4. Pest Management

In this chapter, we briefly describe pest management issues and the technologies and practices designed to reduce risks to human health and the environment. The Area Studies survey data are described with respect to the use of specific practices. The results of simple adoption models for these practices are reported for the combined-areas and single-area models, and the factors affecting the adoption of pest management practices are described. The modeling framework and the core set of variables used in these analyses are described in chapter 2.

Pests are defined as weeds, insects, nematodes, fungi, or any living organism that is undesirable or hazardous to a crop. Damage to crops by pests can result in reductions in yield, quality, or both. The severity of a pest problem is influenced by many factors including rainfall, humidity, wind patterns, soil type, and other growing conditions. The relative effectiveness of pest management strategies will vary as a function of these factors.

Summary of Pest Management Practices and Data

There are two main pest management categories: *chemical control methods* and *nonchemical control methods*. The use of chemical controls has been the dominant form of pest management since the 1950's (Osteen and Szmedra, 1989). The use of pesticides has produced high yields, and pesticides are relatively easy to apply. More than $7 billion per year is spent in the United States on agricultural pesticides (USDA, ERS, 1996). Recently, however, alternative, nonchemical pest management strategies and services have been promoted as a result of concerns about pesticide exposure effects on human health and environmental quality (U.S. EPA, 1990, 1992; Barbash and Resek, 1995). There is also a concern that the widespread use of chemical pesticides has led to an acceleration of pest resistance to those chemicals (Padgitt, 1997). Greene (1997) gives an excellent summary of current pest management issues.

The potential risk of pesticide use to human health or the environment depends on the toxicity and persistence of the chemical, the availability of residuals, and the mechanism of transport. These factors are functions of the characteristics of the chemicals, the practices used, and the physical properties of the land. The environmental-impact characteristics of the natural resource base are an important determinant of potential damages. The relative effectiveness of alternative pest management strategies for sustaining profitability and reducing damages will be site specific (Caswell and Shoemaker, 1993). The Area Studies survey was designed to collect data on both the chemical and nonchemical control methods employed. Data were also collected on other farm management practices and the production-impact and environmental-impact characteristics of the field.

A farmer's decision to adopt a particular pest management strategy will be based on his or her assessment of the increase in net benefits to be gained by a change in practice. The assessment would include costs, yields, and on-site health or environmental risks. The decision would not be expected to include off-site benefits that would accrue to others.

Chemical Pest Management

The three major classes of chemical pesticides are insecticides, herbicides, and fungicides. Insecticides are used to destroy or control insects. Herbicides are used to control weeds or unwanted vegetation. They can be applied either before or after emergence of the weeds. Fungicides are used to kill or inhibit the growth of fungi that cause disease in plants or seeds. Pesticides other than insecticides, herbicides, or fungicides can be classified as miscellaneous chemicals, such as defoliants or desiccants, soil fumigants, and growth regulators.

Pesticide usage varies greatly by crop. In the Area Studies survey data, for instance, insecticides were applied to almost 64 percent of the cotton acres planted, but to only 3 percent of the wheat acreage. This is due to the specific nature of the pest problems associated with each crop. For example, cotton is often plagued by the boll weevil; corn is susceptible to corn rootworm damage; and potatoes may require fungicides to treat early and late blight. See table 4.1 for a summary of the distribution of pesticide usage in the Area Studies data by pesticide class and by crop.

The amount of active ingredient (*ai*)—the active chemical in a formulation of pesticide—also varies substantially by crop. Corn growers apply 0.7 pounds *ai* of insecticide per acre, whereas cotton growers apply more than double this amount—1.88 pounds *ai* per acre. Figure 4.1 shows the distribution of the pounds of active ingredient applied on a per acre basis by pesticide class and crop. Regional differences in pounds applied of pesticides reflect local growing and economic conditions. Figures 4.2 and 4.3 show some of the regional differences in the pounds of *ai* applied of insecticides and herbicides. The pounds of *ai* of herbicides applied on cotton, for instance, in the Southern High Plains is 1.15, but rises to 3.1 in the Mississippi Embayment. There is much less variation, on the other hand, in the amounts of herbicides applied to soybeans—which ranges from a low of 0.90 pounds of *ai* in the Southern Georgia Coastal Plain to a high of 1.36 in the Albemarle-Pamlico region.

Nonchemical Pest Management Practices and Services

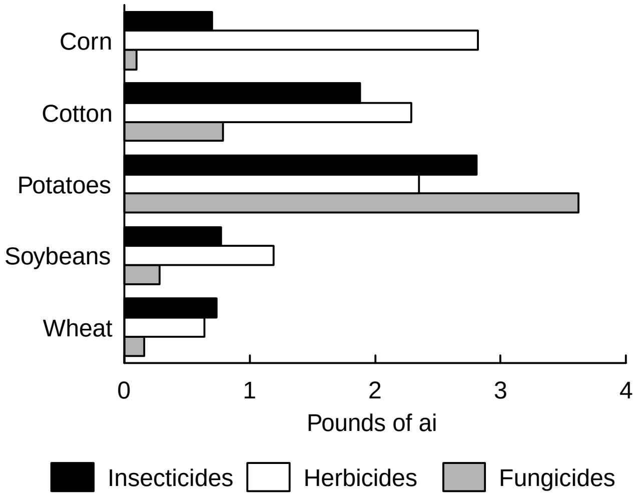
Farmers often use nonchemical pest management practices and services in conjunction with, or as a supplement to, traditional chemical control methods. Some of these practices are used only on specific crops. For instance, pruning and canopy management is often used for tree crops, but rarely for any other crops. The specific mix of practices a farmer chooses often depends on the crop grown, the type of pest, and the extent of the pest problem. The box on page 50 provides definitions of some of the more common nonchemical pest management practices covered in the Area Studies survey, and table 4.2 presents the adoption rates of each of these practices within the Area Studies survey area.

Table 4.1—Crop acres receiving pesticide applications—combined areas

	Corn	Cotton	Potatoes	Soybeans	Wheat
			Percent		
Insecticides	30.1	63.5	65.2	3.9	2.9
Herbicides	90.8	94.8	76.3	92.7	36.2
Fungicides	0.1	12.5	35.5	0.5	0.9
Other	0.3	64.9	15.7	0.5	0.2

Figure 4.1

Average pounds of active ingredient applied per acre, by crop

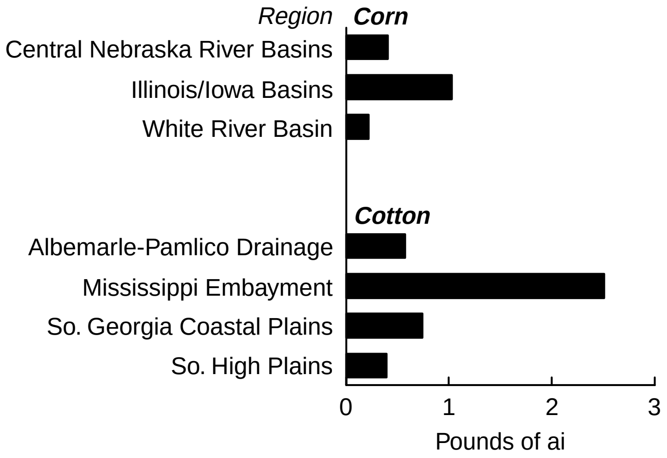


The USDA and EPA have initiated programs to encourage the use of integrated pest management (IPM) strategies as a means of reducing pesticide use and risks. IPM is a systems approach to pest management that combines a wide array of crop production practices with careful monitoring of pests and their natural enemies (Lynch et al., 1997). Pest treatments are prescribed when pest populations reach a threshold level above which economic damage to the crop would occur. An IPM strategy may include the application of synthetic chemicals in combination with cultural and biological practices. The USDA and EPA goal has been to promote the use of ecologically based pest management approaches that reduce the risks to health and the environment associated with the use of synthetic chemical pest controls while ensuring the economic viability of providing a safe, affordable, and plentiful supply of agricultural products (Lynch et al., 1997). Because IPM can encompass several different strategies at once and because there is no consensus on a single definition for IPM, we refer to nonchemical control methods individually in our analysis.

