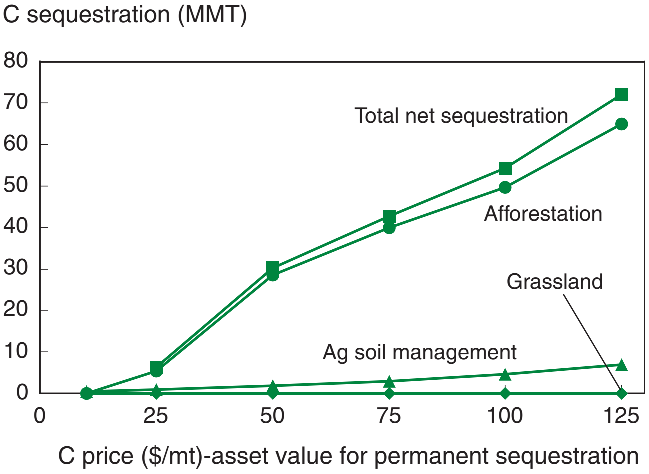
The dominance of afforestation reflects the significantly higher per acre carbon payments relative to those for other activities—due to the significantly higher per acre sequestration rates associated with shifting land into trees (see table 4.2 and fig. 4.2). Between 68 and 77 percent of the carbon from afforestation comes from conversion of pasture, with the share from cropland generally increasing as the payment level rises. Pasture is generally less productive than cropland, so this pattern is consistent with farmers afforesting more marginal lands first. No payment level in this scenario is sufficient to induce farmers to sequester carbon by converting cropland to permanent grasses.[1]

As the asset value for permanent sequestration increases from \$10 to \$125 per mt, annual carbon sequestration from expanding conservation tillage increases from 0.4 to 7.5 MMT. Some of the carbon sequestered through additional use of conservation tillage, however, is offset by other cropland management decisions that increase carbon emissions. These other activities include shifting land from conservation tillage to conventional tillage, switching to rotations with higher emissions, and bringing idle land into crop production.[2] Net emissions from these activities, reflected in the category "other changes in cropland

Figure 5.1

Annual net carbon sequestration

Scenario 1: Rental payments on net sequestration



Source: Economic Research Service, USDA.

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[1] It is important to note, however, that the simulations only incorporate incentives for land-use *change* to grassland—we do not take into account any continuing sequestration that may occur due to past land-use change, until a new C-stock equilibrium is reached. Nor do we capture the sequestration potential for improved *management* of range or pasture because we lack cost data for the associated activities.

[2] To track flows in and out of conservation tillage, we report the sequestration impacts of changes into conservation tillage in the "changes to conservation tillage" category, and the impacts of changes out of conservation tillage in the "other changes in cropland management" category, along with the net impacts on carbon sequestration of rotation changes.

Table 5.1—Average annual change in total carbon sequestered by practice/land-use change, for alternative policy scenarios and carbon-payment levels

	Price per metric ton of permanent carbon sequestration*					
Activity	$10	$25	$50	$75	$100	$125
	Million metric tons					
Scenario 1: Rental payment on net sequestration, with no cost-share:						
Afforestation	0.0	5.4	28.5	39.9	49.7	65.0
From cropland	0.0	1.7	6.7	10.6	13.3	18.5
From pasture	0.0	3.7	21.8	29.3	36.4	46.4
Additional grasses	0.0	0.0	0.0	0.0	0.0	0.0
Changes to conservation tillage**	0.4	1.0	2.0	3.2	5.0	7.5
Other changes in cropland management	0.0	-0.1	-0.2	-0.3	-0.4	-0.5
Total	0.4	6.3	30.3	42.8	54.3	72.0
Scenario 2: Asset payment on net sequestration, with no cost-share:						
Afforestation	8.5	38.4	72.4	103.1	125.2	133.1
From cropland	2.6	10.2	20.2	26.6	33.1	40.1
From pasture	6.0	28.2	52.2	76.6	92.1	93.1
Additional grasses	0.0	0.0	0.0	0.0	0.0	0.0
Changes to conservation tillage**	1.1	2.9	8.5	14.0	20.0	27.6
Other changes in cropland management	-0.1	-0.2	-0.5	-1.0	-1.0	-0.7
Total	9.5	41.1	80.4	116.1	144.2	160.0
Scenario 3: Rental payment on net sequestration, with cost-share:						
Afforestation	2.8	16.6	34.3	41.1	54.9	68.4
From cropland	0.1	3.2	7.7	10.9	14.4	18.8
From pasture	2.7	13.4	26.6	30.2	40.5	49.6
Additional grasses	0.0	0.0	0.0	0.0	0.0	0.0
Changes to conservation tillage**	1.0	1.4	2.1	2.8	3.5	4.3
Other changes in cropland management	-0.1	-0.1	-0.2	-0.2	-0.2	-0.4
Total	3.7	17.9	36.2	43.7	58.2	72.3
Scenario 4: Rental payment on gross sequestration, with no cost-share:						
Afforestation	0.0	5.4	28.5	39.6	47.4	61.1
From cropland	0.0	1.7	6.7	10.6	13.3	18.5
From pasture	0.0	3.7	21.7	29.0	34.1	42.6
Additional grasses	0.0	0.0	0.0	0.0	0.0	0.0
Changes to conservation tillage**	31.8	32.1	32.5	32.9	34.1	34.4
Other changes in cropland management	-31.7	-31.6	-31.6	-31.5	-31.3	-30.9
Total	0.1	5.9	29.4	41.0	50.3	64.6

* Corresponding payments to farmers during the 15-year contract period are $3.54, $8.85, $17.70, $26.55, $35.40, and $44.25 per mt in rental payment scenarios 1, 3, and 4 and $10, $25, $50, $75, $100, and $125 per mt in asset payment scenario 2.

** These rows report gross sequestration from changes to conservation tillage. Emission increases from changes out of conservation tillage are in “other changes in cropland management.”

Source: Economic Research Service, USDA.

management,” increase from 0.0 to 0.5 MMT over the range of carbon values analyzed.

Table 5.2 reports the effects of land-use and land-management changes associated with the carbon-sequestration quantities reported in table 5.1. For cropland management, at asset carbon prices of $10, $25, $50, $75, $100, and $125 per mt with scenario 1, farmers shift, respectively, 2.1, 5.2, 10.5, 15.9, 20.3, and 27.9 million acres from conventional tillage to conservation tillage. The net effect of these cropland-management decisions on carbon sequestration, however, is partially offset by the reverse shift of some cropland—between 0.3 and 7.3 million acres—from conservation tillage to conventional tillage. (We discuss the shift from conservation tillage to conventional tillage in more detail for scenario 4).

