7. Adoption Impacts on Crop Yields and Chemical Use

In this chapter, we use individual cases from the Area Studies survey data to study the impact of technology adoption on crop yields and chemical use. The case study approach was necessary because results vary widely among crops, locations, and technologies so that an aggregate analysis was not feasible. The analysis is not comprehensive or exhaustive, but rather is offered to provide insights into the types of investigations that can be performed within a given framework.

The following section describes the econometric framework used to assess the impact of technology adoption on yields and chemical input use. The rest of the chapter describes the results of the models of pest, nutrient, soil, and irrigation management adoption impacts.

Econometric Framework

The effects of technology use on use of chemicals and productivity are difficult to assess because we observe farm production in a single time period only. Ideally, we would like information about farm production, economic conditions, and policies both before and after technology adoption in order to measure the causes and effects of technology use. Using only a single observation in time, we measure these factors by comparing adopters to nonadopters, which introduces a potential for errors because of *sample self-selection bias*, i.e., the sample of adopters is not random, farmers who use new technology may differ in systematic ways from farmers who do not. A simple comparison of agricultural chemical use among adopters and nonadopters may not reveal the full effects of technology choice.

Consider an example of self-selection bias. If the sample includes farms located in a microenvironment with unusually severe and common pest outbreaks, farmers there might apply above average amounts of pesticides to control these outbreaks. Because of their high pesticide costs, the farmers may use alternative pest-management strategies, such as integrated pest management (IPM). These producers can be expected to have an above-average rate of IPM adoption. Although IPM adoption might decrease their pesticide applications, they might use more pesticides than does an average farmer outside the microenvironment. If resource variables fail to include a microenvironment's climate conditions, then a correlation of IPM adoption and increased pesticide use is incorrect. IPM adopters, on average, use more pesticides than do nonadopters, although IPM use may reduce pesticide applications by farmers in the microenvironment.

The econometric approach deals with the self-selection problem with a model of the adoption decision and the input demand and crop supply decisions in a recursive framework (Fuglie and Bosch, 1995; Maddala, 1983). This approach takes into account possible systematic differences between adopters and nonadopters in order to evaluate the effects of technology adoption on input use and crop yield. Appendix 7-A provides details of the binomial and multinomial models that we used in the analysis. In order to correct for the possibility of simultaneous adoption and input decisions, the predicted value of adoption obtained from the logit estimation is used as an instrumental variable in the OLS estimations of input use and yield.

Results of the estimations presented as elasticities allow intuitive interpretations (see appendix 7-B for a full description). For example, the elasticity e_{YM} represents the percent change in yield, Y, resulting from a 1-percent change in the probability of adoption, M. Factors that affect both adoption and input use/yield are assessed also with the elasticity concept. The factor can affect input use/yield both directly and indirectly through a change in the probability of adoption. For example, suppose that large farms use chemical inputs more intensively and are more likely to adopt new technology than are small farms other things being equal. The total effect of an increase in farm size on chemical input use is the sum of these two effects: the direct effect (measured by the coefficient of the farm-size variable in the input demand equation) and the indirect effect through technology adoption (the product of the effect of farm size on technology adoption and of technology adoption on input demand). If new technology reduced chemical use, then the direct effect of an increase in farm size is increased chemical use. The indirect effect of technology adoption is to reduce chemical use. The net effect of an increase in farm size on chemical input use depends on which effect is the larger of the two.

Input demand and crop yield were modeled as functions of farmers' characteristics, cropping practices, policy attributes, resource endowments, and technology adoption.[1] Pesticide demand was quantified as pounds of active ingredients per acre, a crude measure of pesticide use since it does not incorporate persistence in and risk to the environment. However, the amount of active ingredients applied does provide some indication of potential risks associated with increased use. Finally, nitrogen applications were measured in pounds per acre, and crop yields were measured in pounds per acre harvested. All variables used in the model are defined in chapter 2 and summarized in table 2.2.

Effects of Soil Conservation Practices on Chemical Use and Crop Yield

The use of soil conservation practices has been promoted to reduce erosion and decrease the movement of chemicals into waterways. However, some of these same practices may also increase the use of chemicals. For example, crop residue management systems, such as no-till, may increase insect and weed infestations, which might lead to a rise in pesticide applications. It has been argued, however, that chemical use may increase only in the short term and might decrease over time as producers become accustomed to a new soil management system.

We analyzed two case studies about technology adoption decisions and how soil conservation practices affected chemical applications and crop yields. Data limitations precluded analysis across all areas and crops. The first case study assesses how the adoption of tillage practices by soybean producers affects input demand and crop yield in the Albemarle-Pamlico Drainage, Southern Georgia Coastal Plain, Illinois/Iowa River Basins, Mississippi Embayment, and Central Nebraska River Basins.[2] The second case study examines soil conservation practices used to protect water quality by corn producers in the Central Nebraska, Illinois/Iowa, and White River Basins. Since pesticide and nutrient requirements are often crop-specific, the case studies were divided by crop in order to highlight differences in chemical demand and crop productivity among crops.

Soybeans in the Albemarle-Pamlico Drainage, Southern Georgia Coastal Plain, Illinois/Iowa River Basins, Mississippi Embayment, and Central Nebraska River Basins

Table 7.1 presents the sample means and the number of observations for soybean producers in the Albemarle-Pamlico Drainage, Southern Georgia Coastal Plain, Illinois/Iowa River Basins, Mississippi Embayment, and Central Nebraska River Basins. The change in percent predicted adoption is presented in table 7.2. Producers were separated into three adoption categories; 1) producers who used a no-till system; 2) producers who used other conservation tillage systems; and 3) producers who used conventional tillage systems. Of the chosen sample of soybean producers, 15 percent practiced no-till, 34 percent used

Table 7.1—Sample means from tillage adoption models for soybean producers in Albemarle-Pamlico Drainage, Southern Georgia Coastal Plain, Illinois/Iowa River Basins, Mississippi Embayment, and Central Nebraska River Basins

Variables	Means
NO-TILL	.15
MULCH- or RIDGE-TILL	.34
CONVENTIONAL TILLAGE	.51
COLLEGE	.42
EXPERIENCE	24
WORKOFF	33
TENURE	.32
ACRES	1532
ROTATION	.66
MANURE	.08
IRRIGATION	.18
COMPLY	.09
CVPLAN	.44
INSURE	.36
WATERBODY	.53
SLP	105
PISOIL	.84
EROTON	21
RAIN	3.5
TEMP	55
Number of observations	1683

[1] Area dummy variables were included in the model to account for regional variations, such as differences in prices, policies, incremental weather conditions, or pest infestation levels that may not be covered by the explanatory variables. The results were not presented in the tables, because regional coefficients are meaningful only if compared to the reference region.

[2] Fuglie (1999) analyzed the adoption of tillage practices for corn in the Corn Belt areas of the Area Studies survey area. He looked at the effects of tillage adoption on pesticide and fertilizer use and on crop yields. The results were so similar to what would have been presented here, we will not describe our analysis but will report Fuglie's results in the discussion.

either mulch- or ridge-till, and 51 percent used conventional tillage methods.

The results of the adoption models are generally consistent with those obtained from the tillage choice model reported in chapter 5 (see table 5.6). Soybean producers with larger farm size had a significantly higher probability of using no-till practices and had a lower probability of using conventional tillage systems than smaller-acreage farms. Conservation policies significantly fostered the use of no-till systems and discouraged the use of conventional tillage methods. Producers who were subject to conservation compliance or received technical assistance had a higher probability of using no-till and a lower probability of using conventional-tillage methods. At higher erosion levels, however, the probability of no-till use decreased for soybeans. We have no direct, empirical evidence about the cause of that result.

Table 7.2—Predicted adoption by tillage practice for soybean producers in Albemarle-Pamlico Drainage, Southern Georgia Coastal Plain, Illinois/Iowa River Basins, Mississippi Embayment, and Central Nebraska River Basins

Variables	No-till	Mulch-till/ ridge-till	Conventional tillage
CONSTANT	-1.7831	-6.4993**	8.2824**
COLLEGE	0.0005	-0.0253	0.0248
EXPERIENCE	-0.0611**	0.0054	0.0557*
WORKOFF	0.0029	-0.0007	-0.0021
TENURE	-0.0039	-0.0410	0.0449
ACRES	0.0392**	0.0013	-0.0405**
ROTATION	-0.0681**	0.0785**	-0.0103
MANURE	0.1048**	0.0477	-0.1524**
IRRIGATION	-0.0399	0.1432**	-0.1032**
COMPLY	0.1297**	0.0139	-0.1436**
CVPLAN	0.0985**	0.0009	-0.0994**
INSURE	0.0049	-0.0165	0.0116
WATERBODY	-0.0267	0.0349	-0.0082
SLP	0.0163	0.0439	-0.0602
PISOIL	0.0049	-0.0321	0.0272
EROTON	-0.0225**	0.0026	0.0199
RAIN	0.9723**	-0.6869	-0.2854
TEMP	0.0638	1.8451**	-1.9090*
Mean of dependent variable	0.15	0.34	0.51
Percent predicted adoption	15.5	30.1	54.4
Percent correct predictions		66	
Pseudo R^2 [1]		0.49	

* Significant at the 10-percent level.
** Significant at the 5-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 adoption results were used in the second modeling stage to assess the effects of technology choice on chemical input use and yield. The estimates of input demand and crop yield effects for soybean producers and the R^2 from the models are presented in table 7.3. The elasticity estimates are presented in table 7.4, and they show the percent change in the dependent variable given a 1-percent change in the mean of the regressors. The probability of no-till adoption was the reference variable for the mulch- and ridge-till and conventional tillage variables.