Many of the nonchemical methods for pest control are not widely used. In the Area Studies survey, for

Figure 4.2

Pounds of insecticide applied per acre, by region and crop



instance, roughly 3 percent of the crop acreage reported using any biological controls (table 4.2). The most prevalent method employed was crop rotations, although the primary reason for using this technique is not for pest management. In addition to crop rotations, some of the more commonly used practices include destroying crop residues, planting pest-resistant varieties, using strategic locations and planting times, and professional scouting. Professional scouting can entail the identification of pests in the field, an assessment of the extent of infestation, and recommendations about the chemical or nonchemical pest management strategies to use. The use of scouting has been promoted based on the assumption that it will lead to a more efficient strategy than the use of a fixed schedule of chemical pesticide applications. The adoption of scouting has not been associated with reduced chemical use in all cases, however (Ferguson and Yee, 1995; Fernandez-Cornejo, 1996). Mitra (1997) found that access to information could increase aggregate toxicity or aggregate expenditures of chemicals. These results imply that an increase in economic efficiency does not necessarily lead to an improved environmental outcome.

Farmers often rely on outside sources of information that report pest infestation levels in the area and also give advice on best to control the pests. The farmer may hire someone to aid in the job of pest control. This staff member would be professionally trained in entomology or considered to be a pest management expert. Other sources of information include the pest management services provided by an employee of the Extension Service, university, or State, Federal, or other government agency. Farmers also often receive the advice of professional pest scouts provided by a chemical dealer, supplier, or store as a part of the business' service. Finally, farmers can hire professional scouts to monitor the presence of various types of pests in their fields and to assess the benefits of pest management strategies. A distribution of the percentage of farms using particular sources of advice by crop is presented in figure 4.4. Some farmers, of course, do not receive advice from any of these sources. In general, though, we would expect farmers who receive some form of information or advice to be more aware of the various pest control strategies and alternatives that are available to them when making their pest management decisions. For purposes of the pest management adoption models, a variable was created (ADVICE) to indicate whether farmers had used any of the following for pest management: professional scouts; hired staff; local extension service, university, or State or Federal agencies; or chemical dealers, suppliers, or stores to test the hypothesis that farmers who sought information were more likely to adopt nonchemical strategies.

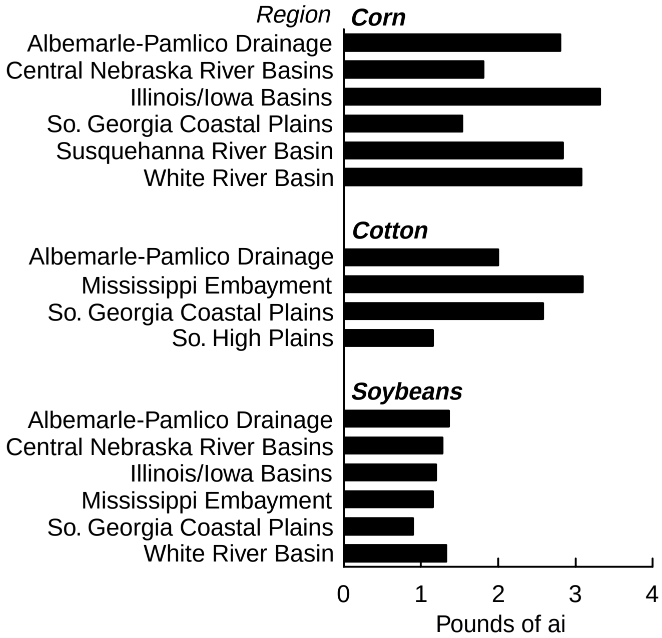
Adoption rates for nonchemical pest management strategies can vary greatly depending on the crop grown. Fifty-three percent of cotton acres were professionally scouted versus only 10 percent of corn acres. Some of the variation in adoption rates between crops can be explained by the specific nature of the pest problems associated with each crop. Dummy variables for certain crops or crop groups (CORN, COTTON, SOYBEANS, GRAIN, FRTVEG) were used in the analyses to capture the effect of crop choice on pest management adoption. Figure 4.5 shows the distribution of the level of adoption for selected practices by crop.

Table 4.2—Adoption of pest management practices—combined areas

Pest management practice	Percent of acres
Biological pest controls	3.2
Crop rotations	53.9
Crop residue destruction	26.1
Nonpesticide sprays	1.8
Pest-resistant varieties	20.4
Pheromones	3.4
Professional scouting	14.9
Pruning and canopy management	2.7
Strategic locations and planting times	12.4

Figure 4.3

Pounds of herbicide applied per acre, by region and crop



Regional differences were also important. In the Southern Georgia Coastal Plain, crop residue destruction is used on 71.9 percent of the cropland as a pest management strategy, compared with only 4.5 percent of cropland acres in the Central Nebraska River Basins. The warm, moist climate in the Georgia area makes it more prone to insect infestations, and therefore makes crop residue destruction a more effective pest management strategy than in the Central Nebraska Basins. Table 4.3 and figures 4.6-4.9 show the distributions of adoption levels by region for each of the four chosen nonchemical practices. Biological controls and pheromones are grouped together since they are similar practices in that they both use natural means of disrupting the pest cycle.

In general, we did not expect natural resource assets on the farm to have much influence on a farmer's decision to adopt particular pest management strategies except for those practices that also contributed to other sources of increased productivity. For example, crop rotations can be used both to break pest cycles and to add nutrients for crop growth. Soil type may influence the decision to use rotations for nutrient management and not pest management. Soil characteristics may not be a factor in the decision to use pheromones. For comparison with the models for soil, nutrient, and water management practices, however, we included the soil leaching potential (SLP) and productivity (PISOIL) core variables in the pest management analyses. Climate was expected to have a strong influence on the choice of pest management practices. Warm, moist weather and mild winters contribute to increases in pest populations.

Adoption of Pest Management Practices

To investigate which factors affected the adoption of nonchemical pest management practices, four models of pest management adoption were selected: (1) rotations; (2) crop residue destruction; (3) biological controls and pheromones; and (4) professional scouting. These particular practices were chosen because they have relatively high adoption rates and they provide the best insight into the human capital, cropping practice, and natural resource factors affecting adoption. In general, these models can be thought of as two distinct categories of technologies—traditional and modern. The use of crop rotations and the destruction of crop residues were well established before the introduction of chemical pest-control strategies. On the other hand, biological controls, pheromones, and professional scouting represent more recent and modern approaches to controlling pests.

