3-1-1983

Expansion Potential for Irrigation within the Mississippi Delta Region

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Publication No. 93

March, 1983

Research Project Technical Completion Report A-054-ARK

Arkansas Water Resources Research Center
University of Arkansas
Fayetteville, Arkansas 72701

AWRRC

Arkansas Water Resources Research Center

Prepared for
United States Department of the Interior

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The work upon which this report is based was supported in part by federal funds provided by the United States Department of the Interior, as authorized under the Water Research and Development Act of 1978 (P.L.95-467),through annual cooperative program aggrement number 14-34-0001-2104. This constitutes the final technical completion report for project A-054-ARK.

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Fayetteville, Arkansas 72701

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ABSTRACT

17.6 million acres, or 73 percent, of the Mississippi Delta Region is currently cropland and possesses the physical characteristics of slope, texture and soil type which are recommended for irrigation. Economic feasibility of expanding irrigation by flood, furrow and center pivot methods were examined under 24 scenarios representing two sets of crop prices, yield levels, production costs, opportunity costs and six crop rotations. Irrigation was economically feasible for 56 to 100 percent of the cropland across all scenarios. Approximately 88 percent of the cropland can be economically irrigated with flood or furrow in its present form, 8 percent yield highest net returns if furrow irrigated following land forming and 4 percent can be economically irrigated only with center pivot systems.

Descriptors: *Irrigation / Irrigation Wells/*Economic Feasibility/ *Cost Benefit Analysis/Sprinkler-Irrigation/Flood Irrigation/Furrow Irrigation/Land Forming/*Arkansas

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ACKNOWLEDGEMENTS

Appreciation is expressed for the cooperation received from farmers, custom land formers, irrigation equipment dealers, representatives of the Soil Conservation Service and the Arkansas Cooperative Extension Service. Initial stages of the project were co-funded by Resources for the Future, Washington, D.C. and their support is also greatly appreciated.

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INTRODUCTION

Increased world demand for food and grains has provided United States farmers incentives to increase crop production. In the Mississippi Delta Region increased crop production may come from extensive expansion, such as the conversion of woodland and pastureland to cropland, or from intensive expansion such as land forming of existing cropland and/or irrigation of existing cropland.

The objective of this study was to determine the potential for expanding irrigation in the Mississippi Delta Region. That is, how many acres of a particular land and soil group can be economically irrigated assuming alternative types of irrigation systems, production costs, product prices, and levels of management.

The detail of the analysis has been documented in M.S. theses by Jon Mark Erstine and Blake Phillips. Thus, I will not provide that detail here but rather, will provide the basic assumptions under which the research was conducted, an example of the in-depth analysis through presentation of eight of the twenty-four scenarios examined, and the major conclusions of the research effort.

The Mississippi Delta Region, which includes parts of Missouri, Arkansas, Louisiana, Mississippi, Tennessee, and Kentucky, comprises approximately 25,360,000 acres. Included in this area are the Mississippi River Valley, the Grand Prairie, and upland areas such as Crowley's Ridge in Arkansas, and the Macon Ridge in Arkansas and Louisiana. However, for purposes of this study, the Grand Prairie of Arkansas which includes most of Arkansas, Monroe, Prairie, and Lonoke Counties was excluded. This is the major rice production area of Arkansas and has experienced decreasing water tables. The ground water resources of the Grand Prairie are currently fully utilized. Consequently, little potential exists for further irrigation expansion in this area. The study region is delineated in Figure 1. The research reported here was funded by Resources for the Future, Inc., the United States Department of the Interior through the Arkansas Water Resources Research Center, and the Arkansas Agricultural Experiment Station.

Data were gathered from a six county sample area determined to be typical of the Mississippi Delta Region in terms of soil types, slopes, drainage, cropping patterns, farm organization, and climate. The sample area consisted of Chicot, Desha, Phillips, Crittenden, Mississippi, and Clay counties in Arkansas. The sample area is delineated in Figure 2.

Cost/benefit ratios were developed to account for all cost and yield factors associated with irrigation. These costs vary according to soil factors such as slope, drainage and crop. Irrigated crop yields vary according to soil type, slope, and crop. All crops do not have the same yield response to irrigation. Therefore, the cost/benefit ratios of different rotations on different soil groups were compared to determine the rotation yielding the highest rate of return. The lower the cost/benefit ratio the higher the rate of return. Given that a producer owns the necessary machinery complement for adopting the best crop rotation, it was assumed that the rotation yielding the highest rate of return would be selected. The economic feasibility of irrigation was analyzed using a 20 year planning horizon and a discount rate of 10 percent.

Since the gross returns resulting from a particular rotation depend entirely upon crop yields and crop prices, cost/benefit ratios were computed with high and average management crop yields and two sets of crop prices. High yield was representative of the top 10 percent of farmers reported on the Soil Conservation Service Form V's, while average yield was the four year weighted average for the sample counties as reported by the Statistical Reporting Service. The sensitivity of production decisions to changes in variable production costs was examined by shifting variable production costs from normal levels as defined by the University of Arkansas Production budgets to 133 percent of normal levels.

Thus, the economic feasibility of irrigation was examined under a wide spectrum of economic conditions, soil productivity classes and crop rotations.

Data from the Resource Inventory Data System (RIDS) developed by the Soil Conservation Service and the Economic Research Service of USDA was used to identify those areas which possessed the physical characteristics required for irrigation. This information was then combined with the economic analysis to determine what portion of the land base could economically be irrigated.

Sufficient water for irrigation was assumed to be available from ground water sources at a depth of 150 feet. The rotation resulting in the highest rate of return was assumed to be adopted.

DESCRIPTION AND COMPARISON OF IRRIGATION METHODS USED IN STUDY

The technology of irrigation for agriculture is rapidly changing. Farmers are demanding labor saving systems that are efficient, functional, and reasonably priced. The three irrigation systems examined include flood irrigation, furrow irrigation, and center pivot sprinkler irrigation.

Not all practices can be used on all farms because of differences in soil type, slope of land, and general outlay of fields.

Flood Irrigation

Irrigation by the flood method (sometimes called contourlevee irrigation) requires that water be applied to nearly level field segments at a rate enough in excess of the intake rate of the soil to permit rapid coverage. The water is held by levees that surround the segments and are constructed longitudinally on the contour. Water is kept on the segments until the desired amount has been absorbed by the soil. The excess is then drained off by gravity and used on a similar segment at a lower elevation. The flood irrigation method has been used for many years for flooding rice fields. It has also been adapted to irrigate hay crops, small grains, and some row crops. If contour levees are used for irrigating row crops, the slope in the direction of the row drainage becomes a limiting factor. The maximum slope should also not be so great that a majority of the crop to be irrigated must be plowed up during construction of the levees. The minimum slope is that which will provide adequate drainage. In the study area, levees in row crops are usually constructed only after the last cultivation has been done. If irrigation is required prior to the last cultivation the levees will be constructed, land irrigated, levees torn down, land cultivated and levees replaced if additional irrigation is required.

Furrow Irrigation with Gated-Pipe

Gated pipe refers to a thin-walled, low pressure aluminum, plastic, or rubber pipe with gates inserted at different spacings to match row width. The gates distribute the water along the ridge of the field to be surface irrigated. This system operates on low pressure with low fuel and horsepower requirements. Gated-pipe commonly comes in sizes of 6, 8, 10 and 12 inches in diameter. The rate of flow from the water source will be used to determine the appropriate size of pipe. Furrow irrigation with gated pipe requires the use of hand labor. The amount of labor varies from farm to farm depending on field layout and accessability. Labor is required to load, lay, and move the pipe, check the gates, and check the furrows to see if the water has reached the prescribed destination.

Furrow irrigation is a gravity flow operation. Row grades range from .1 to .5 percent slope on the irrigated fields. Slopes flatter than this result in poor drainage. The length of run will vary from

600 feet up to ½ mile in some cases. 1320 feet is the recommended maximum length of run for efficient irrigation.

Center-Pivot Sprinkler Irrigation

In the sprinkler method of irrigation, water is applied above the ground surface as a spray somewhat resembling rainfall. The spray is developed by the flow of water under pressure through small nozzles. With careful selection of nozzle sizes, operating pressure, and sprinkler spacing, water can be applied uniformly at a rate based on the intake rate of the soil, thereby preventing runoff and resulting damage to land and crops. The sprinkler method is adaptable to irrigate most crops. The flexibility of present day sprinkler equipment and its efficient control of application make this method adaptable to most topographic conditions without extensive land preparation.

The required capacity of the sprinkler system depends on the size of the irrigated area, the depth of water to be applied at each irrigation and the time allowed to apply this amount of water.

ASSUMPTIONS

Soil Classification System

Dr. E. Moye Rutledge, soil scientist in the Department of Agronomy, Arkansas Agricultural Experiment Station provided his expertise in grouping land resources according to soil properties. Twenty-two soil productivity groups were created based on the criteria of permeability, surface texture, and slope. These groups represented all soil mapping units found in the six county sample area.

Nine of the soil groups possess the physical characteristics needed for irrigation. These nine soil groups are defined in Table 1. The remaining 13 soil productivity groups were eliminated from consideration on the basis of limited occurance, excessive slopes, and severe limitations for crop production.

