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Economic & Environmental Benefits of Rice Production in the Mississippi Delta

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Abstract

The purpose of this report is to provide a summary of the first year of our investigation into the full social net benefits associated with rice production in the Delta region of Mississippi. The tasks that were completed include (1) an exhaustive literature review; (2) compilation of data related to rice production in Mississippi and elsewhere; (3) preliminary simulation analysis of farm-level, agricultural-related environmental and economic benefits of rice production; and (4) preliminary analysis of wildlife-related benefits associated with rice production.

Introduction

The purpose of this study was to develop a full set of economic values associated with rice production in Mississippi. A combination of biophysical, standard economic, and nonmarket economic models were the tools used in the analysis. Preliminary analyses were completed in several key areas that will form the basis for future research. This report consists of three main parts: the first contains a literature review; the second consists of analysis of direct economic impacts; and the third reports on preliminary estimates of indirect economic benefits.

Justification for this study follows from the fact that rice production may yield substantial environmental and other external benefits as compared with the production of other crops. In 1999, rice was the third highest-valued crop in Mississippi ($110 million), following cotton at $481.1 million and soybeans at $110.5 million (Mississippi Department of Agriculture). However, on a per-acre basis, rice was the second highest-valued crop at $342.10 per acre, as compared with cotton at $407.71 per acre. Furthermore, the acreage of cotton and soybean planted far exceeds that of rice — only 323,000 acres of rice compared with 1.18 million acres of cotton and 1.909 million acres of soybean. Thus, under certain conditions, it appears that there is potential for growth in rice acreage.

Circumstances under which increases in rice production should be promoted were investigated. Specifically, the full social value of rice production must be considered, while taking into consideration that there are physical limits to production growth, such as availability of appropriate soils. For instance, rice farmers who use winter flooding practices may receive off-season income in the form of duck-blind rentals for hunters. Such an impact is considered a direct economic impact that, along with on-farm profits, is included in the section of this report dealing with direct economic impacts. In addition, rice production confers positive environmental benefits that are not captured in the $342.10-per-acre 1999 value reported previously; we refer to these impacts as indirect economic benefits. Such impacts can be measured in terms of reductions in nonpoint-source pollution from rice production as compared with other crops and also in terms of willingness to pay of hunters to participate in duck hunting on flooded fields. Preliminary estimates associated with improvements in environmental quality from rice production as compared with alternatives are provided in the report section that deals with indirect values. A glossary of terms is included on page 17.

Background and Literature Review

Rice remains an important crop in Mississippi's agricultural economy. During the period 1959-1998, the average yield per harvested acre for Mississippi and the U.S. were 4,437 pounds and 4,710 pounds, respectively (see Figure 1 for Mississippi per-county yields). Mississippi rice yield experienced an increase of 4% per year in comparison with a 1.96% annual yield increase for the U.S. as a whole. In addition, average nominal rough rice prices received by Mississippi and U.S. farmers were $7.33 and $7.10 per hundredweight, respectively. The average annual Mississippi and U.S. rice production between 1959 and 1998 were 7.2 million hundredweight and 119.6 million hundredweight. Mississippi contributed 6.84% of average total U.S. rice production during the same period (Table 1). For the period 1987-1999, the rice produced in Mississippi accounted for about 25% of the total rice exports from the U.S. Mississippi produced about 15% of the long-grain rice, and almost 40% of this type of grain is exported to foreign markets such as Latin American and Middle Eastern countries. (*Rice Situation and Outlook Yearbook*, various years, USDA).

A study by William, Kubica, and Dixon (1989) indicates that Mississippi placed fifth in revenue with 8.4% of total U.S. cash receipts, proceeded by Arkansas (36.6%), Louisiana (18.1%), California (17.7%), and Texas (14.9%) in 1987. In 1997, Mississippi value of rice production amounted to $143,562,000, which represented roughly 9% of the national value of production. The state also experienced a 26% increase in the nominal value of production between 1980 and 1997. However, rice acreage in Mississippi has generally declined since 1981, raising questions as to whether rice production has reached its peak as a major crop enterprise in Mississippi (ERS/NASS, various years).

Mississippi's average rough rice yield per hectare has been considerably lower than that of the U.S., but it has been higher than world yields. During the period 1961-1997, Mississippi, U.S., and world rice yields averaged 5.8, 6.21 and 3.62 metric tons per hectare, respectively (*World Grain Situation and Outlook*, USDA). During the 20-year period from 1978 to 1998, average annual Mississippi nominal and real rice export values were $80.91-$86.1 million. This indicates that the average annual Mississippi share of total U.S. rice export value was between 15% and 20% during the same period (*Mississippi Agricultural Statistics,* various issues).

Rice prices received by farmers in Mississippi have historically been higher than the U.S. average. During the period 1959-1999, the Mississippi farm price averaged $8.35 per hundredweight, while U.S. farm prices were $7.12 per hundredweight (Figure 2). The higher variability in farm yield and price implies greater business risk for rice farmers (Table 2). Yield variability is higher at the farm level than at the state or national level. Yield varies regionally and depends on soil type, climate, the use of irrigation, and other variables. In contrast, price risk for a given commodity depends on

Table 1. U.S. and Mississippi — average rice production, yield, price, and harvested acres (1955-1999).[1]

Year	United States						Mississippi					
	Planted acres (x1,000)	Harv. acres (x1,000)	Yield	Price	Prod. (x1,000)	Prod. (x1,000)	Planted acres (x1,000)	Harv. acres (x1,000)	Yield	Price	Prod. (x1,000)	Prod. (x1,000)
			lb/A	$/cwt	cwt	$			lb/A	$/cwt	cwt	$
1955-59	1,573	1,547	3,192	5	50	236,824	44	42	2,890	5	2	5,992
1960-69	1,887	1,871	4,048	5	76	383,119	53	52	3,795	5	2	10,552
1970-79	2,364	2,354	4,546	8	112	930,055	110	105	4,244	8	5	43,530
1980-89	2,843	2,811	5,238	9	144	1,098,071	290	286	4,755	9	11	86,568
1990-99	3,063	2,982	5,756	9	178	1,402,390	255	250	5,733	9	14	121,258
Mean	2,443	2,370	4,710	7	120	870,673	155	152	4,437	7	7	58,302
Max	3,827	3,792	6,121	14	206	1,873,007	340	337	6,200	17	16	143,856
Min	1,370	1,340	3,061	4	47	209,425	32	31	2,700	2	1	5,268
STD	647	619	884	2	48	497,059	101	99	974	3	5	47,521

[1]Source: NASS, USDA.