First, the adoption model that includes all 10 of the Area Studies regions combined will be discussed (referred to as the "combined-areas" model), and then the results from selected single areas will be reviewed briefly. Selected single-area models were analyzed to test for the effects of regional heterogeneity on the choices of pest management strategies. The analysis

Figure 4.4
Pest management advice by crop

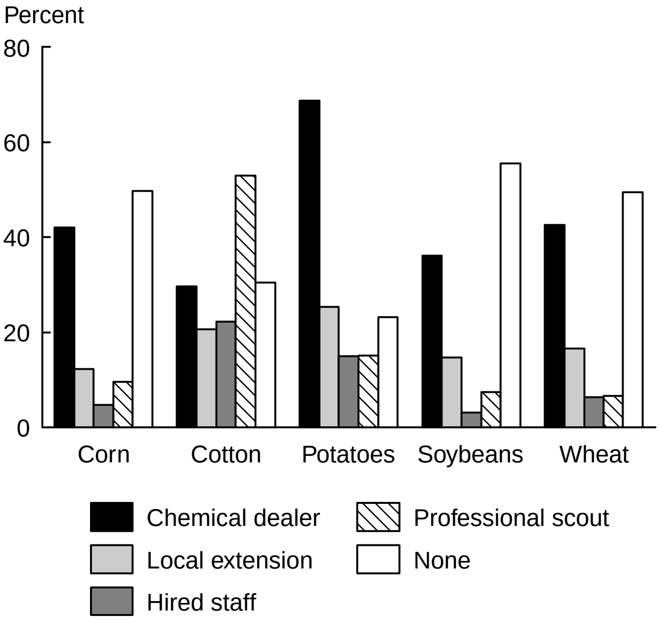
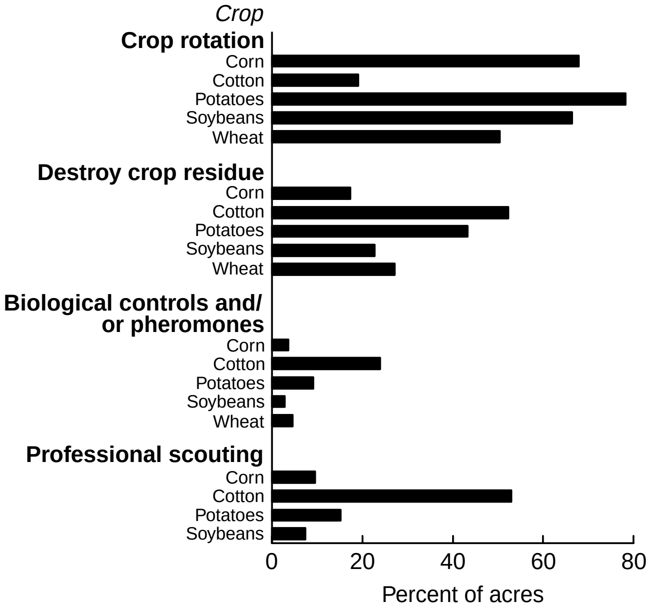


Figure 4.5
Pest management practices by crop



framework and the core set of variables are explained in depth in chapter 2.

Crop Rotations

The sample means for the combined-areas and single-area models are presented in table 4.3. The regions chosen for the single-area adoption models include 8 of the 10 areas; the Central Nebraska, Illinois/Iowa, White, and Snake River Basins, the Southern Georgia Coastal Plain, Southern High Plains, Mississippi Embayment, and Albemarle-Pamlico Drainage areas. The Mid-Columbia and Susquehanna River Basins were not included in the empirical analysis. The empirical results from the adoption study of crop rotations are displayed in table 4.4.

In the combined-areas model, about 54 percent of producers in the sample used crop rotations. Table 4.4 shows that the predicted probability of adopting crop rotations for all areas combined was 0.547 calculated at the sample means. The percent correct predictions was 75 percent and the pseudo R^2 was 0.46.

The human capital variables, COLLEGE, EXPERIENCE, WORKOFF, and TENURE were not statistically significant for the adoption of crop rotations for either the combined- or single-area models. This result may not be surprising given that crop rotations are considered to be a traditional pest management technology that does not require a high level of management expertise or large financial investment. The effect of tenure on the adoption of rotations was negative and significant only in the Southern Georgia model indicating that owners in that area were less likely to adopt crop rotations than renters. Only in Albemarle-Pamlico and Southern Georgia were farmers who had crop insurance more likely to adopt crop rotations.

The number of acres operated had no effect on the adoption of crop rotations in the combined-areas model. In the Albemarle-Pamlico, Snake River, and White River areas, the larger the number of acres operated, the higher the probability of adoption of crop rotations. In the Central Nebraska River Basins, however, the number of acres operated had a negative effect on adoption. A stratified sample shows that the average acres operated for a corn grower in Central

Table 4.3—Sample means from pest management adoption models by area

Variables	Combined areas	Albemarle-Pamlico	Central Nebraska	Illinois/Iowa River Basins	Mississippi Embayment	Snake River Basin	Southern Georgia	Southern High Plains	White River Basin
ROTATIONS	.54	.74	.42	.82	.27	.66	.71	.19	.78
DESTROY RESIDUE	.26	.54	.05	.08	.37	.36	.72	.37	.23
BIOLOGICAL	.06	.13	.04	.02	.11	.04	.17	.04	.01
SCOUTING	.15	.12	.14	.04	.30	.08	.18	.22	.03
COLLEGE	.44	.34	.38	.38	.47	.60	.39	.54	.42
EXPERIENCE	24	25	24	25	23	21	25	23	25
WORKOFF	32	33	30	41	21	35	42	24	64
TENURE	.38	.34	.43	.38	.30	.62	.47	.36	.40
ACRES	1703	1735	1624	910	2332	2550	1499	1972	931
CORN	.30	.28	.50	.57	.07	.01	.26	.07	.51
COTTON	.15	.11	0	0	.30	0	.15	.60	0
SOYBEANS	.31	.33	.23	.43	.49	0	.19	0	.42
GRAIN	.22	.28	.25	.09	.11	.72	.17	.27	.11
DBL-CROP	.06	.16	.01	.02	.08	0	.11	.06	.02
IRRIGATION	.26	.08	.41	.02	.39	.81	.26	.45	0
PROGRAM	.80	.77	.74	.85	.87	.47	.80	.92	.68
ADVICE	.44	.45	.27	.56	.37	.62	.53	.35	.31
INSURE	.40	.26	.42	.63	.14	.27	.32	.70	.18
SLP	119	121	125	91	116	150	148	151	112
PISOIL	.80	.53	.84	.94	.80	.82	.37	.69	.90
RAIN	3.1	4.0	2.1	3.0	4.3	1.2	4.1	1.6	3.4
TEMP	55	60	49	50	61	44	65	58	52
Number of observations	6574	769	709	1276	822	537	511	508	779

Refer to table 2.2 for variable definitions and units.