The nine soil groups examined represent 97.1 percent of all cropland in the region.

Prices

Projections of irrigation feasibility were based on 1985 prices converted to 1980 dollars. The 1985 prices reflect baseline and high demand situations as estimated by the United States Department of Agriculture's Grain-Oil Seeds and Livestock Model (GOL). Baseline conditions assume "world grain trade prices in real terms are likely to average closer to the low levels of 1969/70-1971/72 base period than the high levels of the 1972/73-1974/75 period." The 1985 high

Table 1. Soil Groups

Group	Description
1	Slow permeability, loamy surface texture, 0 to 1% slope. Examples: Desha silt loam, Calloway silt loam, Crowley loam, Sharkey silty clay loam
2	Slow permeability, loamy surface texture, 1 to 3% or gently undulating slopes. Examples: Loring silt loam 1 to 3 percent slope; McGehee silt loam, gently undulating; Sharkey silty clay loam, gently undulating; Stuttgart silt loam, 1 to 3% slope
2F	Those soils of group 2 that have gently undulating slopes
3	Slow permeability, loamy surface texture, land formed. Examples: Any existing land formed cropland previously in soil groups 1 or 2
4	Slow permeability, clayey surface texture, 0 to 1% slope. Examples: Alligator clay, Portland clay, Sharkey clay, Tunica clay
5	Slow permeability, clayey surface texture, 1 to 3% or gently undulating. Examples: Alligator silty clay, gently undulating; Portland clay, gently undulating; Sharkey clay, gently undulating; Tunica clay, gently undulating
6	Slow permeability, clayey surface texture, land formed. Examples: Any existing land formed cropland previously in soil groups 4 or 5
7	Moderate permeability, loamy surface texture, 0 to 1% slope. Examples: Dubbs sandy loam, Dundee silt loam, Hebert silt loam, Rilla silt loam
8	Moderate permeability, loamy surface texture, 1 to 3% or gently undulating slope. Examples: Bosket sandy loam, gently undulating; Dubbs sandy loam, gently undulating; Memphis silt loam, 1 to 3% slope; Rilla silt loam, gently undulating
9	Moderate permeability, loamy surface texture, land formed. Examples: Any existing land formed cropland previously in soil groups 7 or 8

Source: Soils were grouped in consultation with Dr. E. Moye Rutledge.

demand crop prices, derived from the same model, assume "real grain prices...would be substantially higher than in the base 1969/70-1971/72 period but still below the levels of 1972/73-1974/75" (Crosson, 1978).

Only soybean meal, feed grain, and wheat prices were projected in the GOL model. Thus, soybean prices were estimated as a function of soybean meal prices, and corn and grain sorghum as a function of feed grains. Projected rice prices were derived from projections developed for the world rice model (8), and cotton prices were adapted from projections published in Data Resources (3). The baseline and high demand prices used appear in Table 2.

Table 2. Crop Prices in 1980 Real Dollars

Crop	Price: 1985 baseline	Price: 1985 high demand
Soybeans	$6.60/bu	$7.48/bu
Rice	$4.15/bu	$5.56/bu
Cotton lint	$0.72/lb	$0.82/lb
Cotton seed	$0.059/lb	$0.067/lb
Corn	$3.02/bu	$3.50/bu
Wheat	$3.37/bu	$4.09/bu
Grain sorghum	$2.43/bu	$2.91/bu

Normal Per Acre Production Costs

Dryland production cost per acre was obtained from the 1980 Arkansas crop budgets for non-irrigated production. Costs for each specific irrigation system were added to these budgets. The flood, furrow, and center pivot sprinkler system costs were based on irrigating 160 acres. Both diesel and electric power units were analyzed. Systems were designed to reflect typical wells and systems used in the study area. Well costs are presented in Table 3.

Normal per acre production costs for non-irrigated, flood irrigated, furrow irrigated, and center pivot sprinkler irrigated crops are shown in Table 4.

Normal per acre production costs with a 33 percent increase in variable production cost were also derived in order to project near future costs. This was believed necessary because of the major increases that have occurred in variable cost in the past few years.

Irrigation costs were estimated for only four broad soil classes, non-land formed loam, non-land formed clay, land formed loam, and land formed clay soils. Thus irrigation were identical across some of the nine soil productivity classes.

The irrigated budgets were based on crop, irrigation system, power source, and soil class.

Soil groups two and four must be land formed before rice production is attempted on these soils.

Cotton was not considered on land formed land. Although many acres of traditional cotton land have been land formed much of it was done in the 1960's during the cotton acreage diversion program. Cotton on newly land formed land is not recommended.

Table 3. Replacement Cost for Irrigation Wells
Based on 100 Foot Well with 50 Foot Lift

Well "A" 800 gallons per minute for Flood and Furrow Systems

	Electric	Diesel
Drilling casing, and installation	$ 4,300.00	$ 4,300.00
Pump assembly	4,200.00	4,200.00
Power unit and accessories	2,575.00	5,266.00
Gear driver (50 H.P.)	1,100.00	1,100.00
Total Cost	$12,175.00	$14,866.00
Annual Ownership Cost:		
Depreciation	$ 535.83	$ 855.23
Interest	608.75	743.30
Taxes	121.75	148.66
Insurance	47.25	63.39
Annual Ownership Cost	$1,313.58	$1,810.58

Well "B" 1000 gallons per minute for Center Pivot Systems

	Electric	Diesel
Drilling, casing, and installation	$ 4,400.00	$ 4,400.00
Pump assembly	6,300.00	6,300.00
Power unit and accessories	4,337.00	7,537.00
100 H.P. gear drive (flex shaft electric	1,675.00	1,500.00
¼ center pivot system	34,000.00	34,000.00
Total Cost	$50,712.00	$53,737.00
Annual Ownership Cost:		
Depreciation (new cost/n)	$2,968.43	$3,248.51
Interest (((new cost/2)Interest Rate))	2,535.55	2,686.85
Taxes (new cost x .01)	507.11	537.37
Insurance	277.87	296.02
Annual Ownership Cost	$6,288.96	$6,768.75

Base Crop Yields

The irrigated and non-irrigated crop yields for specific soils were derived from several sources. The per acre yields assumed for the top 10 percent of managers for rice, cotton lint, and soybeans came from S.C.S. Form V. A weighted average was calculated for the specific soils found in each group.

Additional information had to be supplied by crop and soils experts to determine yields for double-cropped soybeans, cotton seed, grain sorghum, corn and wheat.

Flood and center pivot sprinkler systems do not allow irrigated production of 100 percent of a field. Levees must be constructed for flood irrigation and soybeans are plowed up in the process. This does not apply to rice irrigation under flooded conditions because rice is usually planted on the levees at the same time that the field is planted.

Yields for flood irrigated soybeans were assumed to be 10 percent below yields from furrow irrigated soybeans due to the construction of levees. In the case of center pivot sprinkler irrigation the corners of the field are not irrigated. This study assumed 135 acres were irrigated by the center pivot system with 25 acres remaining unirrigated. The yield of the 135 irrigated acres and the yield of the 25 non-irrigated acres were used to form a weighted average yield for the 160 acres.

Yields for land-formed land were increased by 10 percent above

Table 4. Normal Per Acre Production Costs

		Soils			
		Non-Land Formed		Land Formed	
Non-Irrigated Crop		Loam	Clay	Loam	Clay
Soybeans		118.86	110.91	123.43	114.26
Corn		146.28	NA	153.61	NA
Cotton		344.51	344.01	NA	NA
Grain Sorghum		155.57	155.57	164.20	164.20
Wheat		81.92	81.92	86.15	86.15
Double-Cropped Soybeans		200.78	192.83	209.58	200.41
Flood Irrigated Rice					
Fuel Source					
Electric		356.11	368.85	367.29	380.54
Diesel		390.95	389.69	399.45	413.04
Irrigated Soybeans					
Irrigated Method	Fuel Type				
Flood	Electric	151.05	NA	155.70	NA
Flood	Diesel	155.34	NA	159.99	NA
Furrow	Electric	155.48	147.98	160.17	151.44
Furrow	Diesel	157.52	150.06	161.59	153.53
Center Pivot	Electric	185.48	177.50	NA	NA
Center Pivot	Diesel	193.50	185.99	NA	NA
Irrigated Corn					
Furrow	Electric	197.53	NA	206.05	NA
Furrow	Diesel	203.96	NA	212.48	NA
Center Pivot	Electric	227.42	NA	NA	NA
Center Pivot	Diesel	237.39	NA	NA	NA
Irrigated Cotton					
Furrow	Electric	373.59	366.17	NA	NA
Furrow	Diesel	377.42	370.00	NA	NA
Center Pivot	Electric	413.93	406.99	NA	NA
Center Pivot	Diesel	422.00	415.07	NA	NA

NA - Flood irrigation applies only to rice, and soybeans grown on loam soils. Center pivot irrigation is not considered on land formed land. Corn is grown on loam soils only. Cotton is not grown on land that has been land formed.

non-land-formed yields to reflect the additional cropland taken into production by land-forming. Additional increases in yields on land-formed land depend on the number of years following land forming, the soil type, and the improvement in drainage and irrigation efficiency.

