5. Soil Management

In this chapter, we briefly describe the impacts of soil erosion on water quality and agricultural productivity. We then present the soil management practices that can be used to reduce erosion. The Area Studies survey data are described with respect to the use of specific practices on highly erodible cropland. The results of simple adoption models for practices designed to keep soil on the field and out of nearby water bodies are reported for the combined-areas and single-areas models using the modeling framework presented in chapter 2. The use of Natural Resource Inventory (NRI) points as the sample locations offers a unique opportunity to test the hypothesis that field characteristics are an important determinant of the choice of soil management practices. We then describe the human capital, production, agricultural policy, natural resource, and climate factors affecting adoption.

The choice of soil management practices can have a significant effect on the environment and on farm productivity. In general, producers have an incentive to adopt a new agricultural technology if it is expected to increase economic benefits relative to current practices, through reduced input costs or increased quantity or quality of output. There are long-term and short-term costs to a farmer associated with soil erosion. The sustainability of agricultural production requires that sufficient topsoil depth remain to support crop production. The immediate costs of erosion to the farmer include clogged ditches, uneven terrain, and local air pollution from wind-blown particles. Many of the costs associated with erosion, however, are imposed on offsite resource users. Estimates of offsite damages to water quality from soil erosion range between $5 billion and $17 billion annually (1986 dollars). Most of the erosion costs accrue from impacts on recreation, flooding, water treatments, and municipal and industrial uses (Ribaudo, 1989). Siltation is one of the leading pollution problems in U.S. water bodies (EPA, 1995, 1998). Dust from wind erosion can damage crops and equipment, and have severe impacts on air quality in surrounding areas. Producers will consider on-site costs associated with the use of some agricultural technologies, but producers have little incentive to factor in offsite costs borne by others.

The use of soil conservation practices, such as no-till cultivation or other crop residue management methods, can prevent soil from being transported to waterways while also preserving productivity. Other practices, such as filter strips, specifically prevent soil from entering waterways once the soil has left the field. The second set of practices primarily reduces the offsite impacts of erosion on water quality. These practices generally provide no direct on-farm benefits, so producers may not adopt them unless provided with an incentive to do so. The conservation compliance provisions discussed below provided such an incentive during the survey period.

Summary of Soil Management Practices and Data from the Area Studies Survey

The Area Studies survey sample contains a wide distribution of soil erosion rates and adoption rates of soil management practices. Figure 2.3 displays the percent of highly erodible cropland acres by region.[1] The areas in the survey that had more than 30 percent of their cropland acres in the highly erodible category are the Susquehanna, Mid-Columbia, Central Nebraska and Snake River Basins, and the Southern High Plains. Cropland in the Snake River Basin and the Southern High Plains was susceptible primarily to wind erosion rather than the sheet and rill erosion that dominates in the other areas. Areas with the least amount of cropland in the highly erodible category were the Southern Georgia Coastal Plain and the Mississippi Embayment. These areas are characterized as floodplains and generally are flat.

Farmers can choose from a variety of soil conservation practices to control erosion, but the profitability and ease of use of these practices will depend on human capital, cropping practices, natural resources, and policy constraints. Farmers must also perceive that soil erosion is a significant problem before they take actions to reduce soil loss (Norris and Batie, 1987). The Area Studies survey instrument included a list of frequently used soil conservation practices, from which the farmer selected the practices used that year. Some of the soil management practices were designed to hold soil on the field, and some were designed to prevent soil from being transported beyond the site.

To identify the factors that affected adoption of soil conservation technologies, we separated the models of soil conservation adoption into three groups: (1) the

[1] See chapter 2 for a definition of highly erodible land.

choice of any soil conservation practice; (2) the choice of soil conservation practices that specifically prevent soil from entering nearby waterways, thus reducing potential off-site damages; and (3) the choice of selected tillage practices that are associated primarily with on-site benefits. Each of these groups is described more fully below. The factors that influence a farmer's use of a particular soil management practice may differ from those that appear to be significant when several practices are analyzed as a group. In particular, the determinants of the farmer's decision to adopt a technology with on-site benefits may differ from those that affect the farmer's choice of a practice with only off-site benefits. To encourage farmers to use preferred technologies, one needs an understanding of which factors are most important in farmers' decision-making processes.

The core variables that we used to assess a farmer's adoption of a certain production practice are described in chapter 2. The following discussion presents additional variables that we included in the models of farmers' use of soil management practices.

Conservation policies can influence the use of soil management practices by increasing the costs to producers who do not control soil erosion on highly erodible lands. The 1985 Farm Bill linked farm program benefits with soil conservation efforts. Under the 1985 Farm Bill, agricultural producers were subject to conservation compliance if they received farm program benefits and cultivated highly erodible cropland. Land is considered highly erodible if potential soil loss due to sheet and rill, or wind, erosion divided by a soil loss tolerance factor,[2] is greater than or equal to 8. Farmers subject to conservation compliance were required to have an approved conservation plan in place by January 1990 and had to fully implement the plan by January 1995. The conservation plan often included the use of particular soil management technologies or cropping practices. Farm program benefits could be denied if a farmer was not in compliance.

Magleby et al. (1995) estimated that after the conservation compliance provisions were implemented, about 105.5 million cropland acres were considered highly erodible, a decrease of 11.8 percent from the 1987 level of 117.3 million cropland acres. Highly erodible cropland is roughly one-third of total U.S. cropland acres. They also estimated the benefits from reduced soil erosion as a result of conservation compliance as follows: $325 million in productivity benefits, $21.7 billion in water quality benefits, and $3 billion in dust reduction benefits.

Producers who participated in the Area Studies survey were asked if they received farm program benefits (e.g., price supports, crop quotas, or the Conservation Reserve Program (CRP)). About 18 percent of the farmers who were sampled were deemed subject to conservation compliance (COMPLY) if they received farm program benefits and cultivated highly erodible cropland, as defined by the NRCS. For the soil management adoption models, the compliance variable is used instead of the PROGRAM variable described in chapter 2. Farmers may also receive technical assistance from the NRCS to develop a conservation plan (CVPLAN). About 53 percent of farmers had implemented a conservation plan. This number is higher than the number of farmers subject to compliance since farmers can voluntarily receive technical assistance from the NRCS to develop a conservation plan regardless of whether they had highly erodible land or received farm program benefits. CVPLAN is the variable used in the soil management model instead of the ADVICE variable described in chapter 2.

A farmer's selection of soil conservation technology may also be influenced by the crop(s) raised. Certain crops contribute less to soil erosion than others. For example, small grains and hay are closely sown crops, and therefore, expose less soil to the elements than row crops. Agricultural producers who cultivate small grains probably would have less need for adopting soil conservation practices, since they already may have a low rate of soil erosion. Nonetheless, there could be a positive association between such crops and conservation practices, since farmers may be growing small grains as part of an overall soil conservation plan. Grains and hay crops (defined as wheat, barley, oats, rye, alfalfa, or other hay) were produced by about 22 percent of farmers. Row crops, on the other hand, are considered to contribute more to soil erosion than grains. Row crops (defined as corn, soybeans, cotton, tobacco, potatoes, or sorghum) were grown by about 78 percent of farmers. Two crop dummy variables (ROWCROP, GRAIN) were used to capture the effects of cropping patterns on the adoption of soil management practices. The use of animal wastes (MANURE) was also included in the analysis. The incorporation of organic matter to the soil adds structure as well as nutrients and may slow erosion rates.

[2] The soil loss tolerance factor is set by NRCS and is based on the erosion rate above which soil productivity will be reduced.

Natural resource characteristics associated with the farm unit may be an important determinant of adoption. Since some soil management practices are targeted for either sheet and rill or wind erosion, specific variables (RKLS and WIND) were used in some cases rather than the general measure, EROTON. These variables are constructed from the NRI-derived data associated with each field observation. In addition, a variable (WATERBODY) was included that indicates whether the field is next to a water body.[3]

As mentioned above, three groupings of soil management practices are analyzed using the framework described in chapter 2. We report the results of the analyses on (1) the adoption of any conservation practice, (2) the adoption of soil conservation practices to protect water quality, and (3) the adoption of conservation tillage. Figure 5.1 shows the adoption of these soil management practices by crop. For each soil management category, the first adoption model includes all 10 of the Area Studies regions combined (referred to as the "combined-areas" model) and the other models analyze individual regions (referred to as the "single-area" models). An analysis of the individual Area Studies regions was conducted to show the location-specific nature of adoption, and how the factors affecting adoption may differ between regions. The selection criteria for choosing the regions for the "single-area" models were based on whether there were a sufficient number of observations in an adoption category and on the severity of the soil erosion problem in the area. That is, results from the adoption models of single areas were not reported if those areas had few producers who adopted a soil conservation technology and had low soil erosion rates on average.