Model results indicate that the tillage practice used did not have a significant effect on the amount of herbicides applied by soybean producers. Fuglie (1999)

Table 7.3—Estimates of input demand and crop yield effects for soybean producers in Albemarle-Pamlico Drainage, Southern Georgia Coastal Plain, Illinois/Iowa River Basins, Mississippi Embayment, and Central Nebraska River Basins—Tillage adoption

Variables	Herbicide use	Crop yield
	lbs/acre	
CONSTANT	-0.7967	4507.7**
COLLEGE	0.0994**	35.111
EXPERIENCE	0.0002	-2.4879*
WORKOFF	-0.0005	-0.6302**
TENURE	-0.0206	6.2437
ACRES	0.0181	71.621**
ROTATION	0.0785	160.90**
DBL_CROP	—	-164.71**
IRRIGATION	—	292.89**
ADVICE/INFO	0.0700	—
PROGRAM	0.0400	-40.883
INSURE	-0.0510	-68.206**
WATERBODY	0.0692	13.317
SLP	0.0004	-0.4516
PISOIL	0.3464*	559.40**
EROTON	-0.0015**	-2.7373**
RAIN	1.2489**	44.797
TEMP	—	-58.132**
PROB(CONSERVATION)	-0.1110	115.67
PROB(CONVENTIONAL)	-0.0894	-156.47
Mean of dependent	1.11	2174
Adjusted R^2	0.019	0.467

* Significant at the 10-percent level.
** Significant at the 5-percent level.

found, however, that the increased probability of no-till use by corn producers actually reduced herbicide applications. In our model, high erosion rates were associated with decreased herbicide applications. Conversely, herbicide applications were elevated in higher rainfall areas.

The choice of tillage practice also had no significant effect on crop yields for soybean producers in the Area Studies sample, but the probability of adopting a conservation tillage method had a negative effect on corn yields in the Fuglie model. The greater the years of experience and the greater number of days a producer worked off the farm were associated with decreased soybean yields per acre. Farm size and cropping practices also had a significant effect on soybean yields. Producers who operated larger farms, rotated crops, or irrigated the field had significantly higher crop yields. On the other hand, producers who double-cropped experienced lower yields. Yields were also less for producers with crop insurance.

Crop productivity varied depending on natural resource endowments of the field and weather conditions. Soil quality had a large influence on soybean yields. The elasticity estimates in table 7.4 show that soybean yields increased about 0.22 percent given a 1-percent change in the soil productivity index. Furthermore, increased erosion levels on the field had a negative effect on crop productivity. This result provides evidence that soil quality can be diminished when erosion depletes productive top soil. High temperatures were also associated with decreased productivity. A 1-percent increase in temperature led to a 1.5 percent decrease in crop yields.

Table 7.4—Elasticity estimates for soybean producers in Albemarle-Pamlico Drainage, Southern Georgia Coastal Plain, Illinois/Iowa River Basins, Mississippi Embayment, and Central Nebraska River Basins—Tillage adoption

	Adoption model			Chemical input use and crop productivity models	
Variables	No-till	Conservation tillage	Conventional tillage	Herbicide use	Crop yields
				- - - - lbs/acre - - - -	
CONSTANT	-11.93	-18.94**	16.32**	-0.7181	2.074**
COLLEGE	0.0014	-0.0309	0.0205	0.0375**	0.0068
EXPERIENCE	-0.4091**	0.0157	0.1098*	0.0042	-0.0269*
WORKOFF	0.0191	-0.0021	-0.0042	-0.0134	-0.0094**
TENURE	-0.0084	-0.0381	0.0282	-0.0059	0.0009
ACRES	0.2624**	0.0039	-0.0799**	0.0163	0.0329**
ROTATION	-0.3022**	0.1515**	-0.0135	0.0469	0.0490**
DBL_CROP	—	—	—	—	-0.0067**
MANURE	0.0565**	0.0112	-0.0242**	—	—
IRRIGATION	-0.0946	0.0538**	-0.0085**	—	0.0241**
ADVICE/INFO	—	—	—	0.0264	—
COMPLY	-0.0477**	0.0744	-0.0363**	—	—
CVPLAN	0.0330**	-0.0936	0.0536**	—	—
PROGRAM	—	—	—	0.0301	-0.0158
INSURE	0.1088	0.1280	-0.1186	-0.0164	-0.0113**
WATERBODY	-0.1506	0.0075	0.0392	0.0330	0.0032
SLP	0.0812	0.0038	-0.0265	0.0342	-0.0217
PISOIL	0.2877	0.0012	-0.0855	0.2608*	0.2163**
EROTON	-0.0117**	-0.0172	0.0082	-0.0294**	-0.0269**
RAIN	6.5083**	-2.0019	-0.5624	1.1257**	0.0729
TEMP	0.4273	5.3777**	-3.7616**	—	-1.475**
PROB(CONSERVATION)	—	—	—	-0.0343	0.0185
PROB(CONVENTIONAL)	—	—	—	-0.0409	-0.0362

* Significant at the 10-percent level. ** Significant at the 5-percent level.

Note: Elasticities represent a percent change in the dependent variable given a 1-percent change in the mean of the explanatory variable.

Corn in the Illinois/Iowa, Central Nebraska, and White River Basins

Table 7.5 presents the sample means and the number of observations for corn producers in the Illinois/Iowa, Central Nebraska and White River Basins. The change in percent predicted adoption is presented in table 7.6, and elasticity estimates for the adoption model are displayed in table 7.8. The category of soil management practices assessed in this section include those designed primarily to prevent soil from entering waterways once sediment has left a field. This category and the motivation behind its choice are described in chapter 5.[3]

The results of the adoption model show no significant effects associated with any of the human capital variables. The probability of adoption was significantly less for producers who operated larger farms, however. This result differs from results shown in table 5.4, which included all crops and areas. Producers who practiced crop rotations were more likely to use water quality protection practices, whereas irrigators were less likely to use water quality practices.

[3] Water quality protection practices include grassed waterways, filter strips, grade stabilization structures, and critical area planting.

Table 7.5 - Sample means from water quality practices adoption models for corn producers in Illinois/Iowa, Central Nebraska, and White River Basins regions

Variables	Means
WATER QUALITY PRACTICE	.37
COLLEGE	.40
EXPERIENCE	24
WORKOFF	40
TENURE	.39
ACRES	995
ROTATION	.68
MANURE	.18
IRRIGATION	.18
COMPLY	.15
CVPLAN	.53
INSURE	.59
WATERBODY	.34
SLP	103
PISOIL	.92
EROTON	31
RAIN	2.8
TEMP	50
Number of observations	1518

Conservation policies significantly increased the probability of adoption of water quality practices. The elasticity estimates from table 7.8 show that the probability of adoption increased about 0.06 for producers who were subject to conservation compliance compared to those who were not subject. Producers who received technical assistance show a greater increase in the adoption probability, about 0.26, compared to those who did not seek assistance in developing a conservation plan.

The location of the field, soil quality, and weather conditions were significant determinants in corn producers' decisions to adopt water quality practices.

Table 7.6—Change in percent predicted adoption of soil conservation practices to protect water quality for corn producers in Illinois/Iowa, Central Nebraska, and White River Basins Regions

Variables	Water quality practices
CONSTANT	0.7344**
COLLEGE	0.0422
EXPERIENCE	-0.0497*
WORKOFF	0.0040
TENURE	0.0318
ACRES	-0.0348**
ROTATION	0.1012**
MANURE	0.0264
IRRIGATION	-0.1283**
COMPLY	0.1401**
CVPLAN	0.1786**
INSURE	0.0047
WATERBODY	0.0743**
SLP	0.0658
PISOIL	0.3985**
EROTON	0.0175
RAIN	1.3290**
TEMP	-3.0427**
Percent predicted adoption	34.4
Percent correct predictions	69.8
Pseudo R^2 [1]	0.23

* Significant at the 10-percent level.
** Significant at the 5-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.

Producers who had fields near a lake or a stream (WATERBODY) were more likely to use water quality practices. Additionally, water quality practices were more often adopted on fields with higher soil quality. These results indicate that producers with high-quality soil and fields near a water body may be applying intensive measures both to maintain soil quality and to protect water quality.

Table 7.7 displays the estimates of input demand and crop-yield effects for corn producers. The elasticity estimates are shown in table 7.8. The factors that determined herbicide applications differed from the factors that affected insecticide use. Insecticide applications by farmers who used more intensive soil conservation efforts was 0.44 pounds of active ingredients per acre higher than those who did not use these practices. Herbicide applications, however, were not affected by use of water-quality protection practices.

Results from the herbicide-use model indicate that increased amounts of herbicides were applied by producers who operated a greater number of acres, received pest management advice, had crop insurance, or were located in areas with higher rainfall levels. Producers with more experience used lower quantities of herbicides.

Although producers used less insecticide if they used crop rotations for pest management than did producers who grew corn continuously, the total effect of crop rotations on insecticide use depends on the influence of this variable on adoption decisions as well.[4] The

[4] Determining the total effect of a variable on input demand or crop yield, given its effect on technology adoption decisions, makes sense only if the variables used to calculate total effects are significant.

Table 7.7—Estimates of input demand and crop yield effects for corn producers in the Central Nebraska, Illinois/Iowa and White River Basins Regions — Adoption of soil conservation practices to protect water quality

Variables	Herbicide use	Insecticide use	Nitrogen use	Crop yields
			lbs/acre	
CONSTANT	2.1521*	-0.8010**	-173.28**	-1324.2
COLLEGE	0.0126	0.0032	3.5823	328.05**
EXPERIENCE	-0.0063**	0.0006	0.0402	-2.6869
WORKOFF	-0.0006	-0.0002	0.0062	-1.8951**
TENURE	0.0256	0.0022	-10.383**	67.262
ACRES	0.1632**	0.0858	0.0034**	144.40**
ROTATION	-0.0050	-0.2482**	-6.6337*	380.93**
IRRIGATION	0.2166	0.1335**	43.763**	2991.7**
ADVICE	0.1580**	0.0192	0.1833	—
PROGRAM	0.1154	-0.0364	7.3854*	150.43
INSURE	0.3033**	0.0237	-0.3360	232.32**
WATERBODY	-0.0424	-0.0395*	-8.4738**	-85.228
SLP	-0.0011	0.0008*	0.0969	-4.6321**
PISOIL	-0.0091	0.2213**	27.450**	1469.2**
EROTON	-0.0015	-0.0002	-0.1706**	-3.7653**
RAIN	0.8027**	-0.1334	7.4449	-1451.8**
TEMP	-0.0567	0.0122	5.0659**	194.38**
PROB(WATER)	0.3310	0.4401**	0.5396	-625.45
Mean of dependent variable	2.72	0.23	127.58	7799.2
Adjusted R^2	0.216	0.089[1]	0.151	0.449

* Significant at the 10-percent level.
** Significant at the 5-percent level.