The ability of very modest carbon payments to induce additional use of conservation tillage reflects the sizable set of producers who base decisions to use one system over another on marginal economic considerations. In many areas, conservation and conventional tillage systems exist side by side. In these cases, it is

Table 5.2—Acres changing land use or tillage practice as a result of contract, by policy scenario and carbon-payment level

	Price per metric ton of permanent carbon sequestration*						
Activity	Base	$10	$25	$50	$75	$100	$125
	Total acres (mil.)	*Change in acres (mil.)*					
Scenario 1: Rental payment on net sequestration, with no cost-share:							
Change to forest land:							
From cropland	0	0.0	1.1	4.4	6.9	8.7	12.7
From pasture	0	0.0	4.1	24.2	32.3	40.4	51.9
Total change to forest	0	0.0	5.2	28.6	39.2	49.1	64.6
Total change to grassland	0	0.0	0.0	0.0	0.0	0.0	0.0
Cropland - tillage changes:							
From conventional to conservation tillage	0	2.1	5.2	10.5	15.9	20.3	27.9
From conservation to conventional tillage	0	0.3	0.9	1.7	2.9	3.9	7.3
Net change to conservation tillage		1.8	4.3	8.8	13.0	16.4	20.6
Scenario 2: Asset payment on net sequestration, with no cost-share:							
Change to forest land:							
From cropland	0	1.7	6.6	13.8	18.1	22.5	27.4
From pasture	0	6.7	31.2	58.6	87.5	105.4	106.1
Total change to forest	0	8.4	37.8	72.4	105.6	127.9	133.5
Total change to grasslands	0	0.0	0.0	0.0	0.0	0.0	0.1
Cropland - tillage changes:							
From conventional to conservation tillage	0	5.8	14.6	29.9	42.6	54.3	66.9
From conservation to conventional tillage	0	0.8	2.4	6.9	8.4	12.0	14.2
Net change to conservation tillage		5.0	12.2	23.0	34.2	42.3	52.7
Scenario 3: Rental payment on net sequestration, with cost-share:							
Change to forest land:							
From cropland	0	0.1	2.1	5.0	7.1	9.7	12.9
From pasture	0	2.9	14.9	29.5	33.3	45.7	56.3
Total change to forest	0	3.0	17.0	34.5	40.4	55.4	69.2
Total change to grassland	0	0.0	0.0	0.0	0.0	0.0	0.0
Cropland - tillage changes:							
From conventional to conservation tillage	0	3.2	4.9	9.1	13.4	16.8	21.0
From conservation to conventional tillage	0	1.7	1.3	2.0	2.9	2.6	3.3
Net change to conservation tillage		1.5	3.6	7.1	10.5	14.2	17.7
Scenario 4: Rental payment on gross sequestration, with no cost-share:							
Change to forest land:							
From cropland	0	0.0	1.1	4.4	6.9	8.7	12.7
From pasture	0	0.0	4.1	24.1	31.9	38.1	48.1
Total change to forest	0	0.0	5.2	28.5	38.8	46.8	60.8
Total change to grassland	0	0.0	0.0	0.0	0.0	0.0	0.0
Cropland - tillage changes:							
From conventional to conservation tillage	0	76.8	80.3	79.1	81.5	81.3	82.7
From conservation to conventional tillage	0	76.1	78.1	74.8	74.2	73.1	72.6
Net change to conservation tillage		0.7	2.2	4.3	7.3	8.2	10.1

* Corresponding payments to farmers are $3.54, $8.85, $17.70, $26.55, $35.40, and $44.25 per mt in scenarios 1, 3, and 4 and $10, $25, $50, $75, $100, and $125 per mt in scenario 2.

Source: Economic Research Service, USDA.

expected that the returns to the different tillage systems would be fairly similar and that relatively small carbon payments would be sufficient that some farmers currently using conventional tillage would maximize profits by shifting to conservation tillage.

Across the payment levels analyzed, afforestation of cropland and pasture increases from 0.0 to 64.6 million acres. At payment levels of $100 per mt and below, the Delta States, the Southeast, and Appalachia account for the large share of acres shifting to forest (between 82 and 100 percent) (app. 2). At $100 per mt, some afforestation occurs in all regions in which it is considered feasible, including the Pacific.

Across the carbon-payment range analyzed, U.S. timberland acreage—now estimated at 503.7 million acres (Vesterby and Krupa, 2001)—increases from 0 to 13 percent. Within USMP, we cannot currently identify at what point substantial program-induced price and output effects would occur through carbon-sequestration activities in forestry markets. At least for the higher carbon-payment levels, not accounting for potential carbon leakage in the forestry sector probably results in an overestimate of net sequestration.

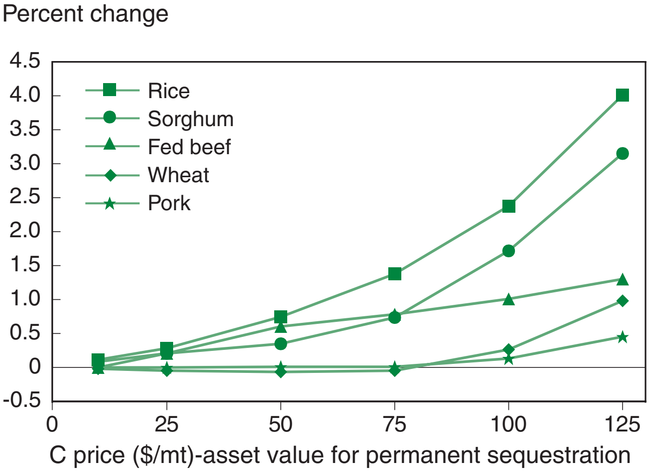
With respect to commodity markets, the carbon-sequestration incentives simulated in scenario 1 typically result in lower output and higher prices (fig. 5.2, table 5.3). This pattern is consistent with the observed shifts of land out of crop and livestock production and into trees. Commodity market impacts, however, are quite modest for carbon payments up to $75 per mt—production declines are all less than 1.7 percent and price increases are all less than 1.4 percent. At a payment of $100 per mt, some price and production impacts start to become more substantial. The price of rice increases 2.4 percent, production of rice drops 2.5 percent, and production of sorghum drops 2.9 percent. At a payment level of $125 per mt, four of the nine commodities in table 5.3 have price increases between 2.4 and 4.1 percent and three have production declines between 2.9 and 5.6 percent. Among the commodity markets, the most affected are the major feed grains (corn and sorghum), rice (for crops), and fed beef (for livestock). The effects on the markets for wheat, soybeans, pork, and milk are relatively small.