Figure 4.6

Adoption of crop rotation by region

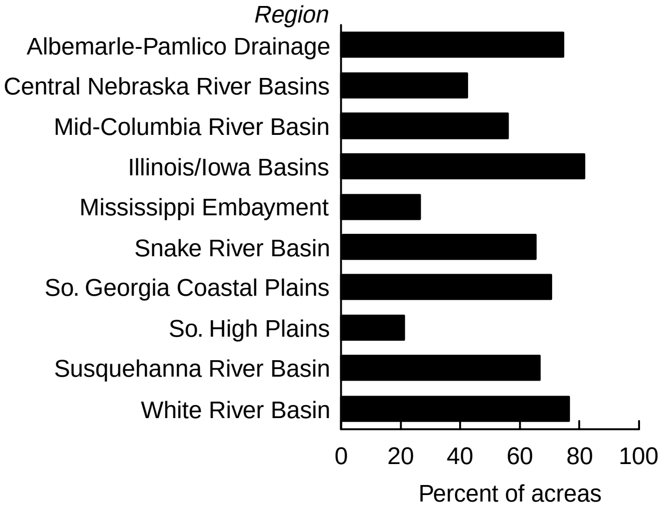


Figure 4.7

Adoption of crop residue destruction by region

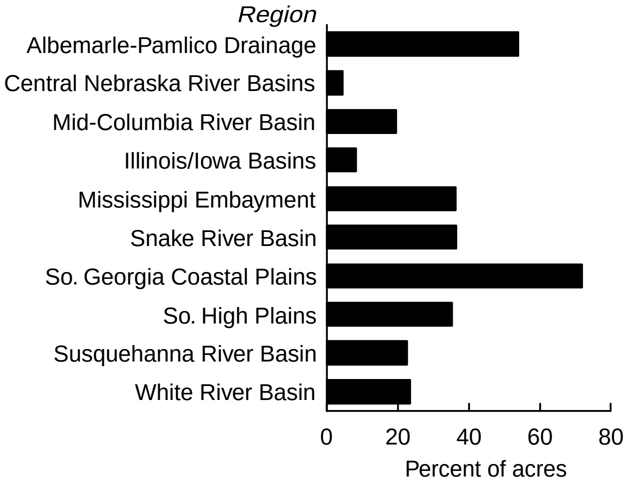


Figure 4.8

Adoption of biological controls and pheromones by region

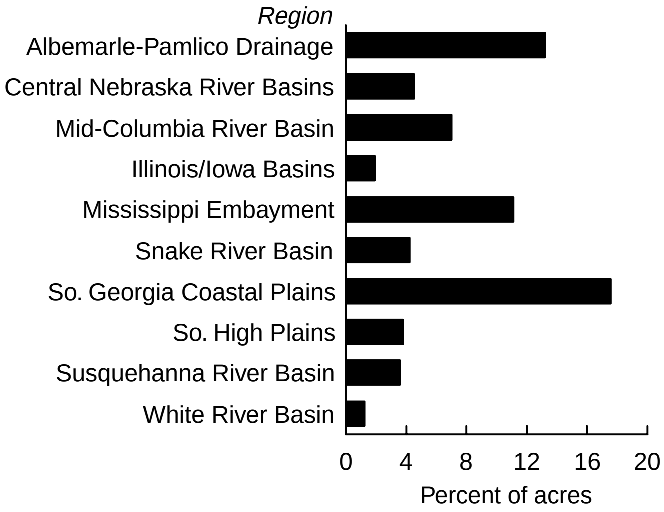
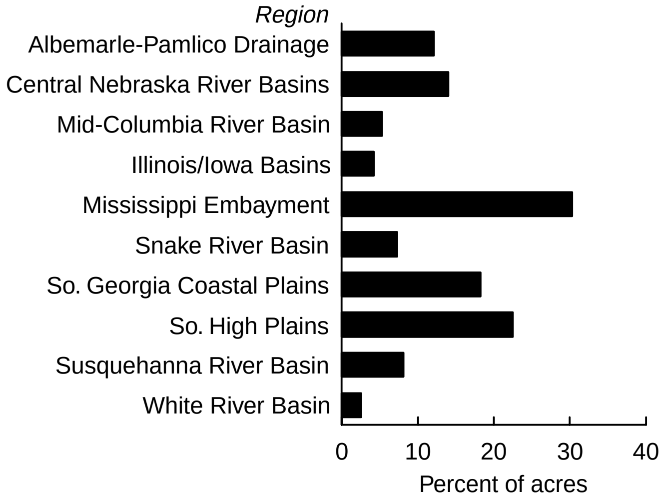


Figure 4.9

Adoption of professional scouting by region



Nebraska was 1,146, whereas the average acres operated for farmers who did not grow corn was 2,103. Because corn is one of the dominant crops in Central Nebraska, this might explain why there is a negative relationship between farm size and adoption. Regional differences were obscured when the areas were combined. Farm size does not appear to have any cost or information advantages with respect to the adoption of crop rotations.

Dummy variables for soybeans and grains and hays were included in the combined-areas model.[1]

Soybeans (SOY) were produced by 31 percent of farmers and grains and hay crops (GRAIN) were produced by 22 percent of the farmers. Grains were defined as either wheat, barley, oats, rye, alfalfa, or other hay. As expected, farmers who grew soybeans were significantly more likely to be rotating crops than farmers who grew other crops for the combined-areas model and four of the single areas. In the Snake River and Southern High Plains areas, soybeans were not produced, so dummy variables for row crops (corn, soybeans, cotton, tobacco, potatoes, or sorghum) and cotton were used respectively. The partial effects in both cases were negative and significant. Similarly, farmers growing grains and hays were significantly less likely to adopt crop rotations.

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[1] Since some agricultural producers cultivated both soybeans and grains in their fields, each crop dummy variable can be considered apart from the other in the combined-areas adoption models.

Double-cropping increased the probability of adopting crop rotations. Farmers may double-crop in order to control for pests and natural enemies that overwinter in the soil or crop residue, and therefore they may be more likely to adopt rotations as part of their pest management strategy. It should be pointed out, however, that the results for double-cropping are driven primarily by a single area, Albemarle-Pamlico.

The use of irrigation had an overall positive and significant effect on the adoption of crop rotations in the combined-areas model and in the Albemarle-Pamlico, Mississippi Embayment, and Southern High Plains models. The use of irrigation had a negative effect on the adoption of rotations in the Corn Belt. This result reflects some regional variations and may be indicative of the fact that some irrigated crops may be more prone to pest infestations and, therefore, more likely to be rotated. Planned rotations can also aid in conserving soil moisture, so farmers who have a need to irrigate may be using rotations to conserve soil moisture in regions with low rainfall.

Farmers were asked whether or not their operation was enrolled in a farm program (e.g., price supports, crop quotas, or the CRP). Farmers who received farm program benefits were significantly more likely to adopt crop rotations than those who did not in the combined-areas model and in Albemarle-Pamlico, Southern Georgia, and White River areas. This result is somewhat surprising since the 1985 Farm Bill, which was in effect during the Area Studies survey period, stated that planting a nonprogram crop on base acres would result in the loss of commodity program eligibility.