Adoption of Soil Management Practices

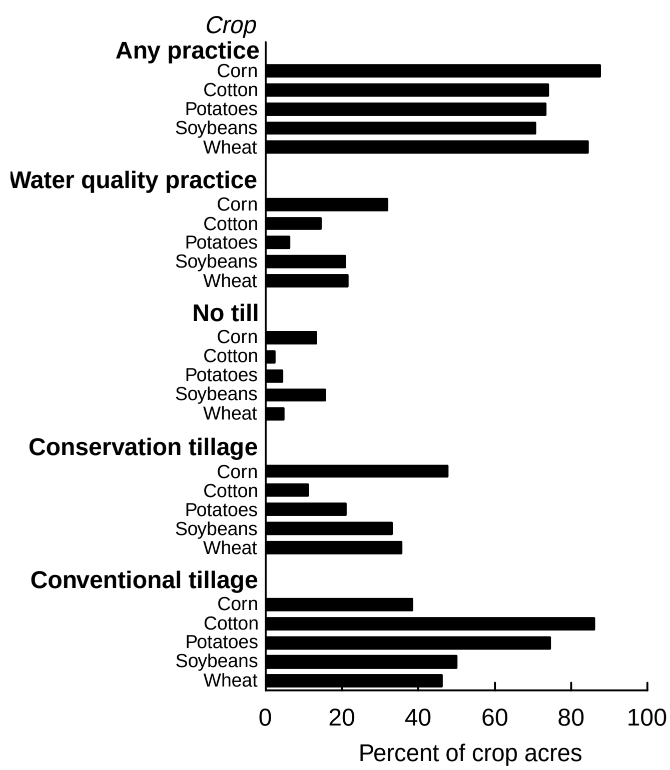
Adoption of Any *Soil Conservation Practice*

The first adoption model focuses on the factors that affect the use of *any* soil conservation practice on cropland, specifically conservation tillage, crop residue use, chiseling and subsoiling, contour farming, conservation cover or green manure crops, grass and legumes in rotation, strip cropping, terracing, grassed waterways, filter strips, grade stabilization structures, and critical area planting. The "Glossary" (box on p. 64) provides definitions of the soil conservation practices covered in the Area Studies survey. This category includes practices that specifically prevent soil from entering waterways once it has left the field as well as those that maintain soil on the field. Conservation practices that keep soil on the field contribute directly to on-farm productivity as well as to off-farm water quality. The large number of practices (12) included in the "any" category may mask the effects of individual factors, therefore we tested whether the factors that affected the adoption of *any* conservation practice differed from those that influenced the choice of a particular practice or group of practices.

Figure 5.2 shows the adoption of *any* soil conservation practice by region, and figure 5.3 presents adoption on highly erodible land. For each area, over half of the highly erodible cropland acres were under some kind of soil conservation practice. The area that cultivated almost all of its highly erodible cropland using *any* soil conservation practice was the Illinois/Iowa Basin.

The sample means for the combined-areas and single-area models are presented in table 5.1. The model results, along with the significance level, from the adoption study of *any* soil conservation practice are displayed in table 5.2.

Figure 5.1
Adoption of soil management practices by crop



[3] Respondents were asked if the field was beside a stream, river, lake, pond, canal, or ditch.

Figure 5.2

Adoption of any soil conservation practice by region

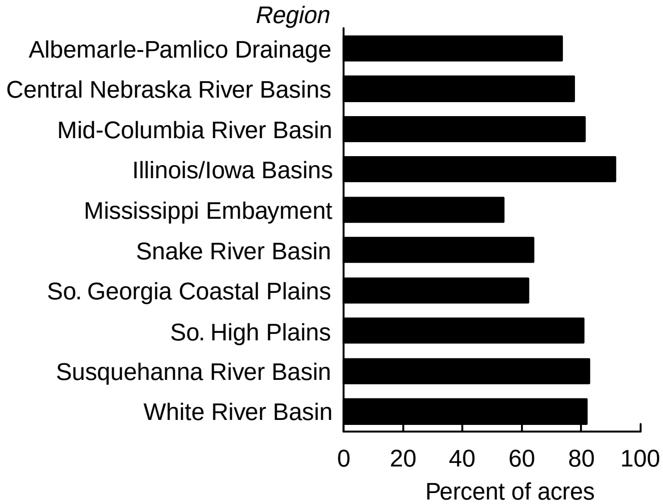


Figure 5.3

Adoption of any soil conservation practice on highly erodible cropland by region

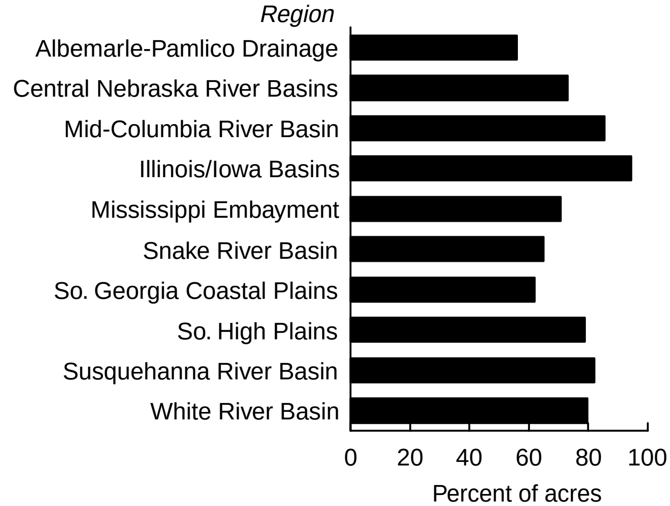


Table 5.1—Sample means from soil conservation adoption models

Variables	Combined areas	Albemarle-Pamlico	Central Nebraska	Mid-Columbia River Basin	Illinois/Iowa River Basins	Snake River Basin	Southern High Plains	Susquehanna River Basin	White River Basin
ANY PRACTICE	.75	.72	.78	.83	.92	.65	.83	.83	.83
WATER QUALITY PRACTICE	.22	.21	.26	.25	.40	.04	.10	.32	.30
COLLEGE	.44	.34	.38	.71	.38	.60	.54	.14	.43
EXPERIENCE	24	25	24	22	25	21	23	22	25
WORKOFF	32	35	30	14	41	35	24	48	64
TENURE	.38	.34	.44	.43	.37	.62	.36	.61	.41
ACRES	1688	1333	1625	3111	910	2550	1972	445	932
ROTATION	.53	.74	.42	.56	.82	.66	.19	.68	.79
ROWCROP	.78	.78	.77	.04	.95	.13[1]	.75	.59	.91
GRAIN	.22	.29	.25	.67[2]	.08	.32[2]	.27	.51	.11
DBL-CROP	.05	.16	.00	.18	.01	.00	.06	.04	.02
MANURE	.09	.05	.10	.02	.19	.09	.05	.63	.10
IRRIGATION	.27	.08	.41	.24	.02	.81	.45	.02	.00
COMPLY	.18	.12	.24	.34	.13	.20	.56	.12	.11
CVPLAN	.54	.48	.50	.76	.56	.78	.78	.51	.43
INSURE	.40	.27	.42	.57	.63	.27	.70	.04	.17
WATERBODY	.42	.58	.27	.23	.35	.34	.07	.17	.39
SLP	119	124	126	143	91	150	151	100	111
PISOIL	.80	.53	.84	.88	.94	.82	.69	.68	.91
EROTON	33	21	47	58	27	37	70	58	28
RKLS	22	21	27	41	25	8	5	58	28
WIND	12	0	19	17	1	29	66	0	.18
RAIN	3.0	4.0	2.1	1.1	3.0	1.2	1.6	3.4	3.4
TEMP	55	60	49	49	50	44	58	51	52
Number of observations	6398	720	703	242	1266	537	508	380	737

Refer to Chapter 2 for variable definitions and units. “Any Practice” includes conservation tillage, crop residue use, chiseling and subsoiling, contour farming, conservation cover or green manure crops, grass and legumes in rotation, strip cropping, terracing, grassed waterways, filter strips, grade stabilization structures, and critical area planting. “Water Quality Practice” includes grassed waterways, filter strips, grade stabilization structures, and critical area planting.

[1] Potatoes.

[2] Wheat.

