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Cotton Production and Water Quality

An Initial Assessment

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Abstract

This report uses data on agricultural chemical use, related production practices, and resource conditions gathered in the 1989 Cotton Water Quality Survey to develop an initial assessment of cotton production's potential to affect the quality of surface and ground water. The survey reported data findings relating to cotton producers' use of agricultural chemicals and to resource conditions. Cotton farmers applied fertilizers to 82 percent, herbicides to 93 percent, and insecticides to 67 percent of surveyed acreage. Data from the survey were used as input to a set of screening and assessment procedures that relate soil and agrichemical properties, production practices, and the potential for impairing water quality. These models were used to assess the relative potential for agricultural chemicals used in cotton production to affect water quality. Results indicate that a potential for nitrates to leach into ground water and possible losses of pesticides to surface water are the most widespread resource concerns. A high potential for pesticide leaching appears less widespread.

Keywords: Cotton, water quality, ground water, surface water, pesticides, herbicides, fungicides

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Summary

The 1989 Cotton Water Quality Survey gathered data on cotton agricultural chemical use and related production practices and resource conditions in 14 cotton-producing States. Data gathered on the use of fertilizers, herbicides, insecticides, and other agricultural chemicals, along with physical data also collected by the survey, were analyzed to assess the potential water quality problems which may be associated with cotton production. Results of this preliminary analysis indicate that a potential for nitrates to leach into ground water and possible losses of pesticides to surface water are the most widespread concerns. Cotton production appears to be less likely to result in pesticides leaching into ground water or to be associated with surface water quality impairments from soil erosion.

Cotton farmers use a wide variety of agricultural chemicals to control pests and promote plant growth. Of the 10.5 million acres covered by the survey, 82 percent of cotton acreage was fertilized with nitrogen, 93 percent was treated with herbicides, and 67 percent was treated with insecticides. Soil conservation was not widely adopted, partly due to climate and topography in cotton-growing regions. About 60 percent of the surveyed acreage contained a well on the operation, but not many respondents knew if the well contained pesticides or nitrates.

Using data from the survey, researchers applied several screening procedures to assess the potential for cotton agricultural chemical use to affect water quality. Estimates of cropland erosion on cotton acreage, which ranged from a low of 0.4 ton/acre/year in California to a high of 16.4 tons/acre/year in Arkansas, were used to estimate delivery of suspended sediment to surface water systems. Other screening procedures used information on soil properties and the chemical properties of applied agrichemicals to characterize cotton cropland by the relative potential for pesticides or fertilizers to leach into ground water or to move to adjacent surface water bodies. These agrichemicals can reach surface water by dissolving in runoff or attaching to suspended sediment.

Results of this analysis show that controlling erosion on cotton cropland would not greatly improve surface water quality in terms of sediment loadings, because the contribution of erosion from cotton acreage to total pollutant loadings in any one region is not great. Vulnerability of cotton acreage to leaching pesticides similarly does not appear to be widespread. Only a small proportion (3 percent) of all surveyed cropland was given the highest relative potential for pesticides to leach into ground water. Thirty-two percent of cotton acreage, primarily in the West, was classified as having the highest relative potential for nitrates to leach into ground water. A high relative potential for pesticides to leave cropland either dissolved in runoff or attached to eroding soils was estimated for surveyed cotton cropland, primarily in the Delta States.

Cotton Production and Water Quality

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Introduction

In recent years, there has been an increasing amount of attention placed on water pollution thought to be associated with agricultural production. That nutrients, animal wastes, pesticides, and sediment from farmland contribute to the Nation's surface water pollution problem has long been recognized. However, over the past 5 years public policy has shifted significantly toward addressing nonpoint sources of pollution (such as agricultural and urban runoff) as well as point sources like municipal and industrial plant discharges. Public concern about the presence of pesticides and nitrates in ground water from the use of agricultural chemicals has risen following some well publicized findings of pesticides in drinking water. In response to this concern, many Federal and State agencies have begun to develop programs to prevent possible pollution of ground water by agricultural chemicals.

As part of the President's 1989 Water Quality Initiative, the U.S. Department of Agriculture (USDA), the Environmental Protection Agency (EPA), and the U.S. Departments of Interior and Commerce have developed a 5-year plan to address the problem of agricultural sources of water pollution (see box). The USDA's Economic Research Service and National Agricultural Statistics Service conducted a survey of cotton producers in 14 Southern and Western States in 1989. Information from the survey provides a comprehensive accounting of field applications of pesticides and fertilizers on the 1989 cotton crop. The survey also provided an opportunity to test data collection procedures and to begin accumulating chemical use data that will cover all major field crops, vegetables, fruits, and nuts by 1993.

The survey accounted for cotton production practices on 10.5 million acres (99 percent of the total U.S. planted cotton acreage of 10.6 million acres). This report gives a brief overview of survey results, providing summary information on pesticide and fertilizer use, soil conservation and tillage practices, and water use. The data from the survey are used with some simple screening and assessment models to characterize the scope and extent of the potential for cotton production to adversely affect ground and surface water quality. It also gives some initial estimates of the potential for protecting water quality by modifying cotton production practices.

It is important to emphasize that the analysis of the relationships between cotton production, agricultural chemical use, and potential water quality effects is preliminary. Additional research is underway at the Economic Research Service to better refine understanding of the linkages between cotton production, resource conditions, water quality, and the economic tradeoffs between producing agricultural products and protecting water users from water quality degradation.

Potential Impacts of Agricultural Production on Water Quality

Several general links to water quality exist. When agricultural chemicals are applied to cropland, some residues of a pesticide or its degradates may remain in the soil after plant uptake and may leach to

Agricultural Chemical Use Surveys and the President's Water Quality Initiative

- The President's Water Quality Initiative is a multiagency program under the leadership of USDA to provide farmers, ranchers, and foresters the knowledge and technical means to respond independently and voluntarily to on- and off-farm environmental concerns and related State water quality requirements. The USDA Water Quality Program is three-pronged: education and technical assistance, research and development, and database development and evaluation.

- The 1989 Cotton Water Quality Survey is the first in a series of surveys conducted as part of the USDA database development and evaluation activities. The goal is to develop, analyze, and report timely, statistically reliable, and detailed data on farm use of pesticides, fertilizers, and related inputs.

- Future surveys will gather chemical use and farm economic data for different commodities on a continuing cycle. Cropping practice surveys will be conducted in 1990 on corn, soybeans, wheat, rice, cotton, and potatoes. Farm chemical use and economic data will be gathered every 2 years for vegetable, fruit, and nut producers. Selected area studies in specific regions of the country will be conducted to help evaluate the connections between resource characteristics, farm production practices, and water quality.

subsurface waters. Alternatively, residues may move to surface water by dissolving in runoff or adsorbing to sediment. When a pesticide is applied, spray drift may carry pesticides to surface water. Atmospheric volatilization or runoff may also take place. Finally, chemical or physical processes may transform residues into products that may also degrade the quality of water resources. For example, nitrogen fertilizer or nitrogen from animal waste may be transformed first into ammonium and then into nitrates.

The potential for fertilizers and pesticides to reach water bodies depends on a combination of factors. Soil characteristics, other geologic factors, and rainfall all influence the likelihood that chemicals applied to cropland but which are not taken up by crops will leach into ground water or will be washed away into lakes and streams. The physical and chemical characteristics of a particular pesticide influence its interactions with various soils. In general, areas that are most at risk for chemicals leaching into ground water have sandy, highly permeable soils with little organic matter, receive enough rainfall or irrigation to promote leaching, and are located over shallow, unconfined aquifers. The seriousness of any surface or ground water pollution from cropland runoff also depends on the soil type, the land slope characteristics, the type of tillage practice used, and the intensity of agricultural chemical use. Some cropping patterns are thought to be more erosive and some use more farm chemicals than others, so these will have a greater potential for runoff to enter adjacent waters.

The potential for chemicals to reach either surface water or ground water is also strongly influenced by the history of fertilizer and pesticide use on the farm (for example, the method, timing, and rate of applications), the chemical and physical properties of the materials applied (such as solubility in water or the tendency to adsorb onto soil particles), and the management practices used on the farm. In particular, some chemicals may persist in the soil after they are applied, or they may break down into nonbenign components that percolate through the soil profile into ground water. The nonbenign compounds may also may leave cropland dissolved in runoff or adsorbed to sediment. These chemicals may have a greater potential impact on water quality than do those chemicals that are less mobile and persistent.

When runoff from cropland reaches lakes, streams, and estuaries, the residues from nutrient applications, sediments, and pesticides can contribute to water quality problems. Nutrients, particularly nitrogen and phosphorus, promote algae growth and premature aging of lakes, streams, and estuaries (a process called eutrophication). Suspended sediment impairs aquatic life by reducing sunlight. It also damages spawning grounds and may be toxic to aquatic organisms. Pesticide residues that reach surface water systems may also affect the health and vigor of fresh water and marine organisms. The primary concern with agricultural chemicals in ground water is the risk to humans and the environment. Contaminated ground water that resurfaces may affect nontargeted plants, birds, or aquatic organisms (some of which are endangered) in the environment. A well documented human health risk from nitrate contamination is infant methemoglobinemia, a condition where nitrates are converted into nitrites in the digestive system, impairing the ability of the infant's blood to carry oxygen. Nitrites are also considered carcinogenic by some analysts. Some pesticides are considered carcinogenic in large doses, and as a result, the EPA has issued health standards defining maximum allowable contaminant levels for 26 pesticides. The concentration of nitrates or pesticides in drinking water may be below levels at which acute health effects have been observed. However, continued exposure to low levels of pesticides or nitrates may result in chronic effects (for example, reproductive impairments or cancer) to humans or other organisms. The degree of health risk associated with ingesting water containing traces of pesticides or nitrates at levels below those in which human health is considered endangered is poorly understood.

Even though water quality problems arising from agricultural production have been recognized for some time, developing programs to control these types of pollution is a difficult task. Unlike the case of water pollution from point sources (such as industrial plant discharges), analysts find it very difficult to establish a cause and effect relationship between agricultural production, agricultural chemical use, and the eventual effect on water quality when the sources of pollutant loadings are widespread and diffuse. Moreover, when water quality is affected by many different sources of pollution, it can be difficult to assess the degree to which controlling one pollutant source (such as cropland runoff) can contribute to the overall quality of a specific water resource.

Finally, economics must be considered. The economic losses associated with impaired water quality such as lost recreation opportunities or increased cost of drinking water depend not only on the quality of the water but the number of consumers using the resource and the alternative uses of the water resource. In addition, efforts to reduce agriculture's effect on water quality may in turn lead to production losses and reduced farm income if farm practices are restricted. Ideally, if we understood the technical and economic linkages between agricultural production, fate and transport of chemicals and sediment in the environment, effects on water quality, and the value of clean water to consumers, we could evaluate policies to protect water quality on the basis of their relative benefits and costs. This would help us design policies that incorporate the economic tradeoffs of reducing losses from impaired water quality while minimizing the adverse effects on farm income and commodity production. These linkages are now poorly understood.[1]

In this study, we take a general approach. We use the data on agricultural chemical use and management practices in cotton farming in conjunction with physical data on resource conditions to identify the likelihood that cotton farming may contribute to water quality problems. Using several screening models, we characterize the surveyed cotton acreage based on the potential for chemicals and sediment to harm ground and surface water quality.

Patterns of Agricultural Chemical Use and Cotton Production Practices

The 1989 Cotton Water Quality Survey gathered detailed data on agricultural chemical use, production practices, and resource conditions associated with cotton production. Appendix A presents a copy of the survey instrument. The survey was conducted in the fall of 1989. A stratified sample was taken to be representative of cotton cropland. The survey represents acreage totaling about 10.5 million acres, about 99 percent of all cotton acreage planted in 1989 (fig. 1). The survey was field-based; that is, data

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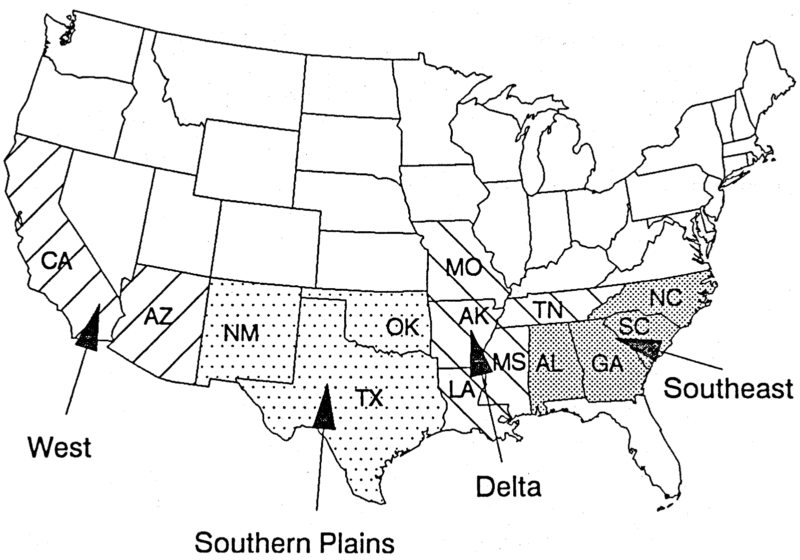
[1] A major component of the President's Water Quality Initiative is a broadly based research effort to quantify the linkages between agricultural chemical use, farm management practices, and delivery of chemical residuals to ground water.

Figure 1

Regions examined by the 1989 Cotton Water Quality Survey



on agricultural chemical use and resource characteristics are relevant for the sample field. However, some additional economic and demographic data were collected that pertain to the farm operation as a whole. Total sample size was about 1,750. A complete summary of all data collected in the survey is beyond the scope of this report. However, complete details on the data and collection methods are available from the authors on request.