Table 4.4—Change in the percent predicted adoption of rotations

Variables	Combined areas	Albemarle-Pamlico	Central Nebraska	Illinois/Iowa River Basins	Missis-sippi Embayment	Snake River Basin	Southern Georgia	Southern High Plains	White River Basin
CONSTANT	-1.0790	-1.6367**	-0.3787	-1.8514**	6.4122**	-0.4948	2.5563	-0.7896	1.9604**
COLLEGE	0.0044	0.0373	-0.0692	0.0066	-0.0221	-0.0621	0.0485	0.0107	0.0236
EXPERIENCE	0.0054	-0.0261	0.0121	-0.0302	-0.0075	0.0377	-0.0017	0.0371	-0.0089
WORKOFF	-0.0038	-0.0120*	-0.0109	-0.0065	0.0048	0.0026	-0.0070	0.0035	0.0091
TENURE	-0.0297*	-0.0239	-0.0830*	-0.0326	0.0444	0.0226	-0.1162**	0.0500	-0.0513*
ACRES	0.0062	0.0405**	-0.0529**	0.0026	0.0192	0.0851**	0.0066	0.0272	0.0328**
SOYBEANS	0.2574**	0.0031	0.2926**	0.1538**	0.1862**	-0.3521**[1]	0.1449**[1]	-0.1647**[2]	0.1235**
GRAIN	-0.1325**	-0.0852*	-0.0983	-0.0506*	0.1010	-0.4667**	-0.1386**	-0.1815**	-0.1515**
DBL-CROP	0.1146**	0.1510**	—	—	-0.0122	—	0.1044	0.1127	0.2079
IRRIGATION	0.1371**	0.1539**	-0.1568**	-0.1763**	0.2556**	0.1256*	0.0795	0.1773**	—
PROGRAM	0.0767**	0.1111**	-0.0204	-0.0233	0.0694	-0.0420	0.2279**	0.1596*	0.0757**
ADVICE	0.1739**	0.0691**	0.0718	0.0472**	0.2291**	0.1626**	0.1431**	0.0657**	0.0257
INSURE	0.0025	0.1469**	0.0175	0.0225	-0.0550	0.0657	0.2649**	0.0037	0.0695*
SLP	-0.2320**	-0.0078	-0.0550	-0.2063**	-0.1368*	0.0898	-0.1823	0.1376	-0.0835
PISOIL	0.2365**	-0.1108	0.3152**	-0.1804*	0.1971**	0.2062**	0.0934	0.1492**	-0.3275**
RAIN	-0.0497	1.1337**	0.5863**	—	—	-0.3923**	-0.1089	—	-1.3258**
TEMP	0.3045	—	—	0.6166**	-1.7444**	—	-0.6088	-0.0212	—
Number of observations	6574	769	709	1276	822	537	511	508	779
% predicted adoption	54.7	78.7	39.1	86.2	21.8	70.6	76.1	13.3	81.5
% correct predictions	75.3	79.6	71.7	84.2	80.9	73.9	76.5	82.9	80.9
Pseudo R^2 [3]	.46	.36	.36	.22	.33	.29	.37	.33	.28

— Variable not included in the adoption model.

** Significant at the 5-percent level.

* Significant at the 10-percent level.

[1] Rowcrop

[2] Cotton

[3] 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, 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.

Receiving some form of pest management information or advice (ADVICE) was positively and significantly related to use of crop rotations in all models except in the Central Nebraska and White River Basins. Table 4.5 shows that 64.2 percent of agricultural producers who sought out pest management advice used crop rotations, versus 47.1 percent of producers who did not seek advice. The technical assistance and advice farmers received appears to have encouraged them to adopt crop rotations. However, it is also possible that farmers who sought advice were already prone to pest or weed problems. They may have been more likely to adopt a pest management strategy like crop rotations because of a current infestation and not necessarily because they received advice.

Soil characteristics are important in explaining where farmers tend to use crop rotations. SLP had a significant and negative impact on the adoption of crop rotations. In other words, producers with sandier soils were less likely to adopt crop rotations. This result, however, is driven by a single area, the Illinois/Iowa River Basins. For the combined-areas model and three single areas, the greater the productive capacity of the soil, the more likely were producers to use crop rotations. On the other hand, producers with more productive soils in the White River Basin were less likely to adopt crop rotations. The resource characteristics combined within the PISOIL index may not be capturing the production-impact characteristics that are important in individual areas. The use of crop rotations is a nutrient management strategy as well as a pest control strategy.

Table 4.5—Percent predicted adoption—combined areas

Variables	Rotations	Destroying crop residues	Professional scouting	Biological controls
College		*	*	*
Yes	55.0	17.1	10.2	3.8
No	54.5	22.3	6.7	2.4
Land tenure			*	
Yes	52.9	20.1	7.1	3.2
No	55.8	19.8	8.8	2.8
Land operated			*	*
500 acres	54.3	20.2	6.2	2.6
5,000 acres	55.7	19.2	15.4	4.0
Cotton	*1	*	*	*
Yes	71.2	32.6	42.6	22.5
No	46.6	18.1	5.7	2.0
Use irrigation	*	*	*	*
Yes	64.5	22.8	16.6	3.9
No	51.1	19.0	6.2	2.7
Received advice	*	*	*	*
Yes	64.2	25.7	12.0	4.8
No	47.1	16.2	5.9	2.0
Percent adoption at means	54.7	19.9	8.1	3.0

* Significant at the 5-percent level.
[1] Soybeans, not cotton.

Climate can play a major role in the need for pest management practices. Higher monthly average rainfall and higher monthly temperatures can be proxies for humidity levels and the potential for pest outbreaks. Warmer climates also often have more types of pests. It would be expected that producers in hot, humid regions would be more likely to adopt pest management strategies and practices as a means of controlling pest infestations. Average rainfall and temperature did not significantly influence the farmer's decision to use crop rotations in the combined-areas model, but they did influence the use of crop rotation in all single-area models, except Southern Georgia and the Southern High Plains.[2] In Albemarle-Pamlico and Central Nebraska, rainfall had a positive effect, and temperature had a positive effect in the Illinois/Iowa Basins. In these areas, a warmer or more humid climate appears to encourage the adoption of rotations as a possible pest management strategy. However, in the Mississippi Embayment, temperature had a negative effect, and rainfall had a negative influence in the Snake and White River Basins. The results from the single-area adoption models provide evidence that climate is selectively important in how it affects use of crop rotation and climate's importance varies substantially in its effect across regions.

Crop Residue Destruction for Pest Management

Like crop rotations, destruction of residues is considered to be another traditional pest management strategy (see box, p. 50). Therefore, we expected that some of the same factors that affect the use of rotations to affect the use of this technology. However, from a whole-farm perspective, crop residue destruction may not be the best pest management strategy, particularly for farmers with soil erosion problems.

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[2] The temperature and rainfall variables in the single-area adoption models were so highly correlated, we retained only one variable in each region, the choice depending on variation and model fit.

The sample means for the combined-areas and single-area models are presented in table 4.3, which shows that about 26 percent of farmers in the entire sample practiced crop residue destruction for pest management. A stratified sample statistic indicated that these farmers had soil with a lower-than-average inherent potential to erode due to rainfall and wind. For the combined sample, the average potential soil erosion rate was 35 tons per acre per year, whereas the erosion rate for farmers who destroyed crop residue was only 26 tons per acre per year.