Average crop yields for cotton, rice, and soybeans are from the Agricultural Statistics for Arkansas for 1974-1977. Yields for non-irrigated corn and grain sorghum are from the Statistical Reporting Service. These average yields were not defined by soil type because they are reported as county average yields without reference to soil type. To estimate the specific soil type crop yields, the four year average yields were divided by the average of the high crop yields used in the first part of the analysis. The resulting percentage was then multiplied by the specific soil type crop yield to derive an estimate of the average yields on particular soil groups.

Base crop yields under non-irrigated conditions are reported in Table 5. Irrigated yields are presented in Table 6.

Table 5. Base Crop Yields for Top 10 Percent of Managers and Average Managers: Non-Irrigated

Crop	Soil Group											
	1	2	2F	3	4	5	5F	6	7	8	8F	9
Top 10 percent soybeans(bu)	29	26	26	38	35	30	30	42	37	37	37	48
Double-cropped soybeans(bu)	25	22	22	34	31	26	26	38	33	33	33	44
Cotton lint(lb)	620	612	612	NA	599	584	584	NA	733	771	771	NA
Cotton seed(lb)	1240	1224	1224	NA	1198	1198	1168	NA	1466	1542	1542	NA
Grain Sorghum(bu)	58	52	52	77	61	53	53	74	74	74	74	96
Corn(bu)	73	65	65	97	NA	NA	NA	NA	93	93	93	120
Wheat		37	37			43	43			53	53	
Average Managers												
Top 10 percent soybeans(bu)	19	17	17	26	23	20	20	30	25	25	25	33
Double-cropped soybeans(bu)	15	13	13	22	19	16	16	26	21	21	21	29
Cotton lint(lb)	415	410	410	NA	401	391	391	NA	491	517	517	NA
Cotton seed (lb)	830	820	820	NA	802	782	782	NA	982	1034	1034	NA
Grain Sorghum(bu)	49	44	44	65	51	45	45	62	62	62	62	80
Wheat		24	24			29	29			36	36	

Table 6. Base Crop Yields for Top 10 Percent of Managers and Average Managers: Irrigated

Flood Irrigation

	Soil Group											
Crop	1	2	2F	3	4	5	5F	6	7	8	8F	9
Top 10 percent												
rice(bu)	130	NA	143	143	126	NA	139	139	NA	NA	NA	NA
Soybeans(bu)	32	NA	NA	39	NA	NA	NA	NA	42	NA	NA	49
Double-cropped soybeans(bu)	28	NA	NA	35	NA	NA	NA	NA	38	NA	NA	45
Average Managers												
Rice(bu)	103	NA	113	113	100	NA	110	110	NA	NA	NA	NA
Soybeans(bu)	26	NA	NA	31	NA	NA	NA	NA	34	NA	NA	39
Double-cropped soybeans(bu)	22	NA	NA	27	NA	NA	NA	NA	30	NA	NA	35

Furrow Irrigation

	Soil Group											
Crop	1	2	2F	3	4	5	5F	6	7	8	8F	9
Top 10 percent												
soybeans(bu)	36	NA	41	43	44	NA	45	48	47	NA	54	54
Double-cropped soybeans(bu)	32	NA	37	39	40	NA	41	44	43	NA	50	50
Cotton lint(lb)	812	NA	NA	NA	659	NA	NA	NA	960	NA	NA	NA
Cotton seed(lb)	1624	NA	NA	NA	1318	NA	NA	NA	1920	NA	NA	NA
Corn(bu)	132	NA	160	160	NA	NA	NA	NA	120	NA	140	140
Average Managers												
Soybeans(bu)	29	NA	32	35	35	NA	35	40	38	NA	43	44
Double-cropped soybeans(bu)	25	NA	28	31	31	NA	31	36	34	NA	39	40
Cotton lint(lb)	544	NA	NA	NA	441	NA	NA	NA	643	NA	NA	NA
Cotton seed(lb)	1088	NA	NA	NA	882	NA	NA	NA	1286	NA	NA	NA

Table 6. (Contd)

Center Pivot Irrigation

Crop	Soil Group 1	2	2F	3	4	5	5F	6	7	8	8F	9
Top 10 percent soybeans(bu)	NA	32	32	NA	NA	37	37	NA	NA	45	45	NA
Double-cropped soybeans(bu)	NA	32	32	NA	NA	37	32	NA	NA	45	45	NA
Cotton lint(lb)	NA	772	772	NA	NA	633	633	NA	NA	973	973	NA
Cotton seed(lb)	NA	1554	1554	NA	NA	1226	1226	NA	NA	1946	1946	NA
Corn(bu)	NA	109	109	NA	NA	NA	NA	NA	NA	116	116	NA
<u>Average Managers</u>												
Soybeans(bu)	NA	25	25	NA	NA	28	28	NA	NA	36	36	NA
Double -cropped soybeans(bu)	NA	25	25	NA	NA	28	28	NA	NA	36	36	NA
Cotton lint(lb)	NA	517	517	NA	NA	424	424	NA	NA	652	652	NA
Cotton seed(lb)	NA	1034	1034	NA	NA	848	848	NA	NA	1304	1304	NA

IRRIGATION OF EXISTING CROPLAND

The economic feasibility of irrigating existing cropland was examined under 24 scenarios.

The cost/benefit ratio was used to determine the irrigated rotation providing the highest rate of return on a given soil group. If the cost/benefit ratio was estimated to be greater than one, i.e. costs greater than benefits, the land would not be irrigated. The scenarios considered two sets of crop prices, baseline and high demand; nine soil groups; two levels of crop yields; three irrigation methods using two different fuel types, six possible rotations; normal and increased variable costs; and two types of opportunity costs. Opportunity costs are the net returns forgone by not leaving the land in non-irrigated production. Situations A through H assume all land is planted to that crop which will provide the highest return under dry land conditions. Situations I through X assume the same crop is produced under both irrigated and non-irrigated conditions.

Twenty-four scenarios were analyzed assuming a 10 percent discount rate and a 20 year planning horizon. The scenarios for irrigation of existing cropland are presented in Table 7.

The three irrigation methods evaluated were flood, furrow, and center pivot. Each irrigation method was used only on those soil groups whose slopes and internal soil structure would allow efficient water use. Flood irrigation was assumed to be usable on soil groups one, three, four, six, seven and nine. Therefore, flood and

Table 7. Identification of Alternative Crop Prices, Production Cost, Yield Situations, and Irrigation System Fuel Types For Irrigation of Existing Cropland

Situation	Scenario
A	1985 baseline crop prices, high yields, normal production costs, diesel power, "highest dryland use" opportunity cost
B	1985 high demand crop prices, high yields, normal production costs, diesel power, "highest dryland use" opportunity cost
C	1985 baseline crop prices, high yields, normal production costs, electric power, "highest dryland use" opportunity cost
D	1985 high demand crop prices, high yields, normal production costs, electric, "highest dryland use" opportunity cost
E	1985 baseline crop prices, average yields, normal production costs, diesel power, "highest dryland use" opportunity cost
F	1985 high demand crop prices, average yields, normal production costs, diesel power, "highest dryland use" opportunity cost
G	1985 baseline crop prices, average yields, normal production costs, electric power, "highest dryland use" opportunity cost
H	1985 high demand crop prices, average yields, normal production costs, electric power, "highest dryland use" opportunity cost
I	1985 baseline crop prices, high yields, normal production costs, diesel power, "non-irrigated versus irrigated rotation" opportunity cost
J	1985 high demand crop prices, high yields, normal production costs, diesel power, "non-irrigated versus irrigated rotation" opportunity cost
K	1985 baseline crop prices, high yields, normal production costs, electric power, "non-irrigated versus irrigated rotation" opportunity cost
L	1985 high demand crop prices, high yields, normal production costs, electric power, "non-irrigated versus irrigated rotation" opportunity cost
M	1985 baseline crop prices, average yields, normal production costs, diesel power, "non-irrigated versus irrigated rotation" opportunity cost

Table 7 (Contd.)

Situation	Scenario
N	1985 high demand crop prices, average yields, normal production costs, diesel power, "non-irrigated versus irrigated rotation" opportunity cost
O	1985 baseline crop prices, average yields, normal production costs, electric power, "non-irrigated versus irrigated rotation" opportunity cost
P	1985 high demand crop prices, average yields, normal production costs, electric power, "non-irrigated versus irrigated rotation" opportunity cost
Q	1985 baseline crop prices, high yields, 33% increase in variable costs, diesel power, "non-irrigated versus irrigated rotation" opportunity cost
R	1985 high demand crop prices, high yields, 33% increase in variable costs, diesel power, "non-irrigated versus irrigated rotation" opportunity cost
S	1985 baseline crop prices, high yields, 33% increase in variable costs, electric power, "non-irrigated versus irrigated rotation" opportunity cost
T	1985 high demand crop prices, high yields, 33% increase in variable costs, electric power, "non-irrigated versus irrigated rotation" opportunity cost
U	1985 baseline crop prices, average yields, 33% increase in variable costs, diesel power, "non-irrigated versus irrigated rotation" opportunity cost
V	1985 high demand crop prices, average yields, 33% increase in variable costs, diesel power, "non-irrigated versus irrigated rotation opportunity cost
W	1985 baseline crop prices, average yields, 33% increase in variable costs, electric power, "non-irrigated versus irrigated rotation" opportunity cost
X	1985 high demand crop prices, average yields, 33% increase in variable costs, electric power, "non-irrigated versus irrigated rotation" opportunity cost

furrow irrigation competed on some soil groups. The methods with the lowest cost/benefit ratio under one was chosen as best. Any rice in rotation was flood irrigated. Furrow irrigation refers only to crops other than rice.

