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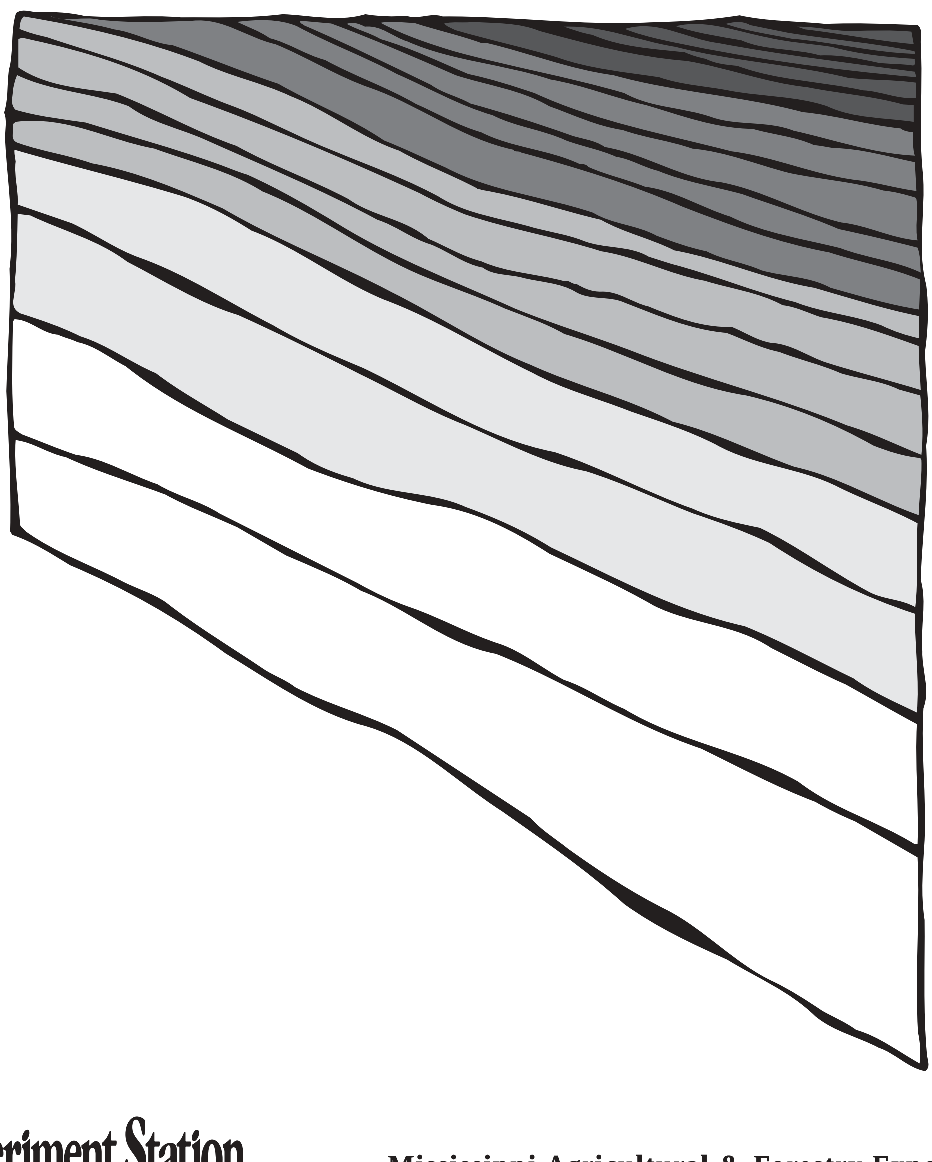
Economic & Environmental IMPACTS of Variable-Rate Fertilizer Application in Mississippi



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Economic and Environmental Impacts *of Variable-Rate Fertilizer Application in Mississippi*

Abstract

A number of programs have been introduced to limit environmental nonpoint pollution (NPP) associated with agricultural practices. One such program, precision agriculture, involves a range of management practices that utilize site-specific information at the field level. These practices can limit the amount of nutrient and chemical runoff to the environment because they precisely match fertilizer and pesticide application to the needs of the crop. This study used bioeconomic modeling to investigate the environmental and economic impacts of precision agriculture technology associated with variable-rate fertilizer application, as compared with a conventional, single-rate application. The empirical results demonstrated that one particular precision-agricultural technology, variable-rate fertilizer application, could provide both environmental and economic benefits when used on cotton, soybeans, and corn in Mississippi. However, our results depend on several factors, such as soil variability, and the results may be different depending on local conditions.

Introduction

Environmental nonpoint pollution (NPP) problems associated with agricultural practices have come under increasing scrutiny in recent years. Agricultural practices are considered the largest contributor of surface water quality degradation in terms of sediment, runoff of nutrients, and leaching of chemicals (Crutchfield et al., 1993). Among the list of environmental damages, nutrients (such as nitrate and phosphorus) are suspected to be major contributors to nonpoint pollution of surface water. They are the primary source of impairment to fresh water bodies, affecting one third of the surveyed lake acres, streams, and rivers in the U.S. (USEPA, 1998). Nitrate-contaminated water can pose health risks to humans and animals that drink it (Crosson and Brubaker, 1982) and is a source of public concern (Hite et al., 1999). Phosphorus loss in sediment is responsible for eutrophication, causing a reduction of oxygen levels in lakes and rivers. Reduced oxygen levels in turn have a negative impact on aquatic organisms, upsetting the balance of ecosystems (Torrent and Delgado, 2001).

A number of government programs have been introduced to directly limit environmental degradation. Precision-agriculture programs allow farmers to employ alternative technologies and cultural practices to deal with environmental problems, offering another approach.

Precision agriculture involves a range of management practices that attempt to utilize site-specific information at the field level — such as soil characteristics and weather conditions — in order to adjust the inputs used and ultimately achieve optimal output (National Research Council, 1997). Precision-agriculture technology is hypothesized to limit the amount of nutrient and chemical runoff to the environment because it precisely matches fertilizer and pesticide applications to the needs of the crop (in both quantity and timing). Kitchen et al. (1995) found that precision-agriculture technology could help reduce the level of residual nitrogen found in soils, thereby reducing nitrogen contamination through erosion.

Precision agriculture involves three application processes: gathering information inputs such as yield mapping; processing the precision information; and prescribing recommendations for input applications. To collect the data, farmers could choose a technique called local sensing, which takes place simultaneously with recommended input application. Alternatively, they could use a global positioning system (GPS) to collect information related to crop production — including grid soil sampling, yield monitoring, remote sensing, and crop scouting, all of which provide information inputs for management decisions (Hrubovcak et al., 1999).

Precision technology is applied in a variety of agricultural management systems and agricultural products such as crops, livestock, and forestry. For this study, only the variable-rate fertilization component of precision agriculture is reported. In using precision-agriculture technology, nitrogen fertilizer recommendations are varied in accordance with soil cation exchange capacity (C.E.C.) and yield, while phosphorus fertilizer is prescribed in compliance with the soil phosphorus level. Soil C.E.C. is a measure of the quantity of sites on soil surfaces that can retain positively charged ions by electrostatic forces. Cations retained electrostatically are easily exchangeable with other cations in the soil solution and are thus readily available for plant uptake.

To apply this technology, site-specific data collected in advance using GPS or collected in real time using local sensing is utilized. In practice, it is extremely difficult and time-consuming to estimate environmental impacts on Mississippi as a whole by collecting site-specific data. We propose to measure the potential environmental impact of this technology through hypothetical fertilizer prescriptions based on soil C.E.C. obtained from secondary data sources. Despite the potential environmental benefit that would be realized from adopting precision-application technology, farmers must at least perceive some economic benefits. This study, therefore, attempted to investigate the environmental and economic impacts of precision-agriculture technology associated with variable-rate fertilizer applications, as compared with a conventional, single-rate application.

METHODS

We used the Erosion Productivity Impact Calculator (EPIC) to assess the effect of precision-agriculture practices on environmental parameters and farm net returns. The EPIC model was designed to simulate biophysical processes over a long period of time in a wide range of soil, climate, and crop conditions. The EPIC model is also capable of simulating agricultural yields and related environmental parameters under various management scenarios (Sharpley and Williams, 1990).

To estimate environmental impacts, we compared an agricultural practice consisting of a single fertilizer application rate on cotton, soybeans, and corn to a variable rate as prescribed by soil characteristics. The single application rate refers to an unvaried fertilizer application rate on crops, regardless of the variability of soil characteristics within the field. The variable rate is adjusted in accordance with soil C.E.C. and phosphorus levels (NRCS-USDA, http://vmhost.cdp.state.ne.us:96). The single-rate fertilizer application in this study was obtained from a survey of producers' planning budgets for major crops in four soil resource areas of Mississippi: Delta, Brown Loam, Coastal Plain, and Black Belt (Mississippi State University, 1999, various issues). Agricultural practices, as well as single-rate fertilizer application rates used, are included in each budget. Information on recommended variable rates was obtained from an agricultural consulting firm, while the C.E.C. of each soil type used in our simulation was acquired from the Natural Resources Conservation Service Soil Laboratory and Mississippi County Soil Surveys.

To estimate economic net returns, farm budget data were used, so that net returns from conventional single-rate fertilizer applications on cotton, soybeans, and corn could be calculated and compared with those from the scenario in which variable rates were applied. According to Lambert and Lowenberg-DeBoer (2000), there are a number of cost items involved with precision agriculture, including those associated with the input applicator, information and data management, computer training, discount rates, equipment rental and depreciation rates, consulting charges, soil and mapping costs, and labor. For this study, only partial budgets on fertilizer input cost were considered.