Table 5.4 reports the impacts on agricultural-sector welfare and Government spending under alternative policy scenarios. Aggregate producer welfare impacts are shown as changes in net farm income and domestic producer surplus. In USMP, net farm income nets out variable costs while producer surplus nets out both variable and fixed costs. For payment levels of $50 per mt and below, increases in net farm income in scenario 1 are less than 2.0 percent. As payments increase from $75 to $125 per mt, net farm income increases from 3.3 to 7.6 percent.

Figure 5.2

Commodity price changes

Scenario 1: Rental payments on net sequestration



Source: Economic Research Service, USDA.

For full carbon payments of $10, $25, $50, $75, $100, and $125 per mt, Government payments to farmers total $1.3 million, $55.7 million, $537.1 million, $1,137.1 million, $1,924.4 million, and $3,181 million, respectively. For context, annual outlays during 1989-2000 for USDA's CRP varied between $1.40 billion and $1.73 billion, including rental payments, cost-share assistance, and technical assistance for the 29.2 to 35.1 million enrolled acres during the period (USDA, FSA, 2001).

The higher commodity prices and lower production levels associated with carbon payments to producers hurt U.S. consumers of agricultural products. This impact is measured by changes in domestic consumer surplus, which is the difference between the amount that consumers would be willing to spend and the amount they actually have to spend for a specific quantity of a good. Reductions in consumer surplus indicate a decline in consumer welfare. Across the payment levels, however, declines in domestic consumer surplus are relatively modest—between 0.0 and 0.2 percent (or never more than $1.9 billion).

Table 5.3—Estimated commodity market impacts, by policy scenario and carbon-payment level

	Price per metric ton of permanent carbon sequestration*						
Activity	$0	$10	$25	$50	$75	$100	$125
	Baseline (units noted)	*Percent change from baseline*					
Scenario 1: Rental payment on net sequestration, with no cost-share:							
Commodity production:							
Corn	11.234 bil. bu	0.0	0.0	- 0.1	-0.1	-0.3	-0.5
Sorghum	0.670 bil. bu	-0.1	-0.3	-1.0	-1.6	-2.9	-5.6
Wheat	2.545 bil. bu	0.0	0.0	0.1	0.0	-0.3	-1.0
Rice	0.194 bil. cwt	-0.1	-0.3	-0.8	-1.4	-2.5	-4.2
Soybeans	3.245 bil. bu	0.0	0.0	0.1	0.0	-0.7	-1.5
Cotton	17.50 mil. bales	-0.1	-0.2	-0.5	-0.9	-1.6	-2.9
Fed beef	152.20 mil. cwt	0.0	-0.2	-0.3	-0.4	-0.5	-0.6
Pork	189.80 mil. cwt	0.0	0.0	0.0	0.0	0.0	0.0
Milk	1,794.00 mil. cwt	0.0	0.0	0.0	0.0	0.0	-0.1
Commodity prices:							
Corn	$2.60 bu	0.02	0.04	0.00	0.07	1.02	2.67
Sorghum	$2.35 bu	0.09	0.21	0.35	0.74	1.72	3.15
Wheat	$3.70 bu	-0.02	-0.04	-0.06	-0.04	0.27	0.98
Rice	$7.71 cwt	0.12	0.29	0.75	1.38	2.38	4.01
Soybeans	$6.30 bu	-0.01	0.01	0.20	0.34	1.04	1.87
Cotton	$312.00 bale	0.07	0.17	0.40	0.71	1.33	2.35
Fed beef	$334.04 cwt	0.00	0.21	0.61	0.79	1.01	1.30
Pork	$262.93 cwt	0.00	0.01	0.02	0.04	0.15	0.34
Milk	$14.30 cwt	0.00	-0.02	-0.07	-0.50	0.80	0.29
Scenario 2: Asset payment on net sequestration, with no cost-share:							
Commodity production:							
Corn	11.234 bil. bu	0.0	-0.1	-0.7	-1.7	-3.0	-4.1
Sorghum	0.670 bil. bu	-0.4	-1.5	-6.6	-10.1	-14.4	-17.4
Wheat	2.545 bil. bu	0.0	0.0	-1.3	-3.9	-8.4	-12.1
Rice	0.194 bil. cwt	-0.3	-1.4	-5.3	-8.3	-11.6	-16.0
Soybeans	3.245 bil. bu	0.0	0.0	-1.9	-4.2	-7.9	-11.2
Cotton	17.50 mil. bales	-0.2	-0.8	-3.3	-5.7	-9.5	-16.1
Fed beef	152.20 mil. cwt	-0.4	-0.4	-0.7	-1.1	-1.5	-1.9
Pork	189.80 mil. cwt	0.0	0.0	-0.1	-0.1	-0.2	-0.3
Milk	1,794.00 mil. cwt	0.0	0.0	-0.2	-0.4	-0.7	-0.9
Commodity prices:							
Corn	$2.60 bu	0.04	0.06	3.53	7.79	13.35	17.15
Sorghum	$2.35 bu	0.22	0.68	3.68	7.77	13.47	17.29
Wheat	$3.70 bu	-0.04	-0.04	1.27	3.82	8.16	11.73
Rice	$7.71 cwt	0.32	1.30	5.07	7.94	11.06	15.23
Soybeans	$6.30 bu	0.03	0.32	2.29	4.49	8.18	11.31
Cotton	$312.00 bale	0.19	0.67	2.71	4.68	7.76	13.14
Fed beef	$334.04 cwt	0.35	0.77	1.46	2.23	3.11	3.76
Pork	$262.93 cwt	0.01	0.03	0.44	0.91	1.58	2.05
Milk	$14.30 cwt	-0.02	-0.06	0.41	0.97	1.64	2.10

See notes at end of table.