Background of the Cotton Industry

Cotton has been a major U.S. cash crop for nearly 200 years. In 1988, cotton was the fifth most valuable field crop (production of $4.8 billion) after corn ($13 billion), hay ($10.6 billion), soybeans ($7.8 billion), and wheat ($6.6 billion). Approximately 12 million acres were harvested in 1988, or about 4 percent of harvested U.S. cropland devoted to major field crops. Production in 1989 in the 14 States covered by the survey (Alabama, Arkansas, Arizona, California, Georgia, Louisiana, Missouri, Mississippi, North Carolina, New Mexico, Oklahoma, South Carolina, Tennessee, and Texas) was estimated to be 12.2 million bales on 9.5 million harvested acres. The 14 States are divided up into the following regions: Southeast (North Carolina, South Carolina, Georgia, Alabama), Delta (Mississippi, Tennessee, Missouri, Arkansas, Louisiana), Southern Plains (Texas, Oklahoma, New Mexico), and West (California, Arizona).

Agricultural Chemical Use on Cotton Cropland

Cotton production is chemical intensive, including the use of fertilizers, insecticides, defoliants, and herbicides. Fertilizers, such as nitrogen, phosphate, and potash, are applied at the time the seed bed is prepared to enhance plant yield and quality. Herbicides and insecticides are applied to control weeds and pests such as cotton aphids, boll weevil, bollworm, and tobacco budworm. Growth regulators are applied to help produce uniformly sized plants. Defoliants are used to facilitate harvest.

Table 1--Cotton fertilized and application rates, 1989

The Southeast and the Delta had the highest shares of acres treated.

State/region	Nitrogen: Share of acres treated	Nitrogen: Application rate	Phosphate: Share of acres treated	Phosphate: Application rate	Potash: Share of acres treated	Potash: Application rate
	Percent	*Lbs/acre*	*Percent*	*Lbs/acre*	*Percent*	*Lbs/acre*
Alabama	100	85	91	52	95	54
Arizona	95	181	55	34	5	1
Arkansas	98	88	71	25	72	44
California	97	117	41	22	13	2
Georgia	100	62	100	53	95	79
Louisiana	100	89	70	31	71	39
Mississippi	100	103	54	27	61	39
Missouri	97	86	77	37	97	64
New Mexico	71	51	68	39	24	4
North Carolina	75	66	67	14	83	63
Oklahoma	62	33	51	22	25	4
South Carolina	100	108	94	58	94	102
Tennessee	100	78	97	65	97	71
Texas	63	31	52	19	23	4
Southeast	98	81	92	52	94	75
Delta	99	93	69	48	73	63
Southern Plains	65	53	54	38	23	16
West	97	133	45	55	11	12
All regions	82	77	60	44	42	34
All U.S.: Corn	97	131	84	59	75	81
All U.S.: Wheat	81	62	53	37	18	46
All U.S.: Soybeans	17	18	28	46	32	74

Fertilizer Use

Chemical fertilizers are an important part of the cotton production process. Nearly all cotton farmers contacted in the survey treated their fields with nitrogen, phosphate, or potash at least once during the season.

Table 1 presents data on the use of nitrogen, phosphate, and potash on cotton acreage covered by the survey. For the 14 States surveyed, 82 percent of cotton acres were treated with nitrogen, 60 percent with phosphate, and 42 percent with potash.

There was some variability in fertilizer use among regions, reflecting differences in soil types, climate, drought and moisture conditions, previous crops, crop yields, and farming practices. Application rates for nitrogen and phosphate were highest in the West, while farmers in the Southeast used potash most intensively. For the 14 States as a whole, average application rates were 77 pounds per acre for nitrogen, 44 pounds per acre for phosphate, and 34 pounds per acre for potash.

As another means of comparison, table 1 also reports 1989 fertilizer use on other selected field crops (*Agricultural Resources: Inputs Situation and Outlook Report*, February 1990). Corn producers apply more pounds per acre of all three fertilizer nutrients than do cotton farmers. Cotton production uses

Table 2--Herbicide use on cotton acreage by region, 1989

Herbicides are widely used on cotton cropland in all regions, most intensively in the Southern Plains.

Item	Unit	Southeast	Delta	Southern Plains	West	All surveyed regions
Amount of acres treated	1,000 acres	830	2,955	4,609	1,053	9,436
Share of acres treated	Percent	97	99	91	82	93
Estimated application rate	Lbs AI[1]/acre	4.6	6.2	1.4	1.6	3.2
Average treatments per acre	Number	2.9[2]	2.3	1.4	1.4	2.1

[1] AI = Active Ingredient.
[2] Includes combinations of active ingredients or tank mixes.

nitrogen more intensively than wheat and soybeans, about the same amount of phosphate, and less potash per acre than the other two major crops.

Herbicide Use

Herbicides are extensively used in cotton production. Weeds reduce yield by competing for available light, moisture, and nutrients. Weeds also can reduce the quality and marketability of cotton lint (for instance, grasses can stain the lint during harvest). The bedded land is usually tilled before planting to reduce grass and weed infestation. Both pre- and post-emergence herbicides are applied.

The survey instrument asked respondents to indicate whether herbicides were used on cotton cropland, what types of herbicides were used, and how the product was applied for each application. Since quantity information was not collected by the survey, alternative estimates of herbicide use had to be constructed. Recommended application rates were obtained for all herbicides reported in the survey.[2] Under an assumption that farmers or applicators followed label recommendations, these recommended application rates were used to construct estimates of total pounds of herbicides applied at each sample point, taking into account the number of treatments reported (an application of chemical to the cropland is considered one treatment).

For the 14 States surveyed, nearly 93 percent of the 1989 planted acreage received at least one treatment of herbicides. Nearly 100 percent of the acreage in the Southeast and Delta was treated with herbicides. Producers in the West are a little less reliant on chemical weed control. The percentage of acres treated there is 82 percent (table 2).

The survey reported that 39 herbicides were applied to cotton cropland. The most widely used product was trifluralin, used on nearly 64 percent of surveyed acres. Other popular products include fluometuran (31 percent), pendimethalin (21 percent), MSMA (21 percent), norflurazon (19 percent), prometryn (16 percent), cyanazine (15 percent), and glyphosate (14 percent) (table 3). The application rates reported in table 3 are estimates based on a sample of cotton producers. Table 3 also reports the standard error of mean application rates for cotton herbicides, and the 95-percent confidence interval around this mean application rate.

Most of the cotton producers face a number of different target weed species, and the severity of the control problem varies considerably depending on environmental conditions and region. Of the surveyed acreage, 4.4 million acres (43 percent) received one herbicide treatment. Five million acres (49 percent) received more than one treatment. Treatments are often spread out over the season. Early season weed control is important to allow the plant to become established. Late season weed control is important to

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[2] Personal communication with Stanford Fertig of the Agricultural Research Service, USDA.

Table 3--Herbicide use on cotton acreage by product, 1989

Trifluralin was the most widely used herbicide of the 39 reported in the survey.

Chemical	Share of acres treated	Average treatment per acre	Mean application rate	95-percent confidence interval of mean application rate[1]		Standard error of mean
				High	Low	
	Percent	*Number*	*Lbs/acre*	*Lbs/acre*	*Lbs/acre*	*Lbs/acre*
Trifluralin	63.7	1.1	0.93	0.98	0.88	0.026
Fluometuron	31.3	1.1	1.82	2.00	1.64	.093
Pendimethalin	20.9	1.0	1.02	1.08	.96	.029
MSMA	20.7	1.1	2.55	2.91	2.21	.178
Norflurazon	18.9	1.2	1.78	1.96	1.61	.088
Prometryn	16.1	1.1	1.04	1.19	.91	.071
Cyanazine	15.3	1.1	1.13	1.28	.99	.074
Glyphosate	14.3	1.0	1.21	1.44	.99	.115
Fluazifop-butyl	7.5	1.0	.19	.23	.17	.015
DSMA	7.0	1.0	2.48	2.85	2.13	.184
Methazole	5.5	1.0	.84	.98	.69	.074
Metolachlor	3.2	1.0	1.68	1.76	1.61	.039
Diuron	2.7	1.0	.95	1.17	.73	.112
Sethoxydim	1.0	1.0	.26	.31	.22	.024

[1] 95-percent confidence interval around sample mean.

Note: Herbicides used on less than 1 percent of sampled acreage were not listed.

maintain crop yield and quality. Slightly more than two treatments per acre were reported for the surveyed States as a whole. An estimated 628,000 acres (14 percent), mostly in the Delta States, had five or more treatments.

Insecticide Use

Cotton farmers are faced with several insect pests, including the boll weevil, pink bollworm, bollworm, and tobacco budworm. Insect problems are greatest in the Delta and the Southeast, and the least in the Southern Plains. The severity of the insect control problem varies with a number of factors, including the amount of rainfall, levels of irrigation, and patterns of crop rotation.

Surveyed cotton producers reported using insecticides on 7.1 million acres (68 percent of the 10.5 million acres surveyed) (table 4). The number of treatments averaged 4.7 per acre for the four regions, ranging from 10.8 treatments in the Southeast to 2.5 treatments in the Southern Plains. Reflecting the severity of the pest problem in the Delta and the Southeast, these two regions were the heaviest users of insecticides, with over 70 percent of the surveyed acreage getting five applications or more.

The most popular insecticides were methyl parathion (used on 25 percent of surveyed acres), cypermethrin (20 percent), aldicarb (16 percent), dicrotophos (14 percent), and esfenvalerate (13 percent) (table 5). In terms of total pounds of active ingredient applied, malathion was the most heavily used insecticide, with 3.8 million pounds applied, primarily to control boll weevils that could over-winter. Insecticide application rates were highest in the Southeast, with over 6 pounds of active ingredient applied per acre, in part because of an active weevil eradication program in Georgia and Alabama. That eradication program helped to increase the number of treatments per acre in the Southeast.

Table 5 also reports standard errors of mean application rates and 95-percent confidence intervals around these estimated means. There is more variation in reported applications of insecticides than for

Table 4--Insecticide use on cotton acreage, 1989

The Southeast showed the highest intensity of pesticide application.

Item	Unit	Southeast	Delta	Southern Plains	West	All surveyed regions
Amount of acres treated	1,000 acres	836	2,720	2,578	926	7,062
Share of acres treated	Percent	98	92	51	72	69
Average application rate	Lbs AI[1]/acre	6.1	2.8	.7	3.1	2.4
Average treatments per acre	Number	10.8	7.4	2.5	4.1	4.7

[1] AI = Active Ingredient.

Table 5--Insecticide use on cotton acreage by product, 1989

Cotton farmers use many different chemical insecticides, but not all of the chemicals affect water quality the same way.

Chemical	Share of acres treated	Average treatment per acre	Mean application rate	95-percent confidence interval of mean application rate[1]		Standard error of mean
				High	Low	
	Percent	*Number*	*Lbs/acre*	*Lbs/acre*	*Lbs/acre*	*Lbs/acre*
Methyl parathion	24.6	2.9	1.78	2.27	1.29	.252
Cypermethrin	20.3	2.0	.17	.24	.10	.034
Aldicarb	15.6	1.0	.75	.91	.59	.083
Dicrotophos	13.6	1.9	.38	.51	.25	.067
Esfenvalerate	13.1	2.5	.12	.16	.08	.021
Azinphosmethyl	11.8	2.2	.62	.86	.45	.106
Cyfluthrin	10.2	1.9	.08	.11	.06	.013
Dimethoate	7.6	1.4	.36	.54	.19	.087
Lamdacyhalothrin	7.2	2.1	.07	.10	.04	.014
Acephate	6.8	1.5	.71	1.00	.42	.146
Profenfos	5.7	1.3	1.30	1.78	.82	.247
Thiodicarb	5.2	1.9	.93	1.41	.45	.244
Dicofol	4.8	1.1	1.04	1.29	.80	.125
Malathion	4.6	2.3	8.16	11.20	5.13	1.551
Chlorpyrifos	4.5	2.7	.74	.93	.55	.098
Tralomethrin	4.4	1.7	.04	.06	.02	.010
Chlordimeform	4.2	3.1	.54	.76	.33	.111
Oxamyl	3.5	1.5	.36	.58	.15	.109
Propargite	3.5	1.5	1.97	2.34	1.60	.189
Methomyl	3.3	1.3	.41	.93	-.10	.262
Permethrin	2.9	1.7	.22	.40	.05	.090
Methamidaphos	2.3	1.1	.64	.85	.43	.108
Sulprofos	1.9	1.1	1.00	1.82	.18	.418
Monocrotophos	1.9	1.2	1.15	2.39	-.09	.633
Fenvalerate	1.8	1.5	.21	.38	.04	.089
Ethyl parathion	1.4	2.5	2.34	4.81	-.12	1.262
Bifenthrin	1.2	1.1	.08	.15	.01	.037
Flucythrinate	1.1	4.0	.17	.26	.09	.042

[1] 95-percent confidence interval around sample mean.

Note: Insecticides used on less than 1 percent of sampled acreage were not listed.

Table 6--Other agrichemical use on cotton acreage, 1989

Cotton farmers use few fungicides.