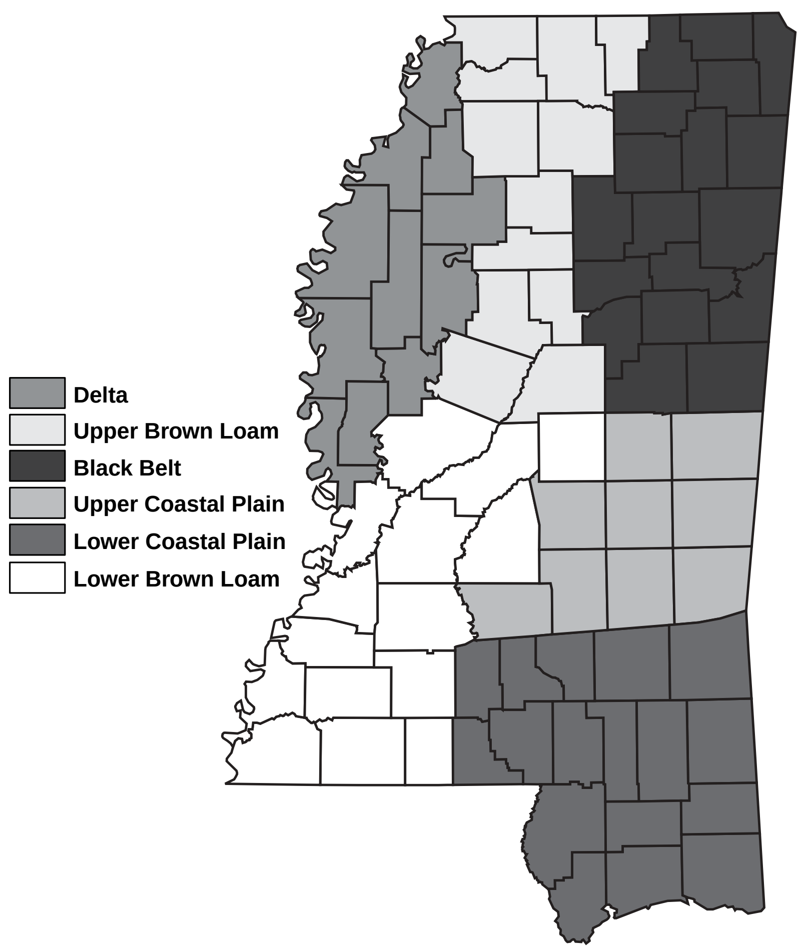
DATA

Six hypothetical farms formed the basis for the bioeconomic modeling of the impact of introducing variable-rate fertilizer application, as compared with a conventional, single-rate application. EPIC was used to estimate yields, input usage, and nonpoint agricultural pollution on each farm. The aforementioned farm budget data and information on nutrients, pesticides, herbicides, farm operations, and management practices were used as inputs for the regional hypothetical farms. Nitrogen runoff and phosphorus losses in sediment were the primary environmental parameters of interest because these are the primary factors contributing to NPP.

The six regional hypothetical farms were developed by first recognizing the predominant soil and topographic features of different parts of Mississippi; counties were assigned to the regions with the assistance of a specialist from the Department of Plant and Soil Sciences at Mississippi State University (personal communication, Larry Oldham, 2000). The soil types that cumulatively comprise at least 80% of the agricultural land within a region were included in the appropriate proportion for each hypothetical farm. For instance, the Delta region is composed of four major soil types: Alligator (20%), Dundee (15%), Forestdale (15%), and Sharkey (31%). The 10 major soil resource areas were split among 6 regions: Delta, Upper Brown Loam, Black Belt, Upper Coastal Plain, Lower Coastal Plain, and Lower Brown Loam. About 80% of these areas are comprised of 4, 11, 26, 15, 10, and 12 different major soil types, respectively. For our simulation, only soil types appropriate for the crops of interest were simulated. For example, because corn is not suitable for clay soils such as Sharkey and Alligator soils, we did not simulate corn in such soil types.

Meteorological data for each region were obtained from the nearest weather station in each simulation region. Topographic and geological data on slope length, roughness of terrain, watershed size, and location of the nearest stream were used for each region as well. Most of these physical inputs were derived from Natural Resource Inventory data collected by the U.S. Natural Resources Conservation Service (NRCS). Figure 1 shows the regional divisions used in the EPIC modeling. The soil information used is available at the county level (i.e., acres of each soil type for each county). Therefore, regions are defined by county boundaries. Acreages of each soil type in each county were aggregated to the region level by following soil resource areas as a guideline. Our regions, therefore, were developed under county and soil region boundaries.

Six scenarios including continuous cotton, corn, and soybeans with single-rate and variable-rate fertilizer applications were simulated. Conventional tillage systems were assumed in all practices. The Planning Budgets contain information from experts on agricultural chemical use and other practices for major field crops in the Delta, Upper and Lower Brown Loam, Upper and Lower Coastal Plain, and Black Belt soil resource areas of Mississippi. Prices and costs were



obtained from several sources including the Mississippi Agricultural Statistics Service. In association with precision agriculture, variable nitrogen fertilizer rates for cotton are prescribed in accordance with soil C.E.C. levels. Nitrogen fertilizer is not recommended for soybeans. Nitrogen fertilizer application for corn is recommended according to the target corn yield, not soil C.E.C. as for cotton. Soil C.E.C. varied even within the same soil type collected from different locations. For example, the C.E.C. in the first layer of Dundee soil collected in Tallahatchie County is 13.2; in Tate County, 8.1. However, within the same soil type, the variation is not wide, and most of them fall in the same range of nitrogen fertilizer recommended rates. In this case, the average C.E.C. from a number of collected samples was used (Appendix A). The soil C.E.C. rates used in this study were obtained from the NRCS Soil Laboratory and the Mississippi County Soil Survey. The recommended rates for nitrogen fertilizer according to soil C.E.C. for cotton were obtained from Agricultural Information Management, LLC, of Lambert, Mississippi.

Phosphorus fertilization recommendations are based on phosphorus levels in soil samples collected from cropland in each county. This information is reported in the 1999 publication *Summarization of Soil Test Data by Crop Selection* by the Extension Soil Testing Laboratory.

Empirical Results

Delta Region

Nitrogen fertilization of cotton is complex and involves a variety of factors, including potential yield, soil type, weather, etc. Nitrogen fertilizer rates vary from farm to farm and from field to field within a farm. Weather, particularly intense rainfall, has great influence on the efficiency of applied nitrogen fertilizers since nitrogen can be lost through leaching and runoff. Another form of nitrogen loss is denitrification, which occurs in heavier textured soils. When these soils are saturated with water, bacteria break down nitrate, and the nitrogen releases into the atmosphere as nitrogen gas. Heavy and prolonged periods of rainfall can result in nitrogen losses severe enough to require additional nitrogen applications to correct the problem. Therefore, soil texture, which is represented by the soil C.E.C., is a significant factor in prescribing nitrogen fertilizer.

For Delta cotton yields of 700-800 pounds per acre, Agricultural Information Management, LLC, recommends a nitrogen fertilizer application rate of 70 pounds per acre for less than 8 C.E.C.; 90 pounds, 8-18 C.E.C.; 120 pounds, 18-24 C.E.C.; and 130 pounds, more than 24 C.E.C. These rates are compared with the120 pounds per acre used for single rate. For the Delta, nitrogen fertilizer of 130 pounds per acre is recommended for Alligator soil, while 120 pounds per acre is recommended for Dundee and Forestdale soils. According to the USDA-NRCS soil survey, Sharkey is not suitable for cotton, so it is not included in our cotton simulations.

Out of 6,194 soil samples from cotton fields in the Delta, more than 80% contain a high level of phosphorus (P-level). At a high P-level, phosphorus fertilizer is not recommended. EPIC results showed no change in yields between the recommended variable rates and the single-rate application scenario for cotton. However, nitrate runoff and phosphorus loss in sediment declined by 4.3% and 3.39%, respectively (Table 1). Economic net returns increased about $4.96 per acre as a result of decreased input costs with variable-rate applications.

On soybean-planted acreage, out of 1,708 soil samples, about 70% contain a high level of phosphorus.

Table 1 Delta. A comparison of environmental and economic impacts of single-rate and variable-rate fertilizer applications.

Soil type	Soil proportion	Change in yields	Change in P-loss	Change in N-runoff	Change in net return
		%	%	%	$/A
Cotton					
Alligator	0.4089	0.0000	-3.1056	-2.8313	3.86
Dundee	0.2965	0.0000	-4.4610	-5.6670	5.73
Forestdale	0.2945	0.0000	-2.7027	-4.9512	5.73
Sum Wgt.	**1.0000**	**0.0000**	**-3.3888**	**-4.2966**	**4.96**
Soybean					
Alligator	0.2536	0.0000	0.0000	0.0000	8.23
Dundee	0.1839	0.0000	0.0000	0.0000	8.23
Sharkey	0.3798	0.0000	0.0000	0.0000	8.23
Forestdale	0.1827	0.0000	0.0000	0.0000	8.23
Sum Wgt.	**1.0000**	**0.0000**	**0.0000**	**0.0000**	**8.23**
Corn					
Dundee	0.5017	-4.3011	-2.9412	-9.8219	0.00
Forestdale	0.4983	-2.1505	-1.3928	-2.2253	6.67
Sum Wgt.	**1.0000**	**-3.2294**	**-2.1696**	**-6.0364**	**3.33**

Generally, farmers do not add nitrogen fertilizer to soybeans. However, they do apply phosphorus, which is not recommended in the Delta when P-levels are high. EPIC results indicated no change in environmental parameters, while the economic net return increased by $8.23 per acre through the reduction in phosphorus fertilization (Table 1).