The model results from the adoption study of crop residue destruction are displayed in table 4.6. The predicted probability of the adoption of crop residue destruction for the combined-areas model at the sample means was 0.199. The percent correct predictions was 77 percent and the pseudo R^2 was 0.37. The single-area adoption models cover three regions: Albemarle-Pamlico, Mississippi Embayment, and Southern Georgia. These areas were chosen because they had the largest individual adoption rates for crop residue destruction. The proportion of farmers who destroyed crop residues was 54 percent in Albemarle-Pamlico, 37 percent in the Mississippi Embayment, and 72 percent in Southern Georgia (table 4.3).

For the combined-areas and Albemarle-Pamlico models, COLLEGE and EXPERIENCE had a negative and significant association with crop residue destruction. Table 4.5 shows that for the combined-areas model, the predicted adoption for farmers with some

Table 4.6—Change in the percent predicted adoption of crop residue destruction for pest management

Variables	Combined areas	Albemarle-Pamlico	Mississippi Embayment	Southern Georgia
CONSTANT	-2.9584**	-13.307**	-2.5266	4.1624
COLLEGE	-0.0528**	-0.1787**	-0.1237**	-0.0670
EXPERIENCE	-0.0326**	-0.1214**	-0.0514	0.0184
WORKOFF	0.0042*	-0.0012	0.0111*	-0.0089
TENURE	0.0024	-0.0148	0.0476	-0.1107**
ACRES	-0.0043	0.0377*	0.0097	-0.0165
COTTON	0.1249**	0.2444**[1]	0.2638**	0.1955**
GRAIN	-0.0669**	-0.1014	—	-0.2565**
DBL-CROP	-0.0103	-0.1038	-0.1022	0.1674**
IRRIGATION	0.0367**	-0.0208	0.1031**	0.0646
PROGRAM	0.0154	0.2475**	0.0756	0.2194**
ADVICE	0.0934**	0.0623	0.1958**	0.1225**
INSURE	-0.0019	-0.0004	-0.0387	0.1999**
SLP	-0.0070	0.0513	-0.0668	0.2789
PISOIL	0.0340	-0.0072	0.0170	0.2385**
EROTON	-0.0259**	-0.0955**	-0.0086	0.0098
RAIN	0.1892**	—	—	-0.5117
TEMP	0.6468**	3.2113**	0.5394	-0.9322
Number of observations	6574	769	822	511
% predicted adoption	19.9	53.1	34.9	77.5
% correct predictions	77.4	69.7	73.8	77.7
Pseudo R^2 [2]	.37	.34	.23	.38

— Variable not included in the adoption model.

** Significant at the 5-percent level.

* Significant at the 10-percent level.

[1] Tobacco

[2] 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, 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.

college education is 17.1 percent compared with 22.3 percent for farmers without any college education. Education also had a negative impact on adoption in the Mississippi Embayment area. Farm ownership (TENURE) had no effect on crop residue destruction except in the Southern Georgia model for which it had a negative effect. The use of insurance had a positive effect on adoption in the Southern Georgia model. In general, the human capital effects were stronger for crop residue destruction than for crop rotations.

Farm size was not a significant influence on adoption in any of the models. Crop choices were significantly associated with crop residue destruction. In all models, the choice of cotton as a crop had a positive impact on adoption. Cotton was produced by 15 percent of all the farmers in the combined-areas model. In a stratified sample, 53 percent of cotton growers destroyed crop residues as a pest management technology, compared with 22 percent of producers who did not grow cotton. Because cotton is often produced in

Glossary of Nonchemical Pest Management Practices

Biological pest controls — the use of beneficial insects or natural enemies, such as praying mantises and ladybugs, which are collected and introduced into locations because of their value in biologic control. These insects prey on other harmful insects and parasites. Biological pest control also includes the use of trap crops. A trap crop is any crop planted to attract or divert insects or other pests away from the primary host crop. Other examples of biological pest controls are microbial agents, cover crops, and mulching.

Crop rotations — the practice of successively growing different crops on the same piece of land over a span of 2 or more years in order to combat pests. Crop rotations are used primarily to improve or maintain soil productivity, but have the secondary benefit of breaking up the pest life cycle. Rotations provide, in many situations, a cheap and effective means of control.

Crop residue destruction — helps to provide a host-free zone. Host-free zones are areas in which the natural or preferred habitat for a pest has been removed or destroyed so that the pest's breeding patterns are disturbed. Destroying crop residue can also alter a habitat by producing changes in the physical environment, i.e., by modifying the soil texture, moisture, temperature, and other characteristics that may affect a pest's ability to survive.

Nonpesticide sprays — nonchemical solutions used to control pests. These sprays include lime water, insecticidal soaps, and elemental and organic compounds used for pest control.

Pest-resistant varieties — crop plants with known resistance to one or more pests. Host-plant resistance is often the result of breeding plants to enhance genetic properties that make them less susceptible to pest damage or disease or to interrupt the normal host-selection process.

Pheromones — chemical sex attractants which can be used to capture insects for measuring population counts or to reduce populations by disrupting mating. The use of pheromones for monitoring pests enables farmers to accurately determine the size of the population and the rate at which it is growing. Pheromones are insect specific and are not available or do not exist for all insect types.

Professional scouting — monitoring the presence and population counts of various types of pests in the field by taking samples. These samples are taken by entomologists or other professionally trained specialists, and are reported to the grower. The population counts or scouting reports are then used to schedule pesticide applications only when a pest population has reached a point that threatens the profitability of the crop.

Pruning and canopy management — pruning and leaf removal done to control pests or diseases. Although removing infested or diseased twigs may reduce the spread of infestation, it can be labor intensive.

Strategic locations and planting times — another means of keeping pests off the crop grown in a particular field. By selecting planting sites on a farm where insects may not exist or exist in fewer numbers, or by manipulating planting dates, a farmer may exercise some control over potential pest infestations. Planting dissimilar crops adjacent to one another may also be a means of keeping pests off the primary crop if the other crop is useful at attracting pests away from the primary crop.

warm, humid areas it may be more prone to pest infestations. Grain crops, on the other hand, were negatively associated with the adoption of crop residue destruction in the combined-areas and the Southern Georgia models.

Producers who irrigated were positively and significantly associated with crop residue destruction for the combined-areas and Mississippi Embayment models. The Mississippi Embayment area had the highest average monthly rainfall, 4.3 inches, of all the regions and had a substantial amount, 39 percent, of irrigation (see table 4.3). Farmers who irrigate in this region may have more severe pest problems than farmers who do not.

Participating in a government program had no impact in the combined-areas model, but had a significant positive influence in the Albemarle-Pamlico and Southern Georgia models. Producers who received some form of information or advice from hired staff, extension service, or chemical dealers were more likely to destroy crop residues as a pest management practice than those who did not receive any advice for all single-area models except Albemarle-Pamlico.

In general, the natural resource variables defining soil quality, SLP and PISOIL, did not significantly affect a farmer's use of crop residue destruction. The coefficient for PISOIL in the Southern Georgia model was positive and significant. The inherent potential of the soil to erode (EROTON) had a significant and negative influence on adoption for the combined-areas and Albemarle-Pamlico models. This outcome is reasonable since farmers with potential soil erosion problems would generally not want to leave the soil in their field vulnerable by destroying crop residues. There may be a link between program participation and access to information. In a stratified sample, 45.8 percent of farmers participating in a program indicated they received some form of advice, whereas only 35.2 percent of farmers not in a program indicated receiving any advice.