Agrichemical type	Unit	Southeast	Delta	Southern Plains	West	All surveyed regions
Desiccants/defoliants:						
Amount of acres treated	1,000 acres	636	2,360	837	1,243	5,075
Share of acres treated	Percent	79	75	16	96	50
Average application rate	Lbs AI[1]/acre	1.0	1.4	1.9	4.5	2.1
Average treatments per acre	Number	1.1	1.0	1.4	1.7	1.4
Growth regulators:						
Amount of acres treated	1,000 acres	424	1,094	653	703	3685
Share of acres treated	Percent	64	50	13	54	36
Average application rate	Lbs AI/acre	.7	.5	.2	.5	.6
Average treatments per acre	Number	1.7	1.8	1.3	1.3	1.5
Fungicides:						
Amount of acres treated	1,000 acres	131	645	34	9	819
Share of acres treated	Percent	22	15	1	1	8
Average application rate	Lbs AI/acre	1.1	1.5	.9	.8	1.4
Average treatments per acre	Number	1.0	1.0	1.0	1.0	1.0

[1] AI = Active Ingredient.

herbicides. That is to be expected, because recommended application rates were used to construct herbicide applications, whereas actual quantities of insecticides applied were gathered by the survey instrument. Considerable variation in pesticide application rates is to be expected across the sample, because pest problems and chemical treatments vary among regions. The estimated mean application rates for several insecticides have high standard errors and wide confidence intervals around those estimated means. Three chemicals (methomyl, monocrotophos, and ethyl parathion) have such large standard errors that the lower bound of the 95-percent confidence interval is negative. The reported application rates should be considered unreliable for estimating any aggregate chemical use on cotton cropland for these insecticides.

Other Chemical Use

Cotton farmers use agrichemicals for a variety of purposes other than fertilizing and controlling weeds and insects. Chief among these are growth regulation, foliage control, and disease control. Table 6 reports use of desiccants and defoliants, growth regulators, and fungicides by region. Table 7 shows use of these chemicals by product type.

Defoliants and desiccants are applied to cotton plants to aid the harvesting process as the bolls on the plants mature. Half of the surveyed cotton acreage was treated with defoliants and desiccants, predominately in the West, Southeast, and Southern Plains. Phosphorotrihoate is the most frequently used defoliant, applied to more than one-third of all cotton acreage.

Growth regulators are applied to cotton cropland to help produce uniform plant sizes and aid harvesting. Slightly more than one-third of all surveyed acres were treated with growth regulators, most frequently in the Southeast. Two growth regulators are applied: mepiquat chloride (25 percent of surveyed acreage) and ethephon (19 percent).

Table 7--Other agrichemical use on cotton acreage by product, 1989

A variety of chemicals are applied to cotton to control foliage.

Chemical	Share of acres treated	Average treatment per acre	Mean application rate	95-percent confidence interval of mean application rate:[1] High	Low	Standard error of mean
	Percent	*Number*	*Lbs/acre*	*Lbs/acre*	*Lbs/acre*	*Lbs/acre*
Desiccants/defoliants:						
Phosphorotrihoate	35.1	1.1	1.10	1.22	1.00	.055
Sodium chlorate	11.3	1.1	5.02	5.74	4.31	.364
Paraquat	10.4	1.0	.16	.19	.12	.017
Thidiazuron	10.3	1.1	.25	.33	.17	.041
Endothall	4.2	1.0	.09	.12	.06	.016
Arsenic acid	3.1	1.0	1.96	2.22	1.71	.131
Dimethipin	2.8	1.0	.30	.36	.25	.029
Sodium cacodylate	2.1	1.0	.78	.93	.64	.074
Growth regulators:						
Mepiquat chloride	24.9	1.5	.03	.03	.02	.003
Ethephon	18.9	1.0	1.07	1.26	.89	.095
Fungicides:						
Etridiazole	2.6	1.0	1.35	1.67	1.03	.163
Etridiazole + disulfoton	2.0	1.0	1.39	1.88	.92	.247
PCNB	1.7	1.0	.68	1.08	.29	.202
Metalaxyl	1.1	1.0	.36	.88	-.15	.265

[1] 95-percent confidence interval around sample mean.

Note: Chemicals used on less than 1 percent of sampled acreage were not listed.

Fungicides are not widely used in cotton production. Of the surveyed acreage, only about 819,000 acres (8 percent) were treated with fungicides, mostly in the Delta States. Of the acres that were treated, one treatment was used. Reflecting the small number of reported fungicide applications, the estimated mean application rates show fairly high standard errors and wide confidence intervals.

Other Production Practices and Factors that Affect Water Quality

Many factors other than agricultural chemical use affect the likelihood that cotton production will affect water quality. These include irrigation, soil conservation practices, and the distance between the cotton field and water bodies (either overland distance to lakes and streams or vertical distance to underlying aquifers). The survey gathered information on several of these factors.

Irrigation

The importance of irrigation in cotton production has increased in recent years. High irrigation rates have been cited as reasons for rising water tables and increasing salinity problems in California's topsoil, subsoil, and irrigation return flows. In addition, the level and timing of irrigation can be an important factor in determining whether pesticides or nitrates will leach below the root zone and potentially enter underground aquifers. Irrigation drainage also may affect water quality, because soluble materials may be carried with it to surface and ground water supplies. Low irrigation efficiencies may mean relatively high drainage and increase the risk of degrading the quality of water bodies that receive this discharge.

Table 8--Cotton irrigation by region, 1989

Every surveyed cotton acre in the West was irrigated.

Item	Unit	Southeast	Delta	Southern Plains	West	All surveyed regions
Acres irrigated	Percent of surveyed acreage	11	29	43	100	43
Cotton water use:						
Average amount applied	1,000 acre feet	32	681	3,159	4,229	8,101
Average application rate	Inches/acre	3.7	9.4	17.9	39.4	--

-- = Not applicable.

In 1974, 30 percent of cotton acreage was irrigated, increasing to 37 percent in 1978 and 43 percent in 1989. This trend has occurred largely as a consequence of the westward shift of cotton acreage. Only 11 percent of all planted acreage in the Southeast was irrigated in 1989, but every surveyed cotton acre in the West was irrigated (table 8).

Much of the irrigated cotton acres water was obtained from underground sources, particularly in the Plains States. In the Southern Plains, which accounted for half of the irrigated cotton acreage, 89 percent of the irrigation water comes from wells. Average rates of water application also varied by region, from 3.7 inches per acre in the Southeast to nearly 40 inches per acre in the West.

Draw-down of ground water supplies from irrigation in the Plains States and the West has led to increased emphasis on increasing irrigation efficiency. Gravity application systems, normally considered the most inefficient irrigation systems from a technical perspective, were used on over 60 percent of cotton acreage in the Southern Plains and 90 percent of cotton acreage in the West. Because of growing demands for water, however, some gravity systems are being replaced by more efficient sprinkler systems.

Chemigation, a newer technology that mixes nutrients and pesticides in irrigation water, is being used on 38 percent of cotton acreage in the West.

Soil Conservation

Conserving soil is an important way to reduce agriculture's impact on surface water quality. Reducing soil erosion by practices such as conservation tillage, contour plowing, and grass waterways reduces movement of sediments and farm chemicals to nearby lakes and streams. Soil conservation practices may also have a perverse effect on ground water quality. For example, conservation practices such as conservation tillage may increase the intensity of pesticide (particularly herbicide) use. This result may increase the vulnerability of underlying aquifers to leached pesticides.

Most cotton is produced using conventional tillage. Conservation tillage[3] is not widespread (used on only 9 percent of all cropland), although other erosion control practices are used in some regions (table 9). Because of climate and topography, there is little use of erosion control practices in the West. Other erosion control practices are somewhat more prevalent, but none are in widespread use. Stalk destruction for control of over-wintering pests eliminates residue on cotton fields (leaving residue on the field is a common erosion control measure).

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[3] Use of one of the the following practices--no-till, ridge till, or mulch till--as defined in the survey.

Table 9--Soil characteristics and soil conservation practices by region, 1989

Terracing is used in three of the four regions.

Item	Southeast	Delta	Southern Plains	West	All surveyed regions
			Percentage of cotton acres		
Erosion control practices:					
Conservation tillage	7	5	13	4	9
Terraces	23	8	27	–	18
Contour	13	4	21	11	13
Strip cropping	--	3	11	--	6
Grass waterways	22	22	–	–	13
Soil type:					
Sand	33	2	12	1	10
Loam	59	77	49	43	57
Clay	8	21	39	56	33
Over 2 percent slope	71	22	30	9	28

-- = Less than 0.5 percent of surveyed acreage.

Soil type and slope are two factors that affect the potential for runoff and soil erosion. Cotton in the Delta, Southern Plains, and West was found to be produced primarily on loams or clays and fields were relatively level. In the Southeast, however, a relatively higher proportion of soils were either sandy, or had slopes greater than 2 percent. These lands are more erosion prone and production there may have an adverse effect on adjacent surface water bodies by increasing sediment and agrichemicals in runoff.

Proximity to Water Bodies

An important determinant of agriculture's effect on water quality is the distance from the field to either a well or a surface water body. If a well is contained within a surveyed field or is found nearby, then cropland may lie over a shallow aquifer, indicating a potential for fertilizers and pesticides to leach into ground water supplies. Similarly, if farming takes place near a lake or a stream (depending on the typography and rainfall intensity), the likelihood that runoff from cropland due to soil erosion or direct contamination from spray drift containing pesticides will degrade surface water quality also increases.

Nearly 60 percent of the cotton acreage surveyed contained a well somewhere in the farm operation. About 75 percent of the fields surveyed were within a half mile of a well of some type. Twenty-three percent of the acreage was within 1 mile of a river or stream, and 15 percent was within 1 mile of a pond or a natural lake (table 10).

In an effort to gain some understanding of cotton farmers' knowledge about the quality of their water supplies, survey respondents were asked whether the well nearest to the surveyed field had been tested for nitrates and/or pesticide residues. For 96 percent of the surveyed acreage, either the well in question had not been tested or the respondents did not know whether testing had been done. Only 4 percent of the acreage contained a well or was near a well that had recently been tested.

These results on farmers' knowledge of contamination problems should be viewed with some caution. The survey was not designed specifically to determine producer awareness of potential well water quality problems. While these values are not necessarily indicative of a water quality problem for cotton producers, it is clear that we need more information about the potential effect of cotton farming on water quality.

Table 10--Cotton land's proximity to water and other resource chacteristics by region, 1989

Nearly 60 percent of all cotton acres surveyed had a well somewhere on the farm.

Item	Southeast	Delta	Southern Plains	West	All surveyed regions
			Percentage of cotton acres		
Acreage containing a well	44	51	61	83	60
Distance to water bodies:					
Acreage within 1 mile of--					
Lake or pond	11	17	18	1	15
River or stream	42	53	6	7	23
City or public well	4	9	2	1	4
Water characteristics:					
Acreage where nearby well has been tested for nitrates or pesticides	1	2	5	7	4

Effects of Cotton Production on Water Quality

We present in this section an initial assessment of some of the possible effects on water quality arising from cotton production and agricultural chemical use on cotton acreage.

The analysis presented in this section represents a first-cut approach at defining the possible extent of water quality problems associated with cotton production. We use data on chemical use, resource conditions, and agricultural practices obtained from the survey as inputs to some simple screening and assessment models. The models were developed to characterize the surveyed acreage by its potential for off-farm water quality effects. In some instances, we use models to estimate delivery of pollutants to water bodies and the possible effects of cotton production on ambient water quality. In other cases, particularly for pesticide leaching and runoff, we take a less definitive approach by characterizing the potential for water quality degradation from cotton production rather than estimating actual pollutant flows or establishing direct linkages between cotton production and measures of water quality.

We use the approach of defining chemical loss potentials rather than directly estimating loadings for several reasons. First, the scientific understanding of the relationships between agricultural production and off-farm water quality effects is imperfect at best. There are models available that simulate the movement of chemical residuals and sediment from cropland to water bodies (AGNPS, CREAMS, STREAM, EPIC), but these models tend to be data intensive and are site specific. As such, they are not particularly well-suited to making national aggregate assessments of agricultural effects on water quality of the sort dealt with here, because the data required to run these models are not available from the survey.

We also face the additional constraint of estimating pollutant flows through time as well as through space, particularly for ground water quality. It may take years for agricultural chemicals applied to cropland to leach into underground aquifers. Again, simulation models are available (GLEAMS, CMLS, PRZM, RUSTIC, AT123D), that can be applied on a site-by-site basis to estimate pollutant flows and ambient ground water quality over time, but they require significant amounts of hydrogeophysical and climate data on a site-specific basis. Because detailed information of this sort was not available from the 1989 Cotton Water Quality Survey, we did not estimate actual chemical pollutant delivery to water bodies. Instead, we characterized surveyed cotton acreage on the basis of the "potential" for chemical leaching losses from cropland.

Additional research is underway at the USDA to estimate actual pollutant delivery and to make more explicit the linkages between agricultural production, chemical use, water quality effects, and the economic damage associated with impaired water quality. The research summarized here should be viewed as a first step, one that defines the potential extent of the water quality problem associated with agricultural production, identifies factors thought to contribute to the problem, and provides initial insight into possible policy options to diminish or prevent these adverse effects.

Surface Water Quality

Agriculture's effect on water quality of lakes, rivers, and streams is primarily driven by soil erosion and runoff from cropland. Using survey data, we calculated estimates of soil erosion as a first step in making the link between cotton production and off-farm surface water effects.

We use in this study a model developed by Ribaudo (1989) that links soil erosion and off-site water quality effects. This model consists of three stages that link soil erosion, movement of pollutants from field to waterway, and the physical effects on water quality.