Center pivot irrigation was analyzed on soil groups two, five, and eight. Although center pivot was usable on all soil groups, it was more expensive than either flood or furrow irrigation. Therefore, center pivot irrigation could not compete on a cost/benefit ratio basis with flood or furrow irrigation on those soil groups where the surface methods were usable. The three soil groups where center pivot systems were used were all gently undulating or had slopes of 1 to 3 percent, slopes that prevent efficient use of surface irrigation methods.

Producers with gently undulating cropland could choose to land form to eliminate excessively steep or short slopes and install either flood or furrow irrigation to the leveled land. Leveling is not recommended for those soils with continuous 1 to 3 percent slopes due to the excess cut and fill required. Soil groups 2, 5, and 8 were subdivided into the gently undulating soils which could be land formed and furrow irrigated and the 1 to 3 percent slope that would be irrigated only with center pivot systems.

The subgroups 2F, 5F, and 8F contain only gently undulating slopes. The potential for land forming these soils prior to irrigation was examined under the conditions of situations I through X.

<u>Effect of Changing Product Prices</u>

Situation "A" assumed 1985 baseline crop prices, normal production costs, high level management, diesel fuel as the source of power for the irrigation systems, and opportunity costs based on the "best" rotation. The cost/benefit ratios for Situation "A" are shown in Appendix Table A-1. Irrigation was economically feasible on soil groups 1, 2, 3, 4, 7, and 8. Soil groups 5, 6, and 9 had no cost/benefit ratios less than one. On soil groups 1, 2, 4, 7, and 8 the irrigated cotton-soybean rotation was determined to be the most favorable. For soil group 3 the irrigated corn-soybean rotation provided the highest rate of return.

Situation "B" was identical to "A" except that crop prices were increased to 1985 high demand levels. Soil groups, 1, 2, 7, and 8 remained favorable for irrigation with the cotton-soybean rotation, as in Situation "A", being the most feasible. Soil groups 3 and 4, which had previously been in the cotton-soybean rotation, and soil group 6, which had not been irrigated in Situation "A", all had cost/benefit ratios of less than one in the rice-soybean/wheat-soybean rotation. The change in rotations for soil groups 3 and 4 is explained by the relative changes in crop prices. Changing crop prices from 1985 baseline to 1985 high demand increased the rice price 34%

and the cotton price only 14%. Soil groups 5 and 9 remained unprofitable for irrigation. The cost/benefit ratios for Situation "B" are shown in Appendix Table A-2.

Effect of Changing Power Source

In Situations "C" and "D" all assumptions were identical to Situations "A" and "B" respectively, except that electric power rather than diesel was used for irrigation. The cost/benefit ratios for Situations "C" and "D", shown in Appendix Tables A-3 and A-4, are lower than in Situations "A" and "B" because electricity was a cheaper power source than diesel. There were no changes in the rotations or the soil groups that would be irrigated except that soil group 9, which was not irrigated in Situation "B", has a cost/benefit ratio less than one with the soybean-soybean/wheat rotation in Situation "D". This soil group had been only marginally unprofitable under the previous situations and the lower cost of electric power enabled irrigation to be cost effective. Irrigation of soil groups 5,6, and 9 remained unfeasible assuming 1985 baseline crop prices and soil group 5 remained unfeasible assuming 1985 high demand crop prices.

The four situations just discussed were based on a high level of management. The differences that exist dealt with the changes in crop prices and fuel sources. Opportunity costs were calculated by multiplying the soil group crop yield for the best dryland production costs were then subtracted from this figure to estimate those returns foregone by producing irrigated crops. Whichever set of crop prices were used, they were also used to compute opportunity costs. Therefore, the changes in total revenue resulting from raising or lowering of crop prices did not necessarily result in a high or lower cost/benefit ratio because the effects were offset to some degree by the changes in opportunity cost.

Effect of Changing Yield Estimates

In situations E through H the potential for increasing irrigation by average managers was analyzed. The corn-soybean rotation was excluded from consideration because it was assumed that farmers raising irrigated corn were representative of high level management.

The cost/benefit ratios of average managers in almost all situations was lower than those for high level managers. That is, the potential for increasing returns through the use of irrigation was greater for average than for high level managers. This resulted from two causes: 1) average managers had lower opportunity costs than high level managers when comparing irrigated to non-irrigated crop production, and 2) the yield response to irrigation was higher on a percentage basis for average managers than it was for high level managers. Irrigation yield data was collected in the survey of farmers in the Delta region. This data was aggregated into two groups based on dryland yields. Those producers who had dryland yields at or below the average dryland yield for the entire sample were representative of average management. Those producers who had dryland yields above the average for the sample were representative of high level management. The irrigation yield responses were averaged for each group. It was found that average managers increase yields by a larger percentage than do high level managers. This difference mightoccur for any or all of three reasons: 1) average managers had lower dryland yields which result in lower bases on which percentages were calculated; 2) it may be that average managers who install irrigation systems begin to pay more attention to other production practices (practices that high level managers already use); 3) average managers may tend to farm less naturally productive land that responds well to water.

Situation "E" assumed 1985 baseline crop prices, normal production costs, average management, and diesel power for irrigation. The cost/benefit ratios for this situation are shown in Appendix Table A-5. The cotton-soybean rotation was the first choice in soil groups 1, 7, and 8. In soil groups 3, 4, 6, and 9 the soybean-soybean/wheat rotation was the best rotation. Irrigation of soil groups 2 and 5 was not profitable under Situation "E" conditions. Both of these soil groups require center pivot irrigation unless land formed. Center pivot was found to be the most expensive of all systems examined. This relatively high cost could not be overcome with the yield increases found for these soils.

Situation "E" was identical to Situation "A" except for yield levels. The changes in yields caused some changes in favored rotations between the two situations. When yields were lowered to average management levels only the best cotton soil groups; 1, 7, and 8; remained in cotton. In this case average cotton yields were simply not high enough to allow the cotton rotation to provide the highest rate of return on soil groups 2 and 4. In soil group 2 no rotation had a cost/benefit ratio less than one and in soil group 4 the soybean-soybean/wheat was most favorable. Soil groups 6 and 9, which were not feasible for irrigation in Situation "A", both come into irrigation with the soybean-soybean/wheat rotation at the average yield level. Soil group 3, which had been in corn-soybeans in Situation "A", remains in irrigated acreage but the rotation was changed to soybean-soybean/wheat since corn was not considered for average management.

Increasing crop prices from 1985 baseline (Situation "E") to 1985 high demand (Situation "F") resulted in several changes. Since all other assumptions were the same, the changes can be traced to changes in crop prices. In Situation "F" all soil groups except soil group 5 had cost/benefit ratios less than one. Soil group 1, which was in the cotton rotation under Situation "E", and soil groups 3, 4, and 6, which were in the soybean-soybean/wheat rotation, changed to rice rotations. This movement was discussed previously and explained by the relative changes in crop prices between the two price levels. Soil group 2, which was not economically attractive for irrigation in Situation "E", was attractive with 1985 high demand prices in cotton rotation. Soil groups 7 and 8 remained in cotton-soybeans and soil group 9 remained in soybeans-soybeans/wheat. Soil group 5 still did not come into irrigation. The cost/benefit ratios for Situation "F" are shown in Appendix Table A-6.

Situation "G" assumed 1985 baseline crop prices, normal production costs, average management, and electric power for irrigation. It was identical to Situation "E" except for the power source. All soil groups except soil group 5 were favorable for irrigation. The cost/benefit ratios, shown in Appendix Table A-7, are lower than in Situation "E" because of the lower relative cost of electricity as opposed to diesel fuel as an irrigation power source. Soil group 2 did not come into irrigation in Situation "E". In Situation "G" it came in with the cotton-soybean rotation. Soil group 3, the highest yielding rice soil group, went out of the soybean-soybean/wheat rotation and into the rice-soybean/wheat-soybean rotation. This can also be explained by the lower cost of electricity since pumping costs for rice production make up a larger proportion of irrigation cost than they do for other crops.

Situation "H" is identical to Situation "G" except that crop prices were changed from 1985 baseline to 1985 high demand. The relatively large price increase for rice coupled with the relatively low irrigation cost of electricity brought several soil groups into rice rotations. Soil group 1 changed from the cotton rotation to rice-soybean-soybean. Soil group 3 remained in the rice-soybean/wheat-soybean rotation and soil groups 4 and 6 moved into this rotation from the soybean-soybean/wheat rotation. Every soil group physically capable of rice production moved into rice rotations under the conditions of Situation "H". Soil groups 2, 7, and 8 all remained in the cotton rotation and soil group 9 remained in soybean-soybean/wheat. For the first time soil group 5 was economically feasible for irrigation with the soybean-soybean/wheat rotation. With the inclusion of group 5, all soil groups would be irrigated. The cost/benefit ratios for Situation "H" are shown in Appendix Table A-8.