In the combined-areas model, about 75 percent of producers used at least one kind of soil conservation practice. Table 5.3 shows that the predicted adoption of these practices for all areas combined was 83.4 percent calculated at the sample means. The percent of correct predictions was 83 percent and the pseudo R^2 was 0.46. The regions chosen for the single-area adoption models were the Albemarle-Pamlico, Central Nebraska, Mid-Columbia River, Illinois/Iowa, Snake River, Susquehanna, and White River Basins, and the Southern High Plains. Row 1 of table 5.1 shows that a large proportion of agricultural producers in each region used soil conservation practices. The lowest proportion of adopters in this model came from the Snake River Basin, with 65 percent of farmers using at least one type of soil conservation practice. The percent of farmers using conservation practices in the Southern Georgia Coastal Plain and the Mississippi Embayment were 64 and 54 percent, respectively. These areas, however, did not have severe soil erosion problems on average and, therefore, were not included in the empirical analysis.

The coefficients for COLLEGE, EXPERIENCE, and WORKOFF were not statistically significant at the 5-percent level in the combined-areas model, but, in the Susquehanna River Basin, more experienced farmers and those who worked more days off-farm were more likely to adopt *any* conservation practice. The effect of farm ownership (TENURE) on the adoption of *any* soil conservation practice was negative and statistically

Table 5.2—Change in percent predicted adoption of any soil conservation practice

Variables	Combined areas	Albemarle-Pamlico	Central Nebraska	Mid-Columbia River Basin	Illinois/Iowa River Basins	Snake River Basin	Southern High Plains	Susquehanna River Basin	White River Basin
CONSTANT	-1.7266**	-2.7967**	0.1719	-0.3041	-0.1989	0.0491	-4.4499*	-2.0234**	-0.7195**
COLLEGE	0.0186*	0.0360	0.0247	-0.0023	0.0251*	-0.0107	0.0024	-0.0033	0.0178
EXPERIENCE	0.0063	-0.0064	0.0193	0.0357*	0.0127	-0.0357	-0.0154	0.0482**	-0.0124
WORKOFF	-0.0016	0.0074	-0.0043	0.0040	0.0030	-0.0012	-0.0036	0.0159**	-0.0006
TENURE	-0.0230**	-0.0518	-0.0460*	-0.0340	-0.0324**	0.1046**	0.0213	-0.0320	-0.0083
ACRES	0.0100**	0.0456**	-0.0350**	0.0023	0.0191**	-0.0366	0.0056	0.0543**	0.0345**
ROTATION	0.0961**	0.1093**	0.1358**	0.0846**	0.0160	0.1709**	0.0133	0.0660**	0.1172**
ROWCROP	0.0603**	0.0835*	—	—	—	0.2444**[1]	—	—	—
GRAIN	-0.0735**	—	-0.2587**	0.1427**[2]	-0.0403**	0.2556**[2]	0.0609*	-0.0916**	-0.1495**
DBL-CROP	0.0443*	-0.0319	—	-0.0390	—	—	—	—	—
MANURE	0.0262	0.1030	0.0792	—	0.0012	-0.0756	0.0233	0.1004**	0.0310
IRRIGATION	0.0132	0.1603	0.0071	0.1279**	—	-0.1155	-0.0126	—	—
COMPLY	0.0222	-0.0667	0.0270	0.1413**	0.0597**	0.1015	-0.0434	0.0019	0.0244
CVPLAN	0.02904**	0.2889**	0.1581**	0.0910**	0.0537**	0.3826**	0.2966**	0.0260	0.1221**
INSURE	0.0253**	0.0434	-0.0172	-0.0132	0.0129	0.1285**	0.0030	—	-0.0022
WATERBODY	0.0043	0.0114	-0.0409	-0.0472	0.0146	-0.1315**	0.0249	0.1303**	0.0252
SLP	0.0091	0.2492**	0.0218	-0.0504	-0.0172	-0.1292	0.0259	-0.0836	-0.0439
PISOIL	0.1174**	0.1272	0.0637	0.1551*	-0.0749	0.1602	0.1680*	0.1595**	-0.1035
EROTON	-0.0037	-0.0059	0.0187	-0.0240	0.0001	-0.0330	0.0213	0.0471**	-0.0038
RAIN	0.1518**	1.4813**	-0.1969	0.1039	0.2053**	-0.0822	—	1.2598**	0.6130**
TEMP	0.3400**	—	—	—	—	—	1.0330*	—	—
Number of observations	6398	720	703	242	1266	537	508	380	737
% predicted adoption	83.4	77.1	89.2	93.9	93.9	68.1	90.8	91.3	86.9
% correct predictions	83	78	89	88	92	75	88	86	84
Pseudo R^2 [3]	.46	.34	.63	.51	.15	.39	.51	.41	.24

— Variable not included in the adoption model.
** Significant at the 5-percent level.
* Significant at the 10-percent level.
[1] Potatoes only.
[2] Wheat only.
[3] Veall and Zimmerman's pseudo R^2.
Note: "Any Practice" includes conservation tillage, crop residue use, chiseling and subsoiling, contour farming, conservation cover or green manure crops, grass and legumes in rotation, strip cropping, terracing, grassed waterways, filter strips, grade stabilization structures, and critical area planting. For the table, the coefficients estimated from the limited dependent model have been converted into change in percent predicted adoption. For continuous variables (EXPERIENCE, WORKOFF, ACRES, SLP, PISOIL, EROTON, RKLS, WIND, RAIN AND TEMP), the reported value is the change in the percent predicted adoption given a one-percent change in the variable mean. For binomial variables that have a value of either 0 (no) or 1 (yes), the reported value indicates the change in the percent predicted adoption with a unit change of 0.01 from the variable mean. See Appendixes 2-A and 2-B for further details.

significant, -0.023 in the combined-areas model. Farm ownership reduced predicted adoption to 82 percent, whereas predicted adoption is 84.3 percent for producers who did not own their farm (table 5.3). From a policy perspective, however, this relatively small difference in adoption may not be important. In the Illinois/Iowa Basins, land tenure was negatively and significantly correlated with the adoption of *any* soil conservation practice, but was positively correlated with adoption in the Snake River Basin. The result obtained here indicates that, contrary to commonly held notions, renters may have the same, if not more, incentives to make investments to preserve soil on the field as landowners. Some reasons for this could be that renters lease land for long periods or they could be related to landowners, and therefore, may have an incentive to maintain soil productivity for subsequent growing seasons. In addition, renters may be held accountable for property damages or may have rental contracts that require the use of conservation practices. The data do not allow for testing these hypotheses. In the combined-areas and Snake River Basin models, farmers who had crop insurance (INSURE) were more likely to adopt any soil conservation practice.

Many studies on the factors that motivate soil conservation investments have found that larger farms are more likely to invest in soil conservation practices (Young and Shortle, 1984; Napier et al., 1984; and Norris and Batie, 1987). Larger farms are often associated with lower management and information costs per unit of output. The result from this model supported this hypothesis. Farm size (ACRES) had a positive influence on the adoption of *any* soil conservation practice in most areas. Agricultural producers in the combined sample who cultivated 500 acres of land were less likely to adopt any soil conservation practice, about 82.8 percent, compared with 85 percent for farmers who operated 5,000 acres (table 5.3). However, the number of acres operated had no impact on the adoption rates in the Mid-Columbia River, Snake River, and the Southern High Plains areas, and had a negative effect on adoption in the Central Nebraska Basins. These four areas had larger farms than other areas in the study. This result indicates that there may be some positive effect on adoption from farm size in regions with relatively small farm sizes, but the effect is less pronounced as average farm size increases.

Crop rotations can be used as a strategy for both nutrient and pest management, since planting the same crop over many years can contribute to depleted soil nutrients as well as increased pest problems, such as weediness and insect infestation. The use of soil conservation systems that leave the soil relatively undisturbed, e.g., crop residue management and conservation tillage, can increase weed levels and the need for more herbicides. However, these soil conservation technologies also help to replenish soil nutrients and increase water-holding capacity of the soil (Gill, 1997). The effect of crop rotations (ROTATION) on the adoption of *any* soil conservation practice were positive for six of the eight areas and the combined sample. The rotation variable was not significant for the Illinois/Iowa Basins and the Southern High Plain regions.

The type of crop grown had a significant effect on the adoption of *any* soil conservation practice.[4] In almost all cases, the probability that a farmer is adopting *any* soil conservation practice significantly increased with row crops, which are generally erosive, and decreased with grains. This result suggests that farmers may view crop choice as a substitute for conservation practices. Only in the Mid-Columbia and Snake River Basins, where wheat is the major crop grown in the area, was the adoption of any soil conservation practice more likely if a grain was grown.