Soil Erosion

A universal soil loss equation (USLE) was used to estimate soil erosion on surveyed cotton acreage. The survey instrument collected several variables of the USLE directly: LS (land slope factor), R factor (rainfall), and C factor (cropping). The K factor (erodibility) was obtained by linking soil classifications obtained by the survey with associated soil characteristics in the USDA-SCS Soils V database. Survey data were used to calculate the P factor (practices). We calculated estimates of soil erosion for each sample point in the survey. Weighting factors calculated as part of the survey were used to aggregate individual estimates to State and regional bases.[4]

Table 11 presents estimates of soil erosion on surveyed cotton acreage. The average erosion rate on U.S. cotton is estimated at 5.3 tons per acre per year (tons/a/y). Erosion rates varied between 0.4 ton/a/y in California to 16.4 tons/a/y in Arkansas.

Surface Water Sediment Loadings

Using the procedure developed by Ribaudo (1989), we estimated soil erosion on cotton cropland and used it as input into a pollutant delivery model. The pollutant delivery model accounts for movements of soil and nutrients from the edge of the field to natural or constructed waterways. The amount of sediment that reaches a waterway depends on factors such as the distance, slope, and vegetation characteristics of the watershed.

The model is set up on a watershed (U.S. Geologic Survey Aggregated Subarea, or ASA) basis. Erosion data from survey sample points were distributed among ASA's, and estimates of soil erosion on cotton cropland were used to estimate pollutant loadings into surface waters. Table 11 presents estimates of the amount of sediment delivered to surface water bodies from erosion on cotton cropland in the 14 surveyed States. Sediment loadings are based on sediment delivery ratios estimated by Resources for the Future (Gianessi, Peskin, and Puffer, 1985). Arkansas showed the highest relative rate of sediment loading (loadings per acre of cropland), which reflects the high estimated rate of cropland erosion.

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[4] Since the survey is based on a stratified sample of cotton acreage, weighting factors are associated with each sample point. The factors measure the contribution of the sample field to total surveyed acreage. They are used to aggregate from individual sample acreage to aggregate acreage.

Table 11--Estimated soil erosion and sediment delivery to surface waters from cotton cropland by State and region, 1989

Erosion rates on cotton cropland were highest in the Delta States.

State/region	Erosion rate	Total gross erosion	Total sediment delivered
	Tons/acre/year	---------------*Tons*---------------	
Alabama	12.0	4,197	2,251
Arizona	12.6	614	278
Arkansas	16.4	9,974	5,624
California	.4	448	205
Georgia	5.0	1,363	444
Louisiana	8.3	5,368	3,017
Mississippi	8.6	9,093	5,095
Missouri	4.0	874	465
New Mexico	2.4	146	61
North Carolina	4.6	517	220
Oklahoma	5.0	1,908	928
South Carolina	8.0	960	408
Tennessee	10.5	4,721	2,592
Texas	3.1	14,091	6,772
Delta	10.1	30,030	16,793
Southeast	8.3	7,037	3,323
Southern Plains	3.2	16,046	7,761
West	.8	1,062	483
All regions	5.3	54,175	28,360

Surface Water Agrichemical Effects

The model used by Ribaudo accounts only for delivery of sediment to surface waters. Estimates of losses of pesticides and other agricultural chemicals are more difficult to develop. The model estimates nutrient delivery to water bodies, but only for all cropland within a watershed. It is not now possible to estimate nutrient loadings to surface water attributable solely to runoff from cotton cropland. Such estimates would have to be constructed using site-specific physical transport models such as AGNPS.

The model also does not calculate delivery of pesticides to surface waters. A screening procedure developed by Goss and Wauchope (1990), however, can be used to estimate the potential for applied pesticides to be removed from cropland dissolved in runoff and attached to sediment. Their methodology categorizes cropland by the potential for pesticides to move from the soil to surface waters.

The Goss and Wauchope procedure creates a qualitative index that describes the relative potential of pesticides put on cropland to leave the field. The physical properties of the soil and the chemical properties of the pesticides applied jointly determine an ordinal measure of the overall propensity of the pesticides to leave the field attached to soil particles (adsorption) or dissolved in runoff. Cropland is placed in one of three loss potential categories, with "category 1" representing acreage with the highest potential for pesticides to leave the field and "category 3" representing acreage with the lowest potential for pesticides to leave the field. Appendix B gives a full discussion of the screening model and loss potential algorithms.

Table 12--Estimated surface water vulnerability potential: Pesticides attached to sediment by State and region, 1989

Cotton cropland with a high potential for pesticide losses attached to dissolved sediment is primarily in the Delta and Southeastern States.

State/region	Potential 1[1]		Potential 2		Potential 3		Unknown	
	1,000 acres	*Percent*	*1,000 acres*	*Percent*	*1,000 acres*	*Percent*	*1,000 acres*	*Percent*
Alabama	25	7	181	52	12	4	131	37
Arizona	17	7	31	13	60	25	131	55
Arkansas	258	42	156	26	7	1	190	31
California	183	17	100	10	25	2	742	71
Georgia	0	0	13	5	236	87	20	8
Louisiana	326	51	254	39	0	0	65	10
Mississippi	686	65	275	26	0	0	89	8
Missouri	44	20	66	31	22	10	82	38
New Mexico	22	35	25	41	13	21	2	3
North Carolina	23	21	33	29	0	0	56	50
Oklahoma	237	62	122	32	22	6	0	0
South Carolina	19	16	23	19	27	23	50	42
Tennessee	254	56	80	18	0	0	120	26
Texas	3,727	81	609	13	134	3	130	3
Delta	1,568	53	830	28	29	1	546	18
Southeast	68	8	251	29	276	32	258	30
Southern Plains	3,985	79	756	15	168	3	132	3
West	200	16	132	10	85	7	873	68
All regions	5,821	57	1,969	19	557	5	1,810	18

[1] Potential 1 classifies cropland as most vulnerable to pesticide loss, while potential 3 indicates little or no likelihood of pesticide loss.

Tables 12 and 13 present estimates of the proportion of cropland in each State and region that falls into the three defined pesticide loss potential categories. A fourth category, called "unknown," is also included to account for uses of agricultural chemicals that are not included in the Goss and Wauchope assessment procedure. Two loss potentials are identified: the potential for pesticides applied to cropland to leave the field attached to soil particles (table 12) and the potential for pesticides to leave the field dissolved in runoff (table 13). A fairly significant proportion (57 percent) of the total acreage for all the 14 States surveyed fell into the category of highest potential for pesticide loss through adsorption. A somewhat smaller share (29 percent) of the cropland showed a high potential for pesticide loss dissolved in runoff.[5]

Ground Water Quality

The precise effects of agricultural chemical use on ground water quality are not as well understood as surface water effects. However, to measure the potential losses of pesticides to ground water, we used the methodology developed by Goss and Wauchope (1990) to categorize the likelihood that pesticides applied to cropland leach into ground water.

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[5] Recent field reconnaissance studies by the U.S. Geological Survey have shown that high levels of some herbicides in surface waters in the Midwest were detected for several months after those chemicals were applied to cropland.

Table 13--Estimated surface water vulnerability potential: Pesticides dissolved in runoff by State and region, 1989

About 29 percent of all cotton acreage in the survey was given the highest relative potential for losses of pesticides dissolved in runoff.

State/region	Potential 1[1]		Potential 2		Potential 3		Unknown	
	1,000 acres	*Percent*	*1,000 acres*	*Percent*	*1,000 acres*	*Percent*	*1,000 acres*	*Percent*
Alabama	25	7	231	66	6	2	87	25
Arizona	9	4	71	30	31	13	129	54
Arkansas	258	42	142	23	14	2	197	32
California	139	13	140	13	49	5	722	69
Georgia	6	2	0	0	243	90	20	7
Louisiana	319	49	225	35	0	0	101	16
Mississippi	686	65	261	25	0	0	103	10
Missouri	49	23	121	56	0	0	44	21
New Mexico	27	44	30	50	2	3	2	3
North Carolina	23	21	33	29	0	0	56	50
Oklahoma	50	13	308	81	22	6	0	0
South Carolina	15	13	58	48	8	6	39	32
Tennessee	248	54	73	16	0	0	134	29
Texas	1,108	24	3,110	68	255	6	126	3
Delta	1,660	52	822	28	14	1	578	19
Southeast	71	8	322	38	257	30	202	24
Southern Plains	1,185	24	3,449	68	279	6	128	3
West	148	11	211	16	81	6	851	66
All regions	2,963	29	4,805	47	630	6	1,760	17

[1] Potential 1 classifies cropland as most vulnerable to pesticide loss, while potential 3 indicates little or no likelihood of pesticide loss.

Potential Pesticide Leaching

Based on this procedure, the leaching potential measures for each sample point were constructed using survey data on soil properties and information about the chemical properties of the pesticides applied. Weighting factors calculated as part of the survey were used to construct regional estimates of the amount of cotton cropland in each category of pesticide leaching potential. Table 14 presents these estimates. Cropland covered by the survey is given a loss potential score ranging from "potential 1" (highest probability of pesticide leaching) to "potential 4" (virtually no probability of pesticide leaching).

The results from our screening assessment show that acreage with a high potential for pesticide leaching is much less widespread than acreage with a high potential for loss to surface water, in contrast to the loss of pesticides to surface water. Although the leaching potential index is an ordinal measure and not directly comparable to surface water pesticide loss indexes, it is revealing that only 3 percent of the cropland fell into the highest leaching loss potential category. Thus, it appears that pesticide leaching to ground water from cotton production may not be a widespread problem. Of course, specific sites could experience serious pollution problems, depending on local conditions.[6]

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[6] For example, localized cases of ground water contamination may arise from improper mixing, loading, disposal, or storage of pesticides near wellheads. This may result in ground water contamination which is not caused by normal field application of chemicals.

Table 14--Estimated groundwater vulnerability potential: Pesticide leaching by State and region, 1989

Only 3 percent of surveyed cotton cropland in all regions was given the highest relative potential for pesticides to leach.

State/region	Potential 1[1]		Potential 2		Potential 3		Potential 4		Unknown	
	1,000 acres	*Percent*	*1,000 acres*	*Percent*	*1,000 acres*	*Percent*	*1,000 acres*	*Percent*	*1,000 acres*	*Percent*
Alabama	69	20	94	27	75	21	0	0	112	32
Arizona	23	10	54	23	29	12	9	4	126	52
Arkansas	44	8	102	17	305	50	81	13	75	12
California	15	1	36	3	66	6	177	17	756	72
Georgia	0	0	81	30	176	65	0	0	13	5
Louisiana	22	3	58	9	348	54	210	33	7	1
Mississippi	13	1	124	12	638	61	172	16	103	10
Missouri	33	15	44	21	77	36	22	10	38	18
New Mexico	16	26	20	32	22	36	0	0	4	6
North Carolina	19	17	28	25	33	29	0	0	33	29
Oklahoma	7	2	72	19	200	53	43	11	57	15
South Carolina	27	23	35	29	43	35	0	0	15	13
Tennessee	7	1	74	16	241	53	80	18	54	12
Texas	38	1	1,405	31	1,809	39	1,024	22	323	7
Delta	123	4	401	13	1,608	54	565	19	277	9
Southeast	115	13	238	28	326	38	0	0	174	20
Southern Plains	62	1	1,497	30	2,031	40	1,068	21	383	8
West	38	3	90	7	94	7	186	14	882	68
All regions	336	3	2,225	22	4,059	40	1,819	18	1,716	17

[1] Potential 1 classifies cropland as most vulnerable to pesticide loss, while potential 4 indicates little or no likelihood of pesticide loss.

Potential Nitrate Leaching

The Goss and Wauchope procedure does not address the possibility that nitrogen applied to cropland may result in nitrates leaching into ground water. We used a methodology developed by Pierce, Shaffer, and Halvorson (1990) to measure the potential for nitrates losses from cotton cropland. Their approach considers both annual and seasonal precipitation with soils information to construct an ordinal measure, called the Leaching Index, of the relative likelihood that nitrates will leach below the root zone. Appendix B gives details of this procedure.

As with the pesticide leaching measures, survey data were used to construct a nitrate leaching index at each sample point. Using the overall potential loss scores at each sample point, we used weighting factors obtained in the survey to compute aggregate estimates of the acreage in each category. Table 15 shows the overall and regional breakdown of cropland by nitrate leaching potential.

Overall, slightly less than one-third of the cropland was rated as having a high nitrate leaching potential. This acreage was concentrated primarily in the West: 76 percent of acreage in that region was classified as having high potential for nitrate leaching. In contrast, the States in the Southeast showed predominately moderate or low potential for nitrate leaching.

It should be emphasized that both the pesticide and nitrate screening procedures establish only an indication of potential chemical losses from the root zone and do not quantify or estimate the actual

Table 15--Estimated groundwater vulnerability potential: Nitrate leaching by State and region, 1989

Cotton cropland in the Southeast showed less potential vulnerability to leaching nitrates than did other regions.

State	High vulnerability		Moderate vulnerability		Low vulnerability	
	1,000 acres	*Percent*	*1,000 acres*	*Percent*	*1,000 acres*	*Percent*
Alabama	6	2	313	89	31	9
Arizona	189	79	51	21	0	0
Arkansas	129	21	474	78	7	1
California	792	75	257	24	0	0
Georgia	0	0	270	100	0	0
Louisiana	225	35	405	63	14	2
Mississippi	254	24	789	75	7	1
Missouri	33	15	181	85	0	0
New Mexico	9	15	52	85	0	0
North Carolina	0	0	103	92	9	8
Oklahoma	86	23	294	77	0	0
South Carolina	0	0	97	81	23	19
Tennessee	100	22	354	78	0	0
Texas	1,465	32	3,097	67	38	1
Delta	740	25	2,205	74	28	1
Southeast	6	1	782	92	64	7
Southern Plains	1,560	31	3,443	68	38	1
West	981	76	308	24	0	0
All regions	3,287	32	6,739	66	130	1

losses of pesticides or nitrates to ground water. Actual leaching to ground water occurs only to the extent that the chemicals applied fail to be taken up by the plant or fail to bind to soil particles in the upper layers of soils. Neither should these estimates be used to make inferences about any contamination of ground waters. Rather, they are should be viewed only as a general assessment of the potential for pesticides applied to cotton cropland to leach past the root zone.