Effect of Changing Calculation Method for Opportunity Costs

Situations I through P were identical to the scenarios of situation A through H, respectively, except for changing the method of calculating opportunity costs. These situations recognized that not all farmers have their land planted to that crop which provides the highest rate of return. Thus, in all the remaining situations, I through X, the net return from irrigated production was compared to the net return from non-irrigated production of the same crop.

This change produced the anticipated result. All cost/benefit ratios either remained the same or decreased for the rotation selected as providing the highest rate of return under irrigated conditions.

Effects of Increasing Variable Production Costs by 33 Percent

In situations Q through X variable production costs were increased by 33 percent with all other assumptions identical to situations I through P, respectively. The cost/benefit ratios for situations Q through T, all of which assumed high level management, increased by from one to three percent above those same situations computed with normal production costs (i.e., I-L). Only the marginally favorable cost/benefit ratios in situations I through L became unfavorable with the 33 percent increase in variable production costs. These marginal cost/benefit ratios were generally in the .98 to .99 category with normal production costs.

In situations U through X, which assumed average management, significant increases in the cost/benefit ratios occurred for some rotations and soil groups. This is explained by the narrower profit margins for average managers as opposed to high level managers. Average managers were much more sensitive to increased costs than are high level managers. Even though average managers increased yields by a greater percentage with irrigation than do high level managers, average management yields were assumed to have essentially the same production costs, profit margins were smaller for average managers. In some situations the 33 percent increase in variable costs converted a favorable irrigation decision to an unfavorable decision.

IMPLICATIONS OF THE ANALYSIS

The major objective of this study was to determine the potential for irrigation expansion in the Mississippi Delta Region. That is, how many acres of a particular soil group could be economically irrigated assuming alternative types of irrigation systems, production costs, product prices, and levels of management.

The economic analysis incorporated all irrigation cost and yield factors determined for a six county representative area in eastern Arkansas. Two levels of crop prices, two levels of crop yields, two levels of production costs, two types of opportunity costs calculations, and six different crop rotations were used to simulate twenty-four situations.

A total of 17.6 million acres within the Mississippi Delta Region possess the physical characteristics that permit irrigation. A total of 15.5 million acres or 88 percent could be irrigated through the use of any of the three techniques examined, furrow, flood, or center pivot irrigation. An additional 2.1 million acres had potential for center pivot irrigation only due to excessive or uneven slope. If this slope could be altered through land forming, furrow irrigation would be possible.

Furrow irrigation was the most economical alternative for all soils where the technique was physically possible. Under the assumptions examined for 16 of the 24 situations it was economically feasible to irrigate all of the potential 15.5 million acres of cropland with furrow irrigation. The feasibility for increasing irrigation within the Delta region was decreased only under the most unfavorable situation examined; 1985 baseline crop prices, 33 percent increase in variable production costs, and average yields. If these conditions prevailed it was economical to irrigate only 60 percent of the potential furrow irrigated acres, or 9.4 million acres.

There are 2.1 million acres of Delta cropland that are either too steep or undulating to permit furrow irrigation. This is 12 percent of the total Delta cropland acreage. In order to irrigate these acres in their current topography center pivot irrigation was evaluated. The potential for center pivot irrigation ranged from 2.1 million acres, or 100 percent of the potential center pivot irrigated acreage, to 465,000 acres across the various situations examined. In 17 of the 24 situations examined center pivot irrigation was feasible on 1.5 million acres. This figure would account for 72 percent of the potential center pivot irrigated acreage.

Of the 2.1 million acres of steep or undulating slopes, 1.7 million acres or 9.8 percent of the Mississippi Delta cropland is considered gently undulating. This acreage can be land formed.

Land forming followed by furrow irrigation resulted in higher net returns than center pivot irrigation on 43 percent of the undulating acreage. An additional 35 percent of the undulating acreage, specifically the slow permeable clayey soils of soil group 5 could be profitably irrigated only after landforming. Twenty-two percent of the undulating soils, i.e. those loamy soils with moderage permeability were not profitable for land forming but were profitable for center pivot irrigation under all scenarios.

The bottom line for irrigation in the Mississippi Delta Region is staggering. When all economic situations were examined soil groups 1, 2F, 4, 7, 8 and 8F consistently showed a high rate of return to investment in irrigation. These groups represent 90 percent of the Mississippi Delta cropland.

This conclusion is dependent on the assumptions of the study. Prices were those projected for 1985 and assume a normal expansion of total production in the United States would take place and be equated with baseline or high demand conditions in the world market. If irrigation expansion were to occur very rapidly from our current level of under 20 percent of Delta cropland to the projected 90 percent, increased crop production would result in lower prices than those assumed.

The analysis assumed the availability of water and loanable funds to allow for expanded irrigation. Water of sufficient quantity and quality has not limited irrigation use to date and is not seen as a major limitation in the Mississippi Delta region (Note: Region does not include the Grand Prairie). However, there may be significant environmental impacts resulting from expanded water use and the volume of flow in the region rivers and streams will be decreased through withdrawal and ground water pumping.

The availability of loanable funds may be a barrier to rapid irrigation expansion. Installation of irrigation systems on all profitable soil groups in the Delta region would require 1.8 to 2.2 billion dollars at 1980 costs. Bankers and producers will move caustiously but the expansion will continue to progress.

The Mississippi Delta Region will be in a position to make significant contributions toward meeting the increased world demand for agricultural products. However, expanding irrigated production will require increased monitoring and analysis to predict its environmental and resource implications.

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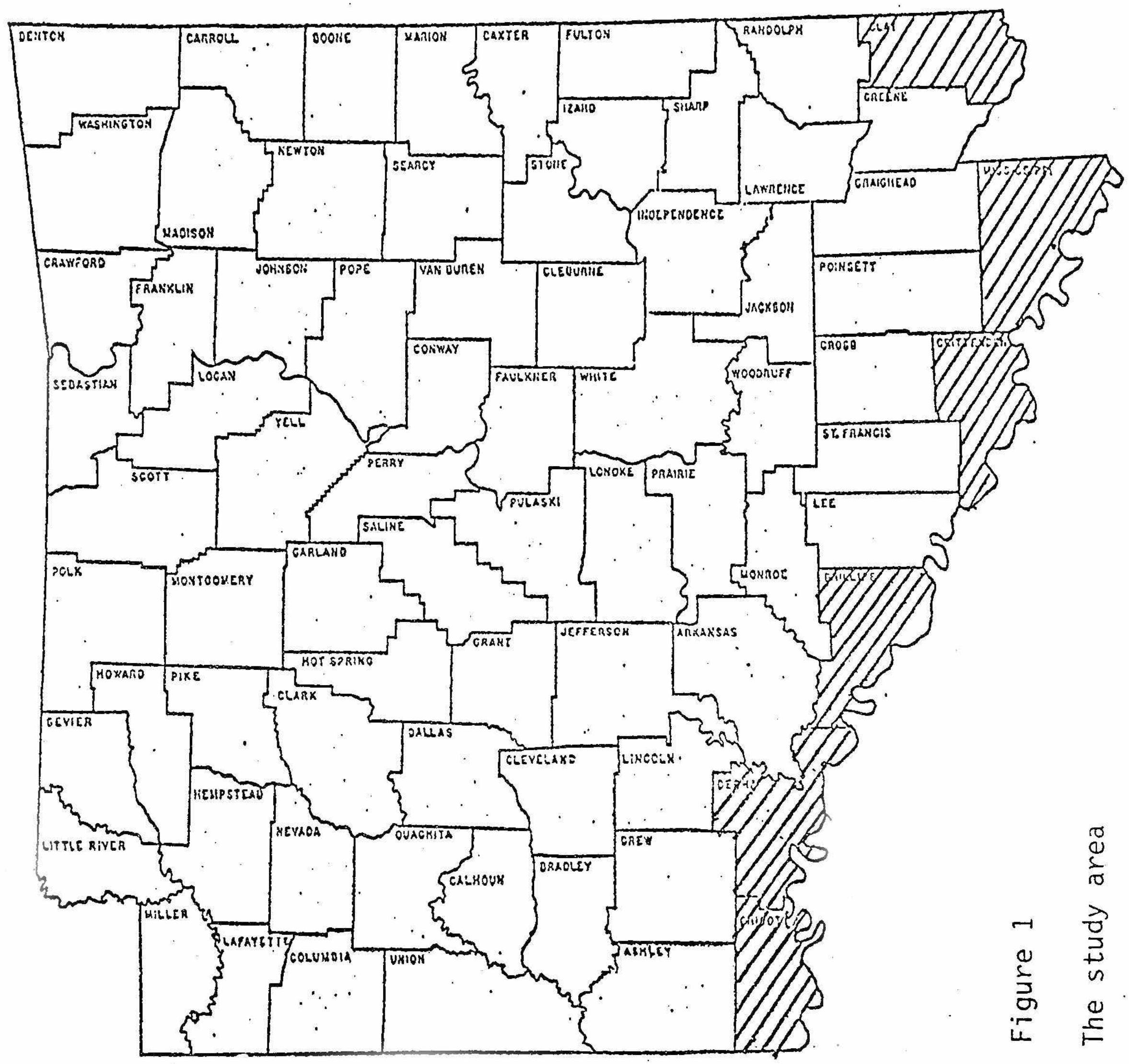