[1] Adjusted R^2 for insecticide use model is from the OLS estimation.
Note: The coefficients estimated from both the insecticide use and yield equations have been converted to the change in insecticide use or yields. For continuous variables (EXPERIENCE, WORKOFF, ACRES, SLP, PISOIL, EROTON, and TEMP), the reported value is the change in insecticide use or yields 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 insecticide use or yields with a unit change of 0.01 from the variable mean. See Appendixes 7-A and 7-B for further details.

elasticities in table 7.8 show that the *direct* effect of a 1-percent increase in the use of crop rotations is to decrease insecticide use by 0.7185 percent. Also, it is shown that the effect of a 1-percent increase in rotation increases the adoption of water-quality practices by 0.1865 percent, while a 1-percent increase in the adoption of these practices increased insecticide use by 0.6916 percent. Hence, the *indirect* effect of crop rotations on insecticide applications would be (0.1865)*(0.6916), or 0.1290 percent. Therefore, the total factor effect of a 1-percent increase in the use of crop rotations on insecticide use would be (0.1290) + (-0.7185), or -0.5895 percent. In this case, incorporating the indirect effect of crop rotations on insecticide use reduced the magnitude of the effect.

Nitrogen applications by corn producers in the sample averaged about 128 pounds per acre. While many factors had a significant influence on nitrogen use, the adoption of water-quality protection practices did not significantly affect the amount of nitrogen applied.

Nitrogen use was significantly greater for producers who operated more acres. Cropping practices were also significant factors in determining nitrogen applications. Irrigation use was positively correlated with nitrogen use.

Nitrogen applications were also dependent on the location of the field, soil quality, and weather conditions. Fields adjacent to a water body received significantly less nitrogen, about 8.5 pounds per acre less (table 7.7), than fields that were not near a lake or stream. This result is encouraging, since it is important to protect water quality by reducing nutrient contamination of waterways. Producers using soil conservation practices to protect water quality may reside in regions where water quality improvement is a priority, or they may be more attentive to water quality problems in general. While higher soil productivity levels increased the amount of nitrogen used, higher soil erosion levels decreased nitrogen applications.

Table 7.8—Elasticity estimates for corn producers in the Central Nebraska, Illinois/Iowa, and White River Basins Regions — Adoption of soil conservation practices to protect water quality

	Adoption model	Chemical input use and crop productivity models			
Variables	Water quality practices	Herbicide use	Insecticide use	Nitrogen use	Crop yields
		lbs/acre			
CONSTANT	1.992**	0.7906*	-3.415**	-1.358**	-0.1698
COLLEGE	0.0453	0.0018	0.0054	0.0112	0.0166**
EXPERIENCE	-0.1348*	-0.0567**	0.0614	0.0077	-0.0084
WORKOFF	0.0109	-0.0084	-0.0271	0.0019	-0.0096**
TENURE	0.0335	0.0037	0.0037	-0.0316**	0.0034
ACRES	-0.0945**	0.0600**	0.5633	0.0270**	0.0185**
ROTATION	0.1865**	-0.0012	-0.7185**	-0.0355*	0.0332**
MANURE	0.0130	—	—	—	—
IRRIGATION	-0.0610**	0.0140	0.1000**	0.0601**	0.0672**
ADVICE	—	0.0281**	0.0398	0.0004	—
COMPLY	0.0582**	—	—	—	—
CVPLAN	0.2574**	—	—	—	—
PROGRAM	—	0.0354	-0.1293	0.0483*	0.0161
INSURE	0.0076	0.0662**	0.0599	-0.0016	0.0178**
WATERBODY	0.0684**	-0.0053	-0.0571*	-0.0226**	-0.0037
SLP	0.1783	-0.0423	0.3726*	0.0780	-0.0611**
PISOIL	1.081**	-0.0031	0.8687**	0.1985**	0.1734**
EROTON	0.0474	-0.0178	-0.0266	-0.0419**	-0.0152**
RAIN	3.606**	0.8233**	-1.588	0.1629	-0.5198**
TEMP	-8.255**	-1.036	2.581	1.974**	1.239**
PROB(WATER)	—	0.0448	0.6916**	0.0016	-0.0296

* Significant at the 10-percent level.
** Significant at the 5-percent level.

Note: Elasticities represent a percent change in the dependent variable given a 1-percent change in the mean of the explanatory variable.

As we expected, the use of water-quality protection practices did not significantly affect corn yields. However, other factors did have a significant effect. Producers with some college education had higher crop yields than those with no college education. Larger farms were also associated with higher yields. Producers who worked more days off the farm experienced yield declines. Cropping practices also affected crop productivity. Producers who used crop rotations for pest management or used irrigation technology had significantly higher yields. The same was true for producers who obtained crop insurance.

Finally, as expected, crop productivity depended greatly on soil quality and weather conditions. High levels of soil productivity and temperature were correlated with increased corn yields. Conversely, yields were significantly lower for producers who had high soil-leaching potential, erosion levels, or rainfall levels.

Effects of Pest Management Adoption on Chemical Use and Crop Yields

Pest management practices may have a significant effect on chemical use and crop yields. One of our underlying hypotheses is that producers who adopt nonchemical pest management practices have lower costs because of less use of synthetic chemicals such as pesticides. Producers may have an incentive to adopt nonchemical pest management practices if they expect an increase in the quantity or quality of output. Many studies have shown significant increases in yields for farmers who adopt pest management practices such as scouting, or using beneficial insects, or who destroy crop residues (Adkinsson et al., 1981; Frisbie et al.,1976; Masud et al., 1981; and Napit et al., 1988).

The analysis in this section examines two case studies about the effects of nonchemical pest management use decisions on chemical use and crop yields. Most farmers implement pest management strategies to target a specific commodity with specific pests. In addition, chemical requirements are often crop-specific. Therefore, the case studies we present are commodity-specific.

The first case study investigates input demand and crop productivity of cotton producers in the Albemarle-Pamlico Drainage, Mississippi Embayment, Southern Georgia Coastal Plain, and Southern High Plains. We chose cotton to study because it requires intensive use of insecticides compared with other crops. Cotton is often plagued by the bollworm or the boll weevil. Practices such as scouting or biological controls may combat these pests without use of synthetic chemicals. The second case study examines corn producers in Central Nebraska, Illinois/Iowa, and White River Basins. Corn growers in general do not use as much insecticide as cotton growers, but corn rootworm is a primary pest problem for corn farmers. Practices that break up the rootworm's cycle, such as rotations, may be an effective control.

Cotton in the Albemarle-Pamlico Drainage, Mississippi Embayment, Southern Georgia Coastal Plain, and Southern High Plains

Table 7.9 presents the sample means and the number of observations for cotton producers in the Albemarle-Pamlico Drainage, Mississippi Embayment, Southern Georgia Coastal Plain, and Southern High Plains regions. The pest management practices chosen were the use of biological controls, scouting, destroying crop residues, and rotations. Each practice is described more fully in chapter 4. The adoption model results are presented in table 7.10. The results of the adoption models are consistent with those reported in chapter 4.

Table 7.9—Sample means from pest management adoption models for cotton growers in the Albemarle-Pamlico Drainage, Mississippi Embayment, Southern Georgia Coastal Plain, and Southern High Plains

Variables	Means
BIOLOGIC	.23
SCOUTING	.51
DESTROY_RES	.53
ROTATION	.18
COLLEGE	.51
EXPERIENCE	23
WORKOFF	19
TENURE	.28
ACRES	2170
DBL-CROP	.04
IRRIGATION	.37
PROGRAM	.95
INSURE	.50
ADVICE	.47
WATERBODY	.44
SLP	136
PISOIL	.73
EROTON	38
TEMP	60
Number of observations:	747

The results from the input demand equation for insecticide use are presented in table 7.11. Farmers with crop insurance applied significantly lower amounts of insecticides. Farmers with a higher soil-leaching potential apply more pounds of insecticides than do those with less leachable soils. Temperature also has a positive and significant effect on insecticide use. Warmer climates may be more prone to pest infestations, and therefore, farmers in these areas may apply more chemicals to control pest outbreaks.

Biological controls, crop residue destruction, and rotations had no significant effect on insecticide applications. Scouting, however, had a significant and positive effect on insecticide use, which is consistent with findings from other studies (Hatcher et al., 1984; Napit et al., 1988; Ferguson et al., 1993), and may indicate that monitoring pest populations per se is not a chemical-reducing activity.

The results from the yield equation for cotton growers are presented in table 7.11. Farmers who worked more days off the farm had significantly lower yields than farmers who spent more time working on the farm. On the other hand, farmers who owned the land, as

Table 7.10—Change in the percent predicted adoption of pest management practices for cotton growers in the Albemarle-Pamlico Drainage, Mississippi Embayment, Southern Georgia Coastal Plain, and Southern High Plains — Pest management practice adoption

Variables	Biological controls	Scouting	Destroying crop residues	Rotations
CONSTANT	-7.2499**	-1.5085	-7.4372**	1.4668
COLLEGE	0.0333	0.0991**	-0.0296	0.0154
EXPERIENCE	-0.0199	-0.0593	-0.0652	0.0119
WORKOFF	0.0012	-0.0020	0.0150**	0.0028
TENURE	-0.0208	-0.1184**	0.0087	0.0208
ACRES	0.0359**	0.1316**	-0.0500**	0.0263
DBL-CROP	-0.0784	0.1545	-0.3338**	0.0031
IRRIGATION	0.0151	0.1643**	-0.0656	0.1194**
PROGRAM	0.0006	0.0226	-0.0894	0.0393
INSURE	-0.0048	0.0854	0.0789	0.1052**
ADVICE	0.0774**	0.2563**	0.1701**	0.0693**
SLP	-0.0327	-0.5941**	0.1634	-0.0501
PISOIL	-0.0692	-0.0424	0.1034	-0.0070
EROTON	—	—	0.0133	—
TEMP	1.636**	0.1716	1.8289**	-0.5034
% predicted adoption	15.4	51.8	54.4	12.1
% correct predictions	79.9	73.0	69.1	87.8
Pseudo R^2 [1]	.39	.45	.24	.47

— Variable not included in the adoption model.
** Significant at the 5-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, 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.