Double-cropping (DBL-CROP), or growing more than one crop per year on a field, is a measure of cropping intensity. Double-cropping had no impact on the adoption of *any* soil conservation practice. Whether or not a farmer applied manure (MANURE) to a field did not affect the adoption of *any* soil conservation practice, except in the Susquehanna region, where manure applications increased the probability of adopting *any* soil conservation practice. In the Susquehanna River Basin, dairy farms predominate, and close to 63 percent of the sample in the soil conservation adoption model indicated that they applied manure on the field.

The use of irrigation (IRRIGATION) also did not influence farmer decisions to use *any* soil conservation system. In general, irrigation may contribute to the movement of soil in areas subject to sheet and rill erosion, but in areas subject to wind erosion, irrigation may help keep soil on the field. In fact, the results show that the effect of irrigation use on the adoption of

[4] Since some agricultural producers cultivated both grain and row crops in their fields, each crop dummy variable can be considered apart from the other in the combined regional adoption models. For the single areas, the crop dummy variable chosen to be incorporated into the model depended on either model fit, predominant crop in a region, or number of observations.

soil conservation practices may be either positive or negative, depending on the area.

Conservation compliance (COMPLY) was not a significant factor in motivating farmers to adopt *any* soil conservation practice, except in the Mid-Columbia River and Illinois/Iowa Basins where the effect of conservation compliance was positive. However, technical assistance (CVPLAN) had a positive and significant effect on the use of any soil conservation system in all regions, except the Susquehanna River Basin. This is an interesting result since most of the producers who developed a conservation plan voluntarily obtained technical assistance from the Extension Service or Soil Conservation District. Only a subset of these producers were subject to conservation compliance (table 5.1). This indicates that technical assistance is used by farmers who voluntarily seek soil management technologies to control erosion. Table 5.3 highlights this difference. There is only a 2.2-percentage-point difference in farmers' use of any conservation practice between farmers who are subject to conservation compliance versus those who are not. On the other hand, 93.1 percent of farmers with a conservation plan used a conservation practice compared with 62.1 percent of farmers who did not have a conservation plan.

The effectiveness of soil conservation technologies on a field depends on the natural resource endowments of that site. However, farmers may gain no direct benefits from preventing off-site damages. Field location next to a water body had no effect on the use of any conservation practice except in the Susquehanna Basin. Soil leaching potential (SLP) is an index that measures the potential of chemicals to leach through soil into ground water. As expected, SLP did not have a significant impact on the adoption of soil conservation practices overall.

A soil productivity index (PISOIL) was calculated to measure soil quality for root growth (see Chapter 2). The index values range from 0 to 1, with higher values indicating more productive soils. Highly productive soils were hypothesized to encourage farmers to adopt soil conservation practices that maintain soil on the field. Since high levels of soil erosion will reduce a field's productive topsoil, agricultural producers may have an incentive to prevent potential decreases in crop yields resulting from erosion. In other words, the private costs of erosion are higher for productive soils. For the combined-areas and Susquehanna models, the greater the productive capacity of soil the more likely that producers employed soil conservation practices.

The inherent potential of soil to erode (EROTON) due to rainfall and wind is measured in tons per acre per year. A farmer's perception of an erosion problem is an important determinant of soil management decisions (Norris and Batie, 1987; and Ervin and Ervin, 1982). Inherent erosion levels had no significant

Table 5.3—Percent predicted adoption: Combined areas

Variables	Any conservation practice	Conservation practices to protect water quality	No-till	Mulch-till/ ridge-till	Conventional tillage
Land tenure	**			**	**
Yes	82.0	16.7	8.9	28.3	62.8
No	84.3	16.8	9.8	31.3	58.9
Land operated	**		**	**	**
500 acres	82.8	17.0	8.4	28.2	63.3
5,000 acres	85.0	16.3	12.2	35.0	52.8
Conservation compliance		**	**		**
Yes	85.2	25.7	14.3	30.2	55.5
No	83.0	15.2	8.6	30.1	61.3
Conservation plan	**	**	**		**
Yes	93.1	24.0	11.2	30.7	58.1
No	62.1	10.7	7.6	29.5	62.9
Percent adoption at means	83.4	16.8	9.4	30.2	60.3

** Significant at the 5-percent level.
* Significant at the 10-percent level.
Note: "Any Practice" includes conservation tillage, crop residue use, chiseling and subsoiling, contour farming, conservation cover or green manure crops, grass and legumes in rotation, strip cropping, terracing, grassed waterways, filter strips, grade stabilization structures, and critical area planting. "Water Quality Practice" includes grassed waterways, filter strips, grade stabilization structures, and critical area planting.

Glossary of Soil Conservation Practices

Chiseling and subsoiling loosens the soil, without inverting and with a minimum of mixing of the surface soil, to shatter restrictive layers below normal plow depth to improve water and root penetration and aeration.

Conservation cover is the establishment and maintenance of permanent vegetative cover to protect soil and water resources.

Conservation tillage refers to any tillage and planting system that leaves at least 30 percent of the soil surface covered by plant residue after planting to reduce soil erosion by water; or, where wind erosion is the primary concern, at least 1,000 pounds per acre of flat small grain residue-equivalent are on the surface during the critical erosion period. Some examples of conservation tillage include mulch-, ridge-, and no-till. For the Area Studies survey, the following definitions apply (Bull and Sandretto, 1996).

No-till - A tillage system that leaves the soil undisturbed from harvest to planting except for nutrient injection. Planting or drilling is accomplished in a narrow seedbed or slot.

Ridge-till - A tillage system that leaves the soil undisturbed from harvest to planting except for nutrient injection. Planting is completed in a seedbed prepared on ridges that retain residue on the surface between ridges.

Mulch-till - Any other tillage system, besides ridge or no-till systems, that disturbs the soil before planting, but leaves 30 percent or more plant residue after planting.

Contour farming refers to farming sloping land in such a way that preparing land, planting, and cultivating are done on the contour. This includes following established grades of terraces or diversions.

Cover or green manure crops are crops of close-growing grasses, legumes, or small grains grown primarily for seasonal protection or soil improvement. Use of these crops adds organic matter, such as nitrogen when plowed into the field, and improves infiltration, aeration, and tilth.

Critical area planting refers to planting vegetation on highly erodible or critically eroding areas.

Crop residue use refers to using remains of crop plants after harvest to protect cultivated fields during critical erosion periods and supply organic matter to the soil.

Filter strips are strips or vegetative areas for removing sediment, organic matter, and other pollutants from runoff and waste water. Filter strips are typically applied at the lower edge of fields, on fields, on pastures, or in manure-spreading areas adjacent to water bodies.

Grade stabilization structures are used to control the grade and head cutting in natural or artificial channels.

Grass and legumes in rotation refers to planting grasses and legumes or a mixture of them and maintaining the stand for a definite number of years as part of a conservation cropping system.

Grassed waterways are natural or constructed channels that are shaped or graded to required dimensions and established with suitable vegetation for the stable conveyance of runoff.

Strip cropping refers to growing crops in a systematic arrangement of strips or bands, on the contour or across the general slope, to reduce water erosion. The crops are arranged so that a strip of grass or close-growing crop is alternated with a strip of clean-tilled crop or fallow or a strip of grass is alternated with a close-growing crop. To control wind erosion, wind-resisting crops are grown in strips alternating with row crops or fallow and arranged at angles to offset adverse wind effects.

Terracing refers to an earth embankment, a channel, or a combination ridge and channel constructed across the slope.

Source: National Water Data Exchange, U.S. Department of the Interior, Geological Survey.

impact on the adoption of *any* soil conservation practice except in the Susquehanna model. This unexpected result seems to indicate that producers base adoption decisions on other factors, such as labor cost savings associated with reduced tillage or conservation compliance policies, rather than sustaining on-site productivity by reducing soil erosion levels. Farmers' concern about erosion may have been lessened due to technologies that enhance yields, such as pesticides and chemical fertilizers (Young and Shortle, 1978). And, as previously discussed, farmers may also use their choice of crops to manage erosion instead of adopting the conservation practices included in this study. In addition, the higher adoption of practices on HEL captured by the conservation compliance variable indicates that farmers have an increased incentive to control erosion when the costs of erosion (noncompliance) are high.