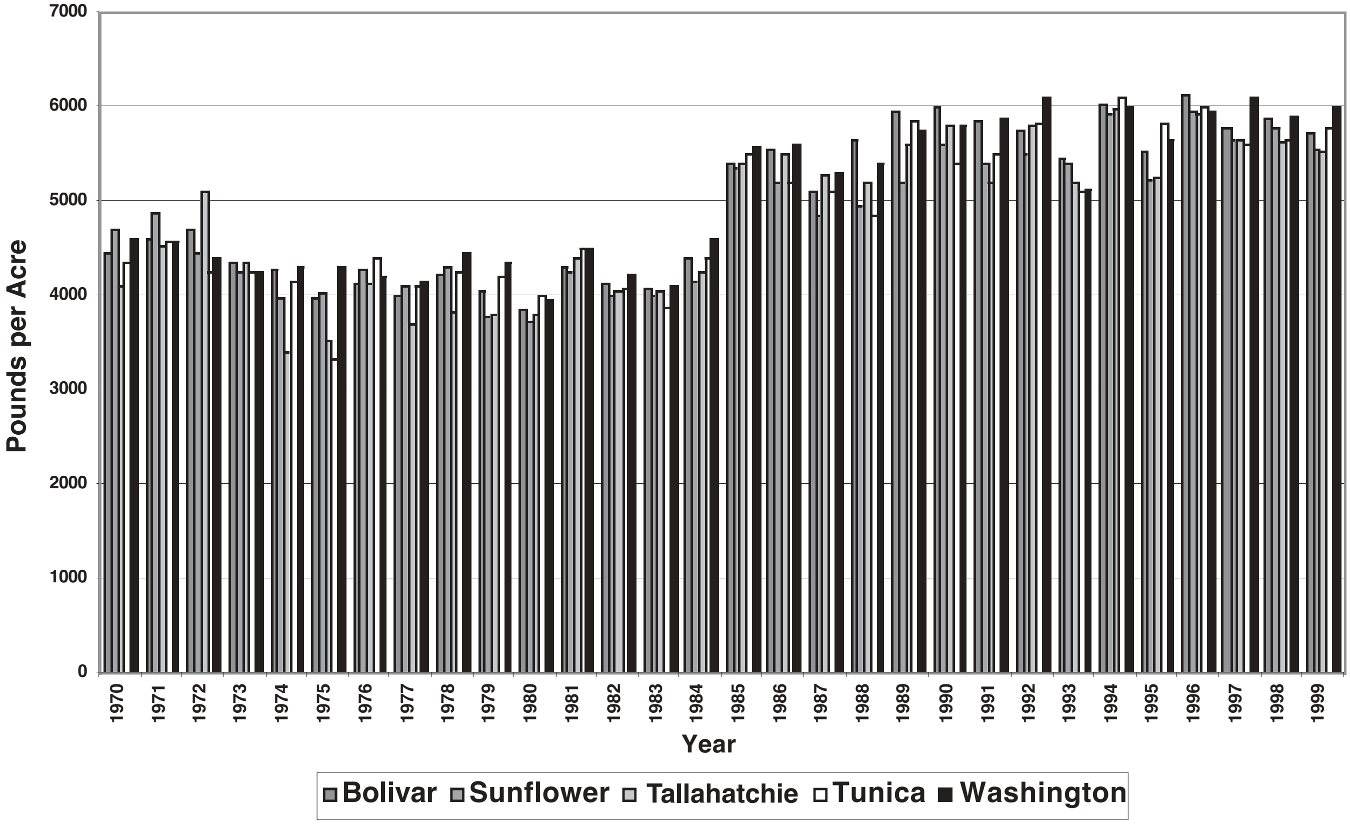

Figure 1. Rice Yield by Top Five Producing Counties in Mississippi (1970-1999).

such factors as commodity stock levels and export demand (Howard et. al 1999).

The rising cost of production remains another factor that has affected long-term growth of the industry. Initially, the introduction of better varieties increased yield, thus offsetting rising costs. Semi-dwarf varieties were introduced on a commercial basis in 1985, and yields jumped dramatically. Accordingly, cost of production per bushel fell. Cost of production per bushel in Mississippi has started an upward trend once again, increasing from $3.04 in 1985 to $3.92 in 1999 (Laughlin and Mehrle 1996, Chambers and Childs 2000). Basic agricultural inputs such as energy/diesel, herbicides, drying, and labor (for drying and hauling) represent almost 50% of total operating costs in Mississippi rice production (Laughlin and Mehrle 1996). All of these inputs have recorded a significant average increase of more than 10% in the last 5 years (*Agricultural Outlook*, various years). These trends indicate that while yields reached a new plateau after 1985, costs of production per acre and per bushel have continued to climb, as the price received by farmers has remained stable. With revenues stabilizing and costs increasing, profit margins are narrowing for the average producer.

Table 2. Historical variability in regional average rice yields — Mississippi.[1]

Regions [2]	Yield	Downside yield [3]	Upside yield [4]
	bu/A	bu/A	bu/A
District 10	6,033.2	5,717.2	6,353.2
District 20	4,589.0	4,111.4	5,003.5
District 40	5,877.4	5,603.8	6,175.2

[1]Table shows the average yield in three crop-reporting districts in Mississippi for the period 1978-1995. The second and third columns give an idea of the historical downside and upside variability in regional rice yields. Farm-level crops are much more variable than county or regional average yields. (Source: Mississippi Agricultural Statistics.)
[2]District 10 — Bolivar, Coahoma, Quitman, Tallahatchie, and Tunica counties; District 20 — Benton, Calhoun, DeSoto, Grenada, Lafayette, Marshall, Panola, Tate, and Yalobusha counties; and District 40 — Humphreys, Issaquena, Leflore, Sharkey, Sunflower, Washington, and Yazoo counties.
[3]20% chance that regional average yield will be below.
[4]20% chance that regional average yield will be above.

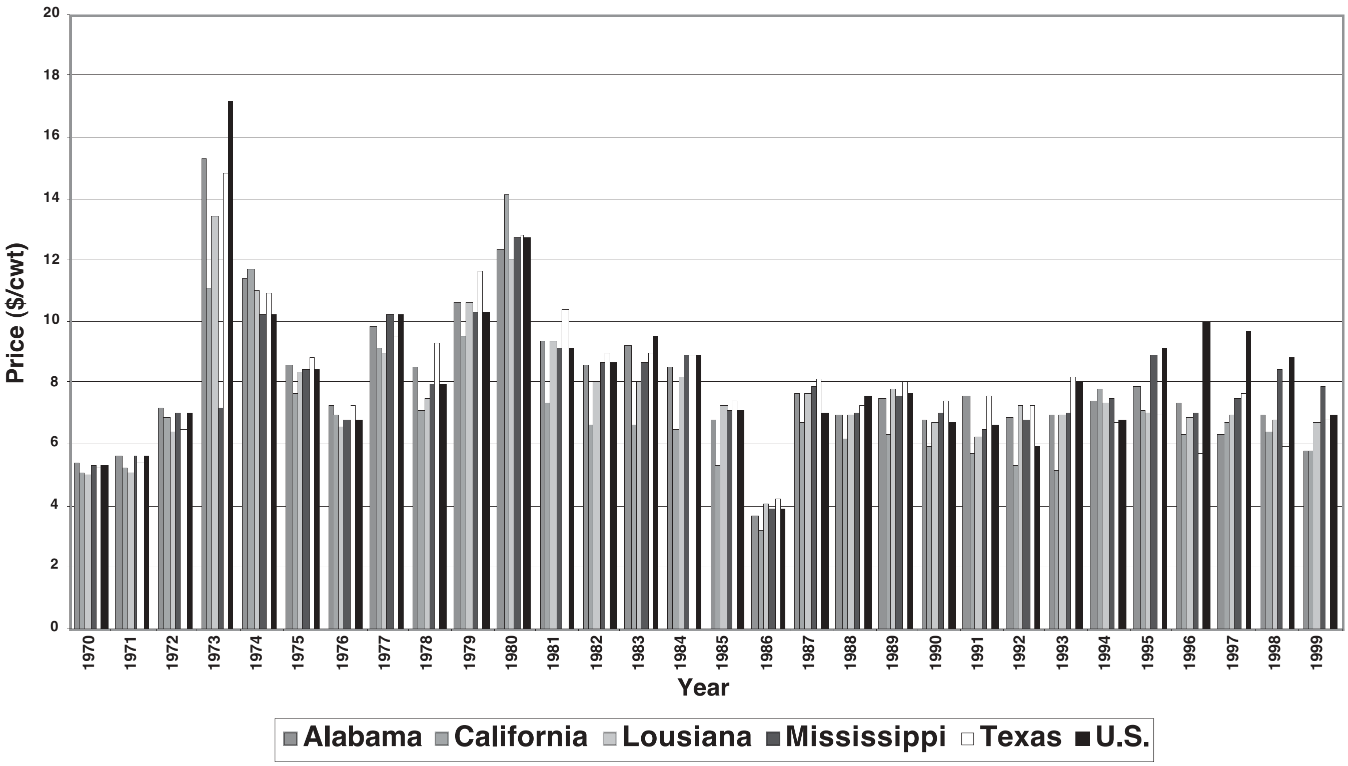

Figure 2. Seasonal Average Price of Rice — Major Producing States and the U.S.