Continued--

Table 5.3—Estimated commodity market impacts, by policy scenario and carbon-payment level—Continued

	Price per metric ton of permanent carbon sequestration*						
Activity	$0	$10	$25	$50	$75	$100	$125
	Baseline (units noted)	*Percent change from baseline*					
Scenario 3: Rental payment on net sequestration, with cost-share:							
Commodity production:							
Corn	11.234 bil. bu	0.0	0.0	-0.1	0.0	-0.2	-0.4
Sorghum	0.670 bil. bu	-0.1	-0.3	-0.8	-1.2	-1.7	-2.8
Wheat	2.545 bil. bu	0.0	0.0	0.0	-0.1	-0.2	-0.6
Rice	0.194 bil. cwt	0.0	0.0	-0.1	-0.3	-1.0	-1.3
Soybeans	3.245 bil. bu	0.0	0.1	0.2	0.1	-0.3	-0.9
Cotton	17.50 mil. bales	0.0	-0.1	-0.2	-0.4	-0.9	-1.2
Fed beef	152.20 mil. cwt	0.0	-0.2	-2.0	-0.4	-0.5	-0.6
Pork	189.80 mil. cwt	0.0	0.0	0.0	0.0	0.0	0.0
Milk	1,794.00 mil. cwt	0.0	0.0	0.0	0.0	0.0	0.0
Commodity prices:							
Corn	$2.60 bu	-0.03	-0.12	-0.25	-0.28	0.12	1.19
Sorghum	$2.35 bu	0.05	0.06	0.21	0.55	1.16	1.64
Wheat	$3.70 bu	0.00	-0.01	0.01	0.08	0.22	0.58
Rice	$7.71 cwt	0.01	0.04	0.08	0.32	1.00	1.20
Soybeans	$6.30 bu	0.00	0.06	0.14	0.18	0.65	1.27
Cotton	$312.00 bale	0.03	0.07	0.15	0.32	0.70	0.98
Fed beef	$334.04 cwt	0.06	0.35	1.78	0.81	1.01	1.25
Pork	$262.93 cwt	0.00	0.00	0.00	0.00	0.06	0.18
Milk	$14.30 cwt	-0.01	-0.05	-0.09	-0.06	0.04	0.20
Scenario 4: Rental payment on gross sequestration, with no cost-share:							
Commodity production:							
Corn	11.234 bil. bu	0.0	0.0	-0.1	-0.1	-0.1	-0.2
Sorghum	0.670 bil. bu	-0.1	-0.2	-0.8	-1.1	-1.5	-2.1
Wheat	2.545 bil. bu	0.0	-0.1	-0.2	-0.3	-0.4	-0.7
Rice	0.194 bil. cwt	-0.1	-0.3	-0.5	-0.8	-1.1	-2.0
Soybeans	3.245 bil. bu	0.0	0.0	0.1	0.2	0 .1	-0.3
Cotton	17.50 mil. bales	0.0	0.0	0.0	0.0	-0.1	-0.4
Fed beef	152.20 mil. cwt	0.0	0.0	-0.3	-0.4	-0.5	-0.5
Pork	189.80 mil. cwt	0.0	0.0	0.0	0.0	0.0	0.0
Milk	1,794.00 mil. cwt	0.0	0.0	0.0	0.0	0.0	0.0
Commodity prices:							
Corn	$2.60 bu	0.01	0.00	-0.08	-0.05	0.08	0.68
Sorghum	$2.35 bu	0.05	0.11	0.11	0.21	0.51	0.90
Wheat	$3.70 bu	0.04	0.09	0.17	0.27	0.41	0.68
Rice	$7.71 cwt	0.10	0.26	0.52	0.77	1.06	1.87
Soybeans	$6.30 bu	-0.02	-0.01	0.12	0.17	0.23	0.70
Cotton	$312.00 bale	0.00	0.00	0.00	0.00	0.06	0.32
Fed beef	$334.04 cwt	0.00	0.09	0.60	0.78	0.92	1.10
Pork	$262.93 cwt	0.00	0.00	0.01	0.02	0.03	0.11
Milk	$14.30 cwt	0.00	-0.02	-0.07	-0.06	-0.02	0.09

bu = bushel. cwt = hundredweight.

* Corresponding payments to farmers are $3.54, $8.85, $17.70, $26.55, $35.40, and $44.25 per mt in scenarios 1, 3, and 4 and $10, $25, $50, $75, $100, and $125 per mt in scenario 2.

Source: Economic Research Service, USDA.

Table 5.4—Estimated changes in annual farm income and agricultural sector welfare, by policy scenario and carbon-payment level