Table 7.11—Estimates for insecticide use and crop yield effects for cotton in the Albemarle-Pamlico Drainage, Mississippi Embayment, Southern Georgia Coastal Plain, and Southern High Plains Regions — Pest management practice adoption

Variables	Insecticide use	Cotton yields
	lbs/acre	
CONSTANT	-40.9648**	538.674**
COLLEGE	-0.1778	-8.1721
EXPERIENCE	0.0447	0.0711
WORKOFF	0.0106	-8.2541**
TENURE	0.2011	78.2296**
ACRES	-0.2368*	5.2589
IRRIGATION	-0.3249	210.622**
INSURE	-0.6487**	-16.4720
ADVICE	-0.4849	67.6538**
WATERBODY	0.0102	—
SLP	2.1579**	-140.910**
PISOIL	0.4292	-58.2138
EROTON	0.0601	—
TEMP	9.4594**	—
PROB(BIOLOGIC)	0.2275	Insignificant[1]
PROB(SCOUTING)	1.9259**	Insignificant[1]
PROB(DESTROY_RES)	0.1891	Insignificant[1]
PROB(ROTATION)	0.2421	Insignificant[1]
Mean of dependent	1.1317	560

** Significant at the 5-percent level.
* Significant at the 10-percent level.

[1] The data were not sufficient to estimate a yield equation model combining the practices together, so the model was run separately for each practice. No coefficients on the practice variables were statistically significant.

Note: The coefficients estimated from both the insecticide use and yield equations have been converted to the change in insecticide use or yields. For continuous variables (EXPERIENCE, WORKOFF, ACRES, SLP, PISOIL, EROTON, and TEMP), the reported value is the change in insecticide use or yields 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 insecticide use or yields with a unit change of 0.01 from the variable mean. See Appendixes 7-A and 7-B for further details.

well as those who irrigated, were significantly more likely to have higher yields than renters or those who did not irrigate. The only natural resource variable that significantly affected yields was soil-leaching potential. The effect was negative, indicating that more leachable soils produced lower yields.

The results indicate that no chosen pest management practices had a significant effect on yields for cotton growers in the sample. The model elasticities (calculated at the means of the variables) are presented in table 7.12. Because elasticities are not scale-dependent, they provide a convenient way to compare the effects described in the model.

Corn in the Central Nebraska, Illinois/Iowa, and White River Basins

Table 7.13 presents the sample means and the number of observations for corn producers in the Central Nebraska, Iowa/Illinois, and White River Basins. Biological controls are not included in the analysis for corn because fewer than 3 percent of the corn farmers in these regions had adopted this practice. The results from the adoption models are presented in table 7.14.

The results from the input demand equation for insecticide use are presented in table 7.15. Farm ownership was positively and significantly associated with insecticide use, and farmers who irrigate apply more insecticides than those who do not irrigate. The natural resource variables of soil-leaching potential and soil productivity were also positively and significantly associated with insecticide use. Warmer temperature on the other hand, had a negative effect on insecticide use. This result may reflect some geographical differences of the regions that were not captured in the dummy variables.

Of the three pest management practices analyzed, only the destruction of crop residues had a significant effect on insecticide use. The coefficient on destroying crop residues is negative, indicating that farmers who have adopted this practice apply less insecticides than those who have not adopted the practice. This result is consistent with our a priori expectations that destroying crop residues may be an effective way to reduce chemical use.

The results from the yield equation also are presented in table 7.15. More highly educated farmers had higher yields, whereas those who worked more days off the farm had significantly lower yields. The size of the

Table 7.12—Elasticity estimates for cotton producers in the Albemarle-Pamlico Drainage, Mississippi Embayment, Southern Georgia Coastal Plain, and Southern High Plain Regions — Pest management practices adoption

Variables	Adoption models				Insecticide use and cotton yield models	
	Biological controls	Scouting	Crop residue destruction	Rotations	Insecticide use	Yield
					- - - *lbs/acre* - - -	
COLLEGE	0.0737	0.0981**	-0.0284	0.0441	-0.0795	-0.0074
EXPERIENCE	-0.0871	-0.1159	-0.1233	0.0671	0.0395	0.0001
WORKOFF	0.0055	-0.0039	0.0284**	0.0159	0.0094	-0.0147**
TENURE	-0.0253	-0.0646**	0.0046	0.0327	0.0496	0.0385**
ACRES	0.1570**	0.2574**	-0.0946**	0.1484	-0.2092	0.0094
DBL-CROP	-0.0121	0.0106	-0.0222**	0.0006	—	—
IRRIGATION	0.0246	0.1196**	-0.0462	0.2504**	-0.1068	0.1401**
PROGRAM	0.0025	0.0417	-0.1599	0.2095	—	—
INSURE	-0.0103	0.0831	0.0742	0.2949**	-0.2851**	-0.0146
ADVICE	0.1605**	0.2379**	0.1527**	0.1852**	-0.2033	0.0572**
SLP	-0.1429	-1.1620**	0.3092	-0.2822	1.9068**	-0.2517**
PISOIL	-0.3023	-0.0829	0.1956	-0.0395	0.3793	-0.1040
TEMP	7.1503**	0.3356	3.4605**	-2.8378	8.3587**	—
EROTON			0.0252		0.0531	—
WATERBODY					0.0040	—
PROB(BIOLOGIC)					0.2010	-0.0077
PROB(SCOUTING)					1.7018**	-0.2116
PROB(DESTROY_RES)					0.1671	0.1056
PROB(ROTATION)					0.2140	0.0917

— Variable not included in model.
** Significant at the 5-percent level.

farm was positively associated with increased yields, and the use of irrigation was also significantly and positively associated with yields. Farmers with crop insurance had increased yields compared to those without insurance.

All natural resource variables appear to be significantly associated with yields. The soil-leaching potential is negative, whereas soil productivity is positively associated with yields. The inherent potential of the soil to erode has a negative relationship to yield. High temperature is positively associated with yields. Of the chosen pest management practices, we observe that only scouting had a significant effect on yield, and that effect was positive.

The effects from the adoption models and insecticide demand and crop yield equations are reported as elasticities (calculated at the means of the variables) in table 7.16. We can observe, for instance, that the direct effect of a 1-percent increase in the use of irrigation on yields is 0.07 percent. The effect of irrigation use on the adoption of scouting is about 0.14 percent, and 1-percent increase in scouting increases yields by 0.04 percent, giving a joint effect on yield from the irrigation/scouting factors of 0.001 percent. When the other practices are included, the total of all the effects of irrigation on yields is 0.098 percent.

Table 7.13—Sample means from pest management adoption models for corn growers in the Iowa/Illinois, Central Nebraska, and White River Basins

Variables	Means
SCOUTING	.09
DESTROY_RES	.09
ROTATION	.68
COLLEGE	.39
EXPERIENCE	24
WORKOFF	40
TENURE	.39
ACRES	991
DBL-CROP	.01
IRRIGATION	.17
PROGRAM	.83
INSURE	.59
ADVICE	.48
WATERBODY	.34
SLP	103
PISOIL	.92
EROTON	31
TEMP	50
Number of observations	1549

Effects of Nutrient Management on Nitrogen Use and Crop Yields

Using nutrient management practices may have a significant effect on nitrogen fertilizer use and crop yields. We would expect that farmers who adopt nutrient management practices will either maintain or increase their yields or reduce input costs. The analysis presented in this section examines the effect of nutrient management decisions on nitrogen use and crop yields.

Nutrient management strategies can be applied to any crop. However, crops vary in nitrogen fertilizer requirements. We chose corn to model the adoption of nutrient management techniques and assess the effects of adoption on nitrogen use and crop yields because it is a nitrogen-intensive crop. Corn accounts for over 40

Table 7.14--Change in the percent predicted adoption of pest management practices for corn growers in the Iowa/Illinois, Central Nebraska, and White River Basins

Variables	Scouting	Destroying crop residues	Rotations
CONSTANT	0.0240	-0.4033	-2.1704*
COLLEGE	0.0345**	-0.0262**	0.0237
EXPERIENCE	0.0016	-0.0129	0.0007
WORKOFF	-0.0008	0.0050*	-0.0056
TENURE	0.0028	0.0039	-0.0499*
ACRES	0.0205**	-0.0147*	0.0168
IRRIGATION	0.0734**	-0.0036	-0.3275**
PROGRAM	0.0457**	-0.0406**	-0.0530
INSURE	0.0137	0.0045	-0.0193
ADVICE	0.0283**	0.0068	0.0340
SLP	0.0344*	0.0093	-0.3077**
PISOIL	-0.0065	0.0472	-0.0682
EROTON	—	-0.0350**	—
TEMP	-0.1026	0.0903	0.6772**
% predicted adoption:	5.3	7.1	69.7
% correct predictions:	89.9	88.4	77.3
Pseudo R^2 [1]	.30	.13	.32

— Variable not included in the adoption model.
** Significant at the 5-percent level.
* Significant at the 10% 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, 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.

percent of nitrogen fertilizer use in the United States (Taylor, 1997).

Corn in the Illinois/Iowa, Central Nebraska, and White River Basins

Table 7.17 presents the sample means and the number of observations for corn producers in Illinois/Iowa, Central Nebraska, and White River Basins. Two separate nutrient management technologies were studied. The first—modern nutrient management practices—includes N-testing, split nitrogen applications, and micronutrient use.[5] The second technology (the use of legumes in rotation) represents a traditional approach to nutrient management. Of the 1,520 observations, 38 percent of the sample use modern practices and non-adopters were 62 percent, while 53 percent grew legumes in rotation with corn.

Table 7.15—Estimates for insecticide use and crop yield effects for corn in the Iowa/Illinois, Central Nebraska, and White River Basins Regions—Pest management practice adoption

Variables	Insecticide	Corn yield
	lbs/acre	
CONSTANT	2.1997*	-13301**
COLLEGE	-0.0385	377.41**
EXPERIENCE	-0.0179	-24.570
WORKOFF	0.0101	-96.991**
TENURE	0.0770**	38.429
ACRES	-0.0296	225.01**
IRRIGATION	0.5246**	3188.3**
INSURE	0.0499*	229.55**
ADVICE	0.0006	-47.875
SLP	0.4558**	-600.91**
PISOIL	0.4430**	1005.4**
EROTON	-0.0053	-111.53**
TEMP	-0.9679**	4166.6**
PROB(SCOUTING)	0.0035	3410.7**
PROB(DESTROY_RES)	-0.1013**	Insignificant[1]
PROB(ROTATION)	0.7286*	Insignificant[1]
Mean of dependent	0.2358	7761

** Significant at the 5-percent level.
* Significant at the 10-percent level.

[1] The data were not sufficient to estimate a yield equation model combining all of the practices together, so the model was run separately for each practice. The only practice with a statistically significant coefficient was scouting.Note: The coefficients estimated from both the insecticide use and yield equations have been converted to the change in insecticide use or yields respectively. For continuous variables (EXPERIENCE, WORKOFF, ACRES, SLP, PISOIL, EROTON, and TEMP), the reported value is the change in insecticide use or yields 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 insecticide use or yields with a unit change of 0.01 from the variable mean. See Appendixes 2-A and 2-B for further details.