Figure 1

The study area

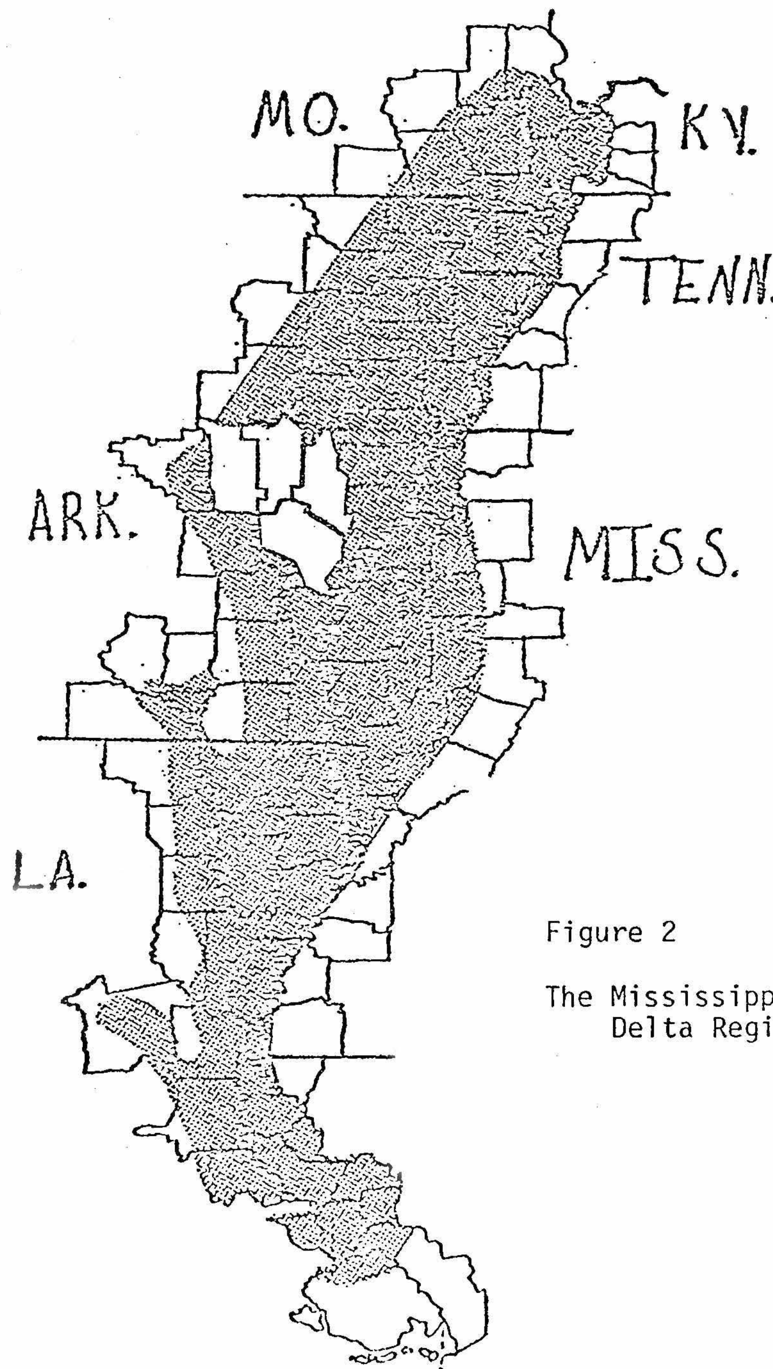

Figure 2

The Mississippi Delta Region

APPENDIX TABLE A-1

COST/BENEFIT RATIOS
FOR ALTERNATIVE IRRIGATION SYSTEMS BY
CROP ROTATION AND SOIL GROUP

Situation "A"

Soil Group	Crop Rotation	Flood	Furrow	Center Pivot
	Rice - Soybeans - Soybeans	1.1004	1.0521	NA
	Rice - Soybeans/Wheat - Soybeans	1.0664	1.0238	NA
1	Soybeans - Soybeans/Wheat	1.2118	1.1072	NA
	Cotton - Soybeans	NA	.8441	NA
	Grain Sorghum - Soybeans	1.6010	1.4989	NA
	Corn - Soybeans	NA	.9446	NA
	Soybeans - Soybeans/Wheat	NA	NA	1.2823
	Cotton - Soybeans	NA	NA	.9634
2	Grain Soybeans - Soybeans	NA	NA	1.7027
	Corn - Soybeans	NA	NA	1.1977
	Rice - Soybeans - Soybeans	1.0009	1.0675	NA
	Rice - Soybeans/Wheat - Soybeans	1.0422	1.0125	NA
3	Soybeans - Soybeans/Wheat	1.1394	1.0722	NA
	Grain Sorghum - Soybeans	1.5143	1.4472	NA
	Corn - Soybeans	NA	.9305	NA
	Rice - Soybeans - Soybeans	NA	1.0267	NA
	Rice - Soybeans/Wheat - Soybeans	NA	.9827	NA
4	Soybeans - Soybeans/Wheat	NA	.9360	NA
	Cotton - Soybeans	NA	.9598	NA
	Grain Sorghum - Soybeans	NA	1.3802	NA
	Soybeans - Soybeans/Wheat	NA	NA	1.1349
5	Cotton - Soybeans	NA	NA	1.0948
	Grain Sorghum - Soybeans	NA	NA	1.6069
	Rice - Soybeans - Soybeans	NA	1.0966	NA
6	Rice - Soybeans/Wheat - Soybeans	NA	1.0296	NA
	Soybeans - Soybeans/Wheat	NA	1.0068	NA
	Grain Sorghum - Soybeans	NA	1.4794	NA
	Soybeans - Soybeans/Wheat	1.0168	.9328	NA
	Cotton - Soybeans	NA	.7546	NA
7	Grain Sorghum - Soybeans	1.3805	1.2950	NA
	Corn - Soybeans	NA	.9989	NA

APPENDIX TABLE A-1 (Cont.)

Soil Group	Crop Rotation	Flood	Furrow	Center Pivot
8	Soybeans - Soybeans/Wheat	NA	NA	1.0644
	Cotton - Soybeans	NA	NA	.8457
	Grain Sorghum - Soybeans	NA	NA	1.4488
	Corn - Soybeans	NA	NA	1.1831
9	Soybeans - Soybeans/Wheat	1.0828	1.0169	NA
	Grain Sorghum - Soybeans	1.4808	1.4127	NA
	Corn - Soybeans	NA	1.1151	NA

NA - Not applicable to soil group and crop rotation.

APPENDIX TABLE A-2

COST/BENEFIT RATIOS
FOR ALTERNATIVE IRRIGATION SYSTEMS BY
CROP ROTATION AND SOIL GROUP

Situation "B"

Soil Group	Crop Rotation	Flood	Furrow	Center Pivot
	Rice - Soybeans - Soybeans	1.0535	1.0083	NA
	Rice - Soybeans/Wheat - Soybeans	1.0094	.9726	NA
1	Soybeans - Soybeans/Wheat	1.2991	1.1872	NA
	Cotton - Soybeans	NA	.8798	NA
	Grain Sorghum - Soybeans	1.7424	1.6325	NA
	Corn - Soybeans	NA	1.0198	NA
	Soybeans - Soybeans/Wheat	NA	NA	1.2708
	Cotton - Soybeans	NA	NA	.9410
2	Grain Soybean - Soybeans	NA	NA	1.7123
	Corn - Soybeans	NA	NA	1.1915
	Rice - Soybeans - Soybeans	1.0924	1.0618	NA
	Rice - Soybeans/Wheat - Soybeans	1.0266	.9991	NA
3	Soybeans - Soybeans/Wheat	1.2657	1.1879	NA
	Grain Sorghum - Soybeans	1.7025	1.6280	NA
	Corn - Soybeans	NA	1.0377	NA
	Rice - Soybeans - Soybeans	NA	1.0087	NA
	Rice - Soybeans/Wheat - Soybeans	NA	.9562	NA
4	Soybeans - Soybeans/Wheat	NA	1.0241	NA
	Cotton - Soybeans	NA	1.0179	NA
	Grain Sorghum - Soybeans	NA	1.5313	NA
	Soybeans - Soybeans/Wheat	NA	NA	1.1255
5	Cotton - Soybeans	NA	NA	1.0707
	Grain Sorghum - Soybeans	NA	NA	1.6160
	Rice - Soybeans - Soybeans	NA	1.0624	NA
6	Rice - Soybeans/Wheat - Soybeans	NA	.9900	NA
	Soybeans - Soybeans/Wheat	NA	1.0784	NA
	Grain Sorghum - Soybeans	NA	1.5995	NA
	Soybeans - Soybeans/Wheat	1.0120	.9290	NA
7	Cotton - Soybeans	NA	.7414	NA
	Grain Sorghum - Soybeans	1.3820	1.2979	NA
	Corn - Soybeans	NA	1.0004	NA

APPENDIX TABLE A-2 (Cont.)