Activity	Price per metric ton of permanent carbon sequestration*						
	$0	$10	$25	$50	$75	$100	$125
	Baseline (units noted)	*Percent change from baseline*					
Scenario 1: Rental payment on net sequestration, with no cost-share:							
Net farm income:	$76.937 bil.	0.0	0.2	1.9	3.3	4.9	7.6
Value of crop production	$80.027 bil.	0.0	0.0	0.1	0.1	0.3	0.6
Variable crop production costs	$44.695 bil.	0.1	0.2	0.3	0.4	-0.1	-1.0
Value of livestock production	$110.667 bil.	0.0	0.0	0.4	0.5	0.8	1.2
Variable livestock production costs	$74.064 bil.	0.0	0.0	-0.2	-0.3	0.1	0.6
Payments to farmers for:							
New rotations and tillage systems (in mil. $)	$0.0	1.3	8.0	32.1	77.2	164.0	306.9
Planting trees/grasses (in mil. $)	$0.0	0.0	47.7	505.0	1,059.9	1,760.4	2,874.1
Surplus measures:							
Domestic consumer surplus	$832,469.8 mil.	0.00	-0.01	-0.05	-0.07	-0.13	-0.22
Domestic producer surplus	$53,371.2 mil.	0.00	0.10	1.00	1.94	4.14	7.45
Foreign consumer surplus	$25,759.1 mil.	-0.01	-0.06	-0.28	-0.45	-1.21	-2.40
Foreign producer surplus	$954.3 mil.	0.00	0.15	1.03	1.34	1.73	2.30
Scenario 2: Asset payment on net sequestration, with no cost-share:							
Net farm income:	$76.937 bil.	0.4	3.0	9.2	17.7	27.9	37.3
Value of crop production	$ 80.027 bil.	0.1	0.1	0.8	1.5	2.2	2.2
Variable crop production costs	$44.695 bil.	0.2	0.4	-1.4	-3.4	-6.8	-10.1
Value of livestock production	$110.667 bil.	0.1	0.5	1.4	2.3	3.5	4.3
Variable livestock production costs	$74.064 bil.	-0.1	-0.2	0.9	2.2	3.9	5.1
Payments to farmers for:							
New rotations and tillage systems (in mil. $)	$0.0	9.8	67.5	399.8	977.0	1,912.5	3,357.6
Planting trees/grasses (in mil. $)	$0.0	85.5	960.3	3,619.0	7,735.6	12,519.4	16,645.2
Surplus measures:							
Domestic consumer surplus	$832,469.8 mil.	-0.01	-0.07	-0.26	-0.50	-0.81	-1.05
Domestic producer surplus	$53,371.2 mil.	0.17	1.78	9.41	19.89	34.42	48.00
Foreign consumer surplus	$25,759.1 mil.	-0.08	-0.43	-2.98	-6.06	-10.42	-13.96
Foreign producer surplus	$954.3 mil.	0.24	1.31	2.66	4.28	5.91	7.19
Scenario 3: Rental payment on net sequestration, with cost-share:							
Net farm income:	$76.937 bil.	0.1	0.9	2.5	3.4	5.1	7.4
Value of crop production	$80.027 bil.	0.0	0.0	0.0	0.0	0.0	0.2
Variable crop production costs	$44.695 bil.	0.1	0.1	0.3	0.4	0.1	-0.5
Value of livestock production	$110.667 bil.	0.0	0.2	0.5	0.5	0.1	1.1
Variable livestock production costs	$74.064 bil.	0.0	-0.1	-0.3	-0.4	0.0	0.3
Payments to farmers for:							
New rotations and tillage systems (in mil. $)	$0.0	3.0	11.1	33.4	69.8	115.6	171.4
Planting trees/grasses (in mil. $) **	$0.0	9.9	147.1	607.9	1,091.4	1,945.1	3,026.0
Surplus measures:							
Domestic consumer surplus	$832,469.8 mil.	0.00	-0.02	-0.05	-0.06	-0.10	-0.16
Domestic producer surplus	$53,371.2 mil.	0.04	0.41	1.22	2.01	3.74	6.34
Foreign consumer surplus	$25,759.1 mil.	-0.01	-0.08	-0.19	-0.25	-0.69	-1.41
Foreign producer surplus	$954.3 mil.	0.10	0.58	1.24	1.39	1.77	2.27

See notes at end of table.

Continued--

Table 5.4—Estimated changes in annual farm income and agricultural sector welfare, by policy scenario and carbon-payment level—Continued

	Price per metric ton of permanent carbon sequestration*						
Activity	$0	$10	$25	$50	$75	$100	$125
	Baseline (units noted)	*Percent change from baseline*					
Scenario 4: Rental payment on gross sequestration, with no cost-share:							
Net farm income:	$76.937 bil.	0.1	0.6	2.7	4.4	5.9	8.1
Value of crop production	$80.027 bil.	0.0	0.0	0.1	0.1	0.1	0.3
Variable crop production costs	$44.695 bil.	0.0	0.1	0.1	0.2	0.2	-0.1
Value of livestock production	$110.667 bil.	0.0	0.0	0.4	0.5	0.7	0.9
Variable livestock production costs	$74.064 bil.	0.0	0.0	-0.2	-0.3	-0.2	0.1
Payments to farmers for:							
New rotations and tillage systems (in mil. $)	$0.0	112.8	284.2	575.6	873.6	1,207.5	1,523.9
Planting trees/grasses (in mil. $)	$0.0	0.0	47.7	503.7	1,050.8	1,678.2	2,703.8
Surplus measures:							
Domestic consumer surplus	$832,469.8 mil.	0.00	-0.01	-0.05	-0.06	-0.08	-0.12
Domestic producer surplus	$53,371.2 mil.	0.18	0.58	1.92	3.25	4.79	7.24
Foreign consumer surplus	$25,759.1 mil.	0.00	-0.04	-0.22	-0.32	-0.45	-0.96
Foreign producer surplus	$954.3 mil.	0.00	0.15	1.04	1.35	1.61	2.04

* Corresponding payments to farmers are $3.54, $8.85, $17.70, $26.55, $35.40, and $44.25 per mt in scenarios 1, 3, and 4 and $10, $25, $50, $75, $100, and $125 per mt in scenario 2.

** Includes cost-share payments.

Source: Economic Research Service, USDA.

Since the United States is a major importer and exporter of agricultural products, changes in U.S. commodity prices and production would also affect foreign producers and consumers. These impacts are measured in USMP as changes in foreign producer surplus and foreign consumer surplus. Following the pattern of domestic impacts, foreign consumers are negatively affected by the carbon payments while foreign producers benefit. Across payment levels, reductions in foreign consumer surplus range from 0.01 to 2.4 percent. In relative terms, the negative impacts of the carbon payments are significantly higher for foreign consumers than for U.S. consumers. Conversely, foreign producers receive no carbon payments so their gains are relatively small, compared with gains of domestic producers.

Scenario 2: *Asset Payment (Assuming Permanent Sequestration)* for Net Sequestration, No Cost-Share—*Traditional Approach to Permanence*

Scenario 2 most closely represents the traditional static approach to modeling incentive payments to encourage farmers to adopt carbon-sequestering land uses and/or production practices, developed in the early economic literature on farm sequestration (see Parks and Hardie, 1995: Antle et al., 2001; and Pautsch et al., 2001). The payment structure implicitly assumes that a unit of carbon sequestered in a given year will be permanently removed from the atmosphere. From this perspective, a unit of carbon sequestration has the same GHG-mitigation value as a similar unit of carbon emissions reduction. Hence, in scenario 2, farmers receive payments equal to the full asset value of permanent carbon sequestration rather than the 15-year rental payments they received in scenario 1.