The changes in percent predicted adoption are shown in table 7.18. In the modern practices model, human capital was not a significant predictor of use, except that farmers with a college education were more likely to adopt modern practices. The use of irrigation had a positive and significant effect on the adoption of modern practices. Also, receiving outside information on fertilizer use had a significant and positive influence on the adoption of modern practices.

Producers who have farmed the longest are more likely to use legumes in rotation. Farmers who own the field and who use irrigation were less likely to plant legumes in rotation. Soil-leaching potential had a significant negative effect on the adoption of legumes in rotation among corn farmers.

Effects of modern practices on nitrogen use and yields Nitrogen fertilizer use by corn producers in the combined areas averaged 127 pounds per acre, and average crop yield for the three regions was 7,789 pounds per acre. The estimates of nitrogen demand and crop yield effects for corn producers are presented in table 7.19. The R^2 for the nitrogen use model was 0.11 and was 0.15 for yield.

The factors that had a significant impact on nitrogen use were: tenure, acres operated, the use of irrigation, erosion levels, and the amount of rainfall. More highly educated producers have increased corn yields. In addition, farmers who operated large farms (5,000 acres or more), or had crop insurance, or irrigated had higher yields. On the other hand, farmers who worked more days off farm had lower crop yields of about 2.4 pounds per acre per day worked off farm. As expected, productive soils were associated with increases in corn yields, and erodible soils were associated with decreases in yields. In addition, warmer temperatures significantly enhanced crop yields.

The results of the model showed that the use of modern practices (MODPRAC) had no significant effect on nitrogen fertilizer use and no significant effect on corn yields. The model elasticities are presented in table 7.20.

Effects of legumes in rotation on nitrogen use and yields The estimates of nitrogen demand and crop

[5] More detail on the category of "modern practices" is given in chapter 3.

yield effects for the legumes in rotation model are presented in table 7.21. Increased nitrogen use was associated with larger farms and with farmers who irrigated their corn fields. Farmers with productive soils applied about 27 pounds more nitrogen per acre than farmers with less productive soils. In addition, warmer temperatures had a positive effect on nitrogen use. Conversely, erosive soils were associated with a significant but slightly lower use of nitrogen fertilizer.

Farmers with more education had significantly higher corn yields, whereas those who worked more days off the farm had significantly lower yields. Also, corn farmers who owned the field had higher crop yields than renters. The size of the farm was positively associated with increased yields. The use of irrigation also significantly increased yields. Soil productivity, as expected, was positively associated with yields, and the potential of soil to erode was negatively associated with yields. Crop productivity was increased by warm, dry weather.

The results of the model showed that using legumes in rotation had no significant effect on nitrogen fertilizer use, but using legumes in rotation significantly increased corn yields. The elasticity estimates for the

Table 7.17—Sample means from nutrient management adoption models for corn producers in the Illinois/Iowa, Central Nebraska, and White River Basins

Variables	Means
MODERN PRACTICES	.38
LEGUMES IN ROTATION	.53
COLLEGE	.40
EXPERIENCE	24
WORKOFF	39
TENURE	.38
ACRES	998
IRRIGATION	.17
PROGRAM	.83
ADVICE	.28
INSURE	.60
SLP	103
PISOIL	.92
EROTON	31
RAIN	2.8
TEMP	50
Number of observations:	1520

Table 7.16—Elasticity estimates for corn producers in the Iowa/Illinois, Central Nebraska, and White River Basins — Pest management practice adoption

	Adoption models			Insecticide use and corn yield models	
Variables	Scouting	Crop residue destruction	Rotations	Insecticide use	Crop yield
				- - - lbs/acre - - -	
COLLEGE	0.1461**	-0.1132**	0.0139	-0.0645	0.0191**
EXPERIENCE	0.0173	-0.1407	0.0010	-0.0761	-0.0032
WORKOFF	-0.0091	0.0545	-0.0083	0.0428	-0.0125**
TENURE	0.0114	0.0166	-0.0285	0.1258**	0.0019
ACRES	0.2202**	-0.1605	0.0249	-0.1256	0.0290**
IRRIGATION	0.1367**	-0.0069	-0.0842**	0.3867**	0.0713**
PROGRAM	0.4078**	-0.3696**	-0.0653	—	—
INSURE	0.0867	0.0288	-0.0169	0.1252	0.0176**
ADVICE	0.1463**	0.0362	0.0243	0.0011	-0.0030
SLP	0.3686	0.1014	-0.4553**	1.9332**	-0.0774**
PISOIL	-0.0697	0.5164	-0.1009	1.8788**	0.1295**
TEMP	-1.0998	0.9880	1.0021**	-4.1048**	0.5369**
EROTON		-0.3827**		-0.0224	-0.0144**
PROB(SCOUTING)				0.0147	0.0413**
PROB(DESTROY_RES)				-0.4295**	0.0177
PROB(ROTATION)				3.0902	-0.2506

— Variable not included in model.
** Significant at the 5-percent level.

nitrogen fertilizer demand and corn yield models are presented in table 7.22.

Effects of Irrigation on Chemical Use and Crop Yields

The analysis in this section examines the effect of irrigation decisions on chemical use and crop yields. Two case studies are presented. The first investigates input demand and crop productivity for corn producers in the Central Nebraska River Basins. The second case study examines differences between cotton producers who irrigate and those who do not irrigate in the Albemarle-Pamlico Drainage, Mississippi Embayment, Southern Georgia Coastal Plain, and Southern High Plains.

Both cases include changes in insecticide and nitrogen use.[6]

Corn in the Central Nebraska River Basins

Table 7.23 presents the sample means and the number of observations for corn producers in the Central Nebraska River Basins. These producers were separated into three categories used in the adoption analyses

[6] A tobit model was used to estimate the insecticide-use model, because many producers did not use insecticides. The tobit model provides unbiased estimates that reflect the truncated distribution of the data.

Table 7.18—Change in percent predicted adoption of nutrient management practices for corn producers in the Illinois/Iowa, Central Nebraska, and White River Basins

Variables	Modern practices	Legumes in rotation
CONSTANT	0.4248	-0.4693
COLLEGE	0.0624**	-0.0459
EXPERIENCE	-0.0485*	0.2325**
WORKOFF	-0.0061	-0.0164
TENURE	0.0283	-0.6260**
ACRES	0.0289	-0.0094
IRRIGATION	0.3185**	-1.9116**
PROGRAM	0.0037	0.1971
ADVICE	0.0865**	0.2249*
INSURE	0.0512*	-0.0360
SLP	0.0558	-1.0862**
PISOIL	-0.0898	0.4243
EROTON	0.0006	-0.0067
RAIN	0.2367	-1.2451
TEMP	-0.8075	2.2930
% predicted adoption	38.0	51.0
% correct predictions	74	68
Pseudo R^2 [1]	.29	.28

** 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 elasticities or percent change in predicted adoption. For continuous variables (EXPERIENCE, WORKOFF, ACRES, SLP, PISOIL, EROTON, 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 between the values of 0 and 1. See Appendixes 2-A and 2-B for further details.

Table 7.19—Estimates of nitrogen use and crop yield effects for corn in the Illinois/Iowa, Central Nebraska, and White River Basins— Modern nutrient management practices adoption

Variables	Nitrogen use	Corn yield
	lbs/acre	
CONSTANT	-96.8037**	963.4624
COLLEGE	2.7885	455.2075**
EXPERIENCE	0.0859	-6.6705
WORKOFF	0.0221	-2.3699**
TENURE	-9.2128**	73.1260
ACRES	5.5589**	219.6795**
IRRIGATION	47.2214**	3909.282**
PROGRAM	4.2325	116.8808
ADVICE	-1.3067	—
INSURE	—	284.5593**
SLP	—	-4.2693*
PISOIL	19.5692	955.6261**
EROTON	-0.1382**	-4.7247**
RAIN	51.5423**	—
TEMP	—	70.3895**
PROB(MODPRAC)	19.7487	-2687.786
Mean of dependent	127	7789
Adjusted R^2	.11	.15

** Significant at the 5-percent level.
* Significant at the 10-percent level.

Note: The coefficients estimated from both the insecticide use and yield equations have been converted to the change in insecticide use or yields. For continuous variables (EXPERIENCE, WORKOFF, ACRES, SLP, PISOIL, EROTON, and TEMP), the reported value is the change in insecticide use or yields 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 insecticide use or yields with a unit change of 0.01 from the variable mean. See Appendixes 7-A and 7-B for further details.

described in chapter 6: 1) nonirrigators; 2) producers who used a sprinkler system; and 3) producers who used a gravity system. Of the 61 percent of producers who irrigated, half used a sprinkler system and the other half used a gravity system. The changes in percent predicted adoption are shown in table 7.24. The R^2 for the model is 0.66 and the percent correct predictions is 69 percent.

Farmers with a college education were more likely to irrigate and more likely to use a sprinkler system. Larger, owned operations had a higher probability of using irrigation. Farmers who practiced crop rotations for pest management were more likely not to irrigate and less likely to use a sprinkler system. Producers who had crop insurance had a lower probability of using irrigation. The largest, most significant determinants of irrigation use were natural resource and weather factors. The results closely reflected what was expected, given the attributes of each irrigation system. Producers were more likely not to irrigate on land with steep slopes and low soil leaching potential. Producers had a higher probability of using sprinkler systems if the field had low soil quality, as measured by the soil productivity index, or had a steep slope. In general, producers in areas with high rainfall and low temperatures were less likely to irrigate.

The estimates of pesticide and nitrogen demand and crop yield effects for corn are presented in table 7.25. Corn producers in the Central Nebraska River Basins use about 1.5 and 0.2 pounds active ingredients of herbicides and pesticides per acre.