Analysis and Interpretation

When the survey data and the results of the screening and pollutant delivery models are taken together, several general conclusions about the effect of cotton production on water quality emerge. First, relatively less cropland is rated at the highest vulnerability for pesticide leaching than is rated at the highest vulnerability for pesticide losses to surface water dissolved in runoff or adsorbed to suspended sediment. For the 14 surveyed States, only about 3 percent of all cotton acreage fell into the "potential 1" category for leaching of pesticides. However, 57 percent of all cropland devoted to cotton fell into the highest potential category for losses of pesticides through adsorption to suspended sediment in runoff, and 29 percent fell into the highest potential category for pesticide losses through solution in runoff.

Second, based on the screening procedures employed in our assessment, relatively more cotton cropland seems to be at risk for nitrate leaching than for pesticide leaching. Although the nitrate leaching potential index and the pesticide leaching potential index use different methods for assessing vulnerability, a higher proportion of the surveyed cotton acreage is classified as highly or moderately vulnerable to nitrate leaching than is classified as having a high potential for pesticide leaching.

Finally, the patterns of pesticide vulnerability associated with the chemicals used in cotton production seem to reflect more the effect of soil characteristics on pesticide losses from the root zone than the influence of chemical properties on pesticide losses from the root zone. While a direct comparison between soil and chemical loss potentials is not possible, the surveyed acreage tended to fall more often into the "high" or "intermediate" range for soil loss potential than the "large" or "medium" range for pesticide loss potential. The relative vulnerability of cotton cropland to pesticide losses seems to be influenced more by the soil characteristics than by the properties of the applied chemicals (see Appendix B).[7]

Potential Water Quality Effects of Changing Cotton Production Practices

The suspended sediment model developed by Ribaudo was used to estimate the potential improvements in surface water quality if erosion on cotton acreage were reduced. This involved a two-step procedure. First, potential reductions in erosion on cotton cropland were estimated for two scenarios: installing conservation practices on all cotton acreage and reducing erosion on cotton acreage via conservation compliance. The reductions in erosion were then fed into the model to predict the changes in concentrations of suspended sediment for regions covered by the survey.

The survey obtained information on conservation practices cotton farmers used, such as terracing, contour farming, and strip cropping. The potential reductions in erosion were estimated by assuming that conservation practices would be applied on all acres. The results indicated that total erosion on cropland would be reduced by 50 percent. The average national rate would be 2.6 tons/a/y. Rates range between 0.2 ton/a/y in California to 9.8 tons/a/y in Arkansas (table 16).

An alternative scenario assumed that conservation practices were adopted on acres considered "highly erodible" under the standard used for the conservation compliance provisions of the Food Security Act of 1985. A comparison was made of base erosion and the erosion that would occur if conservation practices were applied on cotton acreage labeled "highly erodible" on the survey. The results indicate that erosion would be decreased by about 19 percent.[8] Average erosion rates would decrease from 5.3 tons/a/y to 4.3 tons/a/y. Erosion rates in several States, notably Arkansas and Alabama, remained high despite the installation of conservation practices on highly erodible land, as called for in the compliance provisions.[9]

The changes in erosion rates from these two scenarios were then used to estimate the expected changes in surface water quality. A baseline level of suspended sediment was calculated from 1982-83 monitoring data. The effects of reduced erosion from installing soil conservation practices and conservation compliance were measured by the changes in concentrations of sediment in these watersheds. Table 17 reports results for the watersheds in the survey States.

These results indicate that reducing erosion on cotton acreage alone would not greatly improve surface water quality regarding sediment loadings, even if the erosion reductions on cotton acreage are substantial. The reason is that there are many sources of sediment in surface water besides cotton cropland, and the contribution from cotton in any one region is not great.

It is not currently possible to estimate the extent to which modifications in cotton production could reduce pesticide loadings to lakes and streams, because estimates of pesticide loadings to surface

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[7] The environmental effect of leaching chemicals will also depend on the relative toxicity of the chemicals, the health effects of human ingestion of or contact with these chemicals, and other adverse effects, such as effects on endangered plants or animals.

[8] Not all acres in the survey were assessed. Unassessed acres were deleted and the results were adjusted to reflect the full base acreage. Since assessment was uneven between States, comparison between States may not be representative.

[9] This scenario implicitly assumes that all farmers harvesting on highly erodible land would, in fact, install conservation measures on that cropland. In practice, farmers may choose to forgo participation in USDA programs rather than install such practices if the costs of conservation outweigh the benefits of program participation.

Table 16--Potential erosion reduction on cotton cropland by State and region, 1989

Applying erosion control measures to cotton cropland could reduce erosion, particularly in the Delta and Southeast.

State/region	Base erosion		With erosion control		With conservation compliance	
	Rate[1]	*Tons of erosion*	*Rate*	*Tons of erosion*	*Rate*	*Tons of erosion*
Alabama	12.0	4,197	3.3	1,164	9.4	3,289
Arizona	12.6	614	1.2	288	1.5	361
Arkansas	16.4	9,974	9.9	6,031	14.7	8,981
California	.4	448	.2	228	.4	408
Georgia	5.0	1,363	1.4	383	5.0	1,363
Louisiana	8.3	5,368	4.4	2,807	7.9	5,082
Mississippi	8.6	9,093	3.9	4,066	7.3	7,648
Missouri	4.0	874	2.0	440	4.0	847
New Mexico	2.4	146	1.4	86	2.0	122
North Carolina	4.6	517	2.1	237	4.2	472
Oklahoma	5.0	1,908	2.9	1,111	4.8	1,809
South Carolina	8.0	960	2.2	269	7.9	945
Tennessee	10.5	4,721	3.3	1,486	7.6	3,469
Texas	3.1	14,091	1.8	8,400	2.0	9,344
Delta	10.1	30,030	4.8	14,830	8.4	26,027
Southeast	8.3	7,037	2.4	2,053	7.1	6,069
Southern Plains	3.2	16,046	1.9	9,525	2.2	11,275
West	.8	1,062	.4	516	.6	769
All regions	5.3	54,175	2.7	26,924	4.3	44,140

[1] Tons per acre per year (tons/a/y).

waters from cotton cropland are not available. Some indirect evidence can be seen, however, using available data on agriculture-related surface water quality problems together with our measures of relative pesticide loss potential.

EPA, under the 1987 Water Quality Act, requires the States to assess the quality of their water resources and report to it any water bodies that do not meet designated uses. EPA has summarized the information on agricultural nonpoint source pollution in a database named AGTRAK. This database was used to identify, on a county level basis, the number of water bodies harmed by pesticides, nutrients, and sediments from agricultural sources.

Data from AGTRAK were combined with survey data to see whether there was any relationship between identified impairment of surface waters by pesticides and potential losses of pesticides from cotton cropland. All sample points were classified according to whether or not an identified surface water impairment from agricultural pesticides was found in the county in which the sample point was located. The surveyed acreage was then cross-tabulated to show how adsorption and runoff solution loss potentials correspond to identified water quality impairments.

A chi-square test was used to determine whether cotton cropland classified as having a high potential for pesticide losses to runoff or adsorbed to sediment was found in counties identified as having surface waters affected by pesticides. Results show a small but statistically significant difference between estimated potential for loss of pesticides to surface waters and identified water quality effects. Cotton cropland with a higher potential for losses of pesticides to surface water tends to be found in areas where there is an identified surface water impairment from pesticides. Conversely, cropland falling into

Table 17--Potential water quality improvements from erosion control by ASA, 1989

Reducing erosion on cotton cropland may not improve surface water quality substantially, because there are other sources of suspended sediment besides runoff from cotton acreage.

ASA[1]	Base case	Erosion control on all acreage		Erosion control HEL[2] land only	
	Sediment concentration[3]	*Sediment concentration*	*Change*[4]	*Sediment concentration*	*Change*
301	28.80	28.47	0.33	28.74	0.06
302	54.31	53.49	.82	54.29	.02
303	24.91	24.57	.34	24.91	.00
304	29.60	29.25	.35	29.60	.00
306	18.74	18.28	.46	18.74	.00
307	28.69	28.58	.11	28.51	.18
308	36.37	35.86	.51	35.89	.48
309	51.19	50.54	.65	50.92	.27
602	14.37	10.57	3.80	13.32	1.05
801	136.58	133.77	2.81	135.71	.87
802	214.85	209.75	5.10	213.70	1.15
1105	243.51	243.48	.03	243.51	.00
1106	663.66	656.97	6.69	662.23	1.43
1107	222.67	221.91	.76	222.67	.00
1201	53.04	53.04	.00	53.04	.00
1202	102.87	102.42	.45	102.17	.70
1203	401.73	394.63	7.10	397.32	4.41
1204	80.03	75.79	4.24	71.98	8.05
1205	138.61	137.78	.83	138.61	.00
1302	2,052.50	2,052.38	.12	2,052.44	.06
1303	403.40	402.80	.60	403.40	.00
1304	504.34	503.67	.67	504.10	.24
1305	345.50	342.85	2.65	343.82	1.68
1502	1,125.02	1,124.95	.07	1,125.02	.00
1503	890.85	883.44	7.41	884.66	6.19
1803	30.63	29.98	.65	30.51	.12
1806	617.67	617.67	.00	617.67	.00

[1] ASA = Aggregated Sub-Area, as defined by U.S. Geologic Survey.
[2] HEL = Highly erodible land.
[3] Concentration of suspended sediment, milligrams per liter.
[4] Change in concentration of suspended sediment, milligrams per liter.

the lowest potential loss categories tended to be found in counties with no identified impairments from agricultural pesticides. Because there are other sources of pesticides in surface water besides cotton production, these results should be taken merely as a general indication that reducing chemical use or controlling erosion from cotton fields would contribute to improved surface water quality. However, the magnitude of such an effect is likely to be small.

The question of whether cotton production harms ground water quality is more difficult to address. The screening procedure used to develop our measures of vulnerability to pesticide and nitrate leaching does not provide estimates of pollutant loadings to ground water supplies. It is not currently possible to directly estimate the extent to which changing cotton production practices may reduce or prevent leaching of nitrates or pesticides.

We used the ground water pesticide and nitrate leaching potential estimates to construct some indirect, associative measures between ground water vulnerability and possible adverse water quality effects. Survey data on whether there were wells on the farm were compared with nitrate and pesticide leaching potential scores. A chi-squared test was used to test the association between cropland classified as most vulnerable to leaching and farms with wells. No statistically significant pattern emerges. Those farms having wells show the same general distribution of vulnerability scores as do farms that do not have wells. Similarly, farms with wells do not seem to use significantly different intensities and types of agricultural chemicals than do those without wells, as measured by pounds of active ingredient of chemical applied per acre and leachability class of the pesticides.

Cotton production, as we have seen, involves a wide variety of chemicals, some fairly intensively. Reductions in the amount of herbicides, insecticides, fertilizers, and other farm chemicals applied to cropland can certainly help prevent possible ground water contamination by chemical residuals. In the case of pesticides, there probably is not much benefit to be obtained in terms of protecting ground water by reducing applications on a wide scale, because nearly 60 percent of the cropland surveyed falls into the lowest leaching potential categories. However, reducing nitrogen fertilizer applications on cotton acreage could help reduce the likelihood of nitrates leaching into ground water. The evidence from our analysis that shows some fairly widespread vulnerability to leaching nitrates indicates that reducing the nitrogen available for leaching on cotton cropland could help protect the quality of ground water.

Conclusions

Our objective was to conduct a preliminary assessment of scope of the potential water quality problems relating to cotton production. The data collected by the survey present a fairly comprehensive picture of agricultural chemical use, associated production practices, and resource conditions in the cotton sector. Screening and assessment models provide an initial characterization of the extent of the potential for ground water problems stemming from pesticide and fertilizer use on cotton acreage. It appears that the most widespread issues of concern over natural resources are the potential for nitrates from cotton cropland to leach into ground water, and for possible movement of pesticides to surface water from cotton land. Major uncertainties remain, particularly in the area of possible leaching of nitrates and pesticides to ground water. This report sets the stage for further, more detailed analysis of the economic and environmental issues associated with cotton production and water quality.

Additional research is underway to more explicitly assess the potential loadings of chemicals and sediment to water bodies from cotton cropland. A more complete accounting of the fate of chemical residuals and sediment in the environment will enable us to assess the linkages between water quality and agricultural production. The economic implications also need to be addressed. Particularly, we need to be able to specify the physical effects of cotton production on water quality, as well as the economic costs associated with impaired water quality. We need to determine how much policies and programs aimed at reducing or preventing water quality impairment will economically affect the agricultural sector. As the data and analysis presented in this report reveal, such analyses may be most important for practices and technologies that reduce nitrate leaching to ground water or prevent delivery of pesticides to surface water.

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Appendix A--Cotton Water Quality Survey Instrument

Agricultural Statistics Board

National Agricultural Statistics Service

U.S. Department of Agriculture

FORM W: WATER QUALITY SURVEY - 1989

Form Approved
OMB Number 0535-0218
Expiration Date 09/30/90

YEAR,CROP,FORM,MONTH (1-5)	
93011	

INTRODUCTION

[Introduce yourself and ask for the operator. Rephrase in your own words.]
We are collecting information on cotton pesticide use and farm production practices related to water quality and need your help to make the information as accurate as possible. Your report is confidential, and used only for statistical purposes and economic analysis. Response is voluntary and your cooperation will be appreciated.