On corn-planted acreage, out of 2,736 soil samples, more than 70% of the samples contain a high level of phosphorus. There is no recommendation for phosphorus fertilizer for Delta corn. Recommended nitrogen fertilization rates were based on yield, not C.E.C. Corn crops are usually planted in soil with lighter texture. Therefore, target yield is the only factor used to determine the recommended nitrogen rate — 130 pounds of nitrogen per 100 bushels of corn per acre. Simulation results indicated that utilizing variable-rate applications resulted in a yield reduction of 3.23%, a phosphorus reduction of 2.17%, and a nitrogen runoff reduction of 6.04%. However, net return increased by $3.32 per acre as a result of cost savings from input use (Table 1).

Upper Brown Loam Region

Recommended nitrogen fertilizer applications for the variety of soil types in this region range from 90-130 pounds per acre for cotton. Out of 1,491 soil samples from the cotton fields in the Upper Brown Loam, 65% contain high levels of phosphorus and 31% contain medium levels. At the medium P-level, 46 pounds per acre of phosphorus fertilizer is recommended for cotton. More than 80% of soil tests in this region indicate high and medium P-levels. Therefore, we simulated two scenarios: 0 and 46 pounds per acre of phosphorus application.

Simulations of both of the recommended applications of phosphorus indicated no change in cotton yields, while nitrogen and phosphorus runoff increased by 0.36% and 0.04%, respectively. Net returns increased by $21.53 and $9.06 per acre for both cases as a result of decreased variable-input costs associated with variable-rate applications (Tables 2A-I and 2A-II).

Nitrogen fertilizer is not recommended for soybeans. Out of 862 soil samples, 56% tested at high phosphorus levels and 32% at medium. Therefore, the two scenarios of high and medium P-levels were simulated. The results for all environmental indicators of both scenarios were similar. As compared with single-rate application, nitrogen loss increased 0.27%, while there was no change in phosphorus loss in sediment and yield (Tables 2B-I and 2B-II). Per-acre returns for soybeans increased by about $8.23 in the high P-level scenario and 10 cents in the medium P-level scenario, as compared with the single-rate scenario, due to savings in input use (Tables 2B-I and 2B-II).

In the case of corn, nitrogen is recommended according to the yield target. Of 774 soil samples, 64% tested at high P-levels and 28% at medium. The simulation results on yield, nitrogen runoff, and phosphorus loss were the same for both cases. Phosphorus and nitrogen losses declined by 0.05% and 2.62%, respectively, while yield decreases by 1.30%, as compared with the single-rate application scenario (Tables 2C-I and 2C-II). Despite a reduction in yield, net returns per acre still increased by $6.70 and $2.34 as a result of decreased expenditures on inputs.

Table 2A-I Upper Brown Loam. A comparison of environmental and economic impacts of single-rate and variable-rate fertilizer applications for cotton (N-vary, P-0 lb/A).

Soil type	Soil proportion	Change in yields	Change in P-loss	Change in N-runoff	Change in net return
		%	%	%	$/A
Loring	0.2152	0.0000	0.0000	0.0000	22.11
Collins	0.2051	0.0000	0.0000	-0.1365	22.11
Falaya	0.1351	0.0000	0.0000	0.0000	22.11
Grenada	0.1033	0.0000	0.0000	0.0000	22.11
Providence	0.0758	0.0000	0.0000	0.0000	22.11
Alligator	0.0669	0.0000	0.2725	5.7536	18.37
Oaklimeter	0.0553	0.0000	0.3378	0.0000	22.11
Dundee	0.0513	0.0000	0.0000	0.0000	22.11
Arkabutla	0.0476	0.0000	0.0000	0.0000	18.37
Lexington	0.0442	0.0000	0.0000	0.0000	18.37
Sum Wgt.	**1.0000**	**0.0000**	**0.0369**	**0.3570**	**21.53**

Table 2A-II Upper Brown Loam. A comparison of environmental and economic impacts of single-rate and variable-rate fertilizer applications for cotton (N-vary, P-46 lb/A).

Soil type	Soil proportion	Change in yields	Change in P-loss	Change in N-runoff	Change in net return
		%	%	%	$/A
Loring	0.2152	0.0000	0.0000	0.0000	9.65
Collins	0.2051	0.0000	0.0000	-0.1365	9.65
Falaya	0.1351	0.0000	0.0000	0.0000	9.65
Grenada	0.1033	0.0000	0.0000	0.0000	9.65
Providence	0.0758	0.0000	0.0000	0.0000	9.65
Alligator	0.0669	0.0000	0.2725	5.7536	5.90
Oaklimeter	0.0553	0.0000	0.3378	0.0000	9.65
Dundee	0.0513	0.0000	0.0000	0.0000	9.65
Arkabutla	0.0476	0.0000	0.0000	0.0000	5.90
Lexington	0.0442	0.0000	0.0000	0.0000	5.90
Sum Wgt.	**1.0000**	**0.0000**	**0.0369**	**0.3570**	**9.06**

Table 2B-I Upper Brown Loam. A comparison of environmental and economic impacts of single-rate and variable-rate fertilizer applications for soybeans (N-0, P-0 lb/A).

Soil type	Soil proportion	Change in yields	Change in P-loss	Change in N-runoff	Change in net return
		%	%	%	$/A
Loring	0.2152	0.0000	0.0000	0.0000	8.23
Collins	0.2051	0.0000	0.0000	0.0000	8.23
Falaya	0.1351	0.0000	0.0000	0.0000	8.23
Grenada	0.1033	0.0000	0.0000	0.0000	8.23
Providence	0.0758	0.0000	0.0000	3.5095	8.23
Alligator	0.0669	0.0000	0.0000	0.0000	8.23
Oaklimeter	0.0553	0.0000	0.0000	0.0000	8.23
Dundee	0.0513	0.0000	0.0000	0.0000	8.23
Arkabutla	0.0476	0.0000	0.0000	0.0000	8.23
Lexington	0.0442	0.0000	0.0000	0.0000	8.23
Sum Wgt.	**1.0000**	**0.0000**	**0.0000**	**0.2662**	**8.23**

Table 2B-II Upper Brown Loam. A comparison of environmental and economic impacts of single-rate and variable-rate fertilizer applications for soybeans (N-0, P-30 lb/A).

Soil type	Soil proportion	Change in yields	Change in P-loss	Change in N-runoff	Change in net return
		%	%	%	$/A
Loring	0.2152	0.0000	0.0000	0.0000	0.09
Collins	0.2051	0.0000	0.0000	0.0000	0.09
Falaya	0.1351	0.0000	0.0000	0.0000	0.09
Grenada	0.1033	0.0000	0.0000	0.0000	0.09
Providence	0.0758	0.0000	0.0000	3.5095	0.09
Alligator	0.0669	0.0000	0.0000	0.0000	0.09
Oaklimeter	0.0553	0.0000	0.0000	0.0000	0.09
Dundee	0.0513	0.0000	0.0000	0.0000	0.09
Arkabutla	0.0476	0.0000	0.0000	0.0000	0.09
Lexington	0.0442	0.0000	0.0000	0.0000	0.09
Sum Wgt.	**1.0000**	**0.0000**	**0.0000**	**0.2662**	**0.09**

Table 2C-I Upper Brown Loam. A comparison of environmental and economic impacts of single-rate and variable-rate fertilizer applications for corn (N-0, P-0 lb/A).

Soil type	Soil proportion	Change in yields	Change in P-loss	Change in N-runoff	Change in net return
		%	%	%	$/A
Collins	0.2857	-0.3247	0.3876	-4.6628	7.02
Falaya	0.1882	0.0000	-0.7143	-3.0755	10.35
Grenada	0.1440	-0.3096	0.0000	-0.0934	3.69
Providence	0.1056	-0.2201	0.0000	-3.6940	3.69
Oaklimeter	0.0770	-0.0828	0.0000	0.0000	7.02
Dundee	0.0715	-0.1571	0.0000	-0.1151	3.69
Arkabutla	0.0664	-0.0721	0.0000	-0.2708	7.02
Lexington	0.0616	-0.1311	-0.3984	-4.5149	3.69
Sum Wgt.	**1.0000**	**-1.2975**	**-0.0482**	**-2.6192**	**6.71**

Table 2C-II Upper Brown Loam. A comparison of environmental and economic impacts of single-rate and variable-rate fertilizer applications for corn (N-0, P-46 lb/A).

Soil type	Soil proportion	Change in yields	Change in P-loss	Change in N-runoff	Change in net return
		%	%	%	$/A
Collins	0.2857	-0.3247	0.3876	-4.6628	2.99
Falaya	0.1882	0.0000	-0.7143	-3.0755	6.33
Grenada	0.1440	-0.3096	0.0000	-0.0934	-0.34
Providence	0.1056	-0.2201	0.0000	-3.6940	-0.04
Oaklimeter	0.0770	-0.0828	0.0000	0.0000	2.99
Dundee	0.0715	-0.1571	0.0000	-0.1151	-0.04
Arkabutla	0.0664	-0.0721	0.0000	-0.2708	2.99
Lexington	0.0616	-0.1311	-0.3984	-4.5149	-0.04
Sum Wgt.	**1.0000**	**-1.2975**	**-0.0482**	**-2.6192**	**2.35**

Black Belt Region

Recommended nitrogen fertilizer application on Black Belt cotton ranges from 70-130 pounds per acre. Out of 1,447 soil samples, 67% tested at high P-levels and 26% at medium. Forty-six pounds per acre of phosphorous is the prescribed application for soils with medium P-levels. Simulation results indicated similar environmental impacts in both cases. There were no changes in yield and phosphorus loss, but nitrate runoff declined by 0.18%, as compared with single rate (Tables 3A-I and 3A-II). At the same time, net returns per acre increased by $8.33 and $16.46 per acre as a result of reductions in input use.