Using either a sprinkler or gravity irrigation system did not influence the amount of herbicide applied. However, the higher the probability of using a gravity system, the greater the pounds of insecticides applied, as compared to nonirrigators. Producers who participated in a commodity program used about 0.39 pounds of ai per acre more than those who did not participate.

Table 7.20—Elasticity estimates for corn producers in the Illinois/Iowa, Central Nebraska, and White River Basins — Modern nutrient management practices adoption

	Adoption model	Nitrogen input use and corn yield models	
Variables	Modern practices	Nitrogen use	Corn yield
		- - - *lbs/acre* - - -	
COLLEGE	0.0644**	0.0087	0.0231**
EXPERIENCE	-0.1263*	0.0165	-0.0209
WORKOFF	-0.0159	0.0068	-0.0120**
TENURE	0.0285	-0.0279**	0.0036
ACRES	0.0753	0.0437**	0.0282**
IRRIGATION	0.1442**	0.0645**	0.0872**
PROGRAM	0.0079	0.0277	0.0125
ADVICE	0.0623**	-0.0028	—
INSURE	0.0794*	—	0.0218**
SLP	0.1452	—	-0.0564*
PISOIL	-0.2337	0.1417	0.1131**
EROTON	0.0015	-0.0335**	-0.0188**
RAIN	0.6163	1.1317**	—
TEMP	-2.1017	—	0.4494**
PROB(MODPRAC)	—	0.0596	-0.1326

** Significant at the 5-percent level.
* Significant at the 10-percent level.

Note: Elasticities represent a percent change in the dependent variable given a 1-percent change in the mean of the explanatory variable.

Table 7.21—Estimates of nitrogen use and crop yield effects for corn in the Illinois/Iowa, Central Nebraska, and White River Basins — Legumes in rotation adoption

Variables	Nitrogen use	Corn yield
	lbs/acre	
CONSTANT	-262.8784**	-5568.090**
COLLEGE	3.9438	312.4849**
EXPERIENCE	-0.0403	-8.1188*
WORKOFF	0.0175	-1.8319**
TENURE	-5.2072	378.2197**
ACRES	4.7136**	147.3754**
IRRIGATION	56.3075**	3907.562**
PROGRAM	5.2059	30.4772
ADVICE	-1.3425	—
INSURE	-0.3490	207.3398*
SLP	0.1701*	-0.2447
PISOIL	27.1332**	1104.910**
EROTON	-0.1616**	-4.5907**
RAIN	—	-1533.454**
TEMP	5.1698**	214.4333**
PROB(LEGUME)	29.0180	2619.715**
Mean of dependent	127	7789
Adjusted R^2	.11	.27

** Significant at the 5-percent level.
* Significant at the 10-percent level.

Note: The coefficients estimated from both the insecticide use and yield equations have been converted to the change in insecticide use or yields. For continuous variables (EXPERIENCE, WORKOFF, ACRES, SLP, PISOIL, EROTON, and TEMP), the reported value is the change in insecticide use or yields 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 insecticide use or yields with a unit change of 0.01 from the variable mean. See Appendixes 7-A and 7-B for further details.

Table 7.22—Elasticity estimates for corn producers in the Illinois/Iowa, Central Nebraska, and White River Basin areas—Legumes in rotation

	Adoption model	Nitrogen input use and corn yield models	
Variables	Legumes in rotation	Nitrogen use	Corn yield
		- - - lbs/acre - - -	
COLLEGE	-0.0087	0.0123	0.0159**
EXPERIENCE	0.1106**	-0.0077	-0.0255*
WORKOFF	-0.0078	0.0054	-0.0093**
TENURE	-0.1150**	-0.0158	0.0188**
ACRES	-0.0045	0.0370**	0.0189**
IRRIGATION	-0.1581**	0.0769**	0.0871**
PROGRAM	0.0780	0.0340	0.0033
ADVICE	0.0296*	-0.0029	—
INSURE	-0.0102	-0.0016	0.0159*
SLP	-0.5164**	0.1374*	-0.0032
PISOIL	0.2018	0.1964**	0.1307**
EROTON	-0.0032	-0.0392**	-0.0183*
RAIN	-0.5922	—	-0.5507**
TEMP	1.0902	2.0189**	1.3692**
PROB(LEGUME)	—	0.1197	0.1767**

** Significant at the 5-percent level.
* Significant at the 10-percent level.

Note: Elasticities represent a percent change in the dependent variable given a 1-percent change in the mean of the explanatory variable.

Table 7.23—Sample means from irrigation adoption models for corn producers in Central Nebraska River Basins

Variables	Means
NONIRRIGATORS	.39
SPRINKLER SYSTEM	.31
GRAVITY SYSTEM	.30
COLLEGE	.40
EXPERIENCE	22
WORKOFF	25
TENURE	.39
ACRES	1148
ROTATION	.38
PROGRAM	.85
INSURE	.58
WATERBODY	.28
SLP	127
PISOIL	.86
SLOPE	3.3
RAIN	2.1
TEMP	49
Number of observations	423

The lack of significant variables in both models, as well as a low model fit, indicates that the variables chosen for the model do not explain fully what factors influence herbicide or insecticide use by corn producers in the Central Nebraska River Basins. Factors, such as target pests and pest intensity, may be more important in determining the amount of pesticides applied. However, the Area Studies survey data did not contain this information.

Nitrogen applications by corn producers in the Central Nebraska River Basins averaged about 108 pounds per acre. The use of irrigation technology, gravity or sprinkler system, was not a significant determinant of nitrogen applications compared to nonirrigators. Producers who used crop rotations applied significantly less nitrogen than those who did not rotate crops, about 18 pounds-per-acre difference. Producers who received fertilizer advice from either a fertilizer company, consultant, or a local extension service applied

Table 7.24—Change in percent predicted adoption of irrigation practices for corn producers in Central Nebraska River Basins

Variables	Nonirrigators	Sprinkler system	Gravity system
CONSTANT	4.4773*	1.4797	-5.9571**
COLLEGE	-0.2209**	0.1608**	0.0600
EXPERIENCE	-0.0210	-0.0023	0.0233
WORKOFF	0.0230*	-0.0008	-0.0001
TENURE	-0.1465**	0.2080**	-0.0615
ACRES	-0.1838**	0.1906**	-0.0067
ROTATION	0.2594**	-0.1564**	-0.1030
PROGRAM	-0.1053	0.0493	0.0560
INSURE	-0.1924**	0.1131	0.0793
WATERBODY	-0.0702	-0.0016	0.0718
SLP	-0.3953**	0.1226	0.2727**
PISOIL	-0.1584	-0.3553**	0.5137**
SLOPE	0.1210**	0.1112**	-0.2321**
RAIN	1.6036**	-0.6680	-0.9356**
TEMP	-5.1470**	-0.9673	6.1141**
% predicted adoption:	42.0	44.6	13.4
% correct predictions:		69	
Pseudo R^2 [1]		0.66	

* Significant at the 10-percent level.
** Significant at the 5-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, SLOPE, 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.

Table 7.25—Estimates of input demand and crop yield effects for corn in the Central Nebraska River Basins— Irrigation adoption

Variables	Herbicide use	Insecticide use	Nitrogen use	Crop yield
		lbs/acre		
CONSTANT	1.6445*	-0.6858	-606.80**	-20801**
COLLEGE	-0.0918	0.0022	0.3266	707.48**
EXPERIENCE	-0.0015	-0.0020	-0.0900	5.0742
WORKOFF	-0.0007	-0.0002	0.0062	-2.6840**
TENURE	-0.0894	-0.0507	2.0910	90.943
ACRES	0.0243	-0.00001	0.0009	0.1960*
ROTATION	-0.1933	0.0848	-17.977**	129.27
ADVICE	0.2662*	0.0023	-19.142**	—
PROGRAM	0.3943**	-0.0237	13.116*	-185.79
INSURE	0.0940	0.0676	1.4551	522.91**
WATERBODY	-0.1026	-0.0934**	10.740*	336.65*
SLP	-0.0043	-0.0004	0.1451	-0.1827
PISOIL	-0.1463	0.1766	20.692	1244.0**
EROTON	-0.0014	0.0020**	-0.1063	-2.5424
RAIN	—	-0.0103	-40.917*	-805.27
TEMP	—	0.0065	15.314**	513.57**
PROB(SPRINK)	0.2610	0.2405	21.080	3380.7**
PROB(GRAVITY)	-0.0088	0.3682**	16.8578	3508.1**
Mean of dependent	1.5	0.2	108	6772
Adjusted R^2	0.022	0.071[1]	0.195	0.664

* Significant at the 10-percent level.
** Significant at the 5-percent level.
[1] Adjusted R^2 for insecticide use model is from the OLS estimation.
Note: The coefficients estimated from both the insecticide use and yield equations have been converted to the change in insecticide use or yields. For continuous variables (EXPERIENCE, WORKOFF, ACRES, SLP, PISOIL, EROTON, and TEMP), the reported value is the change in insecticide use or yields 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 insecticide use or yields with a unit change of 0.01 from the variable mean. See Appendixes 7-A and 7-B for further details.