Earlier this year you were asked about the acres of cotton planted in a selected sample field and some of the cropping practices used in that field.

The questions in this survey relate specifically to that sample field. I would like to ask about the cropping practices which have occurred since the earlier survey.

Date (________________) . . . . . 101 ______

Starting Time . . . . . *(Military Time)* 102 __ __ __ __

FOR NON-OBJECTIVE YIELD COTTON STATES ONLY:

(ALABAMA, GEORGIA, MISSOURI, NEW MEXICO, NORTH CAROLINA, OKLAHOMA, SOUTH CAROLINA AND TENNESSEE)

1. How many total bales were harvested or are expected to be harvested from this sample field (Include gleanings, if any)? . . . . *Bales to Tenths* 103 ____ . __

I. FERTILIZER USE

1. Did you apply ANY chemical fertilizer to the cotton on this sample field since August 1?
( ) YES = 1, *Continue* ( ) NO = 2, *go to page 3* . . . . *Enter Code* 203

Include all amounts applied specifically for this cotton crop since August 1, 1989.

MATERIAL USED (*Enter percent analysis or actual pounds of plant nutrients applied per acre).*			QUANTITY Used Per Acre 1/	UNIT Pounds = 1 Gallons = 2 Actual plant nutrients = 3	How was it applied: 1. Broadcast, Dry 2. Broadcast, Liquid 3. Band, Dry 4. Band, Liquid 5. Band, Solution 6. Injected or knifed in 7. Mixed with irrig. water 8. Foliar 9. Other, (specify)
N NITROGEN	P_2O_5 PHOSPHORUS	K_2O POTASH			
Col. 1	Col. 2	Col. 3	Col. 4	Col. 5	Col. 6
211	212	213	214	215	216
217	218	219	220	221	222
223	224	225	226	227	228
229	230	231	232	233	234

1/ If actual pounds of plant nutrients are reported in columns 1, 2, or 3, leave column 4 blank and enter a code 3 in column 5.

EXAMPLES OF ANALYSIS BY KIND

Kind	Percent Analysis	Kind	Percent Analysis
Anhydrous Ammonia	82 - 0 - 0	Urea	46 - 0 - 0
Diammonium Phosphate	18 - 46 - 0	Ammonium Nitrate	34 - 0 - 0
Nitrogen Solutions	28 - 0 - 0	Potassium Chloride	0 - 0 - 60
Nitrogen Solutions	32 - 0 - 0	Mixed Fertilizers	13 - 13 - 13

ENTER CODE

2. Was SULFUR applied to this cotton sample field since August 1? ( ) YES = 1, ( ) NO = 2 235

a. If YES, how many pounds were applied per acre? .... *Pounds* 236 . ___

3. Were any MICRO NUTRIENTS applied to this cotton sample field since August 1?
( ) YES = 1, ( ) NO = 2 237

4. For any of your fertilizer applications this year, did you use a product to stabilize or inhibit the breakdown of Nitrogen?
( ) YES = 1, ( ) NO = 2, ( ) Don't Know = 3 238

II. HERBICIDES

1. How many times since August 1 was this sample field cultivated for weed control? *(Zero is a valid answer. Enter a positive number or a "0")* . . . Number [301]

2. Were any herbicides used on this sample field since August 1? ( ) YES = 1, ( ) NO = 2 *(If NO to question 2, go to page 4)* . . . . Enter Code [302]

A. If two or more products were mixed together in the spray tank before application to this field, **REPORT** them on the **SAME LINE** using the applicable product codes listed on the card.

B. If the same product was used more than once--**RECORD EACH** application on a separate line.

ASK for the herbicide products used on this field since August 1.

LINE NO.	Product Code(s): *(Listed on card)*			How was it Applied: 1 = Broadcast, Ground 2 = Broadcast, Air 4 = Irrigation water 5 = Banded in/over row 6 = Directed spray 9 = Spot treatment	Who Applied: 1 = Farmer 2 = Custom
	1 st	2 nd	3 rd		
	Col. 1			Col. 2	Col. 3
1	311	312	313	314	315
2	316	317	318	319	320
3	321	322	323	324	325
4	326	327	328	329	330
5	331	332	333	334	335

For herbicides not listed on card:

Herbicides: 190 Other, specify____________________

191 Other, specify____________________

VIII. PEST MANAGEMENT

		ENTER CODE
1. Do you participate in a professional scouting program *(exclude farmer scouting)* in the sample field for weeds and/or harmful insects?	( ) YES = 1, ( ) NO = 2	840
If "YES" is checked, how many times per season does the scout inspect the sample field?	*(Times per season)*	841

2. For insect or disease control on the sample field, do you participate in any of the following; *(Code EACH box "YES" or "NO")*

A. Boll Weevil Eradication	( ) YES = 1, ( ) NO = 2	842
B. Planting Resistant Varieties	( ) YES = 1, ( ) NO = 2	843
C. Stalk Destruction	( ) YES = 1, ( ) NO = 2	844
D. Pheromone Traps	( ) YES = 1, ( ) NO = 2	845
E. Boll Weevil Diapause Control	( ) YES = 1, ( ) NO = 2	846

IX. EROSION CONTROL

1. Common erosion control measures include terracing, contour cropping, stripcropping, and grassed waterways. Did you use any of these measures on this sample field? ( ) YES = 1, *Continue.* ( ) NO = 2, *Go to Item 3*	847

2. Were any of the following erosion control measures used on this sample field?

(Check "YES" to all that apply)

A. Terracing	( ) YES = 1	848
B. Contour cropping	( ) YES = 1	849
C. Stripcropping	( ) YES = 1	850
D. Grassed Waterways	( ) YES = 1	851

3. Which system best describes the tillage practice used on this sample field?

(Check ONLY ONE)

A. No-Till	( ) YES = 1	852
B. Ridge-Till	( ) YES = 1	853
C. Mulch-Till or other conservation tillage	( ) YES = 1	854
D. Conventional without moldboard plow	( ) YES = 1	855
E. Conventional with moldboard plow	( ) YES = 1	856

III. PESTICIDES - - continued

CONTINUATION SHEET

UNITS

1 = Ounces
2 = Pints
3 = Quarts
4 = Gallons
5 = Pounds

TANK MIXES: Report them on the **SAME LINE** using the applicable product codes.

RECORD QUANTITIES TO THE NEAREST TENTH

LINE NO.	When Applied: 1 = Before 2 = At 3 = After Planting	Product 1 Record code, quantity and unit			Product 2 Record code, quantity and unit			Product 3 Record code, quantity and unit			How was it Applied: 1 = Broadcast, Ground 2 = Broadcast, Air 3 = In Furrow 4 = Irrigation water 5 = Banded in/over row 6 = Directed spray 7 = Chisel/knifed in 9 = Spot treatment	Who Applied: 1 = Farmer 2 = Custom
		Code	Qty	Unit	Code	Qty	Unit	Code	Qty	Unit		
	Col. 1	Col. 2			Col. 3			Col. 4			Col. 5	Col. 6
16	600	601	602 •	603	604	605 •	606	607	608 •	609	610	611
17	612	613	614 •	615	616	617 •	618	619	620 •	621	622	623
18	624	625	626 •	627	628	629 •	630	631	632 •	633	634	635
19	636	637	638 •	639	640	641 •	642	643	644 •	645	646	647
20	648	649	650 •	651	652	653 •	654	655	656 •	657	658	659
21	660	661	662 •	663	664	665 •	666	667	668 •	669	670	671
22	672	673	674 •	675	676	677 •	678	679	680 •	681	682	683
23	684	685	686 •	687	688	689 •	690	691	692 •	693	694	695
24	696	697	698 •	699	700	701 •	702	703	704 •	705	706	707
25	708	709	710 •	711	712	713 •	714	715	716 •	717	718	719
26	720	721	722 •	723	724	725 •	726	727	728 •	729	730	731
27	732	733	734 •	735	736	737 •	738	739	740 •	741	742	743
28	744	745	746 •	747	748	749 •	750	751	752 •	753	754	755
29	756	757	758 •	759	760	761 •	762	763	764 •	765	766	767
30	768	769	770 •	771	772	773 •	774	775	776 •	777	778	779

For pesticides not listed on the card, specify Tradename and Formulation:

Insecticides: 290 ____________ 291 ____________
Fungicides: 390 ____________ 391 ____________
Defoliants & Desiccants: 490 ____________ 491 ____________
Growth Regulators: 590 ____________ 591 ____________

IV. IRRIGATION

ENTER CODE

1. Can this sample field be irrigated? .... ( )YES = 1, ( )NO = 2, *go to page 8,* WATER | 780

2. Did you irrigate the sample field in 1989? ( )YES = 1. *Continue* ( )NO = 2, *go to page 8,* WATER | 781

3. What was the quantity of water applied per acre to the sample field in 1989? *(If response is NOT in acre feet, list other pertinent data for office computation).* ____________ *Acre feet/Acre* | 782

____

4. Did you use wells to supply irrigation water to the sample field? ..... ( )YES = 1, ( )NO = 2 | 783

If "YES" how many wells? .... *Number* | 784

5. Did you use surface water to irrigate the sample field? ..... ( )YES = 1, ( )NO = 2, *go to Item 6* | 785

A. Was surface water purchased? .... ( )YES = 1, ( )NO = 2 | 786

If Item 5 A is coded "1", what was the TOTAL COST of surface water purchased for this sample field? .... *Dollars* | 787

6. Did you use irrigation water to apply chemicals (fertilizers, pesticides) to the crop on this sample field? .... ( )YES = 1, ( )NO = 2 | 788

7. Did you use a sprinkler irrigation system? ....( )YES = 1, ( )NO = 2 | 789

If "YES", which of the following apply? If "NO", go to Item 8.

A. Center pivot system .... ( )YES = 1 | 790

B. Low Energy Precision Application (LEPA) system *(Water applied below leaf canopy)* .... ( )YES = 1 | 791

C. All other mechanical move systems .... ( )YES = 1 | 792

D. Hand move system .... ( )YES = 1 | 793

E. Solid set and permanent system .... ( )YES = 1 | 794

COMPLETE ITEMS F AND G FOR THE SYSTEM USED TO IRRIGATE THE LARGEST PORTION OF THE FIELD.

F. What was the system pressure?

60 PSI or more .... ( )YES = 1 | 795

40 to 59 PSI .... ( )YES = 1 | 796

under 40 PSI .... ( )YES = 1 | 797

G. What was the source of power? (Electric motor = 1, gasoline engine = 2, diesel = 3, natural gas = 4, all other = 5) .... | 798

(Continue on next page)

IV. IRRIGATION - Continued

ENTER CODE

8. Did you use a gravity irrigation system? ( ) YES = 1, ( ) NO = 2 800

If "YES", which of the following apply? If "NO", *go to Item 9.*

A. Gated pipe ( ) YES = 1 801

B. Gated pipe with surge control valves or cablegation technique ( ) YES = 1 802

C. Open ditch, with siphon tubes ( ) YES = 1 803

D. Any other gravity irrigation method, including flooding from underground pipe with valves, ditches, canals and dikes ( ) YES = 1 804

E. Special furrowing: wide spaced beds or compact beds? ( ) YES = 1 805

9. Did you use a drip or trickle irrigation system? ( ) YES = 1, ( ) NO = 2 806

10. Did you use subirrigation ?*(Water applied beneath the ground, or the maintenance of water table at a predetermined depth).* ( ) YES = 1, ( ) NO = 2 807

11. Was irrigation water runoff from this sample field captured? *(Use of tailwater pits)* ( ) YES = 1, ( ) NO = 2 808

12. Was the application of irrigation water managed by any of the following:

A. Use of soil moisture sensing devices, such as neutron probes. moisture blocks or tensiometers? ( ) YES = 1, ( ) NO = 2 809

B. Use of commercial irrigation scheduling services? ( ) YES = 1, ( ) NO = 2 810

C. Water delivered by irrigation district in turn (no choice by water user)? ( ) YES = 1, ( ) NO = 2 811

V. WATER

> Note: If Item 4, page 6, is coded "YES" enter a "1" for Item 1, code box 815. Go to Item 2.

ENTER CODE

1. Are there any wells for irrigation or other use on this entire operation?
( ) YES = 1 ,*continue* ( ) NO = 2 , *(Go to Item 3)* 815

2. What is the distance from this sample field to the nearest well? .... *Feet* 816
(Leave blank if well located in field).