For soybeans, out of 2,205 soil samples, 55% tested at high P-levels. Thirty-two percent of the soil samples tested at a medium P-level, which means an application rate of 30 pounds per acre of phosphorus fertilizer is suggested. Simulation with and without P fertilizer resulted in no difference in environmental indicators compared with a single application rate. However, net returns increased between 10 cents and $8.23 per acre (Tables 3B-I and 3B-II).

In the case of corn, out of 1,828 soil samples, 64% tested at high P-levels and 28% at medium. For medium P-levels, 46 pounds per acre is the recommended application rate. Simulation scenarios with or without phosphorus fertilizer applications yielded the same environmental impacts. As compared with the single application rate, yield declined by 3.14%, nitrogen runoff declined by 11.2%, and phosphorus loss in sediment declined by 3.8% (Tables 3C-I and 3C-II). Net returns increased by $4.47 per acre.

Table 3A-I Black Belt. A comparison of environmental and economic impacts of single-rate and variable-rate fertilizer applications for cotton (N-vary, P-0).

Soil type	Soil proportion	Change in yields	Change in P-loss	Change in N-runoff	Change in net return
		%	%	%	$/A
Mantachie	0.1023	0.0000	0.0000	0.0000	17.88
Providence	0.0817	0.0000	0.0000	0.0000	17.88
Leeper	0.0733	0.0000	0.0000	0.0000	14.13
Savannah	0.0648	0.0000	0.0000	-0.7836	19.76
Vaiden	0.0633	0.0000	0.0000	-3.1149	14.13
Ora	0.0615	0.0000	0.0000	0.0000	17.88
Kipling	0.0583	0.0000	0.0000	0.0048	15.07
Prentiss	0.0510	0.0000	0.0000	0.0000	17.88
Falkner	0.0487	0.0000	0.0000	0.0000	15.07
Falaya	0.0409	0.0000	0.0000	0.0000	17.88
Arkabutla	0.0395	0.0000	0.0000	0.0000	14.13
Urbo	0.0377	0.0000	0.0000	0.0000	14.13
Tippah	0.0359	0.0000	0.0000	0.0000	17.88
Oaklimeter	0.0303	0.0000	0.0000	0.0000	17.88
Marietta	0.0258	0.0000	0.0000	0.0000	17.88
Catalpa	0.0256	0.0000	0.0000	-0.0247	14.13
Brooksville	0.0248	0.0000	0.0000	0.0000	14.13
Longview	0.0226	0.0000	0.0000	0.0000	17.88
Okolona	0.0343	0.0000	0.0000	2.0312	14.13
Chenneby	0.0210	0.0000	0.0000	-0.0030	17.88
Adaton	0.0195	0.0000	0.0000	0.0000	15.07
Mathiston	0.0195	0.0000	0.0000	0.0000	17.88
Belden	0.0177	0.0000	0.0000	0.0000	14.13
Sum Wgt.	**1.0000**	**0.0000**	**0.0000**	**-0.1786**	**16.46**

Table 3A-II Black Belt. A comparison of environmental and economic impacts of single-rate and variable-rate fertilizer applications for cotton (N-vary, P-46).

Soil type	Soil proportion	Change in yields	Change in P-loss	Change in N-runoff	Change in net return
		%	%	%	$/A
Mantachie	0.1023	0.0000	0.0000	0.0000	9.75
Providence	0.0817	0.0000	0.0000	0.0000	9.75
Leeper	0.0733	0.0000	0.0000	0.0000	6.00
Savannah	0.0648	0.0000	0.0000	-0.7836	11.63
Vaiden	0.0633	0.0000	0.0000	-3.1149	6.00
Ora	0.0615	0.0000	0.0000	0.0000	9.75
Kipling	0.0583	0.0000	0.0000	0.0048	6.94
Prentiss	0.0510	0.0000	0.0000	0.0000	9.75
Falkner	0.0487	0.0000	0.0000	0.0000	6.94
Falaya	0.0409	0.0000	0.0000	0.0000	9.75
Arkabutla	0.0395	0.0000	0.0000	0.0000	6.00
Urbo	0.0377	0.0000	0.0000	0.0000	6.00
Tippah	0.0359	0.0000	0.0000	0.0000	9.75
Oaklimeter	0.0303	0.0000	0.0000	0.0000	9.75
Marietta	0.0258	0.0000	0.0000	0.0000	9.75
Catalpa	0.0256	0.0000	0.0000	-0.0247	6.00
Brooksville	0.0248	0.0000	0.0000	0.0000	6.00
Longview	0.0226	0.0000	0.0000	0.0000	9.75
Okolona	0.0343	0.0000	0.0000	2.0312	6.00
Chenneby	0.0210	0.0000	0.0000	-0.0030	9.75
Adaton	0.0195	0.0000	0.0000	0.0000	6.94
Mathiston	0.0195	0.0000	0.0000	0.0000	9.75
Belden	0.0177	0.0000	0.0000	0.0000	6.00
Sum Wgt.	**1.0000**	**0.0000**	**0.0000**	**-0.1786**	**8.33**

Table 3B-I Black Belt. A comparison of environmental and economic impacts of single-rate and variable-rate fertilizer applications for soybeans (N-0, P-0).

Soil type	Soil proportion	Change in yields	Change in P-loss	Change in N-runoff	Change in net return
		%	%	%	$/A
Mantachie	0.1169	0.0000	0.0000	0.0000	8.23
Providence	0.0934	0.0000	0.0000	0.0000	8.23
Leeper	0.0837	0.0000	0.0000	0.0000	8.23
Savannah	0.0741	0.0000	0.0000	0.0000	8.23
Kipling	0.0666	0.0000	0.0000	0.0000	8.23
Prentiss	0.0582	0.0000	0.0000	0.0000	8.23
Falkner	0.0557	0.0000	0.0000	0.0000	8.23
Falaya	0.0467	0.0000	0.0000	0.0000	8.23
Arkabutla	0.0451	0.0000	0.0000	0.0000	8.23
Urbo	0.0430	0.0000	0.0000	0.0000	8.23
Tippah	0.0410	0.0000	0.0000	0.0000	8.23
Oaklimeter	0.0347	0.0000	0.0000	0.0000	8.23
Marietta	0.0294	0.0000	0.0000	0.0000	8.23
Catalpa	0.0293	0.0000	0.0000	0.0000	8.23
Brooksville	0.0283	0.0000	0.0000	0.0000	8.23
Longview	0.0258	0.0000	0.0000	0.0000	8.23
Okolona	0.0392	0.0000	0.0000	0.0000	8.23
Chenneby	0.0241	0.0000	0.0000	0.0000	8.23
Adaton	0.0223	0.0000	0.0000	0.0000	8.23
Mathiston	0.0223	0.0000	0.0000	0.0000	8.23
Belden	0.0203	0.0000	0.0000	0.0000	8.23
Sum Wgt.	**1.0000**	**0.0000**	**0.0000**	**0.0000**	**8.23**

Table 3B-II Black Belt. A comparison of environmental and economic impacts of single-rate and variable-rate fertilizer applications for soybeans (N-0, P-30).

Soil type	Soil proportion	Change in yields	Change in P-loss	Change in N-runoff	Change in net return
		%	%	%	$/A
Mantachie	0.1169	0.0000	0.0000	0.0000	0.09
Providence	0.0934	0.0000	0.0000	0.0000	0.09
Leeper	0.0837	0.0000	0.0000	0.0000	0.09
Savannah	0.0741	0.0000	0.0000	0.0000	0.09
Kipling	0.0666	0.0000	0.0000	0.0000	0.09
Prentiss	0.0582	0.0000	0.0000	0.0000	0.09
Falkner	0.0557	0.0000	0.0000	0.0000	0.09
Falaya	0.0467	0.0000	0.0000	0.0000	0.09
Arkabutla	0.0451	0.0000	0.0000	0.0000	0.09
Urbo	0.0430	0.0000	0.0000	0.0000	0.09
Tippah	0.0410	0.0000	0.0000	0.0000	0.09
Oaklimeter	0.0347	0.0000	0.0000	0.0000	0.09
Marietta	0.0294	0.0000	0.0000	0.0000	0.09
Catalpa	0.0293	0.0000	0.0000	0.0000	0.09
Brooksville	0.0283	0.0000	0.0000	0.0000	0.09
Longview	0.0258	0.0000	0.0000	0.0000	0.09
Okolona	0.0392	0.0000	0.0000	0.0000	0.09
Chenneby	0.0241	0.0000	0.0000	0.0000	0.09
Adaton	0.0223	0.0000	0.0000	0.0000	0.09
Mathiston	0.0223	0.0000	0.0000	0.0000	0.09
Belden	0.0203	0.0000	0.0000	0.0000	0.09
Sum Wgt.	**1.0000**	**0.0000**	**0.0000**	**0.0000**	**0.09**

Table 3C-I Black Belt. A comparison of environmental and economic impacts of single-rate and variable-rate fertilizer applications for corn (N-130, P-0).