Climate can play a major role in the use of soil conservation practices. High monthly average rainfall (RAIN) could increase the potential for soils to erode, and high monthly temperatures (TEMP) in arid regions can dry out soil, thereby leaving soil more vulnerable to wind erosion. Rainfall had a positive influence on the adoption of *any* soil conservation practice in all models except those for the Central Nebraska, Mid-Columbia River and Snake River Basins.[5] However, these three areas had lower than average rainfall per month than for all areas combined. High temperatures in the combined areas and the Southern High Plains increased the probability of farmers' adopting soil conservation practices.

[5] The temperature and rainfall variables in the single-area adoption models were highly correlated. Since rainfall is the major contributor to soil erosion, a choice was made to retain the rainfall variable in the model and exclude temperature. One exception was made for the Southern High Plains region, where erosion due to wind was the major contributor to soil erosion.

Soil Conservation Practices to Protect Water Quality

While all the soil conservation practices included in the preceding models prevent soil from entering waterways, a subset of practices is designed specifically to prevent soil from being transported to waterways once the soil has left the field. The second adoption model tries to capture the extra soil conservation efforts that producers undertake to prevent soil from entering waterways. A substantial share of the social benefits from the adoption of these practices likely accrue off the farm, such as to downstream water quality. Factors influencing the adoption of practices designed primarily to enhance environmental quality were expected to differ from those that increased producer profits (Pample and van Es, 1977). Soil conservation practices included in this category were grassed waterways, filter strips, grade stabilization structures, and critical area planting. Ninety-three percent of farmers who had adopted these practices also used at least one soil conservation practice that would maintain soil productivity (an on-farm benefit). The water quality-enhancing practices are typically located at the edge of a field or on steep slopes, and these practices are effective in controlling only sheet and rill erosion.

Figure 5.4
Adoption of water quality practices by region

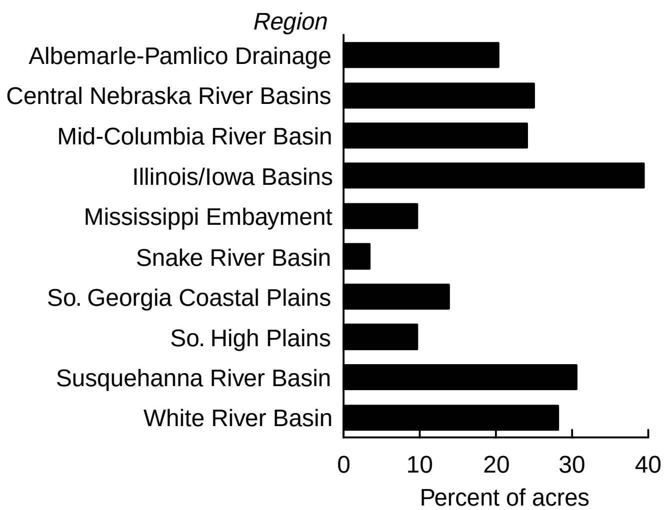


Figure 5.5
Adoption of water quality practices on highly erodible cropland by region

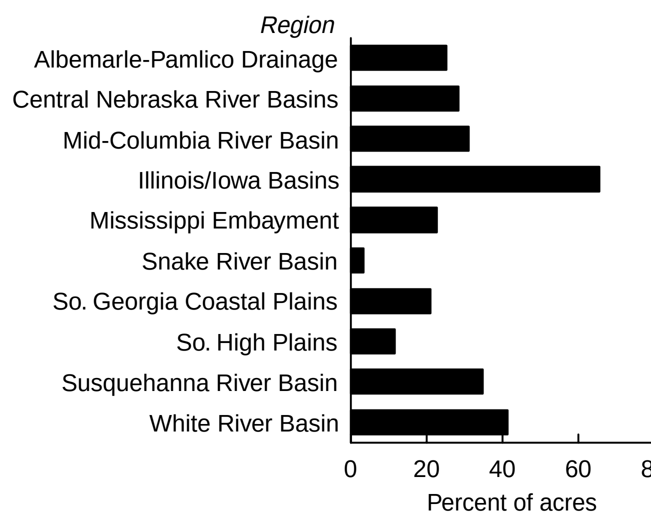


Figure 5.4 shows the use of soil conservation practices that protect water quality by region, and figure 5.5 shows their use on highly erodible cropland. As expected, there was very little adoption of these practices on highly erodible land in the Southern High Plains and the Snake River Basin where wind is the chief cause of soil erosion. The greatest level of highly erodible land cultivated in combination with water quality practices was in the Illinois/Iowa River Basins, 66 percent, and the White River Basin, 41 percent.

The sample means for the variables in the combined-areas and single-area models are presented in row 2 of table 5.1. The model results, along with the significance level, from the adoption study of soil conservation practices to protect water quality are displayed in table 5.4.

Twenty-two percent of farmers in the combined sample had adopted at least one of the soil conservation practices that primarily protect water quality. A stratified sample statistic indicated that these farmers had higher than average potential sheet and rill erosion rates. For the sample, the average potential soil erosion rate was 22 tons per acre per year due to rainfall, whereas the rainfall erosion rate for the farmers who had adopted water quality practices was about 34 tons per acre per year. Column 1 of table 5.4 shows that the predicted

Table 5.4—Change in percent predicted adoption of soil conservation practices to protect water quality

Variables	Combined areas	Albemarle-Pamlico	Central Nebraska	Mid-Columbia River Basin	Illinois/Iowa River Basins	Susquehanna River Basin	White River Basin
CONSTANT	0.1741	-1.2794**	-0.5332**	0.5186	0.9848**	-0.7997	-1.3991**
COLLEGE	0.0118	0.0429	0.0362	0.0613	0.0004	0.1631**	-0.0136
EXPERIENCE	-0.0036	-0.0195	0.0076	-0.0710**	-0.0261	0.0168	-0.0061
WORKOFF	0.0016	0.0004	-0.0012	0.0067	0.0094	0.0064	0.0091
TENURE	-0.0006	0.0116	-0.0475	-0.0522	0.0044	-0.0209	-0.0295
ACRES	-0.0028	0.0250*	-0.0170	0.0090	-0.0342	0.0222	0.0489**
ROTATION	0.0671**	0.0587	0.0575*	0.1645**	0.0954**	0.1006*	0.1451**
ROWCROP	0.0426**	0.0195	0.0768	—	—	—	—
GRAIN	0.0191	—	-0.0528	0.2389**[1]	0.0315	-0.0014	0.0813
DBL-CROP	-0.0140	-0.0703*	—	-0.0740	—	—	—
MANURE	0.0424**	-0.0579	0.0768*	—	0.0451	0.0449	0.0873
IRRIGATION	-0.0143	0.1830**	-0.0250	-0.2505**	—	—	—
COMPLY	0.0921**	0.0032	0.0789**	0.1327**	0.1863**	0.1639**	0.1790**
CVPLAN	0.1349**	0.1976**	0.1242**	0.1251	0.1567**	0.0822	0.1364**
INSURE	0.0122	0.0507*	0.0308	-0.0786	0.0048	—	0.0757*
WATERBODY	0.0492**	0.0904**	0.0182	0.0585	0.1095**	0.0610	0.0255
SLP	0.0043	0.2159**	0.0122	-0.3184	0.0059	0.1058	0.0750
PISOIL	0.0640*	0.2326**	-0.1519	-0.5592**	0.3235*	-0.2552**	0.0267
RKLS	0.0083**	0.0180	—	—	0.0338**	0.0605**	-0.0020
WIND	-0.0143**	—	-0.1543**	0.0173	-0.0381**	—	-0.0083*
RAIN	0.1009*	0.2771	0.6583**	-0.0620	-1.2643**	0.2862	0.6989**
TEMP	-0.1726	—	—	—	—	—	—
Number of observations	6398	720	703	242	1266	380	737
% predicted adoption	16.8	15.7	16.4	17.4	38.8	29.7	27.9
% correct predictions	79	83	79	79	66	73	71
Pseudo R^2 [2]	.30	.32	.39	.39	.18	.20	.17

— Variable not included in the adoption model.
** Significant at the 5-percent level.
* Significant at the 10-percent level.
[1] Wheat only.
[2] Veall and Zimmerman's pseudo R^2.