Rice, Winter Flooding, and the Environment: The Links

Because the potential environmental benefits of winter flooding of rice fields are significant, we devote much of our attention to literature related to this practice. Worldwide loss of wetlands to human development has been extensive. In North America, more than half of all wetland habitats south of the Canada-U.S. border has been drained in the last two centuries (Tiner 1984, Dahl 1990). Similarly, in Asia, more than 320,000 square kilometers of wetlands have been drained since 1985. In particular, the conversion of natural habitats to agricultural land has a significant impact on wetlands because wetlands tend to leave very rich soils when drained. Simultaneously, wetlands are biologically very productive, so habitat losses tend to have a considerable regional environmental impact.

Rice typically is grown in areas where wetlands formerly occurred, and approximately 86% of the land under rice cultivation is inundated for at least part of the year, either through irrigation, rainwater, or deep-water flooding (Chang and Luh 1991). Rice paddies, therefore, offer potential as a surrogate for destroyed wetland habitats. It has long been recognized that rice fields offer potential habitat for water birds. Early studies addressed the role that waterfowl, especially ducks, play as rice plant predators (Neale 1918, Ellis 1940). These studies soon led to the realization that, in many cases, the damage caused by ducks feeding in rice fields was economically trivial (Frith 1957, Bourne and Osborne 1978), and the net benefits gained from the removal of weed seeds could outweigh any impacts to the harvestable crop (Neale 1918, Jones 1940, Smith and Sullivan). Farmers or managers of rice farms realized that residual grain left on the fields after harvest was eaten readily by game species, so they began managing fields as habitat for geese, ducks, pheasants, etc. (Wright 1959, Harmon et. al 1960, McGinn and Glasgow 1963, Forsyth 1965).

Fasola and Ruiz (1996) suggested that flooded rice, sewage ponds, and settling beds could be treated as "approximate facsimile or artificial habitats" to replace the declining natural wetlands that could benefit water bird populations. Since rice is one of the world's most important crops, these results provide support for the notion that appropriately managed rice fields can contribute to enhancement of global wetland habitats (Fasola and Ruiz 1996).

However, a study by Elphick and Oring (1998) shows that flooded rice fields and seminatural wetlands appear to be very different habitats. For example, flooded fields have less surrounding vegetation, have less variable water depths, and receive different nutrient inputs (both in terms of fertilizers and dead vegetation). Flooding rice fields cannot be considered equivalent to the restoration of historic wetlands because it fails to provide suitable conditions for the full suite of species (especially plants) that use these seasonally flooded habitats.

Another study recognizes that a much wider variety of bird species may accrue benefits from the use of rice habitats than originally thought, and it has been proposed that rice fields may play an important role in water bird conservation (Fasola and Barbieri 1978, Fasola 1983, Remsen et. al. 1991, Pain 1994, Fasola and Ruiz 1996, Lane and Fujiko 1998). Elphick (1998) shows that fields that have been intentionally flooded are used by significantly more water bird species than fields that were not. On average, flooded fields had three times the water bird richness of unflooded fields.

Presently, only about 10% of the rice acreage in the Delta is managed to provide winter wetlands for waterfowl (Manley 1999; Forest and Wildlife Research Center, FWRC/MSU 1999). Extraordinary potential exists for rice lands to increase the availability of wetland habitat for waterfowl and other water birds by enhancing waterfowl food availability, in addition to increasing decomposition and weed control. Therefore, winter flooding is expected to contribute significantly towards environmental quality, in addition to its direct economic benefit of reducing production costs among rice farmers in Mississippi.

The discussion of winter flooding for rice does not include the potential of using a water recovery system for rice in Mississippi. Studies have shown that farmers can save on pumping costs if they reuse water. Usually, recovered water is lifted from a holding area, which is less expensive than water lifted from wells. In California, installing the recovery water system has reduced herbicide residue by almost 90% since 1984 (Hiulin Li 1996, Burhham 1995).

Legislation and Technology Changes Affecting Winter Flooding Activities

In the U.S., rice is grown in California and throughout the Southeast. Several recent changes in the U.S. rice industry have resulted in increased interest in the role of rice fields as wildlife habitats. In certain states, such as California, legislation (Rice Straw Burning Act, AB 1378) was introduced in 1991 to restrict the area of harvested rice fields that could be burned during winter. Burning was the preferred method for disposing of residual straw and stubble in preparation for the following year's crop. Introduction of the new law required farmers to seek new ways of removing this material from their fields. Flooding fields soon after harvest and retaining water on the fields until early spring increases the rate of straw decomposition and effectively removes much of the straw.

Two other changes in the U.S. rice industry have occurred since 1991. First is the increased use of the "stripper-header" harvester, which strips the grain off the stalk. The new harvesters are more efficient than conventional combines are; they do not cut the rice stalk, and they leave less spilled grain and taller stubble in the fields. The abundance and availability of grain in winter rice fields may be reduced as a consequence, raising concerns about the effects on birds that feed on spilled grain (Miller 1987). The second change in the industry is the decline in the area of rice farmed in certain parts of the country. This decline in rice acreage (Setia et. al. 1994) has caused rice growers to emphasize the benefits and role of their fields as water bird habitat in order to maintain a healthy rice industry (Elphick and Oring 1998).

Water Depth and Water Bird Species

Water depth of flooded fields has also been considered a major factor in determining the abundance of water bird species in wetlands (Boshoff, Palmer, and Piper 1991; Fredrickson 1991; Helmers 1992; Velasquez 1992). In general, water depth affects species occurrence but not abundance. Increased flooding reduces use of rice fields by certain raptor and passerine species.

In most California rice fields, the levees are built to facilitate water depth management while growing rice. These subdivisions are called "checks." To assess the effect of water depth, each subdivision is treated as a separate plot. Farmers created these water-depth-plots to maintain uniform water depths during the growing season. Consequently, levees between the plots follow contours in the field, and plots varied considerably in size and shape.

In a California study, many of the species found at lower densities in flooded fields were among the most common birds in the Sacramento Valley. In contrast, those that occur at higher densities in flooded fields are species that would likely undergo the greatest declines in the face of wetland destruction. However, reducing depths to a maximum of 20 centimeters during the entire winter is expected to lead to use by a variety of species. Water bird diversity varied also with water depth, with peaks at depths of 10-15 centimeters and 35-40 centimeters. After taking area effects into account, richness varied inversely with water depth, with species richness peaking at intermediate depths and mid-winter (Elphick 1998).

Bird densities were found to be related significantly to water depth and season for all groups of water birds considered. Densities of wading birds, waterfowl, and all water birds combined rose to an asymptote as depth increased, while shorebird densities decreased to an asymptote (Elphick 1998; Elphick and Oring 1998). However, the model only explained about 17% of the variance in bird densities. Flooded plots that were occupied by water birds, waterfowl, or wading birds were significantly deeper than sites without these birds. In contrast, sites that were used by shorebirds were significantly shallower than sites that were not used. Two factors contributed to this effect. Waterfowl species tended to have less positive population trends than other species (Sauer et al. 1996); therefore, they contributed more to the conservation benefit. In addition, there were more species of waterfowl than other groups, and their cumulative effect consequently was greater. However, those that occur at higher densities in flooded fields are species that are likely to have undergone the greatest decline due to wetland destruction (Elphick 1998). Given the "mixed nature" of the relationship between water depth and densities of waterfowl, the same study proposed several recommendations:

(1) Species richness is highest at depths of 10-15 centimeters. Most fields are flooded deeper than this during early winter. Reducing water depths during this period, therefore, can be expected to increase the number of species using each flooded field.

(2) Increasing the area of winter flooded rice fields is likely to benefit a wide variety of water birds, but it could hurt others. However, most species harmed by flooding are of little conservation importance. The method of flooding has little affect on the abundance of most species, and there is no single management method that can be recommended for birds in general.