Soil type	Soil proportion	Change in yields	Change in P-loss	Change in N-runoff	Change in net return
		%	%	%	$/A
Mantachie	0.1160	-4.1667	-2.0979	-7.9721	1.09
Providence	0.0926	-5.1546	-5.2960	-14.1218	-2.24
Leeper	0.0830	-1.1628	-6.8140	-15.2285	11.09
Savannah	0.0734	-7.3684	1.0417	-1.9647	-8.90
Vaiden	0.0717	0.0000	-0.8230	-8.4646	14.42
Ora	0.0697	-6.2500	-0.8197	-4.6524	-5.57
Prentiss	0.0577	0.0000	-1.7316	-2.0641	14.43
Falkner	0.0552	-5.2632	-4.9231	-17.0235	-2.24
Falaya	0.0463	0.0000	-1.2563	-4.5337	14.43
Arkabutla	0.0447	-3.2609	-6.8681	-16.3567	4.43
Urbo	0.0427	0.0000	-6.8182	-16.6159	14.43
Tippah	0.0406	-4.3478	-6.9231	-20.9674	1.09
Oaklimeter	0.0344	-5.2083	-4.4248	-16.5022	-2.24
Marietta	0.0292	-3.1250	-2.3438	-8.0377	4.43
Catalpa	0.0290	0.0000	-4.0000	-11.0156	14.43
Longview	0.0256	-3.0928	-6.8376	-15.3694	4.43
Chenneby	0.0239	-2.0619	-6.5611	-17.9770	7.76
Adaton	0.0221	-2.1739	-7.3099	-17.6935	7.76
Mathiston	0.0221	-2.1739	-7.4380	-16.9306	7.76
Belden	0.0201	0.0000	-7.8723	-17.5634	14.43
Sum Wgt.	**1.0000**	**-3.1413**	**-3.8007**	**-11.1954**	**4.47**

Table 3C-II Black Belt. A comparison of environmental and economic impacts of single-rate and variable-rate fertilizer applications for corn (N-130, P-46).

Soil type	Soil proportion	Change in yields	Change in P-loss	Change in N-runoff	Change in net return
		%	%	%	$/A
Mantachie	0.1160	-4.1667	-2.0979	-7.9721	-11.38
Providence	0.0926	-5.1546	-5.2960	-14.1218	-14.71
Leeper	0.0830	-1.1628	-6.8140	-15.2285	-1.38
Savannah	0.0734	-7.3684	1.0417	-1.9647	-21.38
Vaiden	0.0717	0.0000	-0.8230	-8.4646	1.96
Ora	0.0697	-6.2500	-0.8197	-4.6524	-18.04
Prentiss	0.0577	0.0000	-1.7316	-2.0641	1.96
Falkner	0.0552	-5.2632	-4.9231	-17.0235	-14.71
Falaya	0.0463	0.0000	-1.2563	-4.5337	1.96
Arkabutla	0.0447	-3.2609	-6.8681	-16.3567	-8.04
Urbo	0.0427	0.0000	-6.8182	-16.6159	1.96
Tippah	0.0406	-4.3478	-6.9231	-20.9674	-11.38
Oaklimeter	0.0344	-5.2083	-4.4248	-16.5022	-14.71
Marietta	0.0292	-3.1250	-2.3438	-8.0377	-8.04
Catalpa	0.0290	0.0000	-4.0000	-11.0156	1.96
Longview	0.0256	-3.0928	-6.8376	-15.3694	-8.04
Chenneby	0.0239	-2.0619	-6.5611	-17.9770	-4.71
Adaton	0.0221	-2.1739	-7.3099	-17.6935	-4.71
Mathiston	0.0221	-2.1739	-7.4380	-16.9306	-4.71
Belden	0.0201	0.0000	-7.8723	-17.5634	1.96
Sum Wgt.	**1.0000**	**-3.1413**	**-3.8007**	**-11.1954**	**-8.00**

Upper Coastal Plain Region

Recommended nitrogen fertilizer for cotton in this region ranges from 70-130 pounds per acre. Out of 14 soil samples from the cotton-planted area in the Upper Coastal Plain, 57% contain high P-levels, 7% contain medium levels, and 29% contain low levels. For medium P-levels, 46 pounds per acre is the recommendation for P fertilization; for low P-levels, 90 pounds. Simulation results indicated no change in yield, as compared with the single-rate application, while nitrogen runoff increased by 0.62% and 0.9% (Tables 4A-I, 4A-II, and 4A-III). Per-acre returns increased between $9.49 and $21.96 as a result of savings in input costs with variable-rate fertilization. However, in the scenario using 90 pounds per acre, net return was negative because the cost of the added phosphorus outweighs savings from a reduction of nitrogen fertilizer.

In the case of soybeans, out of 47 soil samples, 29% tested at high P-levels, 34% at medium, and 13% at low. For medium P-levels, 30 pounds per acre is the recommendation for P fertilization; for low P-levels, 80

Table 4A-I Upper Coastal Plain. A comparison of environmental and economic impacts of single-rate and variable-rate fertilizer applications for cotton (N-vary, P-0).

Soil type	Soil proportion	Change in yields	Change in P-loss	Change in N-runoff	Change in net return
		%	%	%	$/A
Savannah	0.2271	0.0000	-0.8850	-1.8213	23.99
Ora	0.2105	0.0000	0.0000	0.0000	22.12
Mantachie	0.1426	0.0000	0.0000	0.0000	22.12
Vaiden	0.0939	0.0000	0.0000	7.7793	18.37
Shubuta	0.0851	0.0000	0.0000	0.0000	22.12
Prentiss	0.0567	0.0000	0.0000	-4.1173	23.99
Alligator	0.0552	0.0000	0.0000	6.4402	18.37
Kipling	0.0464	0.0000	0.0000	3.8178	19.31
Providence	0.0335	0.0000	0.0000	0.0000	22.12
Sum Wgt.	**1.0000**	**0.0000**	**-0.2009**	**0.6159**	**21.96**

Table 4A-II Upper Coastal Plain. A comparison of environmental and economic impacts of single-rate and variable-rate fertilizer applications for cotton (N-vary, P-46).

Soil type	Soil proportion	Change in yields	Change in P-loss	Change in N-runoff	Change in net return
		%	%	%	$/A
Savannah	0.2388	0.0000	0.0000	-1.8213	11.53
Ora	0.2214	0.0000	0.0000	0.0000	9.65
Mantachie	0.1500	0.0000	0.0000	0.0000	9.65
Vaiden	0.0987	0.0000	0.0000	7.8052	5.90
Shubuta	0.0895	0.0000	0.0000	0.0000	9.65
Prentiss	0.0596	0.0000	0.0000	-0.0041	11.53
Alligator	0.0581	0.0000	0.0000	6.4563	5.90
Kipling	0.0488	0.0000	0.0000	3.8178	6.84
Providence	0.0352	0.0000	0.0000	0.0283	9.65
Sum Wgt.	**1.0000**	**0.0000**	**0.0000**	**0.8974**	**9.49**

pounds. Simulation results of variable rate, as compared with single-rate application, indicated no change in environmental parameters. Economic net returns increased by $8.23 and 10 cents per acre as a result of savings in input costs with variable rate. However, results indicated a net loss of $13.46 per acre where 80 pounds per acre was used (Tables 4B-I, 4B-II and 4B-III).

Out of 180 soil samples taken from corn fields in this region, 32% tested at high P-levels, 23% at medium, and 19% at low. Thus, phosphorus fertilizer applications of 0, 46, and 90 pounds per acre are recommended in accordance with P-levels in soil. For the 0 phosphorus rate, yield decreased by 0.75%, nitrogen runoff decreased by 0.65%, and phosphorus loss in sed-

Table 4A-III Upper Coastal Plain. A comparison of environmental and economic impacts of single-rate and variable-rate fertilizer applications for cotton (N-vary, P-90).

Soil type	Soil proportion	Change in yields	Change in P-loss	Change in N-runoff	Change in net return
		%	%	%	$/A
Savannah	0.2388	0.0000	0.0000	-1.8213	-0.40
Ora	0.2214	0.0000	0.0000	0.0000	-2.28
Mantachie	0.1500	0.0000	0.0000	0.0000	-2.28
Vaiden	0.0987	0.0000	0.0000	7.8052	-6.03
Shubuta	0.0895	0.0000	0.0000	0.0000	-2.28
Prentiss	0.0596	0.0000	0.0000	-0.0041	-0.40
Alligator	0.0581	0.0000	0.0000	6.4563	-6.03
Kipling	0.0488	0.0000	0.0000	3.8178	-5.09
Providence	0.0352	0.0000	0.0000	0.0283	-2.28
Sum Wgt.	**1.0000**	**0.0000**	**0.0000**	**0.8974**	**-2.44**

Table 4B-I Upper Coastal Plain. A comparison of environmental and economic impacts of single-rate and variable-rate fertilizer applications for soybeans (N-0, P-0).

Soil type	Soil proportion	Change in yields	Change in P-loss	Change in N-runoff	Change in net return
		%	%	%	$/A
Savannah	0.3512	0.0000	0.0000	0.0000	8.23
Mantachie	0.2206	0.0000	0.0000	0.0000	8.23
Shubuta	0.1316	0.0000	0.0000	0.0000	8.23
Prentiss	0.0877	0.0000	0.0000	0.0000	8.23
Alligator	0.0854	0.0000	0.0000	0.0000	8.23
Kipling	0.0718	0.0000	0.0000	0.0000	8.23
Providence	0.0518	0.0000	0.0000	0.0000	8.23
Sum Wgt.	**1.0000**	**0.0000**	**0.0000**	**0.0000**	**8.23**

Table 4B-II Upper Coastal Plain. A comparison of environmental and economic impacts of single-rate and variable-rate fertilizer applications for soybeans (N-0, P-30).

Soil type	Soil proportion	Change in yields	Change in P-loss	Change in N-runoff	Change in net return
		%	%	%	$/A
Savannah	0.3512	0.0000	0.0000	0.0000	0.09
Mantachie	0.2206	0.0000	0.0000	0.0000	0.09
Shubuta	0.1316	0.0000	0.0000	0.0000	0.09
Prentiss	0.0877	0.0000	0.0000	0.0000	0.09
Alligator	0.0854	0.0000	0.0000	0.0000	0.09
Kipling	0.0718	0.0000	0.0000	0.0000	0.09
Providence	0.0518	0.0000	0.0000	0.0000	0.09
Sum Wgt.	**1.0000**	**0.0000**	**0.0000**	**0.0000**	**0.09**

Table 4B-III Upper Coastal Plain. A comparison of environmental and economic impacts of single-rate and variable-rate fertilizer applications for soybeans (N-0, P-80).