Note: "Practices to Protect Water Quality" include grassed waterways, filter strips, grade stabilization structures, and critical area planting. For the table, the coefficients estimated from the limited dependent model have been converted into change in percent predicted adoption. For continuous variables (EXPERIENCE, WORKOFF, ACRES, SLP, PISOIL, EROTON, RKLS, WIND, RAIN AND TEMP), the reported value is the change in the percent predicted adoption given a 1-percent change in the variable mean. For binomial variables that have a value of either 0 (no) or 1 (yes), the reported value indicates the change in the percent predicted adoption with a unit change of 0.01 from the variable mean. See Appendixes 2-A and 2-B for further details.

probability of the combined-areas model at the sample means was 16.8 percent. The percent correct predictions was 79 percent and the pseudo R^2 was 0.30. The single-area adoption models included Albemarle-Pamlico, Central Nebraska, and the Mid-Columbia, Illinois/Iowa, Susquehanna, and White River Basins. The Southern High Plains and the Snake River Basin which were included in the models assessing the adoption of *any* soil conservation, were omitted from this analysis because in these areas wind is the prevalent soil erosion factor, and, therefore, there is very little adoption of practices to protect water quality. The proportion of farmers who adopted water quality practices ranged between 20 and 40 percent (table 5.1) for the combined and six individual areas in this analysis.

The human capital variables had little impact on the use of water quality practices in the combined or individual areas. However, in the Susquehanna River Basin, farmers with a college education were more likely than farmers without a college education to adopt these practices. The importance of a college education in the Susquehanna area may be associated with the fact that only 14 percent of the farmers in the Susquehanna area had a college education, much less than in any other area by at least 20 percent. In the Mid-Columbia River Basin, more years of experience appeared to discourage the adoption of practices aimed primarily at protecting water quality.

The influence of farm size on adoption was not statistically significant for the combined-areas model. The Albemarle-Pamlico and White River areas were the only regions where farm size was positively related to the adoption of soil conservation practices to preserve water quality.

Cropping practices such as crop rotations, growing a row crop, and applying manure were positively and significantly associated with the adoption of water quality practices in the combined-areas model. The effect of crop rotations on the adoption of water quality practices were positive and significant in most individual areas. Only in the Mid-Columbia River Basin, where wheat is the chief crop grown in the area (65 percent of cropland acres) was the adoption of water quality practices more likely if a grain crop was grown.

Irrigation use, overall, was not a significant predictor of farmers' use of soil conservation practices, except in the Albemarle-Pamlico Drainage and the Mid-Columbia River Basin regions. In the Albemarle-Pamlico region, farmers who irrigated were more likely to adopt water quality practices. Alternatively, irrigators in the Mid-Columbia River Basin were less likely to adopt practices to preserve water quality. The Mid-Columbia River Basin is an area that is highly susceptible to wind erosion, so farmers may have had less need to adopt soil conservation practices that prevent soil from entering waterways.

Conservation compliance and technical assistance played important roles in farmers' use of water quality practices. Farmers subject to conservation compliance were more likely to make the extra investments in water quality practices, except in the Albemarle-Pamlico area. Farmers in the Albemarle-Pamlico region had very low erosion rates and very few producers were subject to compliance. Conservation compliance has a more significant influence on farmers' use of water quality practices than on their use of other soil conservation systems relative to other factors. Table 5.3 shows that the adoption rate for producers subject to conservation compliance was 25.7 percent compared with 15.2 percent for those not subject to conservation compliance.

Technical assistance also had a strong influence on farmers' use of water quality practices in most regions. Producers who developed a conservation plan with assistance from the Extension Service or Soil Conservation District had a 24 percent adoption rate compared with 10.7 percent for those who did not receive assistance. These results indicate that the compliance provisions and the availability of technical assistance significantly encourage the use of practices designed to provide off-site benefits.

The proximity of a field to a lake or a stream influenced a farmer's decision to adopt practices that are used for the sole purpose of preventing soil from entering waterways once it has migrated from the field for the combined areas and in the Albemarle-Pamlico and the Illinois/Iowa River Basin.

The natural resource variables defining soil quality, SLP and PISOIL did not significantly increase the probability of farmers' use of water quality practices except in Albemarle-Pamlico. However, in the Mid-Columbia and Susquehanna River Basins, the greater the productive capacity of soil, the lower the probability of adoption. This result could indicate that producers may not fully experience the impacts that erosion can have on soil productivity. Expanded nutrient use, for example, may have obscured any productivity losses from soil erosion.

The source of inherent erosion did explain some patterns of farmers' use of conservation practices. In the water quality adoption models, erosion levels were separated into two erosion types, sheet and rill or rainfall (RKLS) and wind (WIND) erosion.[6] In the combined-areas model, inherent erosion due to rainfall increased the likelihood of farmers' use of conservation practices, and alternatively, inherent wind erosion reduced farmers' use of such practices. In the models for the Illinois/Iowa and Susquehanna River Basins, the higher inherent erosion from rainfall, the greater expected adoption. In the Central Nebraska and Illinois/Iowa Basins, higher wind erosion levels decreased the likelihood that a producer would make the extra investments in water quality practices. These outcomes are reasonable since the water quality practices are generally placed at the edge of fields or within channels, and would not be effective against wind erosion. Furthermore, sheet and rill erosion was greater on average for producers using water quality practices. Farmers with high sheet and rill erosion levels were significantly more likely to undertake extra investments to prevent soil from washing into waterways.

[6] In many areas, wind erosion was nonexistent and this variable was excluded from the estimation. RKLS was also omitted from some of the single-area models that had higher rates of wind erosion because this variable was highly correlated with the conservation compliance variable

The effects of RAIN and TEMP varied depending on the region. The higher the monthly rainfall in the Central Nebraska and the White River Basins, the more likely were producers to adopt water quality practices. However, higher rainfall levels discouraged adoption in the Illinois/Iowa River Basins.

Conservation Tillage

The third category of conservation practices that we analyzed was tillage. There have been many recent studies of farmers' use of reduced tillage, and many of these studies build on the work done by Rahm and Huffman (1984) on conservation tillage adoption in Iowa corn production. They found that use differed widely across farms due to soil characteristics, cropping systems, and the size of the farm. Norris and Batie (1987) found that the "factors influencing the adoption of conservation tillage are different from those which influence the decision to use other conservation practices." Tillage practices were combined into three groups: no-till, mulch- or ridge-till, and conventional tillage. The term "conservation tillage" typically includes the use of no-till, ridge-till, or mulch-till systems (see box, "Glossary of Soil Conservation Practices," p. 64). In the Area Studies survey, the designation of practices within the mulch- and ridge-till category relies on the farmer's judgment of how much crop residue was left on the ground after planting, and therefore, is not as clearly defined as the no-till or con-

Figure 5.6

Adoption of tillage practices by region

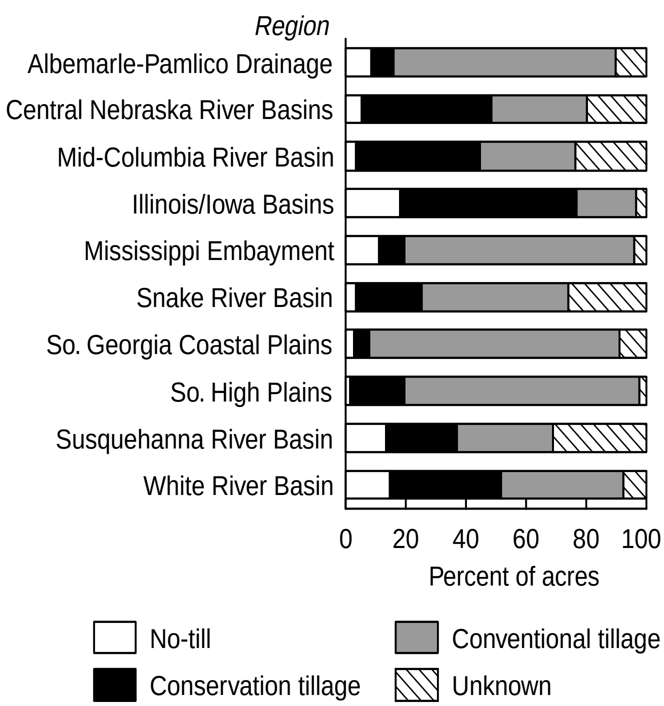
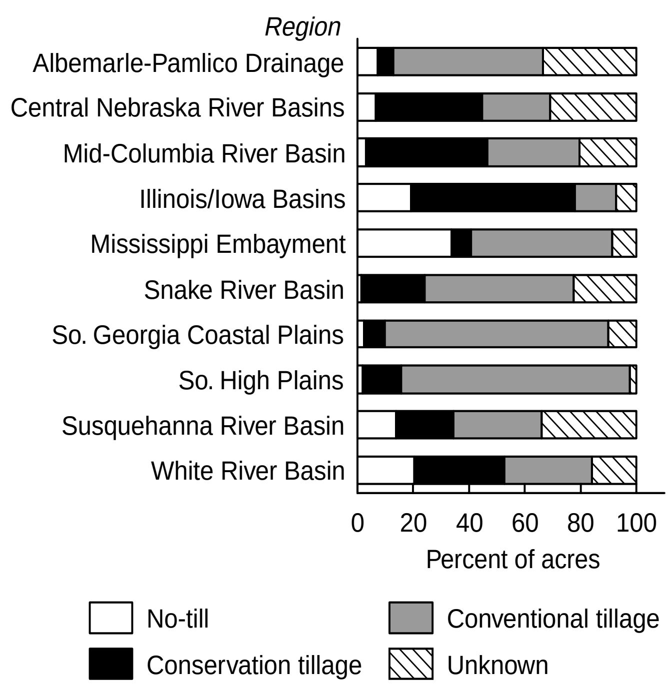