Soil Group	Crop Rotation	Flood	Furrow	Center Pivot
8	Soybeans - Soybeans/Wheat	NA	NA	1.0545
	Cotton - Soybeans	NA	NA	.8285
	Grain Sorghum - Soybeans	NA	NA	1.4509
	Corn - Soybeans	NA	NA	1.1778
9	Soybeans - Soybeans/Wheat	1.0732	1.0073	NA
	Grain Sorghum - Soybeans	1.4707	1.4033	NA
	Corn - Soybeans	NA	1.1115	NA

NA - Not applicable to soil group and crop rotation.

APPENDIX TABLE A-3

COST/BENEFIT RATIOS FOR ALTERNATIVE IRRIGATION SYSTEMS BY CROP ROTATION AND SOIL GROUP

Situation "C"

Soil Group	Crop Rotation	Flood	Furrow	Center Pivot
	Rice - Soybeans - Soybeans	1.0924	1.0485	NA
	Rice - Soybeans/Wheat - Soybeans	1.0612	1.0214	NA
1	Soybeans - Soybeans/Wheat	1.1996	1.1019	NA
	Cotton - Soybeans	NA	.8379	NA
	Grain Sorghum - Soybeans	1.5894	1.4938	NA
	Corn - Soybeans	NA	.9249	NA
	Soybeans - Soybeans/Wheat	NA	NA	1.2584
2	Cotton - Soybeans	NA	NA	.9451
	Grain Soybean - Soybeans	NA	NA	1.6799
	Corn - Soybeans	NA	NA	1.1646
	Rice - Soybeans - Soybeans	1.0939	1.0553	NA
	Rice - Soybeans/Wheat - Soybeans	1.0377	1.0044	NA
3	Soybeans - Soybeans/Wheat	1.1297	1.0554	NA
	Grain Sorghum - Soybeans	1.5052	1.4330	NA
	Corn - Soybeans	NA	.9083	NA
	Rice - Soybeans - Soybeans	NA	1.0308	NA
	Rice - Soybeans/Wheat - Soybeans	NA	.9867	NA
4	Soybeans - Soybeans/Wheat	NA	.9436	NA
	Cotton - Soybeans	NA	.9583	NA
	Grain Sorghum - Soybeans	NA	1.3858	NA
	Soybeans - Soybeans/Wheat	NA	NA	1.1126
5	Cotton - Soybeans	NA	NA	1.0740
	Grain Sorghum - Soybeans	NA	NA	1.5849
	Rice - Soybeans - Soybeans	NA	1.0935	NA
6	Rice - Soybeans/Wheat - Soybeans	NA	1.0276	NA
	Soybeans - Soybeans/Wheat	NA	1.0028	NA
	Grain Sorghum - Soybeans	NA	1.4754	NA
	Soybeans - Soybeans/Wheat	1.0075	.9288	NA
7	Cotton - Soybeans	NA	.7494	NA
	Grain Sorghum - Soybeans	1.3716	1.2991	NA
	Corn - Soybeans	NA	.9801	NA

APPENDIX TABLE A-3 (Cont.)

Soil Group	Crop Rotation	Flood	Furrow	Center Pivot
8	Soybeans - Soybeans/Wheat	NA	NA	1.0474
	Cotton - Soybeans	NA	NA	.8315
	Grain Sorghum - Soybeans	NA	NA	1.4327
	Corn - Soybeans	NA	NA	1.1552
9	Soybeans - Soybeans/Wheat	1.0751	1.0036	NA
	Grain Sorghum - Soybeans	1.4735	1.4013	NA
	Corn - Soybeans	NA	1.0931	NA

NA - Not applicable to soil group and crop rotation.

APPENDIX TABLE A-4

COST/BENEFIT RATIOS FOR ALTERNATIVE IRRIGATION SYSTEMS BY CROP ROTATION AND SOIL GROUP

Situation "D"

Soil Group	Crop Rotation	Flood	Furrow	Center Pivot
	Rice - Soybeans - Soybeans	1.0423	1.0038	NA
	Rice - Soybeans/Wheat - Soybeans	1.0036	.9691	NA
1	Soybeans - Soybeans/Wheat	1.3295	1.2198	NA
	Cotton - Soybeans	NA	.8971	NA
	Grain Sorghum - Soybeans	1.7926	1.6844	NA
	Corn - Soybeans	NA	1.0356	NA
	Soybeans - Soybeans/Wheat	NA	NA	1.2500
2	Cotton - Soybeans	NA	NA	.9249
	Grain Soybean - Soybeans	NA	NA	1.6925
	Corn - Soybeans	NA	NA	1.1627
	Rice - Soybeans - Soybeans	1.0872	1.0516	NA
	Rice - Soybeans/Wheat - Soybeans	1.0217	.9913	NA
3	Soybeans - Soybeans/Wheat	1.2875	1.2013	NA
	Grain Sorghum - Soybeans	1.7412	1.6573	NA
	Corn - Soybeans	NA	1.0457	NA
	Rice - Soybeans - Soybeans	NA	1.0107	NA
	Rice - Soybeans/Wheat - Soybeans	NA	.9583	NA
4	Soybeans - Soybeans/Wheat	NA	1.0567	NA
	Cotton - Soybeans	NA	1.0380	NA
	Grain Sorghum - Soybeans	NA	1.5779	NA
	Soybeans - Soybeans/Wheat	NA	NA	1.1060
5	Cotton - Soybeans	NA	NA	1.0523
	Grain Sorghum - Soybeans	NA	NA	1.5970
	Rice - Soybeans - Soybeans	NA	1.0585	NA
	Rice - Soybeans/Wheat - Soybeans	NA	.9871	NA
6	Soybeans - Soybeans/Wheat	NA	1.1003	NA
	Grain Sorghum - Soybeans	NA	1.6361	NA
	Soybeans - Soybeans/Wheat	1.0040	.9255	NA
7	Cotton - Soybeans	NA	.7369	NA
	Grain Sorghum - Soybeans	1.3743	1.2945	NA
	Corn - Soybeans	NA	.9840	NA

APPENDIX TABLE A-4 (Cont.)

Soil Group	Crop Rotation	Flood	Furrow	Center Pivot
8	Soybeans - Soybeans/Wheat	NA	NA	1.0397
	Cotton - Soybeans	NA	NA	.8160
	Grain Sorghum - Soybeans	NA	NA	1.4369
	Corn - Soybeans	NA	NA	1.1535
9	Soybeans - Soybeans/Wheat	1.0665	.9957	NA
	Grain Sorghum - Soybeans	1.4643	1.3935	NA
	Corn - Soybeans	NA	1.0924	NA

NA - Not applicable to soil group and crop rotation.

APPENDIX TABLE A-5

COST/BENEFIT RATIOS
FOR ALTERNATIVE IRRIGATION SYSTEMS BY
CROP ROTATION AND SOIL GROUP

Situation "E"

Soil Group	Crop Rotation	Flood	Furrow	Center Pivot
	Rice - Soybeans - Soybeans	.9745	.9359	NA
	Rice - Soybeans/Wheat - Soybeans	.9933	.9564	NA
1	Soybeans - Soybeans/Wheat	1.0386	.9564	NA
	Cotton - Soybeans	NA	.8778	NA
	Grain Sorghum - Soybeans	1.1968	1.1300	NA
	Corn - Soybeans	NA	NA	NA
	Soybeans - Soybeans/Wheat	NA	NA	1.1412
2	Cotton - Soybeans	NA	NA	1.0239
	Grain Soybean - Soybeans	NA	NA	1.2885
	Corn - Soybeans	NA	NA	NA
	Rice - Soybeans - Soybeans	1.0184	.9795	NA
	Rice - Soybeans/Wheat - Soybeans	1.0057	.9696	NA
3	Soybeans - Soybeans/Wheat	1.0387	.9622	NA
	Grain Sorghum - Soybeans	1.2302	1.1675	NA
	Corn - Soybeans	NA		NA
	Rice - Soybeans - Soybeans	NA	.9407	NA
	Rice - Soybeans/Wheat - Soybeans	NA	.9438	NA
4	Soybeans - Soybeans/Wheat	NA	.8344	NA
	Cotton - Soybeans	NA	1.0522	NA
	Grain Sorghum - Soybeans	NA	1.1023	NA
	Soybeans - Soybeans/Wheat	NA	NA	1.0501
5	Cotton - Soybeans	NA	NA	1.1755
	Grain Sorghum - Soybeans	NA	NA	1.2800
	Rice - Soybeans - Soybeans	NA	1.0376	NA
6	Rice - Soybeans/Wheat - Soybeans	NA	1.0088	NA
	Soybeans - Soybeans/Wheat	NA	.9181	NA
	Grain Sorghum - Soybeans	NA	1.2574	NA
	Soybeans - Soybeans/Wheat	.9143	.8386	NA
7	Cotton - Soybeans	NA	.8071	NA
	Grain Sorghum - Soybeans	1.1144	1.0489	NA
	Corn - Soybeans	NA	NA	NA

APPENDIX TABLE A-5 (Cont.)