The climate variables RAIN and TEMP also had a significant influence on adoption for the combined-areas model. Both were positive, indicating that farmers in warm, humid climates were more likely to destroy crop residues. Limited variation within a single area may not be sufficient to capture subtle climate effects. Temperature and rainfall may be a proxy for the likelihood of pest infestations and outbreaks.

Biological Controls

The use of biological controls is a more recent and modern approach to pest management. Research efforts have focused on identifying and introducing natural enemies as pest control agents. Scientists have also isolated and identified an increasing number of pheromones, which can be used to attract insect pests away from the primary food crop or disrupt breeding. The success of biological controls often depends on the complexity of the pest problem and environmental factors, which may vary from area to area. Although biological controls and pheromones have rather low adoption rates, they are similar practices in that they both use natural means to disrupt the pest cycle. Therefore, these practices are combined for analysis under the general heading of "biological controls."

The sample means for the combined-areas and single-area models are presented in table 4.3. The regions chosen for the single-area adoption models include the Albemarle-Pamlico, Mississippi Embayment, and Southern Georgia areas. These areas were chosen because they had the highest levels of adoption. At least 10 percent of the farmers in each of these areas used biological controls. The model results from the adoption study of biological controls are displayed in table 4.7.

For all areas combined, table 4.3 shows that only about 6 percent of farmers had used any biological control methods. Table 4.7 shows that the predicted probability of adoption for the entire sample was 3 percent calculated at the sample means. The percent correct predictions was 93.9 percent and the pseudo R^2 was 0.34.

The human capital variables did not have strong effects on adoption of biological controls. Farmers who had some college education were significantly more likely to use biological controls in the combined-areas model, but this effect was not evident within the individual areas. In the Southern Georgia model, experience was a positive factor, while having insurance was a negative factor.

The number of acres that a farmer operated had a positive and significant influence on use of biological controls in all models except the Mississippi Embayment model. When natural enemies are absent from the environment, the costs of rearing and releasing a large number of insects for biological control may be prohibitively high, especially for small farm operations. Biological controls may also be more effective over a larger area, where it may be easier to control an infestation if a farm is less likely to have its efforts undermined by pest problems from neighboring farms. In these cases, we would expect larger farms to have economies of scale, with lower management and information costs per unit of output. The results support this notion.

A farmer's use of biological controls may also be influenced by crop choice. On low-value per acre crops, biological controls may be too expensive. They may be economical only for high-value crops. Similarly, the most successful biological control programs have been for crops persisting for more than 1 year, such as tree crops. The cropping practices of annual crops are often not suitable for biological controls. Eliminating weeds and disturbing the soil every year may control pests, but may also eliminate natural enemies that overwinter in the soil or crop residue. Farmers who grow cotton (COTTON) or fruit and vegetable crops (FRTVEG) were significantly more likely to adopt biological controls in the combined-areas model. These are both high-value crops, and the fruit and vegetable crops variable includes tree crops. Table 4.5 shows that the predicted probability of adopting biological controls for farmers growing cotton was 22.5 percent, compared with only 2 percent for farmers who did not grow cotton. The use of irrigation had a positive and significant influence on the use of biological controls only in the combined-areas and Southern Georgia models.

Participating in government farm programs had no effect on a farmer's use of biological controls. However, farmers who received some form of pest management information or advice were more likely to adopt biological controls in all models except Southern Georgia. As a pest management strategy, biological

Table 4.7—Change in the percent predicted adoption of biological controls for pest management

Variables	Combined areas	Albemarle-Pamlico	Mississippi Embayment	Southern Georgia
CONSTANT	-0.8572**	-0.2514	-2.3620**	-0.0380
COLLEGE	0.0129**	0.0034	0.0159	0.0206
EXPERIENCE	-0.0060*	-0.0069	-0.0225*	0.0498**
WORKOFF	0.0007	-0.0060	0.0014	0.0058
TENURE	0.0033	0.0205	-0.0146	0.0121
ACRES	0.0056**	0.0282**	0.0112*	0.0403**
COTTON	0.0760**	0.1593**	0.1153**	0.2496**
FRTVEG	0.0476**	—	—	0.0846**
DBL-CROP	-0.0045	-0.0223	-0.0495	-0.0785*
IRRIGATION	0.0107**	0.0118	-0.0048	0.0512**
PROGRAM	-0.0013	-0.0241	-0.0315	0.0071
ADVICE	0.0257**	0.0890**	0.0428**	0.0456*
INSURE	-0.0001	0.0153	-0.0043	-0.0636**
SLP	-0.0094	-0.0087	-0.0002	-0.2980**
PISOIL	-0.0097	-0.0640*	-0.0391	-0.0201
RAIN	0.0188	-0.0431	—	0.1750
TEMP	0.1713**	—	0.5324**	-0.1104
Number of observations	6574	769	822	511
% predicted adoption	3.0	6.7	4.7	7.3
% correct predictions	93.9	90.2	88.4	88.3
Pseudo R^2 [1]	.34	.44	.41	.57

— Variable not included in the adoption model.
** 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, 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.

controls are a relatively new approach, which is rapidly evolving as more and more natural enemies and pheromones are isolated and identified. The number of pests for which biological controls are available is constantly increasing. Therefore, it is expected that farmers who have access to information sources would be more likely to be aware of new types of controls, and more apt to adopt this method as a pest management strategy.

The natural resource variables defining soil quality, SLP and PISOIL, had an insignificant effect on a farmer's use of biological controls in all models with the exception of soil leaching potential, which had a negative impact in the Southern Georgia model. This example illustrates the importance of understanding both the *production-impact* and *environmental-impact* characteristics of the natural resource base on which agricultural production takes place. A producer may be less likely to adopt a chemical-reducing strategy on soil with a high leaching potential, but that land may be the most vulnerable to the transport of chemical residuals.

Higher monthly average rainfall also had no effect on adoption rates. Higher temperature levels, however, were positively associated with higher adoption rates of biological controls in the combined-areas and Mississippi Embayment models. Again, warmer climates may be an indication of a greater potential for pest infestations.

Professional Scouting

Another more recent approach toward pest control involves using a professional scouting service. Professional scouts essentially offer farmers another piece of information or advice about the extent and severity of potential pest infestations. Because professional scouts are trained specialists, they have a special understanding of insect population dynamics and potential impacts on crop yield. Farmers who use scouting often rely on information received from the scout to determine the extent of any pest problem, what pest management strategy to use, and when to use it. With more accurate information, one would expect reduced amounts (if any) of economically wasteful chemical use, but not reduced use of chemicals *per se*. The monitoring of pest populations is usually a component of an integrated pest management system, but does not define IPM.

The sample means for the combined-areas and single-area models are presented in table 4.3. The single area adoption models include the Central Nebraska River Basins, Mississippi Embayment, Southern Georgia Coastal Plain, and Southern High Plains. These areas were chosen because they had the highest levels of adoption. The proportion of farmers who used professional scouting was 14 percent in the Central Nebraska River Basins, 30 percent in the Mississippi Embayment, 18 percent in the Southern Georgia Coastal Plain, and 22 percent in the Southern High Plains (table 4.3). The model results from the adoption study of professional scouting are displayed in table 4.8.