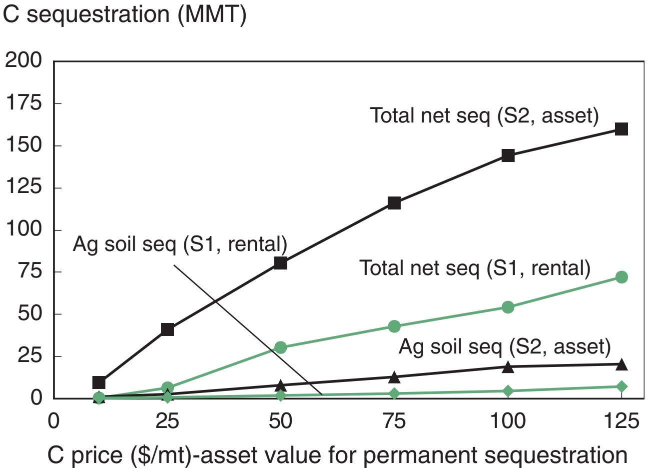
Because payments to farmers per mt of carbon sequestered in scenario 2 are 2.8 times the amount received in scenario 1 (i.e., 1 / 0.354 = 2.8), the anticipated effect of using the “full” (i.e., emissions reduction) values will be to increase the levels of sequestration activities and of economic impacts for the various payment levels relative to the levels observed for scenario 1. Inspection of tables 5.1-5.4 and figure 5.3 reveals this to be the case. As we would expect, the empirical results for the $25 per mt simulation of scenario 2 (which represents a carbon asset value of $71) are very similar in direction and magnitude to results for the $75 per mt simulation of scenario 1.

Annual net carbon sequestration in scenario 2 ranges from 9.5 MMT for a payment level of $10 per mt to 160.0 MMT per year for a payment of $125 per mt,

Figure 5.3

Annual net carbon sequestration

Asset (S2) versus rental (S1) net sequestration payments



Source: Economic Research Service, USDA.

compared with a range of 0.4 to 72.0 MMT per year for scenario 1 (table 5.1). The increases in carbon sequestration relative to scenario 1 are the result of farmers responding to the higher payment levels by making more changes in land uses and production practices.

Unlike scenario 1, afforestation dominates sequestration activities in scenario 2 at all payment levels—although there is a general decrease in the share of sequestration accounted for by afforestation in scenario 2 as the payment level increases. Relative to scenario 1, afforestation accounts for a larger share of total carbon sequestration for payments of $10 and $25 per mt and a smaller share of the total sequestration for payments of $50 per mt and above. Turning to land-use change, land afforested increases from 8.4 million acres at a payment of $10 per mt to 133.5 million acres at a payment of $125 per mt. As in scenario 1, afforestation is dominated by land shifting out of pasture; however, the share of afforested lands related to pasture conversions is somewhat smaller in scenario 2—at least when permanent sequestration is valued at $25 per mt or more (70-74 percent in scenario 2 versus 78-85 percent in scenario 1).

Regional patterns of afforestation differ significantly between scenarios 1 and 2 (app. 2). While the Delta States, Appalachia, and the Southeast still provide virtually all of the afforested acres at payment levels of $10 and $25 per mt, at $50 per mt, the quantity of additional pasture available for conversion to trees in these regions starts to become more limited. At payment levels of $50 per mt and above, the Pacific region becomes the largest supplier of afforested acres, and, producers in the Lake States and the Corn Belt become much more active—that is, relative to scenario 1—with afforestation.

With respect to cropland management, carbon payments of $10, $25, $50, $75, $100, and $125 per mt induce farmers to shift, respectively, 5.8, 14.6, 29.9, 42.6, 54.3, and 66.9 million acres from conventional tillage to conservation tillage systems (table 5.2). Across payment levels, these amounts are about 2.5 times the acres that make this shift relative to the associated discount payment levels in scenario 1. The carbon sequestration on lands moving from conventional to conservation tillage, however, is offset somewhat by emissions from land moving in the opposite direction. Shifts from conservation to conventional tillage systems increase from 0.8 million acres for a payment of $10 per mt to 14.2 million acres for a payment of $125 per mt. When carbon emissions from these land management changes are added to the net emissions related to changes in rotations, net carbon sequestration from cropland management is 1.0, 2.7, 8.0, 13.0, 19.0, and 26.9 MMT for payment levels of $10, $25, $50, $75, $100, and $125 per MT, respectively. Cropland management assumes a larger share of total sequestration activity as the carbon payment increases, rising from about 10 percent of total net sequestration at $10 per mt to about 17 percent of total net sequestration at a payment of $125.

As in scenario 1, conversion of cropland to grassland is not economically attractive across the range of carbon payments analyzed. However, the “full” carbon payment of $125 per mt in scenario 2 appears to be a threshold price for conversions of cropland to permanent grasses. At that payment level, 100,000 acres of cropland in the Southern Plains shift to grasses, resulting in about 0.032 MMT of carbon sequestration. In understanding the limited appeal of grasslands, it is important to note that while the per ton carbon payments significantly increase the incentives to convert cropland to grasses, the opportunity costs of removing cropland from production also significantly increase due to the crop price increases. While the actual carbon payments to farmers are much higher in scenario 2 relative to scenario 1, the increases in commodity prices are much higher as well—because larger quantities of land are being afforested leading to greater decreases in commodity production.

These results strongly reinforce the scenario 1 finding that, while technically feasible, conversion of cropland to grassland does not appear to be an economically feasible option to sequester carbon in the farm sector. This finding is consistent with studies by Antle et al. and McCarl and Schneider.

In scenario 2, commodity market impacts are still quite modest for carbon payments of $10 and $25 per mt—all production declines are less than 1.5 percent and all price increases are less than 1.3 percent (table 5.3). At $50 per mt, commodity market impacts start to become more pronounced. Of the nine commodities shown in table 5.3, three have price increases larger than 3 percent and three have production declines greater than 3 percent. For carbon payments of $100 per mt and above, double-digit decreases in production and increases in prices are common. The commodity markets most affected by the sequestration incentives are corn, sorghum, rice, and cotton. Conversely, the markets for wheat, pork, and milk are relatively unaffected.

The farm sector income and welfare impacts associated with scenario 2 are also magnified versions of their counterpart impacts in scenario 1 (table 5.4). Table 5.4 highlights how costly it could be to design a set of carbon sequestration incentives based on an assumption of permanent carbon storage but without actually incorporating any features to ensure permanent storage. For payment levels of $10, $25, $50, $75, $100, and $125 per mt, annual program costs are $100 million, $1.03 billion, $4.02 billion, $8.17 billion, $14.43 billion, and $20.00 billion, respectively. These amounts are 73.3, 18.5, 7.5, 7.6, 7.5, and 6.3 times higher than the associated payment levels in scenario 1. In addition to the higher program costs, there are also additional costs to consumers of U.S. agricultural commodities associated with the higher commodity prices. Focusing on U.S. consumers, the decreases in consumer surplus for payments of $10, $25, $50, $75, $100, and $125 per mt are, respectively, $83.3 million, $583 million, $2.2 billion, $4.2 billion, $6.7 billion, and $8.7 billion. For the associated payments, these represent increased costs to U.S. consumers of about $83 million, $500 million, $1.6 billion, $3.6 billion, 5.6 billion, and 6.9 billion relative to scenario 1.