Figure 5.7

Adoption of tillage practices on highly erodible cropland by region



ventional tillage categories. Since no-till systems offer the best protection from soil erosion (i.e., the soil is broken only at seeding), it is considered separately in the model. Conventional tillage is defined as any tillage system, such as the use of a moldboard plow, that leaves less than 30 percent of the soil surface covered with crop residues after planting. Conventional tillage is assumed to afford the least protection against soil erosion. Sandretto (1997) presents a comprehensive summary of crop residue management issues.

Agricultural producers, seeking cost-effective technologies that maintain or increase crop productivity, will choose between alternative tillage technologies to substitute increasingly expensive resources for relatively less expensive ones. The adoption of no-till, for example, can reduce labor, energy, and machinery costs (Bull and Sandretto, 1996). However, the use of no-till has sometimes been associated with increased agricultural chemical costs resulting from increased weed populations. A farmer will likely adopt no-till if the cost savings, or benefits, outweighs any expected increases in chemical or management costs or reduction in crop revenue. In some cases, the feasibility of using certain tillage practices may be limited due to location-specific factors. For example, soil conditions may be such that the use of conventional tillage systems is necessary to prevent soil compaction, which can be detrimental to crop growth.

Table 5.5—Sample means from tillage adoption models

Variables	Combined areas	Illinois/Iowa Basins	Susquehanna River Basin	White River Basin
NO-TILL	.11	.19	.19	.16
MULCH- or RIDGE-TILL	.34	.60	.34	.40
CONVENTIONAL TILLAGE	.55	.21	.47	.44
COLLEGE	.45	.39	.13	.44
EXPERIENCE	24	25	22	25
WORKOFF	30	41	54	62
TENURE	.36	.37	.58	.39
ACRES	1631	921	466	958
ROTATION	.56	.84	.75	.82
ROWCROP	.84	.98	.83	.96
GRAIN	.16	.06	.32	.06
DBL-CROP	.05	.01	.05	.02
MANURE	.09	.19	.70	.10
IRRIGATION	.27	.02	.02	.00
COMPLY	.18	.13	.13	.11
CVPLAN	.55	.55	.51	.44
INSURE	.43	.65	.05	.18
WATERBODY	.43	.35	.18	.39
SLP	117	91	100	111
PISOIL	.81	.95	.69	.91
EROTON	32	26	54	24
RAIN	3.1	3.0	3.5	3.4
TEMP	55	50	51	52
Number of observations:	5746	1228	266	686

Refer to Chapter 2 for variable definitions and units.

Figure 5.6 shows tillage practice adoption by area, and figure 5.7 presents adoption on highly erodible cropland. For all the regions combined, 10 percent of highly erodible cropland is cultivated using no-till systems. Highly erodible cropland in the Mississippi Embayment, and the Illinois/Iowa, Susquehanna, and White River Basins had the highest proportion of acres devoted to no-till systems. Only between 1 and 3 percent of the highly erodible cropland in the Mid-Columbia and Snake River Basins, and the Southern Georgia Coastal and High Plains regions were under no-till production. Conventional tillage was applied on about 80 percent of the highly erodible cropland in the Southern Georgia Coastal and the Southern High Plains regions. For the remaining regions, less than 50 percent of the highly erodible cropland was cultivated using conventional tillage.

The sample means for the combined-areas and single-area models are presented in table 5.5. A multinomial logit model was estimated to determine the factors that affect farmers' use of tillage practices. The model results, along with the significance level, from the adoption study of tillage practices for the combined- and single-area models are displayed in tables 5.6 and 5.7. The analysis of the results focuses more on the effect of the exogenous variables on use of no-till and conventional tillage, since the mulch- and ridge-till category is less clearly defined and the results may be less informative.

For all areas combined, about 11 percent of farmers reported using no-till, 34 percent used mulch- or ridge-till, and 55 percent used conventional tillage. The percent of correct predictions was 67, and the pseudo R^2 was 0.44. The regions analyzed for the tillage adoption models included the Illinois/Iowa, Susquehanna, and White River Basins. These regions were the only areas with a sufficient number of observations for the no-till and conservation tillage categories. Furthermore, some variables were not included in the single regional models due to limited numbers of observations, little variation in the observations, or a high degree of correlation between independent variables. The individual regional results are displayed in table 5.7.

Education and the number of days the operator worked off the farm did not have a significant effect on the choice of tillage practice in the combined model, but a college education had a positive influence on the use of no-till in the Susquehanna and White River Basins. The number of days that an agricultural producer worked off-farm increased the probability of no-till adoption in the Illinois/Iowa Basins and mulch- or ridge-till in the Susquehanna River Basin. Land tenure, and to some degree, years of experience did have an effect on farmers' use of these tillage practices. Farmers who owned their land were more likely to use conventional tillage and less likely to use mulch- or ridge-till in the combined area and the White River Basin. Similar results were also observed in the models estimating adoption of *any* soil conservation practice. These results indicate that farm ownership is not a significant impediment for the adoption of conservation tillage systems. Farmers with many years of experience in farming were more likely to use mulch- or ridge-till in the combined sample and the White River Basin. Crop insurance had no impact on tillage choice except in the Illinois/Iowa Basin where farmers who had crop insurance were more likely to use no-till than those without crop insurance.

Table 5.6--Change in percent predicted adoption of tillage practices: Combined-areas model

Variables	No-till	Mulch-till/ ridge-till	Conventional tillage
CONSTANT	-2.0874**	-2.4508**	4.5382**
COLLEGE	0.0044	0.0170	-0.0214
EXPERIENCE	-0.0088	0.0266**	-0.0179
WORKOFF	0.0026*	-0.0001	-0.0025
TENURE	-0.0088	-0.0300**	0.0388**
ACRES	0.0155**	0.0295**	-0.0450**
ROTATION	0.0347**	0.0496**	-0.0843**
ROWCROP	-0.0443**	0.0401	0.0043
GRAIN	-0.0237	0.0620**	-0.0383
DBL-CROP	0.0483**	-0.0574	0.0091
MANURE	0.0242*	-0.0012	-0.0229
IRRIGATION	-0.0411**	0.0596**	-0.0185
COMPLY	0.0488**	0.0046	-0.0534**
CVPLAN	0.0364**	0.0118	-0.0482**
INSURE	0.0065	-0.0025	-0.0040
WATERBODY	-0.0035	0.0185	-0.0150
SLP	-0.0005	-0.0080	0.0085
PISOIL	0.0348	0.0435	-0.0783*
EROTON	0.0059	0.0084	-0.0143*
RAIN	0.1833**	-0.1067	-0.0767
TEMP	0.4155**	0.5553**	-0.9708**
% predicted adoption	9.4	30.2	60.3
Number of observations		5746	
% correct predictions		67	
Pseudo R^2 [1]		.44	

** Significant at the 5-percent level.
* Significant at the 10-percent level.
[1] Veall and Zimmerman's pseudo R^2.

Note: For the table, the coefficients estimated from the limited dependent model have been converted into change in percent predicted adoption. For continuous variables (EXPERIENCE, WORKOFF, ACRES, SLP, PISOIL, EROTON, RKLS, WIND, RAIN AND TEMP), the reported value is the change in the percent predicted adoption given a 1-percent change in the variable mean. For binomial variables that have a value of either 0 (no) or 1 (yes), the reported value indicates the change in the percent predicted adoption with a unit change of 0.01 from the variable mean. See Appendixes 2-A and 2-B for further details.

The number of acres that a farmer operated had a significant and positive influence on the adoption of conservation tillage practices in all areas except the White River Basin. Farmers cultivating a large number of acres were more likely to use no-till or mulch- or ridge-till than those producing on few acres, and were less likely to use conventional tillage. As shown in table 5.3, 12.2 percent of farmers who cultivated at least 5,000 acres used no-till, compared with 8.6 percent of farmers who cultivated 500 acres or less in the combined sample.