Soil type	Soil proportion	Change in yields	Change in P-loss	Change in N-runoff	Change in net return
		%	%	%	$/A
Savannah	0.3512	0.0000	0.0000	0.0000	-13.46
Mantachie	0.2206	0.0000	0.0000	0.0000	-13.46
Shubuta	0.1316	0.0000	0.0000	0.0000	-13.46
Prentiss	0.0877	0.0000	0.0000	0.0000	-13.46
Alligator	0.0854	0.0000	0.0000	0.0000	-13.46
Kipling	0.0718	0.0000	0.0000	0.0000	-13.46
Providence	0.0518	0.0000	0.0000	0.0000	-13.46
Sum Wgt.	**1.0000**	**0.0000**	**0.0000**	**0.0000**	**-13.46**

Table 4C-I Upper Coastal Plain. A comparison of environmental and economic impacts of single-rate and variable-rate fertilizer applications for corn (N-130, P-0).

Soil type	Soil proportion	Change in yields	Change in P-loss	Change in N-runoff	Change in net return
		%	%	%	$/A
Savannah	0.2381	-1.1111	0.0000	0.2406	7.02
Ora	0.2208	-1.0638	0.0000	0.0000	7.02
Mantachie	0.1496	-1.0526	0.0000	-0.1096	7.02
Vaiden	0.0984	0.0000	-1.6026	-3.0779	10.35
Shubuta	0.0892	-1.0753	0.8130	0.2200	7.02
Prentiss	0.0595	0.0000	-0.3534	-4.3007	10.35
Alligator	0.0579	0.0000	-1.4706	-2.5549	10.35
Eutis	0.0514	0.0000	0.0000	0.0000	10.35
Providence	0.0351	0.0000	0.0000	0.0000	10.35
Sum Wgt.	**1.0000**	**-0.7528**	**-0.1914**	**-0.6462**	**8.03**

Table 4C-II Upper Coastal Plain. A comparison of environmental and economic impacts of single-rate and variable-rate fertilizer applications for corn (N-130, P-46).

Soil type	Soil proportion	Change in yields	Change in P-loss	Change in N-runoff	Change in net return
		%	%	%	$/A
Savannah	0.2381	-1.1111	0.0000	0.2406	-5.45
Ora	0.2208	-1.0638	0.0000	0.0000	-5.45
Mantachie	0.1496	-1.0526	0.0000	-0.1096	-5.45
Vaiden	0.0984	0.0000	-1.6026	-3.0779	-2.12
Shubuta	0.0892	-1.0753	0.8130	0.2200	-5.45
Prentiss	0.0595	0.0000	-0.3534	-4.3007	-2.12
Alligator	0.0579	0.0000	-1.4706	-13.4194	-2.12
Eutis	0.0514	0.0000	0.0000	0.0000	-2.12
Providence	0.0351	-1.0526	0.0000	-3.6174	-5.45
Sum Wgt.	**1.0000**	**-0.7898**	**-0.1914**	**-1.4023**	**-4.56**

iment decreased by 0.19%. Net returns increased $8.03 per acre (Table 4C-I) despite this reduction in yield because of cost savings with variable-rate fertilization. For the 46- and 90-pound phosphorus rates, environmental parameters are similar. Compared with single-rate application, yield decreased by 0.79%, nitrogen runoff decreased by 1.40%, and phosphorus loss in sediment decreased by 0.19%. In the 46- and 90-pound phosphorus scenarios, net returns decreased from $4.56 to $16.49 per acre (Tables 4C-II and 4C-III). Adding the cost of phosphorus fertilizer led to this reduction in per-acre net returns.

Table 4C-III Upper Coastal Plain. A comparison of environmental and economic impacts of single-rate and variable-rate fertilizer applications for corn (N-130, P-90).

Soil type	Soil proportion	Change in yields	Change in P-loss	Change in N-runoff	Change in net return
		%	%	%	$/A
Savannah	0.2381	-1.1111	0.0000	0.2406	-17.38
Ora	0.2208	-1.0638	0.0000	0.0000	-17.38
Mantachie	0.1496	-1.0526	0.0000	-0.1096	-17.38
Vaiden	0.0984	0.0000	-1.6026	-3.0779	-14.05
Shubuta	0.0892	-1.0753	0.8130	0.2200	-17.38
Prentiss	0.0595	0.0000	-0.3534	-4.3007	-14.05
Alligator	0.0579	0.0000	-1.4706	-13.4194	-14.05
Eutis	0.0514	0.0000	0.0000	0.0000	-14.05
Providence	0.0351	-1.0526	0.0000	-3.6174	-17.38
Sum Wgt.	**1.0000**	**-0.7898**	**-0.1914**	**-1.4023**	**-16.49**

Lower Coastal Plain Region

Recommended nitrogen fertilizer applications for cotton in this region range from 70-90 pounds per acre. Out of 451 soil samples from the cotton acreage of this region, 50% tested at high P-levels and 44% at medium. Phosphorus fertilizer rates of 0 and 46 pounds per acre, respectively, are recommended for these P-levels. Tables 5A-I and 5A-II show the simulation results of the application with and without recommended phosphorus fertilizer as compared with the single-rate scenario. The results indicate no change in yield, but phosphorus and nitrogen runoff decreased by 0.42% and 20.79%, respectively. Per-acre net returns increased by $10.15 to $23.62.

For soybeans, out of 169 soil samples, 50% tested at high P-levels and 44% at medium. For these P-levels, 0 and 30 pounds per acre, respectively, are the recommended phosphorus applications. Simulation results indicated no change in environmental indicators, while net returns increased by $8.23 and 10 cents per acre as a result of cost savings in input use (Tables 5B-I and 5B-II).

Out of 535 soil samples taken from corn acreage, 53% tested at high P-levels and 27% at medium, thus the phosphorus fertilizer recommendation is 0 and 46 pounds per acre, respectively. Yields and all environmental parameters of both scenarios showed the same results for phosphorous. Yield and nitrogen runoff declined by 0.90% and 0.29%, while phosphorus loss in sediment increased by 0.03%. At the same time, net returns per acre ranged from a loss of $4.83 to a gain of $7.63 (Tables 5C-I and 5C-II). This net loss resulted from reduced yield that could not be compensated by a decrease in input costs with variable-rate application.

Table 5A-I Lower Coastal Plain. A comparison of environmental and economic impacts of single-rate and variable-rate fertilizer applications for cotton (N-vary, P-0).

Soil type	Soil proportion	Change in yields	Change in P-loss	Change in N-runoff	Change in net return
		%	%	%	$/A
McLaurin	0.2657	0.0000	0.0000	-0.4608	22.12
Malbis	0.1781	0.0000	-2.4000	-12.7296	23.99
Savannah	0.1294	0.0000	0.0000	-0.1737	22.12
Poarch	0.1122	0.0000	0.0000	0.0000	23.99
Ora	0.1110	0.0000	0.0000	0.0000	22.12
Prentiss	0.0692	0.0000	0.0000	0.0000	23.99
Providence	0.0523	0.0000	0.0000	0.0000	22.12
Alligator	0.0481	0.0000	0.1580	6.9237	23.99
Falkner	0.0341	0.0000	0.0000	0.0000	22.12
Sum Wgt.	**1.0000**	**0.0000**	**-0.4199**	**-2.0795**	**22.62**

Table 5A-II Lower Coastal Plain. A comparison of environmental and economic impacts of single-rate and variable-rate fertilizer applications for cotton (N-vary, P-46).

Soil type	Soil proportion	Change in yields	Change in P-loss	Change in N-runoff	Change in net return
		%	%	%	$/A
McLaurin	0.2657	0.0000	0.0000	0.0000	9.65
Malbis	0.1781	0.0000	-2.4000	-11.2122	11.53
Savannah	0.1294	0.0000	0.0000	-0.1737	9.65
Poarch	0.1122	0.0000	0.0000	0.0000	11.53
Ora	0.1110	0.0000	0.0000	0.0000	9.65
Prentiss	0.0692	0.0000	0.0000	-0.0029	11.53
Providence	0.0523	0.0000	0.0000	0.0000	9.65
Alligator	0.0481	0.0000	0.1580	6.9237	5.90
Falkner	0.0341	0.0000	0.0000	0.0000	9.65
Sum Wgt.	**1.0000**	**0.0000**	**-0.4199**	**-1.6870**	**10.15**

Table 5B-I Lower Coastal Plain. A comparison of environmental and economic impacts of single-rate and variable-rate fertilizer applications for soybeans (N-0, P-0).

Soil type	Soil proportion	Change in yields	Change in P-loss	Change in N-runoff	Change in net return
		%	%	%	$/A
McLaurin	0.2989	0.0000	0.0000	0.0000	8.23
Malbis	0.2004	0.0000	0.0000	0.0000	8.23
Savannah	0.1455	0.0000	0.0000	0.0000	8.23
Poarch	0.1262	0.0000	0.0000	0.0000	8.23
Prentiss	0.0778	0.0000	0.0000	0.0000	8.23
Providence	0.0588	0.0000	0.0000	0.0000	8.23
Alligator	0.0541	0.0000	0.0000	0.0000	8.23
Falkner	0.0384	0.0000	0.0000	0.0000	8.23
Sum Wgt.	**1.0000**	**0.0000**	**0.0000**	**0.0000**	**8.23**

Table 5B-II Lower Coastal Plain. A comparison of environmental and economic impacts of single-rate and variable-rate fertilizer applications for soybeans (N-0, P-30).