A. Has this well been tested for nitrates or pesticides in the past 12 months?
( ) YES = 1, *(Continue)* ( )NO = 2, *(go to Item 3)*, ( ) DON'T KNOW = 3 , *(go to Item 3)* 817

B. Did the test(s) indicate that there were excessive levels of : .... (1). Nitrates ( ) YES = 1, ( )NO = 2 818
(2). Pesticides ( ) YES = 1, ( )NO = 2 819

3. Is this sample field within 1 MILE of:

A. A perennial *(year around flow)* river or stream? ( ) YES = 1, ( ) NO = 2 820
If "YES", what is the distance? .... *Feet* 821

B. A man-made pond or reservoir of LESS than 10 acres? ( ) YES = 1, ( ) NO = 2 822
If "YES", what is the distance? .... *Feet* 823

C. A man-made pond or reservoir GREATER than 10 acres? ( ) YES = 1, ( ) NO = 2 824
If "YES", what is the distance? .... *Feet* 825

D. A natural lake or pond? ( ) YES = 1, ( ) NO = 2 826
If "YES", what is the distance? .... *Feet* 827

E. A city well or other public water source? ( ) YES =1, ( ) NO = 2 828
If "YES", what is the distance? .... *Feet* 829

4. Is subsurface water drained from this sample field using a tile or plastic drain system ? .... ( ) YES = 1, ( )NO = 2 830

VI. OTHER PROGRAMS

1. Did you participate in the 1989 Cotton Program *(Acreage Reserve Program)*?
( )YES = 1, ( )NO = 2 831

2. Was this sample field covered by Federal Crop Insurance (FCIC) in 1989? .... ( )YES = 1, ( )NO = 2 832

VII. LAND VALUE

1. What is the average MARKET VALUE PER ACRE of this sample field? .... *Dollars per Acre* 833

VIII. PEST MANAGEMENT

ENTER CODE

1. Do you participate in a professional scouting program *(exclude farmer scouting)* in the sample field for weeds and/or harmful insects? ( ) YES = 1, ( ) NO = 2 — 840

   If "YES" is checked, how many times per season does the scout inspect the sample field? . . . . *(Times per season)* — 841

2. For insect or disease control on the sample field, do you participate in any of the following; *(Code EACH box "YES" or "NO")*

   A. Boll Weevil Eradication . . . . ( ) YES = 1, ( ) NO = 2 — 842

   B. Planting Resistant Varieties . . . . ( ) YES = 1, ( ) NO = 2 — 843

   C. Stalk Destruction . . . . ( ) YES = 1, ( ) NO = 2 — 844

   D. Pheromone Traps . . . . ( ) YES = 1, ( ) NO = 2 — 845

   E. Boll Weevil Diapause Control . . . . ( ) YES = 1, ( ) NO = 2 — 846

IX. EROSION CONTROL

1. Common erosion control measures include terracing, contour cropping, stripcropping, and grassed waterways. Did you use any of these measures on this sample field? ( ) YES = 1, *Continue.* ( ) NO = 2, *Go to Item 3* . . . . — 847

2. Were any of the following erosion control measures used on this sample field?

   (Check "YES" to all that apply)

   A. Terracing . . . . ( ) YES = 1 — 848

   B. Contour cropping . . . . ( ) YES = 1 — 849

   C. Stripcropping . . . . ( ) YES = 1 — 850

   D. Grassed Waterways . . . . ( ) YES = 1 — 851

3. Which system best describes the tillage practice used on this sample field?

   (Check ONLY ONE)

   A. No-Till . . . . ( ) YES = 1 — 852

   B. Ridge-Till . . . . ( ) YES = 1 — 853

   C. Mulch-Till or other conservation tillage . . . . ( ) YES = 1 — 854

   D. Conventional without moldboard plow . . . . ( ) YES = 1 — 855

   E. Conventional with moldboard plow . . . . ( ) YES = 1 — 856

X. OPERATOR CHARACTERISTICS

1. How old were you (the operator) on your last birthday? .... Age [860]

2. How much formal education do you (the operator) have? .... Enter Code [861]

Less than high school 1,	Completed college 4
Completed high school 2,	Graduate School 5
Some college 3,	

3. Are the day-to-day decisions for this farming (or ranching) operation made by:

(Check One)

( ) 1. Owner ....
( ) 2. Partnership ....
( ) 3. Hired Manager ....
( ) 4. Tenant ....

} *Enter Code* [862]

That completes the survey. Would you like to receive a free copy of a report containing the results of this survey? ( )YES = 1 .... *Enter Code* [863]

(Thank the respondent then review this questionnaire).

Respondent ______________________ Date ______________________

Phone (   ) ______________________ Enumerator Number .... [864]

Ending Time . . .*(Military Time)* [865]

OFFICE USE

STATUS CODE [866]

(Complete SOIL CHARACTERISTICS Section on next page).

XI. SOIL CHARACTERISTICS

Please complete the following table for all items that are applicable to the sample field. Obtain information from the local soil scientist in the County Soil Conservation Service office.

ITEM	*Enumerator Entry (1 - 7)*	OFFICE USE
1. Latitude	______________	870 __ __ __ __ __
2. Longitude	______________	871 __ __ __ __ __
3. Soil Record Number	______________	872 __ __ __ __ __ __ __
4. USDA Surface texture	______________	873 __ __
5. Soil Modifier Code	______________	874 __ __
6. Flooding Modifier Code ...	______________	875 __
7. Slope Class Code	______________	876 . __ __ __
8. LS Value of Soil Map Unit - (Non-terraced field)		877 __ __ . __ __
9. LS Value of Soil Map Unit - (Terraced field)		878 __ __ . __ __
10. R factor		879 __ __ __
11. C factor		880 . __ __

NOTES:

Appendix B--Assessment of Potential Losses of Pesticides and Nitrates to Ground and Surface Water

Pesticide Loss Potential

We used the methodology proposed by Goss and Wauchope (1990) to measure the potential losses of pesticides to ground water and surface water. They have developed a screening procedure to evaluate the potential loss of pesticides from soil that takes into account both the chemical properties of the pesticides and the physical properties of the soils. Their assessment procedure provides a classification scheme to categorize the likelihood that pesticides applied to cropland will leach into ground water or run off into surface waters. Based on this procedure, surveyed cotton acreage has been classified according to the potential for pesticides applied to this cropland to leave the root zone and enter water bodies.

Figure B-1 describes the assessment procedure. Two ordinal measures are developed which are jointly used to determine overall pesticide leaching or runoff potential: (1) a loss potential derived from the physical properties of the soil to which the pesticides are applied, and (2) a loss potential based on the chemical properties of the individual pesticides.

Soil Leaching Potential

Many soil characteristics influence the environmental fates of chemicals applied to cropland. Factors thought to influence potential leaching of pesticides below the root zone include soil depth, the organic matter content of the soil, surface texture, subsurface texture, and the hydrologic properties of the soil. The screening procedure employs an algorithm to create an index of relative leaching potential based on four characteristics felt to be the most influential in determining pesticide losses: organic matter content of the surface horizon, depth of the horizon, soil erodibility (K factor), and the hydrologic classification (fig. B-2).

For each sample point in the survey, data for these four physical characteristics were obtained for the identified soil type from the USDA-SCS Soils V database. Each sample point was then assigned a qualitative soil leaching potential score based on these characteristics: high, intermediate, low, and very low. Using expansion factors estimated as part of the survey, regional and national estimates of cotton acreage falling into each category were then calculated. The results are presented in table B-1.

Soil Adsorption Loss and Runoff Potential

Pesticides applied to cropland may reach surface waters in two ways. The chemicals may dissolve in surface water runoff or adsorb to sediment and move to surface waters through soil erosion. Whether pesticides applied to cotton acreage will leave the field dissolved in runoff or adsorbed to soil particles will depend partly on the soil's physical characteristics. Two measures were developed to categorize soils by their relative potential for losses to surface waters. A soil adsorption index was constructed based on the hydrologic properties and the soil K factor at each sample point. Similarly, a soil runoff solution potential index was calculated based on the hydrologic grouping of the soil at the sample point (fig. B-2). As with the leaching potential score, regional and national estimates of acreage in each category were made. These are also reported in table B-1.

Chemical Leaching Potential

The chemical properties of individual pesticides also play a large role in determining whether chemical residues will leach below the root zone. The assessment procedure uses an algorithm based on the Groundwater Ubiquity Score (GUS) developed by Gustafson (1989) to classify pesticides according to their propensity to leach. A leaching potential score was developed for each chemical reported in the

Figure B-1: Assessment procedure to measure vulnerability to pesticide leaching and losses to surface water

1. For each sample point in the survey, calculate loss potential based on *soil characteristics*:

   Soil Leaching Loss Potential: High, Intermediate, Low, or Very Low
   Soil Adsorbed Runoff Loss Potential: High, Intermediate, or Low
   Soil Runoff Solution Loss Potential: High, Intermediate, or Low

2. For each pesticide applied at each sample point in the survey, calculate loss potential based on *chemical properties*.

   Pesticide Leaching Loss Potential: Large, Medium, Small, or Extra Small
   Pesticide Adsorbed Runoff Loss Potential: Large, Medium, or Small
   Pesticide Runoff Solution Loss Potential: Large, Medium, or Small

3. For sample points for which more than one pesticide was used, determined the leaching potential of the predominant chemicals. Assign an overall loss potential based on the total pounds of pesticide applied.

4. For all sample points, assign an overall loss potential based on the conjunction of loss potential based on soil properties and loss potential based on chemical properties.

5. Using weighting factors obtained from the survey, expand sample points to achieve State, regional, and national estimates of cropland falling within each loss potential category.

survey, based on the reported persistence in soil (half life), partition coefficient between soil organic carbon and water (K_{oc}), and the solubility of the active ingredient in the pesticide. Categories were defined as large, medium, small, and extra small (fig. B-3).

Chemical Surface Loss Potential

Finally, each chemical used on cotton production was characterized by its relative propensity to leave the site either dissolved in runoff or attached to sediment. Two indexes were constructed: the pesticide adsorption index describes the tendency of pesticides to adhere to soil particles and the pesticide runoff solution index categorizes each chemical according to its tendency to dissolve in runoff. Both indexes are based on the solubility, the organic partitioning component, and the half life of the active ingredient in each pesticide (fig. B-3).

Estimates of Sample Point Chemical Loss Potentials

The Goss and Wauchope methodology is designed only to categorize the relative loss potential for single chemicals. In this analysis, we faced an additional complicating factor, because several different pesticides were used for many sample points. As described earlier, cotton producers use a variety of chemicals for insect, weed, and foliage control. The simple methodology described here is not designed to account for interactions between multiple chemicals applied to a particular parcel of cropland.

To simplify the assessment procedure while retaining the essential elements of the Goss and Wauchope methodology, the properties of the chemicals applied at each sample point were analyzed to determine the predominant properties of the pesticides used. The leaching, adsorption, and runoff solution indexes were calculated for all chemicals for each sample point. Reported application rates (estimated application rates in the case of herbicides) were used to derive an estimate of total chemical application by chemical loss class: high, intermediate, low, or very low leachability; high, intermediate, or low adsorption potential; and high, intermediate, or low runoff solution potential (table B-2).

Each sample point was then assigned a leachability, adsorption, or runoff solution score based on the predominant chemical class used at that sample point. For example, when total pounds of "high leaching" chemicals applied (measured by pounds of active ingredient applied) exceeded applications

Figure B-2: Procedures used to estimate pesticide loss potentials based on soil properties

1. Algorithm used to calculate soil leaching potential

A soil has a *HIGH* leaching potential if:
  Hydrologic group = A and organic matter times horizon depth <= 30, or
  Hydrologic group = B and organic matter times horizon depth <= 9
    and K factor <= 0.48, or
  Hydrologic group = B and organic matter times horizon depth <= 15
    and K factor <= 0.26.

A soil has a *LOW* leaching potential if:
  Hydrologic group = B and organic matter times horizon depth >= 35
    and K factor >= 0.40, or
  Hydrologic group = B and organic matter times horizon depth >= 45
    and K factor <= 0.20, or
  Hydrologic group = C and organic matter times horizon depth <= 10
    and K factor <= 0.28, or
  Hydrologic group = C and organic matter times horizon depth >= 10.

A soil has a *VERY LOW* leaching potential if:
  Hydrologic group = D.

2. Algorithm used to estimate soil adsorbed runoff potential

A soil has a *HIGH* adsorbed runoff potential if:
  Hydrologic group = C and K factor > 0.21, or
  Hydrologic group = D and K factor > 0.10.

A soil has a *LOW* adsorbed runoff potential if:

  Hydrologic group = A or

  Hydrologic group = B and K factor <= 0.10, or
  Hydrologic group = C and K factor <= 0.07, or
  Hydrologic group = D and K factor >= 0.05.

A soil has an *INTERMEDIATE* adsorbed runoff potential in all other cases.

A pesticide has a *MEDIUM* adsorbed runoff potential in all other cases.

3. Algorithm used to estimate soil runoff solution potential

A soil has a *HIGH* runoff solution potential if:
  Hydrologic group = C, or
  Hydrologic group = D.

A soil has a *LOW* runoff solution potential if:
  Hydrologic group = A.

A soil has an *INTERMEDIATE* runoff solution potential if:
  Hydrologic group = B.

Table B-1: Potential for pesticide losses from leaching, adsorption, or runoff based on soil properties

Region	High		Intermediate		Low		Very low	
	1,000 acres	*Percent*	*1,000 acres*	*Percent*	*1,000 acres*	*Percent*	*1,000 acres*	*Percent*
Soil leaching potential:								
Delta	271	9	740	25	1,222	41	741	25
Southeast	236	38	409	48	110	13	6	1
Southern Plains	1,764	35	1,760	35	557	11	960	19
West	335	26	456	35	233	18	266	20
All regions	2,698	27	3,364	33	2,122	21	1,973	19

	High		Intermediate		Low	
	1,000 acres	*Percent*	*1,000 acres*	*Percent*	*1,000 acres*	*Percent*
Soil adsorbed loss potential:						
Delta	1,956	66	1,011	34	7	0
Southeast	93	11	650	76	109	13
Southern Plains	1,558	31	3,443	68	40	1
West	494	38	781	61	14	1
All regions	4,100	40	5,887	58	170	2

	High		Intermediate		Low	
	1,000 acres	*Percent*	*1,000 acres*	*Percent*	*1,000 acres*	*Percent*
Soil runoff solution potential:						
Delta	1,963	66	1,004	34	7	0
Southeast	120	14	714	84	17	2
Southern Plains	1,560	31	3,441	68	40	1
West	508	39	767	59	14	1
All regions	4,151	41	5,928	58	78	1

Figure B-3: Procedures used to estimate pesticide loss potential based on chemical properties

1. Algorithm used to estimate pesticide leaching potential

A pesticide has a *LARGE* leaching potential if:
Log(Half-Life)*(4-Log(K_{oc})) >= 2.8.