(3) The presence of deeper water early in the winter may reflect a widespread belief that ducks, which are hunted in many fields, prefer deeper conditions. Assuming that water is available throughout the winter so that farmers can replace evaporated water, reducing average depths would enable farmers to flood larger areas without needing more water.

(4) To increase the flooded area, it is recommended that farmers block off the field drainage outlets to retain rainwater in fields. Such a practice may also be beneficial to the environment by impounding nutrients. Rainfall may not be sufficiently reliable for farmers to use this method alone to dispose of rice straw. It may be helpful, however, in speeding up decomposition in fields where other methods (e.g., plowing) have been used. Moreover, for little cost, even very shallow flooding could have considerable benefits for some water bird species.

Linked by several great watersheds from the Hudson Bay to the Great Lakes to the Louisiana bayous, the Mississippi Flyway is the continent's most heavily used waterfowl migration route. The Flyway ranks first in abundance of mallards, wood ducks, blue-winged teal, gadwalls, and many other migratory birds. The state of Mississippi is among the Mississippi Flyway's most important waterfowl breeding areas, producing more than 15% of the continent's fall flight of ducks during years with good water conditions. Table 3 shows the number of waterfowl observed in Mississippi on two different dates. Figure 3 shows the winter distribution pattern for mallards (*Anas platyrhynchos)*, which represent the most common species found in flooded rice fields in the Southeast.

Table 3. Waterfowl numbers in Mississippi as recorded at various regions and times of year.[1]

Region	Dec. 7, 2000		Jan. 4, 2001	
	Waterfowl	Number	Waterfowl	Number
North Delta[2]	American Widgeon	390	Canvasback	24
North Delta	Gadwall	18,950	Gadwall	620
North Delta	Green-winged Teal	1,000	Green-winged Teal	900
North Delta	Mallard	43,290	Mallard	38,640
North Delta	Northern Pintail	5,640	Northern Pintail	40
North Delta	Northern Shoveler	2,650		
North Delta	Snow Goose	134,000		
South Delta	American Widgeon	25	American Widgeon	2
South Delta	Canadian Goose	3	Canvasback	8
South Delta	Gadwall	5,240	Gadwall	515
South Delta	Green-winged Teal	920	Green-winged Teal	560
South Delta	Mallard	11,360	Mallard	36,677
South Delta	Northern Pintail	700	Northern Pintail	700
South Delta	Ring-necked Duck	1	Northern Shoveler	540
South Delta	Snow Goose	50,000	Ring-necked Duck	1,000
South Delta	Wood Duck	400	Scaup	20
South Delta			Snow Goose	1,600
South Delta			Wood Duck	10
Natchez/Lake Mary	Gadwall	50	Gadwall	30
Natchez/Lake Mary	Mallard	610	Mallard	920
Northern	Green-winged Teal	50	Green-winged Teal	250
Northern	Northern Pintail	300	Northern Pintail	30
Northern	Snow Goose	100	Snow Goose	7,000

[1]Source: Mississippi Department of Wildlife, Fisheries, and Parks (2000).
[2]Highway 82 is the division line of the North and South Delta.

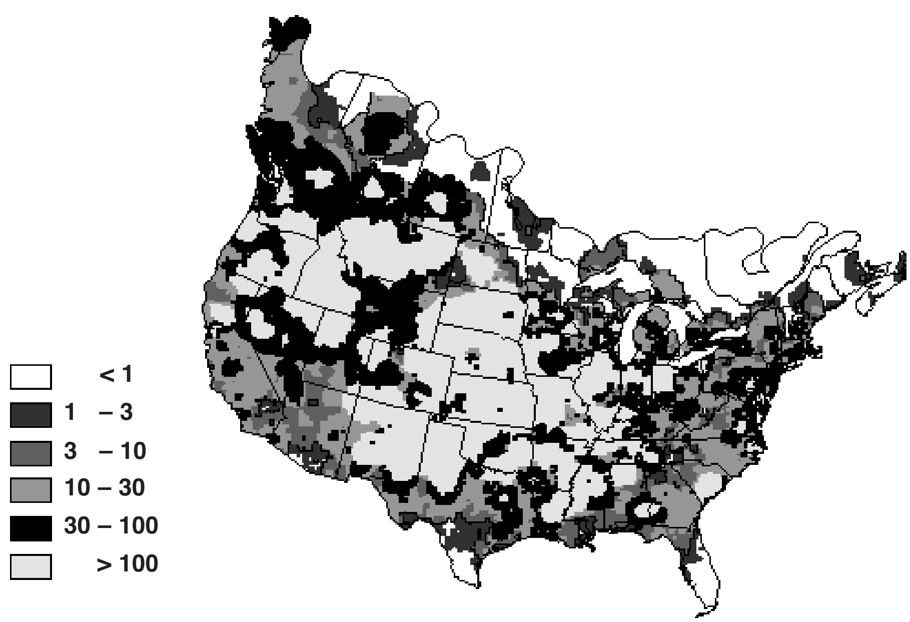

Figure 3: Mallard (Anas platyrhynchos) Count — Map of Winter Distribution (Source: http://www.mbr.nbs.gov/bbs/cbcra/h1320ra.html).

Soil Conservation and Water-Quality Management in Winter-Flooded Rice Fields

Conserving soil and improving water quality are important in protecting our nation's natural resource base. Field experiments by FWRC-MSU (1999) scientists showed that winter flooding conserved soil and increased the quality of runoff waters, especially when rice fields were not disked after harvest. Fall-disked fields that were allowed to drain freely after winter rains lost about 1,000 pounds of soil per acre. Fields with drainpipes closed to impound water during winter and with stubble left undisturbed after harvest lost only 31 pounds of soil per acre. Flooding rice fields not only reduces the impact of rain on exposed soils but also allows fields to act as settling basins to retain the sediment and nutrients that can have adverse down-stream environmental impacts.

Winter Water Management

Tool for Spring Field Preparation

By early spring, rice farmers must contend with the challenges in field preparation for planting, such as disposal of remaining rice straw and growth of cool-season grasses and weeds. Reduction of rice straw is particularly difficult because it is resistant to physical degradation and decay, but it must be disposed of to facilitate planting. FWRC-MSU (1999) researchers have found that winter flooding was as effective as fall disking in that it reduces the estimated 4.5 tons per acre of rice straw left after harvest by 53%.

Elimination of fall-disking operations could save rice growers an average of $14.13 per acre. The combination of fall disking and winter flooding reduced straw most significantly (68%), although disking incurs an added expense. Researchers also found that winter flooding inhibited germination and growth of cool-season grasses and weeds. If rice growers could eliminate aerial applications of spring "burn down" herbicides as a result of winter flooding of rice fields, they could save an average of $13.19 per acre. The total potential cost savings — $27.32 per acre — is the sum of these two individual components. A study by Manley shows that if levees need to be rebutted to impound winter rains, a farmer may incur an average cost of $1.49 per acre ($3.68 per hectare). Maintenance of water levels also may incur additional costs where leakage is prevalent. However, flooding costs could be substantially lower if there are favorable weather conditions with sufficient rainfall (Maley 1999).

Other studies conducted by Fasola and Barbieri (1978) and Elphick (1998) concluded that although a straw management method used to aid decomposition in flooded fields influences water bird richness, this difference was not as significant as that between flooded and unflooded fields. The combination of flooding treatment and field area explained 55.9% of the variance in water bird variety across all fields (Elphick 1998). The straw manipulation method combined with area explained 37% of the variability in richness found in flooded fields.

For most species, bird densities do not increase with food abundance. This could happen if food was not limiting or if other factors modified the birds' distribution and predatory effect. Another possibility is that food abundance follows the predicted pattern, but availability does not (Lima and Dill 1990, Sutherland and Watkinson 1996).