Soil type	Soil proportion	Change in yields	Change in P-loss	Change in N-runoff	Change in net return
		%	%	%	$/A
McLaurin	0.2989	0.0000	0.0000	0.0000	0.09
Malbis	0.2004	0.0000	0.0000	0.0000	0.09
Savannah	0.1455	0.0000	0.0000	0.0000	0.09
Poarch	0.1262	0.0000	0.0000	0.0000	0.09
Prentiss	0.0778	0.0000	0.0000	0.0000	0.09
Providence	0.0588	0.0000	0.0000	0.0000	0.09
Alligator	0.0541	0.0000	0.0000	0.0000	0.09
Falkner	0.0384	0.0000	0.0000	0.0000	0.09
Sum Wgt.	**1.0000**	**0.0000**	**0.0000**	**0.0000**	**0.09**

Table 5C-I Lower Coastal Plain. A comparison of environmental and economic impacts of single-rate and variable-rate fertilizer applications for corn (N-130, P-0).

Soil type	Soil proportion	Change in yields	Change in P-loss	Change in N-runoff	Change in net return
		%	%	%	$/A
McLaurin	0.2665	0.0000	0.0000	0.0000	10.35
Malbis	0.1787	-2.2222	0.0000	-0.1139	3.69
Savannah	0.1298	-2.2472	0.5682	0.2215	3.69
Poarch	0.1125	0.0000	0.0000	0.0000	10.35
Ora	0.1114	-1.0753	0.0000	0.0000	7.02
Prentiss	0.0694	0.0000	-0.5277	-0.5119	10.35
Providence	0.0524	-1.0526	-0.2066	-2.9201	7.02
Eutis	0.0450	0.0000	0.0000	-0.2278	10.35
Falkner	0.0342	-1.0870	0.0000	-2.7512	7.02
Sum Wgt.	**1.0000**	**-0.9009**	**0.0263**	**-0.2847**	**7.64**

Table 5C-II Lower Coastal Plain. A comparison of environmental and economic impacts of single-rate and variable-rate fertilizer applications for corn (N-130, P-46).

Soil type	Soil proportion	Change in yields	Change in P-loss	Change in N-runoff	Change in net return
		%	%	%	$/A
McLaurin	0.2665	0.0000	0.0000	0.0000	-2.12
Malbis	0.1787	-2.2222	0.0000	-0.1139	-8.78
Savannah	0.1298	-2.2472	0.5682	0.2215	-8.78
Poarch	0.1125	0.0000	0.0000	0.0000	-2.12
Ora	0.1114	-1.0753	0.0000	0.0000	-5.45
Prentiss	0.0694	0.0000	-0.5277	-0.5119	-2.12
Providence	0.0524	-1.0526	-0.2066	-2.9201	-5.45
Eutis	0.0450	0.0000	0.0000	-0.2278	-2.12
Falkner	0.0342	-1.0870	0.0000	-2.7512	-5.45
Sum Wgt.	**1.0000**	**-0.9009**	**0.0263**	**-0.2847**	**-4.83**

Lower Brown Loam Region

Recommended nitrogen fertilizer application for cotton in this region ranges from 70-130 pounds per acre. Out of 713 soil samples from cotton acreage in this area, 61% tested at high P-levels and 30% at medium. Tables 6A-I and 6A-II show the simulation results of the recommended application with and without phosphorus applications, as compared with the single rate. Nitrogen runoff in this scenario declined by 0.43%. Yield in both cases did not change, while phosphorus loss in sediment was almost nonexistent — 0.01% for the first scenario and no change for the second scenario. The change in net returns per acre ranged between $9.73 and $22.21 as a result of cost savings in input use.

Out of 523 soil samples from soybean acreage, 50% tested at high P-levels and 30% at medium. Simulations resulted in no change of environmental indicators, while economic net returns increase by $8.23 and 10 cents per acre, respectively (Tables 6B-I and 6B-II).

Out of 666 soil samples of planted corn in this region, 62% tested at high P-levels and 24% at medium. Change in yields and other environmental parameters, as compared with the single rate, were the same in both cases. Other parameters decreased: yield by 0.98%, nitrogen runoff by 0.53%, and phosphorus loss in sediment by 0.14% (Tables 6C-I and 6C-II). Per-acre net returns ranged from a loss of $4.98 to an increase of $7.48.

Table 6A-I Lower Brown Loam. A comparison of environmental and economic impacts of single-rate and variable-rate fertilizer applications for cotton (N-vary, P-0).

Soil type	Soil proportion	Change in yields	Change in P-loss	Change in N-runoff	Change in net return
		%	%	%	$/A
Providence	0.3344	0.0000	0.0000	0.0000	22.12
Loring	0.2114	0.0000	0.0000	-0.0314	22.12
Ora	0.0927	0.0000	0.0000	0.0000	22.12
Oaklimeter	0.0694	0.0000	0.0000	0.0000	22.12
Falaya	0.0686	0.0000	-0.2119	0.0000	22.12
Savannah	0.0502	0.0000	0.0000	-8.4583	23.99
Riedtown	0.0378	0.0000	0.0000	0.0000	22.12
Adler	0.0376	0.0000	0.0000	-0.0347	23.99
Kipling	0.0350	0.0000	0.0000	-0.0038	22.12
Morganfield	0.0339	0.0000	0.0000	0.0000	22.12
Dundee	0.0290	0.0000	0.0000	0.0000	19.31
Sum Wgt.	**1.0000**	**0.0000**	**-0.0145**	**-0.4326**	**22.21**

Table 6A-II Lower Brown Loam. A comparison of environmental and economic impacts of single-rate and variable-rate fertilizer applications for cotton (N-vary, P-46).

Soil type	Soil proportion	Change in yields	Change in P-loss	Change in N-runoff	Change in net return
		%	%	%	$/A
Providence	0.3344	0.0000	0.0000	0.0000	9.65
Loring	0.2114	0.0000	0.0000	0.0000	9.65
Ora	0.0927	0.0000	0.0000	0.0000	9.65
Oaklimeter	0.0694	0.0000	0.0000	0.0000	9.65
Falaya	0.0686	0.0000	0.0000	0.0000	9.65
Savannah	0.0502	0.0000	0.0000	-0.0798	11.53
Riedtown	0.0378	0.0000	0.0000	0.0000	9.65
Adler	0.0376	0.0000	0.0000	0.0000	11.53
Kipling	0.0350	0.0000	0.0000	-0.0038	9.65
Morganfield	0.0339	0.0000	0.0000	-0.0325	9.65
Dundee	0.0290	0.0000	0.0000	0.0000	6.84
Sum Wgt.	**1.0000**	**0.0000**	**0.0000**	**-0.0041**	**9.74**

Table 6B-I Lower Brown Loam. A comparison of environmental and economic impacts of single-rate and variable-rate fertilizer applications for soybeans (N-0, P-0).

Soil type	Soil proportion	Change in yields	Change in P-loss	Change in N-runoff	Change in net return
		%	%	%	$/A
Providence	0.3180	0.0000	0.0000	0.0000	8.23
Loring	0.2010	0.0000	0.0000	0.0000	8.23
Ora	0.0882	0.0000	0.0000	0.0000	8.23
Oaklimeter	0.0660	0.0000	0.0000	0.0000	8.23
Falaya	0.0653	0.0000	0.0000	0.0000	8.23
Sharkey	0.0489	0.0000	0.0000	0.0000	8.23
Savannah	0.0477	0.0000	0.0000	0.0000	8.23
Riedtown	0.0359	0.0000	0.0000	0.0000	8.23
Adler	0.0358	0.0000	0.0000	0.0000	8.23
Kipling	0.0333	0.0000	0.0000	0.0000	8.23
Morganfield	0.0323	0.0000	0.0000	0.0000	8.23
Dundee	0.0276	0.0000	0.0000	0.0000	8.23
Sum Wgt.	**1.0000**	**0.0000**	**0.0000**	**0.0000**	**8.23**

Table 6B-II Lower Brown Loam. A comparison of environmental and economic impacts of single-rate and variable-rate fertilizer applications for soybeans (N-0, P-30).

Soil type	Soil proportion	Change in yields	Change in P-loss	Change in N-runoff	Change in net return
		%	%	%	$/A
Providence	0.3180	0.0000	0.0000	0.0000	0.09
Loring	0.2010	0.0000	0.0000	0.0000	0.09
Ora	0.0882	0.0000	0.0000	0.0000	0.09
Oaklimeter	0.0660	0.0000	0.0000	0.0000	0.09
Falaya	0.0653	0.0000	0.0000	0.0000	0.09
Sharkey	0.0489	0.0000	0.0000	0.0000	0.09
Savannah	0.0477	0.0000	0.0000	0.0000	0.09
Riedtown	0.0359	0.0000	0.0000	0.0000	0.09
Adler	0.0358	0.0000	0.0000	0.0000	0.09
Kipling	0.0333	0.0000	0.0000	0.0000	0.09
Morganfield	0.0323	0.0000	0.0000	0.0000	0.09
Dundee	0.0276	0.0000	0.0000	0.0000	0.09
Sum Wgt.	**1.0000**	**0.0000**	**0.0000**	**0.0000**	**0.09**

Table 6C-I Lower Brown Loam. A comparison of environmental and economic impacts of single-rate and variable-rate fertilizer applications for corn (N-130, P-0).