A pesticide has a *SMALL* leaching potential if:
Log(Half-Life)*(4-Log(K_{oc})) <= 1.8.

A pesticide has an *EXTRA SMALL* leaching potential if:
Log(Half-Life)*(4-Log(K_{oc})) <= 0.0
or
Solubility < 1 and Half-Life <= 1.

A pesticide has a *MEDIUM* leaching potential in all other cases.

2. Algorithm used to estimate pesticide adsorbed runoff potential

A pesticide has a *LARGE* asdorbed runoff potential if:
Half-Life >= 40 and K_{oc} >= 1,000 or
Half-Life >= 40 and K_{oc} >= 500 and solubility <= 0.5.

A pesticide has a *MEDIUM* asdorbed runoff potential if:
Half-Life <= 1 or
Half-Life <= 2 and K_{oc} <= 500 or
Half-Life <= 4 and K_{oc} <= 900 and solubility >= 0.5 or
Half-Life <= 40 and K_{oc} <= 500 and solubility >= 0.5 or
Half-Life <= 40 and K_{oc} <= 900 and solubility >= 2.

A pesticide has a *SMALL* asdorbed runoff potential in all other cases.

3. Algorithm used to estimate pesticide runoff solution potential

A pesticide has a *LARGE* runoff solution potential if:
Solubility >= 1 and Half-life > 35 and K_{oc} < 100,000 or
Solubility >= 10 and solubility < 100 and K_{oc} <= 700.

A pesticide has a *SMALL* runoff solution potential if:
K_{oc} >= 100,000 or
K_{oc} >= 1,000 and half-life <= 1 or
Solubility < 0.5 and half-life < 35.

A pesticide has a *MEDIUM* runoff solution potential in all other cases.

Table B-2: Chemical properties of pesticides covered in the 1989 cotton survey

Chemical name	Chemical class	Chemical leaching potential	Adsorption loss potential	Runoff solution loss potential
Arsenic Acid	Desiccant/Defoliant	Extra Small	Large	Small
Dimethipin	Desiccant/Defoliant	Large	Small	Medium
Endothall	Desiccant/Defoliant	Unknown	Unknown	Unknown
Phosphorotrihoate	Desiccant/Defoliant	Unknown	Unknown	Unknown
Paraquat	Desiccant/Defoliant	Extra Small	Large	Small
Sodium Cacodylate	Desiccant/Defoliant	Unknown	Unknown	Unknown
Sodium Chlorate	Desiccant/Defoliant	Unknown	Unknown	Unknown
Thidiazuron	Desiccant/Defoliant	Medium	Small	Large
Mancozeb	Fungicide	Small	Large	Medium
PCNB	Fungicide	Small	Medium	Small
Etridiazole	Fungicide	Small	Medium	Medium
Etridiazole Disulfoton	Fungicide	Small	Unknown	Unknown
Etridiazole-Phorate	Fungicide	Small	Large	Medium
Sulphur	Fungicide	Unknown	Unknown	Unknown
Pseudomoras Flouroscens	Fungicide	Unknown	Unknown	Unknown
Metalaxyl	Fungicide	Large	Medium	Medium
Ethephon	Growth Regulator	Extra Small	Medium	Small
Mepiquat Chloride	Growth Regulator	Extra Small	Large	Small
Basalin	Herbicide	Unknown	Unknown	Unknown
Cyanazine	Herbicide	Medium	Small	Medium
Prometryn	Herbicide	Medium	Medium	Large
Fluometuron	Herbicide	Large	Medium	Medium
Fluometuron+MSMA	Herbicide	Large	Medium	Medium
DCPA	Herbicide	Small	Large	Medium
Dalapon 85	Herbicide	Large	Small	Medium
Diuron	Herbicide	Unknown	Unknown	Unknown
DSMA	Herbicide	Unknown	Unknown	Unknown
Metolachlor	Herbicide	Large	Medium	Medium
Enide 90W	Herbicide	Unknown	Unknown	Unknown
EPTC	Herbicide	Small	Small	Medium
Fluazifop-P-Butyl	Herbicide	Small	Medium	Medium
Oxyfluorfen	Herbicide	Extra Small	Medium	Small
Alachlor	Herbicide	Medium	Small	Medium
Linuron	Herbicide	Medium	Medium	Large
MSMA	Herbicide	Small	Unknown	Unknown
Paraquat	Herbicide	Extra Small	Large	Small
Sethoxydim	Herbicide	Small	Small	Medium
Bensulide	Herbicide	Small	Large	Medium
Methazole	Herbicide	Small	Medium	Medium
Pendimethalin	Herbicide	Small	Large	Medium
Glyphosate	Herbicide	Extra Small	Large	Medium
Sancap 80W	Herbicide	Unknown	Unknown	Unknown
Paraquat+Diuron	Herbicide	Medium	Large	Large
Oryzalin	Herbicide	Small	Small	Medium
Trifluralin	Herbicide	Small	Large	Medium
Norflurzon	Herbicide	Medium	Medium	Large
Acephate	Insecticide	Small	Small	Medium
Aldicarb	Insecticide	Large	Small	Medium
Azinphosmethyl	Insecticide	Small	Medium	Medium
Bacillus Thuringensis	Insecticide	Unknown	Unknown	Unknown

Continued --

Table B-2: Chemical properties of pesticides covered in the 1989 cotton survey (continued)

Chemical name	Chemical class	Chemical leaching potential	Adsorption loss potential	Runoff solution loss potential
Bifenthrin	Insecticide	Extra Small	Medium	Small
Carbaryl	Insecticide	Small	Small	Medium
Carbofuran	Insecticide	Large	Medium	Medium
Chlordimeform	Insecticide	Extra Small	Large	Small
Chlorpyrifos	Insecticide	Small	Medium	Medium
Cypermethrin	Insecticide	Extra Small	Medium	Small
Cyfluthrin	Insecticide	Small	Large	Medium
Diazinon	Insecticide	Medium	Small	Large
Dimethoate	Insecticide	Medium	Small	Medium
Dicofol	Insecticide	Extra Small	Large	Small
Dicrotophos	Insecticide	Medium	Medium	Small
Diflubenzuron	Insecticide	Small	Medium	Small
Disulfoton	Insecticide	Small	Medium	Medium
Endosulfon	Insecticide	Extra Small	Large	Medium
Esfenvalerate	Insecticide	Small	Medium	Medium
Ethyl Parathion	Insecticide	Small	Medium	Medium
Ethyl methyl Parathon	Insecticide	Small	Medium	Medium
Fenamiphos	Insecticide	Large	Medium	Medium
Fenvalerate	Insecticide	Small	Medium	Medium
Flucythrinate	Insecticide	Extra Small	Medium	Small
Lambdacyhalothrin	Insecticide	Unknown	Unknown	Unknown
Malathion	Insecticide	Small	Small	Small
Metam Sodium	Insecticide	Medium	Small	Medium
Methamidaphos	Insecticide	Large	Small	Medium
Methidathion	Insecticide	Medium	Small	Medium
Methomyl	Insecticide	Large	Small	Medium
Methyl Parathion	Insecticide	Small	Medium	Medium
Moncrotophos	Insecticide	Large	Small	Medium
Naled	Insecticide	Small	Small	Medium
Oxydemetonmethyl	Insecticide	Large	Small	Medium
Oxamyl	Insecticide	Small	Small	Medium
Permethrin	Insecticide	Extra Small	Medium	Small
Phosmet	Insecticide	Small	Small	Medium
Phorate	Insecticide	Small	Large	Medium
Phosphamidon	Insecticide	Medium	Small	Medium
Profenfos	Insecticide	Small	Medium	Medium
Propargite	Insecticide	Small	Medium	Medium
Sulphur	Insecticide	Unknown	Unknown	Unknown
Sulprofos	Insecticide	Small	Small	Medium
Thiodicarb	Insecticide	Small	Small	Large
Tralomethrin	Insecticide	Extra Small	Medium	Small
Trichlorfon	Insecticide	Large	Small	Medium
One-3-D	Insecticide	Medium	Small	Medium
One-3-d-Chloropicrin	Insecticide	Medium	Small	Medium
One-3-D-Mic	Insecticide	Medium	Small	Medium
Methyl para endosulfin	Insecticide	Extra Small	Small	Medium
Methyl para permethrin	Insecticide	Extra Small	Medium	Small

Table B-3: Potential for pesticide losses via leaching, adsorption, or runoff based on chemical properties

Region	Large		Medium		Small		Extra small		Unknown	
	1,000 acres	*Percent*	*1,000 acres*	*Percent*	*1,000 acres*	*Percent*	*1,000 acres*	*Percent*	*1,000 acres*	*Percent*
Pesticide leaching potential:										
Delta	326	10	264	9	2,074	70	33	1	277	9
Southeast	133	16	17	2	523	61	5	1	174	20
Southern Plains	47	1	255	5	3,627	72	728	14	383	8
West	44	3	23	2	212	17	128	10	882	68
All regions	550	5	560	6	6,436	63	894	9	1716	17

	Large		Medium		Small		Unknown	
	1,000 acres	*Percent*	*1,000 acres*	*Percent*	*1,000 acres*	*Percent*	*1,000 acres*	*Percent*
Pesticide adsorbed loss potential:								
Delta	53	2	2,331	78	42	1	547	19
Southeast	30	4	300	35	264	31	257	30
Southern Plains	3,793	75	763	15	352	7	132	3
West	101	8	199	15	117	9	873	68
All regions	3,977	39	3,593	35	777	8	1,810	18

	Large		Medium		Small		Unknown	
	1,000 acres	*Percent*	*1,000 acres*	*Percent*	*1,000 acres*	*Percent*	*1,000 acres*	*Percent*
Pesticide runoff solution potential:								
Delta	55	2	2,312	78	28	1	579	19
Southeast	5	1	396	46	249	39	202	24
Southern Plains	74	1	4,215	84	623	12	128	3
West	8	1	314	24	118	9	851	66
All regions	142	1	7,238	71	1,018	10	1,760	17

of chemicals in other leachability classes, the sample point was assigned an aggregate leaching potential score of "high." Similarly, for those sample points where the largest amount of chemicals fell into the "low runoff solution potential" category, a score of "low" was used to characterize the runoff solution potential for the sample point as a whole, and so on.

Estimates of leaching, adsorption, and runoff solution loss potentials were not available for some chemicals used on cotton production. In those cases, an additional score of "unknown" was used. Table B-3 report results by region.

Figure B-4: Potential pesticide losses screening matrix

1. Potential Pesticide Leaching Loss Screening Matrix

	Pesticide Leaching Potential			
Soil Leaching Potential:	**Large**	**Medium**	**Small**	**Extra Small**
High	Potential 1	Potential 1	Potential 2	Potential 3
Intermediate	Potential 1	Potential 2	Potential 3	Potential 4
Low	Potential 2	Potential 3	Potential 3	Potential 4
Very Low	Potential 3	Potential 3	Potential 4	Potential 4

2. Potential Pesticide Adsorbed Loss Screening Matrix

	Pesticide Adsorbed Loss Potential		
Soil Adsorbed Loss Potential	**Large**	**Medium**	**Small**
High	Potential 1	Potential 1	Potential 2
Intermediate	Potential 1	Potential 2	Potential 3
Low	Potential 2	Potential 3	Potential 3

3. Potential Pesticide Solution Loss Screening Matrix

	Pesticide Solution Loss Potential		
Soil Solution Loss Potential:	**Large**	**Medium**	**Small**
High	Potential 1	Potential 1	Potential 2
Intermediate	Potential 1	Potential 2	Potential 3
Low	Potential 2	Potential 3	Potential 3

Determination of Overall Loss Potential

The overall pesticide loss potential was determined by the interaction of loss potentials defined by soil characteristics and by chemical properties. Each sample point was assigned an overall potential loss rating (fig. B-4). Categories are defined in relative terms, indicating the relative expectation of pesticide losses by taking into account soil and chemical properties. For example, if a sample point showed a large pesticide leaching potential and an intermediate soil leaching potential, then it was given a "potential 1" rating. However, a combination of high soil leaching potential and a small pesticide leaching potential is given a lower relative ranking, called "potential 2." A potential 1 category has a higher likelihood of pesticide losses to water bodies than potential 2, and potential 2 has a higher expectation of pesticide losses than potential 3, and so forth.

Nitrate Leaching Potential

The screening procedure used to estimate the potential for nitrates to leach below the root zone was developed by Pierce, Shaffer, and Halvorson (1990). The procedure calculates several indexes:

- A percolation index, which is a function of the soil hydrologic group and annual precipitation (P):

Hydrologic Group	Percolation Index
A	$(P-10.28)^2/(P+15.43)$
B	$(P-15.05)^2/(P+22.57)$
C	$(P-19.53)^2/(P+29.29)$
D	$(P-22.67)^2/(P+34.00)$

- A seasonal index, based on annual precipitation and seasonal precipitation (October-March, PW)

$$SI = (2*PW/P)^{1/3}$$

- A leaching Index:

$$LI = PI * SI$$

- A leaching severity index, based on LI:

If Leaching Index (LI) is:	Leaching Severity Index is:
0 - 5	Low
5 - 10	Moderate
10 - 20	High
Above 20	Excessive

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