Habitat for Wetland Wildlife

Past studies have shown that rice left after harvest is an excellent source of food for waterfowl (Ringelman 1990, Clark et. al 1986). Table 4 shows the average preharvest and postharvest densities of common agricultural crops planted for waterfowl. On

Table 4. Average preharvest and postharvest densities of common agricultural crops planted for waterfowl.[1]

Crop	Density		Location
	Preharvest	Postharvest	
	lb/A	lb/A	
Barley	2,613	105	Colorado
Corn	5,580	320	Iowa, Illinois, Nebraska, Texas
Sorghum	3,679	258	Texas
Japanese Millet	2,227	89	Colorado
Rice	5,205	160	Mississippi Valley
Soybeans	1,093	53	Mississippi Valley
Wheat	1,768	106	Colorado

[1]Source: Ringelman, J. 1990.

Mississippi rice farms, the availability of waste rice decreased 79-99% between harvest in August-September and early December, when waterfowl typically arrive in the Delta in significant numbers. Waste or residual rice after harvest is typically abundant and diminishes as winter progresses. Studies have revealed that approximately 160-499 kilograms per hectare of residual rice are left after harvest (Reinecke et. al 1989, Manley 1999).

Field studies by Elphick and Oring (1998) and Bird et. al (2000) report that specific ecological factors, such as the water depth and time in the winter season, represent significant factors in determining waterfowl densities. The water depth used in the experiment ranges from 10-40 centimeters, which is considered an intermediate depth, while the time period with high waterfowl densities is observed in mid-winter. This result is derived after controlling land size or area affected in the experiment. Such information may be an important factor for successful management of rice flooding for waterfowl in the Mississippi Delta. Nevertheless, the regional weather and geographical features play an important role in the successful management of winter flooding. Similarly, these factors will also provide important challenges in promoting winter flooding for waterfowl on rice farms in the South.

Emerging Issues in Winter Flooding

The decrease in waste rice during the fall has been due to a combination of factors, including germination of seed laying on the ground, decomposition, and consumption by rodents and birds. The decrease in waste grain has potentially serious implications for the forage-carrying capacity of rice fields and habitat needs for wintering waterfowl. Although availability of waste rice was much less than anticipated, the study found that flooded fields support winter populations of aquatic invertebrates, which are an important source of protein and minerals for waterfowl and shorebirds.

There are several other emerging issues:

(1) Winter food for ducks and geese may be limited in Delta rice fields. This problem is related to possible food shortages for wintering waterfowl. While environmental quality and wildlife conservation are truly important goals, producers most readily adopt practices that also decrease farming costs. Winter water management of rice lands is such a practice.

(2) Winter flooding can be relatively easy and inexpensive for rice growers because rice is grown in an aquatic setting. However, producers need to be fully informed in management practices related to water control systems in order to avoid high costs and still be able to develop the sites that are ideal for developing winter habitat.

(3) The full economic and environmental impact of winter flooding will also depend on the farmers' perception of future prospects of the rice industry in Mississippi. As the U.S. is not a major producer in the world market, prevailing cyclical trends in the world market may affect farmers' decisions to increase or decrease rice acreage and production. More than 40% of the U.S. rice crop is exported each year, making the U.S. market sensitive to movement in international prices. However, the U.S. has technological efficiency advantages over other major rice-producing countries, such as Thailand, Vietnam, Bangladesh, and India (Chambers and Child 2000, Chang and Luh 1991).

Direct Economic Impacts

The primary way in which direct economic values accrue to rice production is in terms of economic profits to farmers. These profits can be obtained through sales of rice itself and, in the case of winter flooding, through revenues collected from waterfowl hunting leases, etc. In addition, profits may be directly impacted in the future through imposition of Total Maximum Daily Load standards (TMDLs) for nutrients. It is possible that other crops, such as soybeans and cotton, will incur significant costs to reduce nutrient and chemical loadings as compared with rice. In this section, we will attempt to provide preliminary estimates of the potential direct benefits to farmers from both conventional rice as compared with other crops and from expanding winter flooding practices to include up to 50% of the area currently under rice cultivation in the Mississippi Delta.

Profitability of Rice Production versus Alternative Crops

Table 7 shows the result of an analysis of per-acre net revenues for conventional rice as compared with other conventional cropping systems based on 2001 Mississippi farm budgets. The potential increase in per-acre revenue ranges from 2.8% (for a change from continuous conventional cotton to a soybean/rice rotation) to 123.42% (for a change from continuous soybeans to continuous rice).

Table 5. Average area of rice planted, harvested, and yield by region (1964-1999).[1]

Year	Upper Delta			Lower Delta		
	Planted acres (X1,000)	Harv. acres (X1,000)	Yield	Planted acres (X1,000)	Harv. acres (X1,000)	Yield
			lb/A			lb/A
1964-69	31,072	30,514	4,104	23,380	22,981	4,252
1970-79	62,034	61,110	4,251	46,408	45,064	4,269
1980-89	120,150	118,650	4,796	179,750	168,570	4,709
1990-99	138,522	127,856	5,663	117,578	117,040	5,766

[1]Source: NASS, USDA.

It is possible to extrapolate from the per-acre net revenue increase an estimate of the potential wealth effect on the entire Delta region in Mississippi. Assuming that Sharkey and Alligator soils are those appropriate for rice production, there are at least 1,304,430 acres available for rice production in the Delta. However, only 309,500 acres of rice were in production in 1999, or about 24% of the available land (Tables 5 and 6). If only 50% of the available land were converted to rice, we would expect a net gain of 342,715 acres. If we then assume that acreage would be converted from the least profitable alternative, soybeans, we would expect a per-acre gain in net revenues of $44.58 (Table 7). This gain applied to the increased acreage suggests that regional farm profits could increase by $15,278,235. The calculation is based on the rough estimate without taking into account the different resources and input constraints

Table 6. Average area of rice for selected Delta counties.[1]

Year	Bolivar		Humphreys		Leflore		Quitman		Sharkey		Sunflower		Tunica	
	Planted acres (X1,000)	Yield	Planted acres (X1,000)	Yield	Planted acres (X1,000)	Yield	Planted acres (X1,000)	Yield	Planted acres (X1,000)	Yield	Planted acres (X1,000)	Yield	Planted acres (X1,000)	Yield
		lb/A		lb/A		lb/A		lb/A		lb/A		lb/A		lb/A
1964-69	3,809	4,084	2,353	4,011	4,104	4,042	3,505	3,787	1,168	4,295	4,832	4,760	2,785	3,944
1970-79	6,316	4,277	5,411	4,128	7,936	3,847	3,029	4,143	2,869	4,293	10,532	4,306	7,760	4,187
1980-89	5,850	4,837	7,098	4,621	5,887	4,726	14,030	4,639	6,700	4,820	12,080	4,566	15,520	4,735
1990-95	9,470	5,809	6,650	5,336	8,730	5,645	15,570	5,483	8,125	5,710	14,680	5,593	19,980	5,677

[1]Source: NASS, USDA.

used by each farm. Once these input prices and variability in the costs for every farm is taken into account, the potential estimate can be affected. However, substantial cost savings can be generated as fertilizers and herbicides (inclusive of spray) represent almost 30-40% of the total production costs. The additional profits could in turn help increase the local tax base of the economically challenged Delta region.

Table 7. Net revenue comparison, rice versus alternative crops — Mississippi.[1]

Cropping practice	Net revenue per acre	Alternative cropping practice	Net revenue per acre	Pct. change in net revenue
	$		$	%
Continuous conventional rice	80.70	Continuous conventional cotton	56.82	42.03
Continuous conventional rice	80.70	Continuous conventional soybean	36.12	123.42
Continuous conventional rice	80.70	Conventional soybean/rice	58.41	27.62
Conventional soybean/rice	58.41	Continuous conventional cotton	56.82	2.80
Conventional soybean/rice	58.41	Continuous conventional soybean	36.12	61.71

[1]Source: 2001 Mississippi Crop Budgets.