Soil type	Soil proportion	Change in yields	Change in P-loss	Change in N-runoff	Change in net return
		%	%	%	$/A
Providence	0.4437	-1.1236	-0.2463	-0.5423	7.02
Ora	0.1230	-1.1364	0.0000	-0.0798	7.02
Oaklimeter	0.0920	-1.1364	0.0000	-0.4114	7.02
Falaya	0.0911	0.0000	-0.3509	-0.3595	10.35
Savannah	0.0666	-1.1765	0.6757	0.0470	7.02
Riedtown	0.0501	0.0000	-0.4684	-3.4916	10.35
Adler	0.0499	-1.1494	0.0000	-0.3758	7.02
Morganfield	0.0450	-1.1905	0.0000	0.0000	7.02
Dundee	0.0385	-1.1494	-0.4717	-0.4345	7.02
Sum Wgt.	**1.0000**	**-0.9765**	**-0.1379**	**0.0000**	**7.49**

Table 6C-II Lower Brown Loam. A comparison of environmental and economic impacts of single-rate and variable-rate fertilizer applications for corn (N-130, P-0).

Soil type	Soil proportion	Change in yields	Change in P-loss	Change in N-runoff	Change in net return
		%	%	%	$/A
Providence	0.4437	-1.1236	-0.2463	-0.5423	-5.45
Ora	0.1230	-1.1364	0.0000	-0.0798	-5.45
Oaklimeter	0.0920	-1.1364	0.0000	-0.4114	-5.45
Falaya	0.0911	0.0000	-0.3509	-0.3595	-2.12
Savannah	0.0666	-1.1765	0.6757	0.0470	-5.45
Riedtown	0.0501	0.0000	-0.4684	-3.4916	-2.12
Adler	0.0499	-1.1494	0.0000	-0.3758	-5.45
Morganfield	0.0450	-1.1905	0.0000	0.0000	-5.45
Dundee	0.0385	-1.1494	-0.4717	-0.4345	-5.45
Sum Wgt.	**1.0000**	**-0.9765**	**-0.1379**	**-0.5284**	**-4.98**

Statewide Impacts

By combining results of the individual regions, we estimated the impact of precision agriculture on cotton, soybeans, and corn for the state as a whole. To perform this exercise, the six regions were aggregated by taking into account the planted areas of cotton, soybeans, and corn in each region. Soil types appropriate for each crop were used in the simulation model. Information regarding appropriate crops for each soil type was obtained from Official Soil Series Data Descriptions, USDA-NRCS, Soil Survey Division (http://www.stat-lab.iastate.edu/soils/osd). Planted areas for each crop are reported in Appendix B. The results indicate all environmental parameters (nitrogen and phosphorus runoff) were reduced by about 2% for cotton (Table A-1), while net returns per acre increased, ranging from $4.96 to $16.78, based on average cotton price of 1999. For soybeans, according to EPIC simulation, there was no change in phosphorus loss, while nitrogen runoff and net returns per acre increased by 0.03% and $7.26, respectively (Table A-2). In the case of corn, nitrogen runoff decreased by 4.9% and phosphorus loss in sediment decreased by 1.55%. Based on average corn price of 1999, net returns per acre increased by $3.15 (Table A-3).

Table A-1. Aggregated economic and environmental impacts of conventional agricultural practices compared with precision-agricultural practice for cotton.

Region	Change in N-runoff	Change in P-loss	Profits	Regional profits
	%	%	$/A	$
1	-2.5440	-2.0066	4.96	3,543,800
2	0.0500	0.0052	17.50	3,097,712
3	-0.0179	0.0000	14.19	1,306,476
4	0.0059	-0.0016	13.41	85,340
5	-0.0253	-0.0056	16.78	162,575
6	-0.0410	-0.0014	14.88	2,646,703
Total	**-2.5724**	**-2.0100**		**10,842,606**

Table A-2. Aggregated economic and environmental impacts of conventional agricultural practices compared with precision-agricultural practice for soybeans.

Region	Change in N-runoff	Change in P-loss	Profits	Regional profits
	%	%	$/A	$
1	0.0000	0.0000	8.23	1,0614,231
2	0.0273	0.0000	5.60	1,622,697
3	0.0000	0.0000	5.96	1,984,286
4	0.0000	0.0000	0.85	2,566
5	0.0000	0.0000	4.42	21,907
6	0.0000	0.0000	5.55	573,112
Total	**0.0273**	**0.0000**		**14,818,800**

Table A-3. Aggregated economic and environmental impacts of conventional agricultural practices compared with precision-agricultural practice for corn.

Region	Change in N-runoff	Change in P-loss	Profits	Regional profits
	%	%	$/A	$
1	-2.1711	-0.7803	3.33	290,376
2	-0.4768	-0.0087	5.29	333,756
3	-2.1301	-0.7231	0.99	98,869
4	0.0067	-0.0018	-0.56	-3,539
5	-0.0080	0.0007	1.80	25,293
6	-0.1202	-0.0313	3.38	233,834
Total	**-4.8994**	**-1.5446**		**978,589**

CONCLUSIONS

Empirical results demonstrated that one aspect of precision-agricultural technology — variable-rate fertilizer application — used on cotton, soybeans, and corn in Mississippi can provide both environmental and economic benefits. Even though our study covered only one aspect of potential benefits of precision-agriculture technology, the results indicated some positive economic and environmental impacts. Since the technology has not been widely adopted, full utilization could lead to substantial economic and environmental benefits. The results from an economic perspective show that the farmer would generally benefit from this technology by decreasing variable costs. At the state level, our analysis suggested that the greatest benefit from this technology could accrue for cotton growers whose average per acre net return would increase by $9.76, based on average cotton price of 1999. From an environmental perspective, applying this technology on corn would result in the maximum benefit to the environment, reducing nitrogen runoff by 4.9% and phosphorus loss in sediment by 1.55%.

The results on economic net return indicated that management of inputs may not lead to maximum yields, and in some cases, could cause a yield reduction. However, economic net returns did increase due to a cost savings in input use despite reduced yield. Our results depend on several factors, such as soil variability, and may not necessary imply such performance on an individual farm. In addition, these results should be tempered by the fact that the net return calculations do not take into account the fixed cost of purchasing equipment. Thus, the net return of technology would be influenced by farm size.

This research was based on precision applications in combination with conventional cultural practices. Future research should include investigation of the impact of precision application technologies in combination with no-till cultural practices. Preliminary results in this line of research suggest that incorporating no-till with variable-rate fertilization could yield a further reduction in environmental degradation. EPIC simulation results (Table A-4) based on no-till corn and soybeans in the Delta indicated a reduction in nitrogen runoff and phosphorus loss in sediment ranging from 13.55% to 43.54%. Results on cotton were less dramatic, with 4.48% reduction in nitrogen and 0.38% reduction in phosphorus loss.

Table A-4 Delta. A comparison of environmental and economic impacts of conventional tillage with single rate and no tillage with variable-rate fertilizer applications.

Soil type	Soil proportion	Change in yields	Change in P-loss	Change in N-runoff	Change in soil erosion	Change in profit
		%	%	%	%	$/A
Cotton						
Alligator	0.4089	0.0000	8.9027	-0.3417	-24.7431	6.7924
Dundee	0.2965	0.0000	-3.7175	-5.7835	-26.0409	5.4800
Forestdale	0.2945	0.0000	-9.9099	-8.8982	-24.5197	5.4431
Sum Wgt.	**1.0000**	**0.0000**	**-0.3808**	**-4.4757**	**-25.0621**	**17.7155**
Soybean						
Alligator	0.2536	3.5714	-11.4120	-7.1651	-60.0509	4.7067
Dundee	0.1839	6.2500	-31.8792	-27.8677	-67.0819	5.2412
Sharkey	0.3798	0.0000	4.8696	5.1355	-53.6613	3.2743
Forestdale	0.1827	6.2500	-55.2561	-46.8466	-70.0444	5.2059
Sum Wgt.	**1.0000**	**3.1967**	**-17.0004**	**-13.5486**	**-60.7424**	**18.4281**
Corn						
Dundee	0.5017	-4.3011	-27.7311	-35.3501	-78.9582	-26.7829
Forestdale	0.4983	-1.0753	-55.4318	-51.7783	-79.1401	-21.6196
Sum Wgt.	**1.0000**	**-2.6936**	**-41.5346**	**-43.5364**	**-79.0489**	**-48.4025**

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APPENDIX

Appendix A. Soil C.E.C. (Cation Exchange Capacity).

Soil	C.E.C.	Soil	C.E.C.
Adler	8.60	Malbis	6.32
Alligator	48.60	Mantachie	9.91
Collins	10.70	McLaurin	6.70
Dundee	14.90	Morganfield	9.10
Eustis	5.05	Ora	9.60
Falaya	17.10	Prentiss	9.85
Falkner	16.52	Providence	13.18
Forestdale	20.05	Sharkey	42.00
Grenada	11.54	Shubuta	12.75
Kipling	18.09	Tippah	9.10
Leeper	31.50	Urbo	26.56
Lexington	10.63	Vaiden	33.35
Loring	14.20		

Note: C.E.C is sum of cation exchange capacity. C.E.C of each soil type is estimated from an average C.E.C. of a number of soil samples.
Source: United States Department of Agriculture, Natural Resources Conservation Service, National Soil Survey Center, Soil Survey Laboratory, http://vmhost.cdp.state.ne.us:96.

Appendix B. Planted acreage in Mississippi, 1999.

Region	Cotton	Corn	Soybeans	Total
	A	*A*	*A*	*A*
Delta	713,900	87,200	1,289,700	2,090,800
Upper Brown Loam	177,000	63,067	289,575	529,642
Black Belt	92,089	100,216	333,143	525,448
Upper Coastal Plain	6,363	6,279	3,004	15,646
Lower Coastal Plain	9,690	14,070	4,953	28,713
Lower Brown Loam	177,814	69,202	103,286	350,302
Total	**1,176,856**	**340,034**	**2,023,661**	**3,540,551**

Source: Mississippi Agricultural Statistics Service.

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