Table 7.26—Elasticity estimates for corn producers in the Central Nebraska River Basins — Irrigation adoption

	Adoption model			Chemical input use and corn yield models			
Variables	Nonirrigators	Sprinkler system	Gravity system	Herbicide use	Insecticide use	Nitrogen use	Crop yield
				- - - - - - - - - - - - - - *lbs/acre* - - - - - - - - - - - - - -			
CONSTANT	11.48*	4.773	-19.86**	1.112*	-3.345	-5.595**	-3.072**
COLLEGE	-0.2269**	0.2079**	0.0802	-0.0249	0.0044	0.0012	0.0417**
EXPERIENCE	-0.0538	-0.0074	0.0776	-0.0229	-0.2173	-0.0186	0.0166
WORKOFF	0.0589*	-0.0658	-0.0086	-0.0119	-0.0198	0.0013	-0.0102**
TENURE	-0.1460**	0.2608**	-0.0797	0.0235	-0.0961	0.0076	0.0052
ACRES	-0.4714**	0.6147**	-0.0224	0.0164	0.0287	0.0092	0.0332*
ROTATION	0.2547**	-0.1932**	-0.1315	-0.0500	0.1584	-0.0642**	0.0073
ADVICE	—	—	—	0.0624*	0.0040	-0.0510**	—
PROGRAM	-0.2288	0.1348	0.1582	0.2261**	-0.0981	0.1021*	-0.0232
INSURE	-0.2860**	0.2115	0.1533	0.0369	0.1911	0.0079	0.0451**
WATER	-0.0495	-0.0014	0.0658	-0.0191	-0.1253**	0.0270*	0.0134*
SLP	-1.014**	0.3956	0.9089**	-0.3702	-0.2492	0.1694	-0.0034
PISOIL	-0.406	-1.146**	1.712**	-0.0856	0.7448	0.1663	0.1586**
SLOPE	0.3102**	0.3586**	-0.7738**	—	—	—	—
EROTON	—	—	—	-0.0397	0.4190**	-0.0415	-0.0159
RAIN	4.112**	-2.155	-3.11 8**	—	-0.1082	-0.8098*	-0.2551
TEMP	-13.20**	-3.120	20.38**	—	1.560	6.980**	3.748**
PROB(SPRINK)	—	—	—	0.0558	0.3706	0.0614	0.1588**
PROB(GRAVITY)	—	—	—	-0.0018	0.5332**	0.0468	0.1511**

* Significant at the 10-percent level.
** Significant at the 5-percent level.

Note: Elasticities represent a percent change in the dependent variable given a 1-percent change in the mean of the explanatory variable.

significantly less nitrogen than producers who did not receive advice. Perhaps these sources promote fertilizer management techniques that encourage efficient applications of fertilizers. In areas with higher rainfall and lower temperatures, producers applied less nitrogen than producers in warm, more arid regions.

Average crop yields were 6,772 pounds per acre. Irrigation use had a large, positive impact on crop yields. Producers who had a college education or who had crop insurance were also associated with increased crop yields. As expected, more productive soils were associated with large increases in crop yields. However, the overall effect of soil productivity on crop yields greatly depends on whether a producer adopted a sprinkler or gravity system.

The model elasticities are presented in table 7.26. The total factor effect of a 1-percent change in soil productivity on crop yields is -0.023 percent with sprinkler systems and 0.417 percent if a gravity system was used. The total effect of soil productivity on crop yields dramatically changes, given the effect of soil productivity on irrigation decisions.

Cotton in the Albemarle-Pamlico Drainage, Mississippi Embayment, Southern Georgia Coastal Plain, and Southern High Plains

Table 7.27 presents the sample means for cotton producers represented in the Area Studies survey. The

Table 7.27—Sample means from irrigation adoption models for cotton producers in the Albemarle-Pamlico Drainage, Southern Georgia Coastal Plain, Mississippi Embayment, and Southern High Plains

Variables	Means
USE IRRIGATION	.37
COLLEGE	.51
EXPERIENCE	23
WORKOFF	19
TENURE	.28
ACRES	2170
ROTATION	.18
PROGRAM	.95
INSURE	.50
WATERBODY	.44
SLP	136
PISOIL	.73
SLOPE	1.0
WIND	26
RAIN	3.2
TEMP	60
Number of observations	747

cotton sample consisted of 747 observations from the Albemarle-Pamlico Drainage, Mississippi Embayment, Southern Georgia Coastal Plain, and Southern High Plains. Of this sample, 37 percent of producers used irrigation. Changes in percent predicted adoption are shown in table 7.28. The R^2 for the model is 0.25 and the percent correct predictions was 72 percent. The only factors in the model that significantly influenced irrigation adoption decisions for cotton producers were the use of crop rotations, field slope, and weather conditions.

The estimates of pesticide and nitrogen demands and crop yield are presented in table 7.29. The elasticity estimates for the models are presented in table 7.30. Cotton producers are among the most intensive users of pesticides, because of the location of cotton farms

Table 7.28—Change in percent predicted adoption of irrigation for cotton producers in the Albemarle-Pamlico Drainage, Southern Georgia Coastal Plain, Mississippi Embayment, and Southern High Plains

Variables	Irrigation use
CONSTANT	-25.073**
COLLEGE	0.0624
EXPERIENCE	-0.0489
WORKOFF	-0.0009
TENURE	0.0107
ACRES	0.0036
ROTATION	0.2262**
PROGRAM	-0.0858
INSURE	-0.0736
WATER	-0.0074
SLP	-0.2002*
PISOIL	0.1762
SLOPE	-0.0582**
WIND	0.0243
RAIN	-3.7871**
TEMP	6.6405**
% predicted adoption:	33.3
% correct predictions:	72.0
Pseudo R^2 [1]	0.25

* Significant at the 10-percent level.
** Significant at the 5-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.

Table 7.29—Estimates of input demand and crop yield effects for cotton producers in the Albemarle-Pamlico Drainage, Southern Georgia Coastal Plain, Mississippi Embayment, and Southern High Plains — Irrigation adoption

Variables	Herbicide use	Insecticide use	Nitrogen use	Crop yield
		lbs/acre		
CONSTANT	-7.759**	-13.5364**	-17.405	-3311.8
COLLEGE	0.2043	0.0864	-1.4837	-3.4190
EXPERIENCE	-0.0096*	-0.0023	0.0188	0.1261
WORKOFF	-0.00005	0.0004	-0.0163	-0.1328
TENURE	0.0782	-0.1496	3.4324	86.393**
ACRES	0.1486**	0.1385**	5.3282**	3.7487
ROTATION	0.0665	-0.1288	10.088**	50.689*
ADVICE	0.1229	0.3470**	-11.133**	—
PROGRAM	0.0137	0.2419	2.8821	44.847
INSURE	-0.4321**	-0.2142*	-9.3834*	5.6046
WATERBODY	0.3326**	-0.0155	10.319**	-11.685
SLP	-0.0037	0.0039**	0.0651	-0.7302*
PISOIL	0.0214	0.1618	18.874*	-138.64*
EROTON	-0.0006	0.0008	0.1288**	-0.0341
RAIN	2.1900**	2.8154**	6.0593	-583.96**
TEMP	—	—	—	1161.3**
PROB(USEIRR)	1.0372**	1.1355**	37.194**	330.87**
Mean of dependent	2.1	1.1	73	584
Adjusted R^2	0.248	0.433[1]	0.266	0.204

* Significant at the 10-percent level.
** Significant at the 5-percent level.
[1] Adjusted R^2 for insecticide use model is from the OLS estimation.
Note: The coefficients estimated from both the insecticide use and yield equations have been converted to the change in insecticide use or yields. For continuous variables (EXPERIENCE, WORKOFF, ACRES, SLP, PISOIL, EROTON, and TEMP), the reported value is the change in insecticide use or yields 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 insecticide use or yields with a unit change of 0.01 from the variable mean. See Appendixes 7-A and 7-B for further details.

Table 7.30—Elasticity estimates for cotton producers in the Albemarle-Pamlico Drainage, Southern Georgia Coastal Plain, Mississippi Embayment and Southern High Plains — Irrigation adoption

	Adoption model	Chemical input use and cotton yield models			
Variable	Irrigation use	Herbicide use	Insecticide use	Nitrogen use	Crop yield
		----------------------------*lbs/acre*	------------------------------		
CONSTANT	-67.38**	-3.668**	-11.96**	-0.2382	-5.666
COLLEGE	0.0848	0.0489	0.0387	-0.0103	-0.0029
EXPERIENCE	-0.1315	-0.1045*	-0.0463	0.0059	0.0050
WORKOFF	-0.0242	-0.0004	0.0068	-0.0042	-0.0039
TENURE	0.0080	0.0103	-0.0369	0.0131	0.0403**
ACRES	0.0097	0.0703**	0.1224**	0.0729**	0.0064
ROTATION	0.1079**	0.0056	-0.0202	0.0244**	0.0151*
ADVICE	—	0.0276	0.1455**	-0.0326	—
PROGRAM	-0.2180	0.0061	0.2020	0.0373	0.0724
INSURE	-0.0983	-0.1016**	-0.0942*	-0.0638*	0.0046
WATERBODY	-0.0088	0.0693**	-0.0060	0.0623**	-0.0090
SLP	-0.5380*	-0.2394	0.4710**	0.1213	-0.1697*
PISOIL	0.4734	0.0074	0.1044	0.1887*	-0.1744*
SLOPE	-0.1564**	—	—	—	—
EROTON	—	-0.0114	0.0282	0.0671**	-0.0021
WIND	0.0653	—	—	—	—
RAIN	-10.178**	3.343**	8.036**	0.2677	-0.9991**
TEMP	17.846**	—	—	—	1.987**
PROB(USEIRR)	—	0.1824**	0.3733**	0.1893**	0.2106**

* Significant at the 10-percent level.
** Significant at the 5-percent level.
Note: Elasticities represent a percent change in the dependent variable given a 1-percent change in the mean of the explanatory variable.

(Greene, 1997). Cotton is generally grown in warmer areas of the United States, and these climates may have greater pest problems, especially in humid areas. The cotton producers in this sample used, on average, 2.1 pounds of herbicide per acre and 1.1 pounds of insecticide per acre.

The factors with the greatest effect on herbicide and insecticide use were average monthly rainfall and the probability of adopting irrigation. Irrigation use had a strong positive impact on pesticide use. The greater the number of acres operated, the greater the amount of herbicide and insecticide applied. Producers who received pest management advice from either a chemical dealer, a local extension service or hired staff also applied significantly more insecticides than those not receiving advice. This result may indicate that producers who seek advice may experience more insect problems, and therefore, would be motivated to use more pesticides. Receiving advice did not affect herbicide use. Increased insecticide use was also associated with increased soil leaching potential of the field. Herbicide use, however, was higher if the field was located near a water body. Producers who had crop insurance had lower herbicide applications.

The amount of nitrogen applied by cotton producers in the sample averaged 73 pounds per acre. Irrigation was associated with greater applications of nitrogen compared with cotton producers who did not irrigate. A unit change in the probability of using irrigation increased nitrogen use by about 37 pounds-per-acre (table 7.29). Increased nitrogen use was also associated with large farms and with farmers who used crop rotations for pest management. Producers who received fertilizer management advice from a fertilizer company, hired consultants or the extension service used significantly less fertilizer than those who did not receive advice. The higher the potential of soil to erode, the greater the application rate of nitrogen.