Cost Saving Potential from Winter Flooding

In this section, we present a simple analysis on the impact of potential cost savings due to winter flooding. We compare cost savings over conventional rice farming received by the 10% of farmers currently practicing winter flooding. We then assume a conservative total adoption rate of 50% of all current rice fields and examine the potential regional cost savings that would be expected. Due to the lack of micro-level information, the calculation is based on market-level, aggregate data.

Baseline: 10% Acreage under Winter Flooding

For the 1995-1997 marketing years, about 10% of the rice acreage in the Delta was managed under winter flooding — on average, representing about 25,780 rice farming acres. If per-acre cost savings are $27.32 (FWC-MSU; 1999), then the aggregate expected savings due to winter flooding on the currently flooded acreage (10% level) is equal to a cost saving of about $704,310. This figure is based on cost savings if farmers practice winter flooding. This figure is generated due to elimination of fall disking ($14.14 per acre) and aerial application of herbicides ($13.22 per acre).

50% Increase in Acreage under Winter Flooding

A 50% increase of acreage under winter flooding will generate additional flooded acreage of about 103,120 acres. Based on a 50% adoption rate, total average cost savings would amount to a net increase in cost savings of $7,043,096, based on a total of 257,800 acres under winter flooding practice (total acreage based on 10% practicing winter flooding). Since the current rice acreage under the standard practice (without winter flooding) is about 232,020 acres, the highest potential for additional cost savings due to winter flooding is estimated at $6,338,786. Based on this rough estimate, there is a vast potential for cost savings and profit enhancement that can be generated from promoting winter flooding practices.

Farmers who rent hunting blinds can experience an additional economic benefit: blind leases are expected to generate about $60-$75 per hunter per season, according to initial estimates obtained from Dr. Richard Kaminski of Mississippi State University. Texas data show that hunting fees are around $5.71 per acre. However, if they are made available during the hunting season, the lease price will increase as much as $2 to $3 per acre. Establishment of the full value of guiding services and rental of blinds will be presented in a future report.

At the regional level, the average income (above specified costs) for rice farms in the Upper Delta and Lower Delta is $59 and $53, respectively (MAFES 1998). The $27.36-per-acre savings due to winter flooding can be translated into an increase of 46.4% in income above specified costs for the Upper Delta; 51.6%, for the Lower Delta.

Indirect Economic Impacts

In this section, we present preliminary estimates of possible indirect economic impacts of rice production. The indirect benefits include public willingness to pay for environmental benefits, also known as external benefits. For example, individuals may have a positive willingness to pay for improvements in water quality that may occur from the ability of rice production to reduce nutrient and chemical runoff in comparison with other crops. In addition, benefits may occur if increased winter flooding is practiced, thereby increasing the potential for wildlife-related recreational activities, such as hunting and bird watching.

Results of Simulations of Environmental Parameters

In order to obtain an analysis of the runoff reductions expected from rice production, we used the Erosion/Productivity Impact Calculator (EPIC) along with the Mississippi Representative Farm Database for Bioeconomic Modeling (Intarapapong 1999) to generate 40-year simulations of rice production as compared with other crops. We ran a number of scenarios that provide comparisons of continuous rice versus continuous cotton, continuous corn, and continuous soybeans, etc., along with comparisons of rice-soybean rotations. The differences in runoffs of nutrients that result from the different cropping systems were also measured (Tables 8 and 9). In all cases, the simulations demonstrate a striking reduction of nutrient runoff from rice production.

Environmental Benefits of Rice/Soybean Rotations

As predicted by the EPIC model, a switch from continuous cotton to a rice/soybean rotation could have positive environmental implications at the field level on affected acreage. Such a change would reduce runoff of total nitrogen by 18.33%, total phosphorus by 23.93%, and sediment by 32.59%. It should be noted that the EPIC model is not capable of extrapolating these results to a total watershed basis. A watershed-level model to further refine environmental impacts will be presented in a future paper.

Environmental Benefits of Continuous Rice

Significant progress in reducing nutrient and sediment loading could be captured if farmers were to convert to continuous conventional rice production. For instance, changing from continuous cotton would reduce total nitrogen loadings by 10.84%, total phosphorus by 19.87%, and sediment loss by 26.07%. If acreage currently under continuous soybean practices were changed to rice, nitrogen loadings would decrease by 15.37%, phosphorus by 28.83%, and sediment by 41.87%. Finally, since a number of farmers practice rice/soybean rotations, we can examine the impact of switching from a rotation to continuous rice. Under this scenario, total nitrogen loadings decrease by 14.59%, phosphorus by 20.88%, and sediment by 46.81%. Such reductions in nutrient and sediment loading would most

Table 8. Results of EPIC simulations — continuous rice versus continuous cotton and soybean.

Soil type	Soil	Total nitrogen			Phosphorus			Sediment		
	proportion	Rice	Cotton	Pct. change	Rice	Cotton	Pct. change	Rice	Cotton	Pct. change
Alligator	0.2536	63.74	63.81	-0.11	4.03	4.96	-18.75	9.94	12.57	-20.92
Dundee	0.1839	10.62	12.68	-16.24	1.21	1.37	-11.68	7.58	11.05	-31.40
Sharkey	0.3798	56.90	62.54	-9.02	4.32	5.59	-22.72	10.16	13.48	-24.63
Forestdale	0.1827	21.91	28.87	-24.11	2.57	3.37	-23.74	7.46	10.79	-30.86
Sum Wgt.	1.0000			-10.84			-19.87			-26.07
Soil Type	Soil	Total nitrogen			Phosphorus			Sediment		
	proportion	Rice	Soybean	Pct. change	Rice	Soybean	Pct. change	Rice	Soybean	Pct. change
Alligator	0.2536	63.74	60.37	5.57	4.03	5.46	-26.19	9.94	15.73	-36.81
Dundee	0.1839	10.62	16.77	-36.67	1.21	1.70	-28.82	7.58	13.97	-45.74
Sharkey	0.3798	56.90	62.27	-8.63	4.32	6.01	-28.12	10.16	17.49	-41.91
Forestdale	0.1827	21.91	34.79	-37.02	2.57	3.89	-33.93	7.46	13.54	-44.90
Sum Wgt.	1.0000			-15.37			-28.83			-41.87

Table 9. Results of EPIC simulations — rice/soybean rotation versus continuous cotton, soybean, and rice.

Soil type	Soil proportion	Total nitrogen			Phosphorus			Sediment		
		Rice/soy.	Cotton	Pct. change	Rice/soy.	Cotton	Pct. change	Rice/soy.	Cotton	Pct. change
Alligator	0.2536	52.33	63.81	-17.99	3.79	4.96	-23.59	8.75	12.57	-30.39
Dundee	0.1839	10.01	12.68	-21.05	1.01	1.37	-26.28	6.75	11.05	-38.91
Sharkey	0.3798	54.92	62.54	-12.19	4.53	5.59	-18.96	9.59	13.48	-28.86
Forestdale	0.1827	20.54	28.87	-28.85	2.28	3.37	-32.34	6.79	10.79	-37.07
Sum Wgt.	1.0000			-18.33			-23.93			-32.60
Soil type	**Soil proportion**	**Total nitrogen**			**Phosphorus**			**Sediment**		
		Rice/soy.	Soybean	Pct. change	Rice/soy.	Soybean	Pct. change	Rice/soy.	Soybean	Pct. change
Alligator	0.2536	57.72	60.37	-4.40	4.59	5.46	-15.93	8.83	15.73	-43.87
Dundee	0.1839	10.15	16.77	-39.47	1.03	1.70	-39.41	6.72	13.97	-51.90
Sharkey	0.3798	62.74	62.27	0.74	5.60	6.01	-6.82	9.66	17.49	-44.77
Forestdale	0.1827	22.42	34.79	-35.55	2.40	3.89	-38.30	6.77	13.54	-50.00
Sum Wgt.	1.0000			-14.59			-20.88			-46.81
Soil type	**Soil proportion**	**Total nitrogen**			**Phosphorus**			**Sediment**		
		Rice/soy.	Rice	Pct. change	Rice/soy.	Rice	Pct. change	Rice/soy.	Rice	Pct. change
Alligator	0.2536	57.72	66.94	-13.78	4.59	4.66	-1.50	8.83	9.85	-10.36
Dundee	0.1839	10.15	10.81	-6.10	1.03	1.24	-16.94	6.72	7.43	-9.56
Sharkey	0.3798	62.74	63.53	-1.25	5.60	5.30	5.66	9.66	10.07	-4.07
Forestdale	0.1827	22.42	23.19	-3.32	2.40	2.76	-13.04	6.77	7.34	-7.77
Sum Wgt.	1.0000			-5.70			-3.73			-7.35

likely make significant progress toward meeting TMDL goals while retaining profitability. In addition, for alternative crops to meet such drastic loading reductions, one would expect to see significant outlays on equipment and infrastructure such as buffer strips.