Alternatively, we can reinterpret the actual payments in scenario 2 within a rental payment framework (as per scenario 1) or we can reinterpret the actual payments in scenario 1 in a "full" payment framework (as per scenario 2). Viewed this way, the sequestration results of the two scenarios can be combined to form a single supply schedule for carbon—with the two alternative interpretations.

Reinterpreting actual payment levels in scenario 2 of $10, $25, $50, $75, $100, and $125 as rental payments, we calculate the associated full prices by multiplying each by 2.8 (1/.354), yielding full prices of $28, $70, $140, $210, $280, and $350 per mt. The axes for the combined supply function in figure 5.4 are labeled from the rental payments perspective. We could alternatively interpret the graph within a full payments perspective by dividing all the prices on the horizontal axis by 2.8.

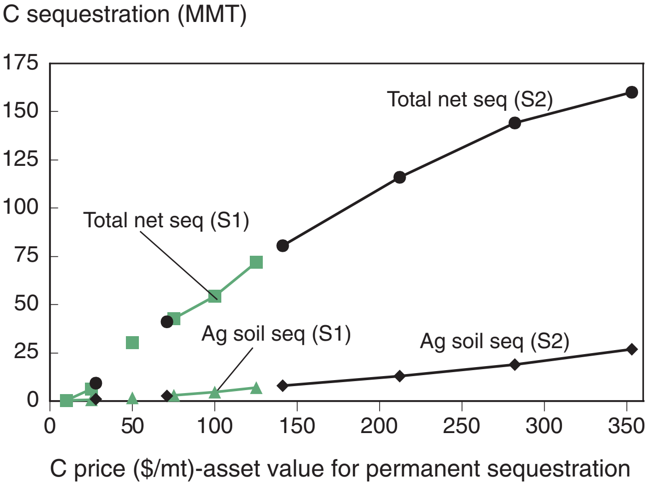
Scenario 3: Rental Payment for Net Sequestration, *With Cost-Share Supplement—Standard Conservation Program Feature*

Scenario 3 employs the reference scenario rental payments structure but augments the incentive package in scenario 1 to include a cost-share subsidy to partially offset the upfront costs of establishing trees on cropland or pasture or establishing permanent grasses on cropland. Assistance is set at 50 percent of the cost of establishing trees and grasses.[3]

Figure 5.4

Annual net carbon sequestration

Actual payments in S1 and S2 interpreted as rental payments



Source: Economic Research Service, USDA.

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[3] USDA's largest conservation program, the CRP, includes a 50-percent cost-share payment for planting trees, establishing grasses, and other approved vegetative practices (USDA, FSA, 2001).

As discussed in chapter 4, cost sharing the establishment of desired land uses and management practices is a common component of USDA conservation programs, including CRP, WRP, and WHIP.

Not surprisingly, the addition of the cost-share subsidy results in more carbon sequestration, more afforestation, and higher levels of total payments to producers in scenario 3 than in scenario 1. The differences in the quantities of carbon sequestered and land afforested, however, are only pronounced at lower payment levels. For example, annual net carbon sequestration in scenario 3 is 3.7, 17.9, 36.2, 43.7, 58.2, and 72.3 MMT for carbon payments of $10, $25, $50, $75, $100, and $125 per mt, respectively (table 5.1). These values are 9.3, 2.8, 1.2, 1.0, 1.1, 1.0 times the associated sequestration values in scenario 1. A similar pattern is evident in the results for afforestation. This pattern is not surprising, since the cost-share is a fixed-dollar amount per acre; consequently, the cost-share increases the total payments available to a much greater extent at low carbon prices. As in scenario 1, afforestation is concentrated in the Southeast, the Delta States, and Appalachia, with the Pacific becoming a source of afforested acres at carbon-payment levels of $100 per mt and above (app. 2).

The major economic impact associated with adding cost-share assistance to scenario 1 is a significant increase in the cost of the sequestration program. Relative to scenario 1, cost-share assistance increases net carbon sequestration 3.3, 11.6, 5.9, 0.9, 3.9, and 0.3 MMT for payment levels of $10, $25, $50, $75, $100, and $125 per mt, respectively (table 5.1). The associated increases in total payments to farmers, however, are $11.6 million, $102.5 million, $104.2 million, $24.1 million, $136.3 million, and $16.4 million. Also worth noting is that the effect of cost-share assistance on net farm income essentially disappears at carbon payments above $75 per mt. For payments of $10, $25, $50, $75, $100, and $125 per mt, net farm income increases, respectively, 0.0, 0.2, 1.9, 3.3, 4.9, and 7.6 percent in scenario 1, and, 0.1, 0.9, 2.5, 3.4, 5.1, and 7.4 percent in scenario 3 (table 5.4).

Scenario 4: Rental Payment *for Gross Sequestration,* No Cost-Share—*Exploring the Leakage Issue*

Scenario 4 differs from scenario 1 in that the incentive payments are based on gross, rather than net, increases in carbon sequestration. That is, scenario 4 pays the farm sector when land is shifted into a carbon-sequestering land use or production practice but does not debit these payments for any related land-based emissions due to shifting cropland out of conservation tillage, switching to rotations that release additional carbon, or bringing idle land into crop production. A comparison of the impacts of scenarios 1 and 4 suggests the consequences of ignoring the potential for feedback effects on market prices, which, in turn, can lead to farm-sector choices that result in emissions from the covered activities. Again, we note that our model is limited to the agricultural sector, so potential leakage due to related activities in the forest sector is not included in the GHG accounting.