In the combined-areas model, about 15 percent of producers used a professional scout for pest management (table 4.3). The predicted probability of adoption for the entire sample was 0.081 calculated at the sample means (table 4.8). The percent correct predictions was 89.3 percent and the pseudo R^2 was 0.44.

Farmers who had some college education were significantly more likely to use professional scouting in the combined areas, Central Nebraska River Basins, and Mississippi Embayment models. Perhaps farmers with more education recognize the value of monitoring the population and presence of pests in order to apply pesticides only when necessary. In addition, less educated farmers may be less familiar with the services provided by professional scouts. Landownership also had a significant effect on use in these models. The influence in this case, however, was negative, indicating that landowners were less likely to use professional scouts. Crop insurance was positively associated with a farmer's use of professional scouting in the combined areas and Southern High Plains models.

It was expected that it would be easier for producers to personally monitor potential pest problems on smaller farms. The more acres operated, the harder it would be to oversee and regulate populations without the assistance of a professionally trained scout who can take samples and make appropriate pest management recommendations. The model results support this hypothesis for all models. Larger farms are more likely to employ professional scouting services than smaller farms.

Growing cotton was a positive and significant factor associated with professional scouting. A stratified sample shows that 51 percent of cotton growers used professional scouts compared with only 9 percent of farmers who did not grow cotton in the combined areas. Cotton is a high-value crop and is often produced in warm, humid climates prone to pest infestations. It is also a pesticide-intensive crop, with 63.5

percent of the cotton crop acres in the Area Studies Survey data receiving insecticide applications (see table 4.1). Professional scouting may provide cotton farmers a means to reduce pesticide costs by enabling them to schedule pesticide applications only when a pest population reaches a level at which it threatens profitability.

Double-cropping did not significantly affect a farmer's use of professional scouting except in the Southern Georgia Coastal Plain, where the effect was negative. Irrigation, however, was positively and significantly associated with the use of professional scouting in all areas. Irrigation may create living conditions favorable to pests, and these areas may have higher infestation levels. Scouting may be one way to ensure that pest populations remain in check. The predicted adoption of professional scouting by farmers who irrigate is 16.6 percent, compared with only 6.2 percent by farmers who do not irrigate for the combined-areas model (table 4.5).

Farmers in the combined areas and the Central Nebraska River Basins receiving program benefits (PROGRAM) were significantly more likely to use professional scouting as a pest management strategy than those who did not. Receiving some form of pest management information or advice was positively and significantly associated with the use of professional scouting for all areas except the Central Nebraska River Basins. Farmers who seek advice from hired staff, extension service, or chemical dealers may learn about the values and benefits of professional scouting, and therefore adopt this technology as part of a pest management strategy.

The natural resource and climate variables all had an insignificant effect on the adoption of professional scouting for the combined-areas model. The natural

Table 4.8—Change in the percent predicted adoption of professional scouting for pest management

Variables	Combined areas	Central Nebraska	Mississippi Embayment	Southern Georgia	Southern High Plains
CONSTANT	-0.5284	-0.3924**	-5.5675**	3.2183	-1.8629
COLLEGE	0.0337**	0.0488**	0.1434**	0.0036	0.0240
EXPERIENCE	-0.0112*	0.0001	-0.0020	0.0140	-0.0352
WORKOFF	-0.0025	0.0013	-0.0121*	0.0005	0.0058
TENURE	-0.0175**	-0.0424**	-0.1268**	0.0061	-0.0021
ACRES	0.0328**	0.0197**	0.0887**	0.0242**	0.0908**
COTTON	0.1863**	0.0306 [1]	0.5112**	0.2060**	0.0040
DBL-CROP	-0.0274*	—	-0.0680	-0.1068**	0.0685
IRRIGATION	0.0824**	0.1059**	0.1018**	0.1068**	0.1786**
PROGRAM	0.0334**	0.0813**	0.0103	0.0342	-0.0190
ADVICE	0.0580**	0.0221	0.1044**	0.1052**	0.1577**
INSURE	0.0243**	0.0160	0.0171	0.0252	0.1671**
SLP	-0.0011	0.0081	-0.0334	-0.1915	-0.2829**
PISOIL	-0.0299*	-0.0199	-0.0779	0.0472	-0.1813**
RAIN	0.0186	-0.0219	—	-0.1661	—
TEMP	0.0018	—	1.1104**	-0.7981*	0.3026
Number of observations	6574	709	822	511	508
% predicted adoption	8.1	5.9	20.7	7.6	14.5
% correct predictions	89.3	83.1	82.1	89.0	80.1
Pseudo R^2 [2]	.44	.41	.56	.57	.37

— Variable not included in the adoption model.
* Significant at the 5-percent level.
[1] Corn
[2] 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, 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.

resource variables measuring soil characteristics were significant only in the Southern High Plains, and those effects were negative. The Southern High Plains area has the highest average soil leaching potential, and one of the lowest soil productivity averages. The temperature variable was significant only in the Mississippi Embayment model. Although we generally would not expect soil characteristics to affect adoption of professional scouting, it is surprising that climate did not play an important role, particularly in the combined-area model. Pest infestations are more likely to occur in warm, humid climates. In these areas, we would expect professional scouting to be a useful pest management strategy. The results indicate that this is not the case, and that climate has no significant effect on adoption. The climate variables chosen for this study may not be accurate proxies for the potential for pest outbreaks, particularly in the single-area models.

Summary

Although the results from the combined-areas and single-area adoption models vary depending on the region and the pest management practice examined in the estimation, there are some general findings. As expected, human capital had a positive effect on farmers' use of modern pest management technologies, i.e., biological controls and professional scouting. On the other hand, human capital actually had a negative effect on farmers' use of the more traditional pest management strategy of destroying crop residues. Another interesting result was that the number of days worked off the farm was not significant. This implies that the pest management practices analyzed may be neither time-intensive nor time-saving technologies.

Farm size was another significant factor in farmers' use of the modern pest management technologies. Larger farms may have economies of scale that make it easier and more worthwhile for them to adopt newer technologies than smaller farms if the unit cost of using the practice declines with acres. Farm size, however, had no influence on farmers' use of the traditional pest management strategies of crop rotations and crop residue destruction. Cropping practices, especially crop choice and irrigation use, significantly affected farmers' use of all of the pest management practices that were analyzed.

Program participation was positively associated with farmers' use of crop rotations and professional scouting. A significant factor in all of the adoption models was if the farmer had received some form of pest management information or advice. The result was strong and positive in all cases, indicating that the technical assistance and advice farmers receive encourages them to use various pest management strategies.

In general, natural resource characteristics were not important in explaining farmers' use of the modern pest management technologies, but were more important in explaining their use of traditional pest management technologies. Farmers who had less sandy, more highly productive soils were more likely to adopt crop rotations. This result characterizes the types of regions in which crop rotations are most likely to occur. Another resource endowment, the average inherent potential of the soil to erode, characterizes the types of soils where farmers' use of crop residue destruction is most likely to occur. Climate had varying effects on farmers' use of pest management technologies. In many places, higher average monthly rainfall and temperature were associated with the adoption of pest management practices. In general, climate seemed to be more important in predicting use of the traditional pest management practices than the modern practices.

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