However, the simulation result also recognized the limitation of practicing continuous rice. A highly acceptable recommendation is to plant no more than 2 years of continuous rice, with a 1-year rotation preferred, which can prevent disease and weed build-up. In short, the recommendation derived from this simulation is more suitable for situations where it is possible to plant more than 2 years of continuous rice, followed by a year of rotation with alternative crops, such as soybeans. This study considered this limitation as an important issue that needs to be considered in recognizing the conclusion proposed.

Wildlife Benefits of Runoff Reduction in Mississippi

Runoff reductions can translate into a number of indirect economic benefits. For instance, a cleaner environment can support a broader range of wildlife species, resulting in increased opportunities for hunting and other wildlife-related recreational activities. A nationwide survey (U.S. Department of Fisheries and Wildlife 1998) reports that 770,000 hunters and anglers recreated in Mississippi in 1996, while 534,000 individuals participated in nonconsumptive wildlife-related activities, such as bird watching and wildlife photography. Associated with these activities were $1.8 billion in expenditures in Mississippi made by both resident and nonresident recreators. Thus, if the environment improves, one could expect to see an overall increase in expenditures on wildlife-related recreational activities. In the case of rice production, increased production would create reductions in runoff that would result in better opportunities for fishing offsite. In addition, the presence of increased rice acreage alone would most likely contribute to the diversity and quantities of waterfowl and other birds, creating more opportunity for hunting and bird watching.

In terms of overall contribution to in-state expenditures, anglers spend the most annually ($599 million), while hunters spend $576 million. Within the subcategories of fishing and hunting, the highest per-hunter expenditures are made by those pursuing big game ($1,098 per person), while those hunting migratory waterfowl expend $430 per person annually. These results should be tempered by the fact that hunting season lengths and accessibility may vary. Since total days of hunting for big game are 8,327, and total days of hunting for migratory waterfowl are only 836, the intensity of spending activity for waterfowl hunters is greater than for big game hunters.

There are two approaches to estimating the overall economic impact of expenditures on wildlife-related activities. The first approach is to use an economic impact analysis, and the second is to develop recreational demand models. Preliminary work on a recreational demand model for increased opportunities for waterfowl hunting has begun and is reported later. Performance of an economic impact analysis is proposed during the second year of the study.

Since rice is grown primarily in the Delta region of Mississippi, some initial estimates of approximate economic impacts of recreation in the Delta are provided. The underlying assumption made is that the hunting fees will be treated as an extra income over the existing income from producing specific crops. In most cases, crops like rice provide a good source of energy-rich food for waterfowl species. The seeds resist decomposition and have a higher nutritional value for waterfowl than soybeans, corn, and sorghum. To this end, data obtained from three sources were used:

(1) The Mississippi Department of Wildlife, Fisheries, and Parks (MDWFP) provides data on resident and nonresident hunting activities in Mississippi (Shropshire 1998).

(2) A survey conducted by MDWFP and Mississippi State University (MSU) provides a wide range of data on resident angler activities in Mississippi.

(3) A survey conducted by the Mississippi Institutes of Higher Learning provides an overview of outdoor activities, allowing for ranking of preferences for hunting, fishing, and, to a certain extent, nonconsumptive activities.

These data are used in an attempt to assess the economic impact of wildlife-related activities in the Delta. It should be noted that the local surveys do not necessarily include the same individuals as the survey conducted by the U.S. Fish and Wildlife Service (USFWS 1998), so results are not directly comparable. Furthermore, with respect to hunting data, fully comparable samples for residents and nonresidents within 1 year were not available; however, because all the surveys consist of statistically reliable samples, one may safely make generalizations of district-level expenditures obtained from the national and state surveys. A shortcoming of the angler survey is that it does not include nonresident anglers. In addition, none of the existing studies deal with nonconsumptive wildlife-related activities in a way that is comparable to the USFWS national survey.

Preliminary Travel Cost Estimates

MDWFP conducted surveys for the 1996-1997 hunting season (nonresidents) and 1997-1998 hunting season (residents). The survey was conducted by randomly sampling both resident and nonresident hunters holding Mississippi hunting licenses and included number of hunters, number of days spent hunting, and the actual harvest by Wildlife Management District (WMD). Expenditures were not obtained in this survey, so all discussion in this section pertains to numbers of hunters and days of hunting.

Altogether, 668,980 hunters were reported in Mississippi during the 1997-1998 hunting season, and 13,978 waterfowl hunters were reported to have visited the Delta (MDWFP 1998). Information on waterfowl hunters was used to estimate gross benefits that accrue from our preliminary recreation demand estimates.

Using data from the 1996 USFWS survey on waterfowl hunting in Mississippi, we estimated per-hunter-per-trip economic benefits related to waterfowl hunting (see appendix for details). First, the consumer surplus (CS) measure associated with a single hunting trip was estimated. CS takes into account the concept of willingness to pay, based on consumer utility theory. According to the theory, individuals are usually willing to pay more than the price they actually pay, thereby accruing additional economic benefits. In this study, the calculation to derive consumer surplus was based on the aggregated or total market for hunting. Different prices and leasing fees based on region, season, and other environmental factors have different impacts on producers and consumers.

In this study, the CS estimate was approximately $366 per trip, which includes the average per-trip expenditure of $27. Assuming that increased waterfowl habitat could increase waterfowl populations, as well as access to hunting opportunities, demand for hunting trips would increase by 10%. Under this scenario, it is expected that CS would increase by about $77, so the total would be $443 per trip. Extrapolating this across the number of hunters in the Delta, the aggregate benefit is $244,846,680 under the baseline scenario, and increasing rice production could potentially bring an incremental benefit of about $5.1 million.

Willingness to Pay for Water Quality Improvements

In addition to wildlife-related benefits that are generally called "use values," individuals often have positive willingness to pay for environmental improvements that are referred to as "non-use values." Among the non-use values are option, bequest, and existence values. Option value is the value that individuals not currently using environmental services may have in order to ensure that they will be able to use those services some time in the future. Bequest value is the value that individuals place on preserving the environment for future generations. Existence value is the value that individuals place on the environment for its own sake. Wide literature on obtaining estimates of these values is in existence; most frequently researchers use a method called Contingent Valuation (CV) to obtain such estimates. CV is a costly method but is the most acceptable means of obtaining non-use values for which no observed market activities exist.

A recent CV study by Hite et al. (2000) suggests that individual taxpayers in Mississippi would be willing to pay a substantial amount in the form of a one-time tax in order to achieve reductions in agricultural runoff. For example, it was found that respondents would be willing to pay $87.59 per person for a 10% decrease in runoff and $108.59 per person for a 20% decrease in runoff. We extrapolated this information to estimate the willingness to pay for the decrease in runoff that would be achieved if rice production replaced other crops.