For carbon values of $10, $25, $50, $75, $100, and $125 per mt, net carbon sequestration in scenario 4 is 0.1, 5.9, 29.4, 41.0, 50.3, and 64.6 MMT, respectively (table 5.1). Across payment levels, these values range between 0.3 and 7.4 MMT less than annual net sequestration values reported for scenario 1. The similarity in the net sequestration values is due to similarities in afforested acres, which typically account for more than 90 percent of all sequestration in both scenarios. Relative to scenario 1, acres of cropland moving into trees in scenario 4 are nearly identical for all payment levels, though acres of pasture moving to trees shows modest decreases at payment levels of $100 per mt and above (table 5.2). Since afforestation decisions in our simulations cannot be offset by related decisions to harvest other forests, forest-related land-use change is strictly a carbon-sequestering activity in our accounting. It is not surprising then that afforestation decisions are largely unaffected by the change in incentives between scenarios 1 and 4. Hence, we focus here on the results relating to changes in cropland management. Within that set of activities in scenario 4, net carbon sequestration falls by about 50 percent across the range of carbon payments.

For carbon payments of $10, $25, $50, $75, $100, and $125 per mt, total payments to farmers for changes in tillage systems and rotations are, respectively, $112.8 million, $284.2 million, $575.6 million, $873.6 million, $1,207.5 million, and $1,523.9 million in scenario 4. These amounts range from 10.8 to 87.0 times the total payments values in scenario 1. Land-management changes help explain the smaller quantities of net sequestration and higher program costs in scenario 4. For carbon payments of $10, $25, $50, $75, $100, and $125 per mt, farmers in scenario 4 shift, respectively, 76.8, 80.3, 79.1, 81.5, 81.3, and 82.7 million acres from conventional to conservation tillage systems. These land-management decisions are a direct response to the carbon-sequestration incentives. At the same time, however, farmers also shift 76.1, 78.1, 74.8, 74.2, 73.1, and 72.6 million acres out of conservation into conventional tillage systems. Unlike scenario 1, scenario 4 does not adjust the payments farmers receive for any land-based emissions that result from scenario-driven shifts of land to uses or production practices with higher carbon emissions. Hence, there is no penalty for moving land from conservation to conventional tillage, whereas there is an opportunity cost associated with leaving many lands in conservation tillage.

At this point, we need to ask whether the large shifts out of conservation tillage suggested by scenario 4 are likely to occur. Based on profit calculations, the shifts both to and from conservation tillage make sense as responses to both carbon incentive and crop price effects, as we outline in the paragraph that follows. However, this component of the model may not incorporate sufficient "stickiness" in the choice of tillage at a particular site, so we may be overpredicting the gross shifts from conventional to conservation and from conservation to conventional. The model does incorporate stickiness in the net changes among tillage options. Consequently, the "excessive" responsiveness would not affect the estimates of net sequestration but would affect the estimates of program cost (which are based on gross sequestration).

The relative profitability of conventional tillage versus conservation tillage depends on a variety of site-specific factors that affect yields and cost differentials. These factors include soil temperature and moisture conditions at planting time (conventional tillage allows soils to warm up and/or dry out quicker), length of growing season (crops with longer growing seasons need to be planted earlier and so in many areas rotations include 2 or 3 years of conservation tillage and one of conventional tillage), and farmer experience with conservation tillage (these systems tend to be management intensive and require sufficient time to learn).

In USMP, crop yields by rotation, tillage system, and region are derived from the biophysical Environmental Policy Integrated Climate (EPIC) model. The yields represent 7-year averages after the crop-rotation tillage-system region combination has been established for at least 5 years. For many region-rotation combinations, these yields are higher with conservation tillage systems, but on average yields tend to be lower. In the crop budgets used in the model, the direction of the cost differential also varies but tends to favor conservation tillage. For systems in which conservation tillage has lower costs but lower yields, crop price will affect the likelihood of revenue loss exceeding the cost gain: as crop prices rise conventional tillage tends to become more profitable. Thus, increasing carbon prices (from 0) will encourage shifts toward conservation tillage. And increasing crop prices due to shifts of cropland to forest lands will provide incentives to shift from conservation tillage to conventional tillage on lands where the cost advantage of conservation is outweighed by the revenue disadvantage as crop prices rise.

Commodity market impacts in scenario 4 tend to be somewhat muted versions of their counterparts in scenario 1 (table 5.3). Without a penalty for land-based emissions, it is profitable for farmers to bring some idle lands into commodity production. As a result, the decline in total cropland is not as large as in scenario 1, and the decreases in commodity production and increases in commodity prices are also more moderate.

Finally, scenarios 1 and 4 are similar with respect to changes in net farm income and agricultural sector welfare relative to the baseline. In scenario 4, the larger increases in program payments for changes in tillage systems are offset by smaller increases in net revenues from crop and livestock production (due to smaller decreases in quantities produced and smaller increases in prices) and marginally smaller payments for afforestation. Hence, the main consequences of ignoring the leakage issue in the design of a farm sector carbon-sequestration program will be that, at a given carbon price, the quantity of net carbon sequestration will be lower and the program cost will be higher. Both effects increase the per ton cost of net carbon sequestration.

Directions for Future Research

The changes in land uses and production practices considered in this analysis are likely candidates for incentives to increase the quantity of carbon stored in agricultural soils and biomass. However, to address the questions of the economic potential for overall GHG mitigation in the agricultural sector, it would be informative to extend the analysis in several directions.

First, it would be useful to expand the scope of the incentive payments to include a broader set of mitigation activities, particularly rangeland and pasture land management, as well as a broader set of GHGs, particularly methane and nitrous oxide.

Second, it would be useful to link a framework such as ours with a forest sector model to account for potential carbon leakage related to forest-sector responses to afforestation decisions on agricultural lands. As noted in chapter 3, agriculture and forestry often compete for the services of land resources. Several studies have looked at this competition and concluded that the shifting of millions of acres of cropland and pasture into trees would change timber harvest patterns in ways that would increase carbon emissions (see app. 1). These studies indicate that ignoring this leakage altogether could result in crediting agricultural afforestation programs with significantly more sequestration than actually occurs.

Finally, any assessment of the relative cost-effectiveness of different incentives to change agricultural land uses and production practices to mitigate GHG emissions needs to reflect the associated institutional costs associated with measuring, monitoring, and crediting the carbon sequestered for the different policy approaches. The carbon sequestration activities analyzed here—and those not analyzed (see table 2.2)—pose a wide variety of challenges with respect to carbon accounting and contract compliance over time. Hence, the costs associated with implementing and administering these activities within a Government carbon-sequestration program are likely to vary significantly. To date, however, all economic studies that have assessed potential to sequester carbon in the farm sector—including our study and those summarized in chapter 3—have assumed a costless institutional process.