Cotton yields for the sample averaged 584 pounds per acre. Cotton farmers who owned the field were associated with higher crop yields than those who rent. Crop productivity was also significantly affected by warm, dry weather.

The results of the model showed that the adoption of irrigation had a significant positive effect on cotton yields, in addition to the positive impact on pesticide and nitrogen use.

Summary

We chose specific crops and areas as case studies to explore the relationship between adoption of management technologies, crop yields, and the use of pesticides and fertilizers. The results of the analyses illustrate the wide range of impacts associated with different technologies. Policies designed to encourage the adoption of specific technologies and practices may have both direct and indirect effects on yields and chemical use.

Variables in the analysis of tillage practices used by soybean producers did little to explain variations in herbicide applications. Although many factors were associated with variations in soybean yields, tillage choices had no effect on yields. Concerns that use of crop-residue management systems, such as no-till or other conservation tillage systems, might increase herbicide applications and adversely affect crop yields are not demonstrated in our results. Also, producers who adopted soil conservation practices to protect water quality did not use statistically different quantities of pesticides or nutrients, nor was there a difference in crop productivity. Soil conservation practices specifically designed to protect water quality, rather than maintain soil productivity, typically are placed at the edge of fields. Therefore, these technologies would not be expected directly to influence management decisions for a field.

In the analysis of alternative, pest-management practices adopted by cotton growers, the adoption of pest management practices had mixed effects on crop yields and chemical input use. Three of the four practices we analyzed—biological controls, destroying crop residues, and rotations—had no impact at all on yields or insecticide use. Scouting, on the other hand, had a significant, positive association with chemical use. Perhaps farmers who scout recognize potential pest infestations and problems more frequently than those who do not, and therefore, apply more chemicals to control pests. Without data on infestation levels, this hypothesis could not be tested directly. Corn producers who adopted the practice of destroying crop residues experienced lower insecticide usage than those who had not adopted the practice. However, the other pest management practices we analyzed—scouting and rotations—did not significantly affect insecticide use on corn. Scouting was positively and significantly associated with corn yield. The other two practices, destroying crop residues and rotations, did not significantly affect crop productivity.

Modern nutrient management practices (N-testing, split nitrogen applications, and micronutrient use) did not have a significant impact on the use of nitrogen fertilizer or crop yields, by corn producers in Central Nebraska, Illinois/Iowa Basins, and the White River Basin. Legumes in rotation as a nutrient management practice had no significant effect on nitrogen fertilizer use for corn producers, but did result in higher corn yields. The use of legumes in rotation did not significantly affect nitrogen fertilizer use on a per-acre basis, but corn yield increased, and the amount of chemical fertilizer input per unit of yield declined.

In general, the choice of irrigation technology did not have a significant impact on the use of chemicals, such as pesticides or nutrients, by corn producers in the Central Nebraska River Basin. However, irrigation significantly increased corn yields. Irrigation increased the use of pesticides and nutrients, as well as increased crop yields in the cotton regions of the Area Studies survey. The larger the farm, the more chemicals applied and the higher the crop yields. Pest management advice was associated with increased applications of insecticides. However, fertilizer management advice reduced nitrogen use. While increased rainfall significantly increased chemical use, it had a negative effect on crop productivity.

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Appendix 7-A

Econometric Model: Sample Self-Selection in the Binomial Case

The following econometric approach is used to correct for sample self-selection. The adoption decision and input demand/crop yield components are modeled as a recursive system. The logit adoption model is presented in Appendix 2-A. The equation that is estimated is

$$M = Z'\gamma + \varepsilon \qquad (7A\text{-}1)$$

where M is management technology choice (M=1 for adoption and M=0 for nonadoption), Z is the set of exogenous variable that influence adoption, γ is a vector of parameters, and ε is an error term that includes measurement error and unobserved factors that affect adoption (Amemiya, 1981).

The decision to adopt a particular management technology or practice is assumed to be made over a relatively long time, but farmers make seasonal or annual decisions on the quantity of variable inputs to use in production. We assume that a farmer chooses the amount of variable inputs, given fixed factors, in order to maximize net return per acre (π):

$$\pi = P_y Y(X,M,R) - P_x X \qquad (7A\text{-}2)$$

where output Y is a function of variable inputs X, management technology choice M (a fixed factor in the short-run), and resource endowments R (a vector of fixed factors). P_y and P_x are output and input prices, respectively. Under the standard assumptions of a quasi-concave production function and profit maximization, optimal input use and output supply can be solved as functions of prices and fixed factors:

$$X^* = X(P_y, P_x, M, R) \qquad (7A\text{-}3)$$

and

$$Y^* = Y(P_y, P_x, M, R) \qquad (7A\text{-}4)$$

where X*, and Y* are the choices of X and Y, respectively, that maximize net returns.

In order to estimate equations (3) and (4) there must be variation in each exogenous variable in the sample, which often poses a problem for including prices in the model, since in a cross-sectional survey, farmers experience little difference in input or output prices. If there is enough regional variation in the sample, then there may be price variation because of differences among farms in the proximity to markets. Including dummy variables for geographic region would then account for regional price variations. Other factors that may affect prices among farmers located in the same geographic area include: the time of the year sales were made, credit terms used for sales, and volume of sales. These factors, in turn, are likely to be functions of the size of farming operation, its geographic location, and the management ability of a farm operator. Thus, many of the same farm characteristics that influence technology adoption are also likely to affect input use. Input demand and output supply in a cross-sectional sample can then be modeled as:

$$X^* = C'\beta_1 + \delta_1 M + \nu_1 \qquad (7A\text{-}5)$$

and

$$Y^* = C'\beta_2 + \delta_2 M + \nu_2 \qquad (7A\text{-}6)$$

where C is a set of farm characteristics, including size of operation, human capital of the farm operator, and resource endowments, such as soil quality, climate, and geographic location, β and δ are parameters to be estimated, and ν_1 and ν_2 are error terms.

The econometric model given by equation's (1), (5), and (6) is a recursive system. Estimates of the parameters of equation (1) provides important indicators about factors that drive adoption of new resource-conserving technology. Estimates of the parameters in equations (5) and (6) describe how farm characteristics and technology use affect input demand and output supply. For example, if $\delta_1 < 0$, then technology adoption has resulted in less input use per acre.

The adoption decision that appears as an explanatory variable in equations (5) and (6) may be endogenous. If the error term ε in equation (1) and the error terms ν_1 and ν_2 in equations (5) and (6) are correlated, then estimating equations (5) and (6) using Ordinary Least Squares (OLS) would result in biased estimates of δ_1 and δ_2 (Green, 1990), which is the case if an unobserved factor affects both decisions to adopt technology and to use chemical inputs, i.e., if Z and C were identical.

To address the simultaneity of technology adoption and input use, an instrumental variables approach is used. In this approach, the technology adoption variable M in equations (5) and (6) is replaced by an instrument, in this case, the predicted values of adoption obtained from

$$\Pr ob(M = 1) = \frac{e^{\gamma' Z}}{1 + e^{\gamma' Z}} \qquad (7A - 7)$$

where e is the exponential function.[7] Using the predicted value of M purges unobserved factors contained in the error term ε in equation (1). The OLS estimates of the parameters to equations (5) and (6) will then be unbiased.

Another consideration is identification. A recursive model is said to be identified if some information included in the instrumental variables is not in the exogenous variables of the model itself. For example, the model would be identified if there is at least one variable in Z that is not in C, since the instrument for M is a function of Z. In the present model, this is not a strict requirement since equation (1) is nonlinear. Thus, the predicted value for M from equation (7) can be used as an instrument for M in equations (5) and (6), even if Z is equivalent to C (Manski, 1989).

In situations where a continuous dependent variable Y is observed only in certain ranges, OLS estimation of the function may give biased results (Maddala, 1983). For example, for some crops in some regions, a significant number of farmers use no pesticide, and the data are said to be *censored*. The tobit model provides an alternative means to find unbiased estimates in these cases. When the number of zero observations on Y is small, OLS and tobit estimates are virtually the same.

Econometric Model: Sample Self-Selection in the Multinomial Case

The multinomial logit form of the adoption model is presented in Appendix 2-A. In the second equation of the recursive model, optimal chemical use, X*, is a function of farm characteristics C and the choice of tillage technology:

$$X^* = C'\gamma_1 + \sum_{j=1}^{J} \alpha_{1j}\tilde{M}_j + \nu_1 \qquad \text{(7A-8)}$$

where $\tilde{M}_j$ is the predicted probability of adoption for technology j, α_1 and γ_1 are vectors of parameters and ν_1 is an error term. The coefficients α_{1j} indicate the difference in chemical use between technology j and the reference technology M_0.

The effect of technology adoption on output or yield Y* is given by:

$$Y^* = C'\gamma_2 + \sum_{j=1}^{J} \alpha_{2j}\tilde{M}_{j+\nu_2} \qquad \text{(7A-9)}$$

where α_2 and γ_2 are vectors of parameters and ν_2 is an error term. The coefficients α_{2j} give the effect of adopting technology j on yield Y between technology j and the reference technology M_0. Requirements for the identification of the recursive system with the multinomial logit model are the same as those described for the recursive system with the binomial logit model.

Appendix 7-B

Interpreting Model Results

The technology parameters δ_1 and δ_2 that are estimated for the input demand and crop supply functions require special interpretation (see equations (5) and (6) in appendix 7-A). Because the adoption variable M has been replaced in these equations with an estimate of the probability of adoption, the unit of this variable is changed. As a consequence, the estimates of δ_1 and δ_2 measure the effect of a change in probability of adoption on crop yield or chemical demand. To make interpretation easier, these effects are translated into elasticities calculated at the means of the variables. The elasticity e_{YM} gives the percent change in the dependent variable Y resulting from a 1-percent change in the probability of adoption:

$$e_{YM} = \delta * \frac{\overline{M}}{\overline{Y}} \qquad \text{(7B-1)}$$

where $\overline{M}$ is the mean value of M and $\overline{Y}$ is the mean value of Y.

A change in an independent variable X can affect Y two ways. First, it affects Y directly, as measured by the coefficient on X, in the input demand or output supply equation. Second, it affects Y indirectly through the probability of adopting a new technology.

[7] A more detailed interpretation of model results is presented in appendix 2-B.