Soil Group	Crop Rotation	Flood	Furrow	Center Pivot
8	Soybeans - Soybeans/Wheat	NA	NA	.9689
	Cotton - Soybeans	NA	NA	.9126
	Grain Sorghum - Soybeans	NA	NA	1.1716
	Corn - Soybeans	NA	NA	NA
9	Soybeans - Soybeans/Wheat	.9951	.9192	NA
	Grain Sorghum - Soybeans	1.2364	1.1697	NA
	Corn - Soybeans	NA	NA	NA

NA - Not applicable to soil group and crop rotation.

APPENDIX TABLE A-6

COST/BENEFIT RATIOS
FOR ALTERNATIVE IRRIGATION SYSTEMS BY
CROP ROTATION AND SOIL GROUP

Situation "F"

Soil Group	Crop Rotation	Flood	Furrow	Center Pivot
1	Rice - Soybeans - Soybeans	.9599	.9250	NA
	Rice - Soybeans/Wheat - Soybeans	.9632	.9304	NA
	Soybeans - Soybeans/Wheat	1.1743	1.0780	NA
	Cotton - Soybeans	NA	.9365	NA
	Grain Sorghum - Soybeans	1.3996	1.3213	NA
	Corn - Soybeans	NA	NA	NA
2	Soybeans - Soybeans/Wheat	NA	NA	1.1151
	Cotton - Soybeans	NA	NA	.9795
	Grain Soybean - Soybeans	NA	NA	1.2867
	Corn - Soybeans	NA	NA	NA
3	Rice - Soybeans - Soybeans	1.0181	.9813	NA
	Rice - Soybeans/Wheat - Soybeans	.9914	.9578	NA
	Soybeans - Soybeans/Wheat	1.1773	1.0858	NA
	Grain Sorghum - Soybeans	1.4284	1.3526	NA
	Corn - Soybeans	NA	NA	NA
4	Rice - Soybeans - Soybeans	NA	.9194	NA
	Rice - Soybeans/Wheat - Soybeans	NA	.9098	NA
	Soybeans - Soybeans/Wheat	NA	.9223	NA
	Cotton - Soybeans	NA	1.0571	NA
	Grain Sorghum - Soybeans	NA	1.2469	NA
5	Soybeans - Soybeans/Wheat	NA	NA	1.0129
	Cotton - Soybeans	NA	NA	1.1151
	Grain Sorghum - Soybeans	NA	NA	1.2549
6	Rice - Soybeans - Soybeans	NA	.9847	NA
	Rice - Soybeans/Wheat - Soybeans	NA	.9482	NA
	Soybeans - Soybeans/Wheat	NA	.9680	NA
	Grain Sorghum - Soybeans	NA	1.3421	NA
7	Soybeans - Soybeans/Wheat	.9016	.8272	NA
	Cotton - Soybeans	NA	.7800	NA
	Grain Sorghum - Soybeans	1.1086	1.0444	NA
	Corn - Soybeans	NA	NA	NA

APPENDIX TABLE A-6 (Cont.)

Soil Group	Crop Rotation	Flood	Furrow	Center Pivot
	Soybeans - Soybeans/Wheat	NA	NA	.9414
8	Cotton - Soybeans	NA	NA	.8731
	Grain Sorghum - Soybeans	NA	NA	1.1539
	Corn - Soybeans	NA	NA	NA
	Soybeans - Soybeans/Wheat	.9839	.9078	NA
9	Grain Sorghum - Soybeans	1.2275	1.1612	NA
	Corn - Soybeans	NA	NA	NA

NA - Not applicable to soil group and crop rotation.

APPENDIX TABLE A-7

COST/BENEFIT RATIOS
FOR ALTERNATIVE IRRIGATION SYSTEMS BY
CROP ROTATION AND SOIL GROUP

Situation "G"

Soil Group	Crop Rotation	Flood	Furrow	Center Pivot
1	Rice - Soybeans - Soybeans	.9617	.9287	NA
	Rice - Soybeans/Wheat - Soybeans	.9840	.9509	NA
	Soybeans - Soybeans/Wheat	1.0841	1.0035	NA
	Cotton - Soybeans	NA	.9058	NA
	Grain Sorghum - Soybeans	1.2675	1.2033	NA
	Corn - Soybeans	NA	NA	NA
2	Soybeans - Soybeans/Wheat	NA	NA	1.1095
	Cotton - Soybeans	NA	NA	.9975
	Grain Soybean - Soybeans	NA	NA	1.2602
	Corn - Soybeans	NA	NA	NA
3	Rice - Soybeans - Soybeans	1.0073	.9637	NA
	Rice - Soybeans/Wheat - Soybeans	.9979	.9572	NA
	Soybeans - Soybeans/Wheat	1.0717	.9820	NA
	Grain Sorghum - Soybeans	1.2814	1.2087	NA
	Corn - Soybeans	NA	NA	NA
4	Rice - Soybeans - Soybeans	NA	.9138	NA
	Rice - Soybeans/Wheat - Soybeans	NA	.9193	NA
	Soybeans - Soybeans/Wheat	NA	.8498	NA
	Cotton - Soybeans	NA	1.0078	NA
	Grain Sorghum - Soybeans	NA	1.1208	NA
5	Soybeans - Soybeans/Wheat	NA	NA	1.0198
	Cotton - Soybeans	NA	NA	1.1455
	Grain Sorghum - Soybeans	NA	NA	1.2522
6	Rice - Soybeans - Soybeans	NA	.9977	NA
	Rice - Soybeans/Wheat - Soybeans	NA	.9736	NA
	Soybeans - Soybeans/Wheat	NA	.9132	NA
	Grain Sorghum - Soybeans	NA	1.2525	NA
7	Soybeans - Soybeans/Wheat	.9023	.8335	NA
	Cotton - Soybeans	NA	.7998	NA
	Grain Sorghum - Soybeans	1.1035	1.0442	NA
	Corn - Soybeans	NA	NA	NA

APPENDIX TABLE A-7 (Cont.)

Soil Group	Crop Rotation	Flood	Furrow	Center Pivot
8	Soybeans - Soybeans/Wheat	NA	NA	.9470
	Cotton - Soybeans	NA	NA	.8924
	Grain Sorghum - Soybeans	NA	NA	1.1518
	Corn - Soybeans	NA	NA	NA
9	Soybeans - Soybeans/Wheat	.9851	.9022	NA
	Grain Sorghum - Soybeans	1.2274	1.1558	NA
	Corn - Soybeans	NA	NA	NA

NA - Not applicable to soil group and crop rotation.

APPENDIX TABLE A-8

COST/BENEFIT RATIOS
FOR ALTERNATIVE IRRIGATION SYSTEMS BY
CROP ROTATION AND SOIL GROUP

Situation "H"

Soil Group	Crop Rotation	Flood	Furrow	Center Pivot
1	Rice - Soybeans - Soybeans	.9497	.9193	NA
	Rice - Soybeans/Wheat - Soybeans	.9558	.9260	NA
	Soybeans - Soybeans/Wheat	1.2138	1.1206	NA
	Cotton - Soybeans	NA		NA
	Grain Sorghum - Soybeans	1.4604	1.3845	NA
	Corn - Soybeans	NA	NA	NA
2	Soybeans - Soybeans/Wheat	NA	NA	1.0874
	Cotton - Soybeans	NA	NA	.9563
	Grain Soybean - Soybeans	NA	NA	1.2623
	Corn - Soybeans	NA	NA	NA
3	Rice - Soybeans - Soybeans	1.0092	.9685	NA
	Rice - Soybeans/Wheat - Soybeans	.9851	.9479	NA
	Soybeans - Soybeans/Wheat	1.2060	1.1030	NA
	Grain Sorghum - Soybeans	1.4724	1.3881	NA
	Corn - Soybeans	NA	NA	NA
4	Rice - Soybeans - Soybeans	NA	.9219	NA
	Rice - Soybeans/Wheat - Soybeans	NA	.9124	NA
	Soybeans - Soybeans/Wheat	NA	.9625	NA
	Cotton - Soybeans	NA	1.0854	NA
	Grain Sorghum - Soybeans	NA	1.3044	NA
5	Soybeans - Soybeans/Wheat	NA	NA	.9865
	Cotton - Soybeans	NA	NA	1.0888
	Grain Sorghum - Soybeans	NA	NA	1.2310
6	Rice - Soybeans - Soybeans	NA	.9798	NA
	Rice - Soybeans/Wheat - Soybeans	NA	.9447	NA
	Soybeans - Soybeans/Wheat	NA	.9953	NA
	Grain Sorghum - Soybeans	NA	1.3859	NA
7	Soybeans - Soybeans/Wheat	.8912	.8227	NA
	Cotton - Soybeans	NA	.7735	NA
	Grain Sorghum - Soybeans	1.0993	1.0402	NA
	Corn - Soybeans	NA	NA	NA

APPENDIX TABLE A-8 (Cont.)

Soil Group	Crop Rotation	Flood	Furrow	Center Pivot
8	Soybeans - Soybeans/Wheat	NA	NA	.9223
	Cotton - Soybeans	NA	NA	.8544
	Grain Sorghum - Soybeans	NA	NA	1.1368
	Corn - Soybeans	NA	NA	NA
9	Soybeans - Soybeans/Wheat	.9751	.8930	NA
	Grain Sorghum - Soybeans	1.2197	1.1493	NA
	Corn - Soybeans	NA	NA	NA

NA - Not applicable to soil group and crop rotation.