The effect of cropping practices on tillage use varied, depending on the region. Only in the Illinois/Iowa Basins and combined-areas models did the probability of a farmer's use of no-till increase if the farmer was using crop rotations for pest or nutrient management. Agricultural producers in the Illinois/Iowa Basins were less likely to adopt no-till and more likely to adopt conventional tillage if they were cultivating grain. An unexpected result in the combined-area model was that farmers who cultivated row crops were less likely to adopt no-till and those who cultivated a grain were more likely to use mulch- or ridge-till. Producers may choose to not cultivate highly erosive crops and to use no-till simultaneously. Farmers who double-cropped had a higher probability of using no-till systems than those who mono-cropped. Bull and Sandretto (1996) also found that there was extensive use of no-till with double-cropping since no-till may reduce moisture loss from seedbeds as well as provide more flexible timing as to when to plant the second crop.

Whether or not a farmer applied manure to the field had differing impacts on the farmer's use of conservation tillage. In the Illinois/Iowa River Basins, manure applications increased the likelihood of no-till use.

However, in the White River Basin, farmers who applied manure were less likely to adopt no-till. Irrigators were less likely than nonirrigators to adopt no-till and more likely to use mulch- or ridge-till. Overall, the irrigated regions covered by the Area Studies survey did not have high use of no-till. One reason is that farmers may find it infeasible to apply no-till on cropland in conjunction with certain types of irrigation technologies.

Conservation compliance and technical assistance were important in encouraging the use of no-till. Table 5.3 illustrates how the adoption rate is expected to change with changes in conservation compliance and the development of a conservation plan for the combined sample. Predicted use of no-till by farmers who were subject to conservation compliance was 14.3 percent, compared with 8.6 percent by farmers not subject to compliance. Farmers who developed a conservation plan had a higher predicted no-till adoption rate than those who did not develop a conservation plan, 11.2 and 7.6 percent, respectively. Of the two policies, conservation compliance had the greater impact on no-till adoption. Farmers subject to conservation compliance were more likely to use no-till systems in the White River Basin, and less likely to use conventional tillage in the Illinois/Iowa and Susquehanna River Basins. The Susquehanna River Basin was the only region where having a conservation plan had no impact on farmers' use of tillage practices.

Natural resource characteristics played a very small role in influencing a farmer's choice of tillage practices. Field location near a water body and soil leaching potential had no effect on the choice of tillage practices, except in the White River Basin. Highly productive soils in the Susquehanna River Basin discouraged use of conventional tillage.

Table 5.7—Change in percent predicted adoption of tillage practices: Single-area models

	Illinois/Iowa River Basins			Susquehanna River Basin			White River Basin		
Variables	No-till	Mulch-till/ ridge-till	Conventional tillage	No-till	Mulch-till/ ridge-till	Conventional tillage	No-till	Mulch-till/ ridge-till	Conventional tillage
CONSTANT	-2.0393**	0.2604	1.7789**	0.6399	-1.1526	0.5127	0.0340	-1.4394**	1.0990*
COLLEGE	-0.0127	0.0372	-0.0246	0.1677**	-0.0680	-0.0997	0.0817**	-0.0531	-0.0286
EXPERIENCE	-0.0214	0.0325	-0.0112	0.0196	0.0700	-0.0896*	-0.0195	0.1044**	-0.0849**
WORKOFF	0.0156**	-0.0090	-0.0066	-0.0314*	0.0513**	-0.0199	0.0033	-0.0127	0.0093
TENURE	-0.0125	-0.0082	0.0209	-0.0866	-0.0009	0.0875	0.0028	-0.1007**	0.0979**
ACRES	0.0530**	0.0211	-0.0741**	0.0676**	0.1179**	-0.1855**	0.0144	0.0259	-0.0403*
ROTATION	0.0685**	-0.0387	-0.0299	0.0874	-0.1642**	0.0767	-0.0597*	0.1192**	-0.0595
GRAIN	-0.1153**	0.0107	0.1046**	0.0961*	-0.2814**	0.1853	0.0383	-0.1312	0.0929
MANURE	0.0674**	-0.0554	-0.0121	-0.0258	0.1694**	-0.1436*	-0.1301**	0.0379	0.0923
COMPLY	0.0294	0.0610	-0.0904**	0.0707	0.1968*	-0.2675**	0.1184**	-0.0607	-0.0577
CVPLAN	0.0851**	-0.0065	-0.0785**	0.0526	0.0210	-0.0736	0.0887**	-0.0477	-0.0411
INSURE	0.0607**	-0.0312	-0.0295	—	—	—	0.0466	0.0334	-0.0801
WATERBODY	-0.0114	0.0362	-0.0248	-0.0077	-0.0461	0.0538	0.0257	0.0615	-0.0873**
SLP	0.0621	-0.0403	-0.0218	-0.0914	-0.1088	0.2002	0.0584	0.2077**	-0.2661**
PISOIL	0.1331	-0.1836	0.0505	0.0930	0.2073	-0.3003**	-0.2137	-0.1758	0.3895
EROTON	—	—	—	0.0074	-0.0828**	0.0753*	0.0011	0.0177	-0.0182
RAIN	1.1606**	0.0648	-1.2254**	-1.0202	0.2297	0.7905	-0.3300	0.7604*	-0.4304
% predicted adoption	16.5	65.4	18.1	16.3	33.9	49.9	13.6	41.6	44.8
Number of observations		1228			266			686	
% correct predictions		60			63			52	
Pseudo R^2 [1]		.22			.40			.21	

— Variable not included in the adoption model.
** Significant at the 5-percent level.
* Significant at the 10-percentlevel.
[1] Veall and Zimmerman's pseudo R^2.

Note: For the table, the coefficients estimated from the limited dependent model have been converted into change in percent predicted adoption. For continuous variables (EXPERIENCE, WORKOFF, ACRES, SLP, PISOIL, EROTON, RKLS, WIND, RAIN AND TEMP), the reported value is the change in the percent predicted adoption given a 1-percent change in the variable mean. For binomial variables that have a value of either 0 (no) or 1 (yes), the reported value indicates the change in the percent predicted adoption with a unit change of 0.01 from the variable mean. See Appendixes 2-A and 2-B for further details.

Temperature had a larger and more significant impact on tillage adoption decisions than rainfall in the combined-areas model. High average monthly temperatures and rainfall significantly encouraged use of no-till practices. However, high temperatures also increased the probability of adopting other conservation tillage methods and discouraged the adoption of conventional tillage. In the single-area models, climate influenced tillage adoption only in the Illinois/Iowa River Basins, where high levels of average rainfall encouraged the use of no-till and discouraged the use of conventional tillage systems.

Summary

The results from the combined-areas and single-area models varied depending on the region and/or soil conservation practice examined in the estimation. The human capital of a farmer (measured by education and experience), overall, did not have a significant influence on the use of soil conservation practices. Human capital did affect a farmer's use of tillage practices, however. Farmers who owned their land were less likely to adopt soil conservation practices for the combined areas, but was only statistically significant in 2 of the 8 individual areas we analyzed. This implies that landowners were no more likely to adopt soil-conserving practices than renters in the areas surveyed. This was particularly true for the use of conservation tillage practices. Since, however, the tenure question was asked with respect to only the field, the data probably do not support an adequate test of hypotheses about ownership and adoption.

Farm size and cropping practices affected the probability of a farmer's use of soil conservation and tillage practices. Larger farm sizes increased the probability that a farmer would adopt soil conservation practices. However, farm size was not a significant factor in determining adoption in regions that have larger farm sizes on average. Although farmers who operated larger farms were positively associated with no-till adoption, the regions that had a sufficient number of no-till observations for modeling adoption were those with low average farm sizes compared with other regions. Cropping practices, especially crop type and the use of crop rotations, were significant determinants of farmers' use of soil conservation practices. Climate also affected farmers' use of soil conservation practices. Higher average monthly rainfall and temperature levels were positively associated with soil conservation and tillage practices in many instances.

The strongest results were obtained for the influence of agricultural policies. Conservation compliance and technical assistance were positively associated with farmers' use of soil conservation and tillage practices, particularly for those practices with primarily off-site benefits. The likelihood of adoption was determined more by these factors than by natural resource characteristics. Natural resource endowments seemed to be more important in predicting the adoption of water quality practices than for *any* soil conservation or tillage practice.

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