For purposes of this analysis, assume that reductions in runoff achieved through conversion to rice would be in the vicinity of 20% at the farm level. If all possible rice land (Sharkey and Alligator soils) were used for rice production, it would account for approximately 33.4% of total agricultural acreage in the state. It is possible that statewide reduction in runoff would be in proportion to this percentage. Thus, one would expect runoff reductions to be approximately 6.68% on a total basis. Interpolating according to the 2000 Hite et al. study, this would amount to a per-taxpayer willingness to pay of about $57.81. By multiplying this amount by the 1,139,085 Mississippi individual tax returns filed in 1998 (IRS 1998), we estimate that the Mississippi taxpaying public would be willing to pay $65,849,820 for a 6.68% reduction in agricultural runoff.

Conclusion

The results of our preliminary analysis show significant economic benefits from rice production in Mississippi. These benefits can be defined in terms of runoff reduction and enhanced wildlife habitat. We identified two primary ways in which significant additional benefits could be obtained: (1) increase rice acreage at the expense of less environmentally friendly and less profitable crops; and (2) increase winter flooding practices on existing rice fields.

We have identified a number of extensions to this existing project, the results of which we intend to present in the future. These extensions include efforts to estimate watershed-level environmental impacts, to survey rice farmers regarding on-site hunting-related revenues, to broaden the scope of our recreational demand model, and to provide an integrated analysis of the full net social benefit associated with rice farming in Mississippi. Included in this exercise will be an attempt to take into account the costs of implementing strategies to address TMDLs for cotton and soybeans and re-estimate changes in profitability under these conditions.

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Glossary

Travel Cost Method — a measure to place value on a nonmarket environmental good (such as a recreation site) by drawing inferences from expenditures made to consume the goods, including the cost of traveling to the site, entry fees, on-site expenditures, and outlays on capital equipment (such as fishing or hunting blinds used in the recreational activities).

Contingent Valuation — a method to state individual preferences to value the quality of the environment through survey techniques where the respondents are asked to place a value on specified changes in environmental quality. The objective is to estimate an individual's willingness to pay for a particular change in environmental quality.

EPIC (Environmental Productivity Impact Calculator) — a biophysical model that is capable of simulating relevant biophysical processes simultaneously, as well as realistically, using readily available inputs. EPIC is also capable of simulating the particular effects of management on soil erosion and productivity in specific environments.

Flooded Rice Field — an artificial, self-contained ecosystem that is also considered the surrogate for a wetland. Rice is the only staple crop normally produced in semisubmerged conditions, and this results in a unique set of ecosystem characteristics that helps to account for the high and sustained yields.

Ecological Effects of Rice Flooding — the process of flooding the rice fields leads to an inflow of silt and clay rich in absorbed nutrients and soluble bases, organic matter, and algae. Fields flooded during the winter, with their rich load of residual grain and native invertebrates, provide excellent habitat for migratory waterfowl.

Mississippi Flyway — the winter migration route for waterfowl, which is composed of the area between the great watersheds from the Hudson Bay to the Great Lakes to the Louisiana bayous. Other migration routes include the Atlantic Flyway, Central Flyway, and Pacific Flyway.

Wetlands — areas of marsh, fens, peat land, or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh or salt, including areas of marine water with a certain depth during low tide.

Ecosystems Structure — composed of tangible items such as plants, animals, soils, air, and water. Ecosystem process refers to the dynamic transformation of this structure. Ecosystem function is the result of interaction between structure and process and may include activities such as floodwater control in rice winter flooding, nutrients retention, and food web support.

Nonuse Value — associated with benefits derived simply from the knowledge that a resource, such as an individual species or entire natural resource, is maintained.

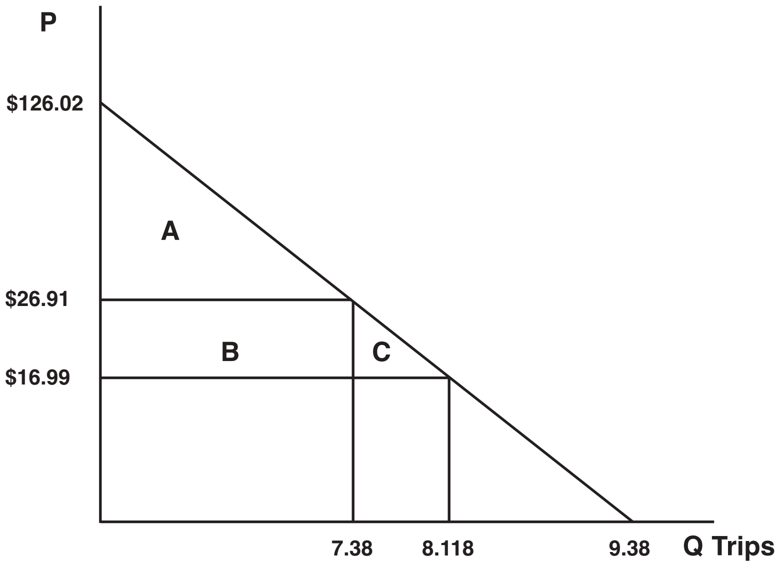
Existence Value — derived simply from the satisfaction of knowing that some feature of the environment continues to exist, whether or not this might also benefit others.

Bequest Value — associated with the knowledge that a resource will be passed on to the descendent to maintain the opportunity for them to enjoy it in the future.

Counter Levee System — production management extensively practiced in rice production where the levees are constructed following the contour of the natural grade of the existing landscape or topographic gradient of the rice farmland. Under the counter levee system, it is common practice that levees will be constructed for every 0.1-0.3 foot of drop in field elevation.

Straight Levee Pattern — the levees are constructed basically straight across the rice field with a zero side slope or constant down slope. This production management practice is gaining popularity because of its cost saving attributes; however, each field that is developed for straight levee will have to incur cost related to land forming.

Methane Emissions and Rice Winter Flooding — rice is a plant that grows best in wet soil with its roots flooded, but flooded rice crops emit substantial amounts of methane to the atmosphere, especially when fresh organic matter — like plant residues — is added back to the soil. Recent scientific studies discovered that periodically draining the soil to aerate roots with atmospheric oxygen drastically decreases methane emissions. This may be an easy on-farm practice that would help manage methane emissions. The release of methane by diffusion through the wet soil column is negligible in clay soil, but it may become significant in sandy soils where larger pores between soil particles prevail. Most rice soils have high clay contents. If bare mud is flooded, most methane is trapped in the soil, and as long as the soil is not heavily amended with organic matter and remains undisturbed, only small amounts of methane will be released.



A demand curve for migratory bird hunting was estimated from U.S. Fish and Wildlife Service as:

Q = 5.4237 – 0.07446P + 0.0001059M

Where: P is expenditure on hunting per trip;
Q is a number on hunting trips; and
M is income.

Individual Benefit Estimation

Consumer surplus (CS), which represents individual economic benefit, is defined as the area above the price and under the demand curve. The area *A* represents consumer surplus before an increase in hunting trips. Areas *A* + *B* + *C* represent individual consumer surplus after an increase in hunting trips. A change in consumer surplus due to a 10% increase in hunting trips can be calculated as follows.

If the number of trips increases by 10% (from 7.38 to 8.118), an individual benefit is estimated as:

$$Q = 9.3834 - 0.07446P$$
$$\Rightarrow P = 126.019 - 13.43(8.118)$$
$$= 16.9942$$

A change in consumer surplus reflects changes in individual benefits as follows:

$$\text{Change in CS} = CS^1 - CS^0$$

$$CS^0 = \tfrac{1}{2}(126.019 - 26.906)(7.38) = \$365.73$$

$$CS^1 = \tfrac{1}{2}(126.019 - 16.994)(8.118) = \$442.53$$

$$\text{Change in CS} = \$76.80$$

Therefore, a 10% increase in migratory bird hunting trips could cause individual benefit to increase by $76.80.

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