SECTION TWO

Agronomic Impacts of Winter Wetland and Waterfowl Management in Ricelands

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ABSTRACT

Sustaining the area of ricelands managed as winter wetlands and waterfowl habitat will require continued participation of a sizable number of producers. To achieve this there will need to be direct and indirect agronomic benefits accrued from land management practices that enhance waterfowl habitat. The purpose of this chapter is to review research on the agronomic effects of managing rice production areas as winter wetlands and waterfowl habitat, and to identify gaps that if filled would advance our knowledge of this subject.

While not extensive, research suggests that managing rice-production areas as waterfowl habitat could enhance straw decomposition, provide a subsequent crop with additional nitrogen, reduce weed densities, abate soil erosion, improve soil and water quality, and reduce spring tillage. Benefits vary from region to region resulting from differences in how rice is produced. To capitalize on these benefits, producers will in some cases need to make capital investments even though the value of the benefits received are difficult to quantify.

Studies on rice straw management have focused on enhancing decomposition. Results indicate that straw biomass left after harvest can be reduced as much as 68% when winter flooding is combined with disking, and 54% by winter flooding alone. Consistent waterfowl foraging aids to reduce straw biomass after harvest by as much as 78%. All studies measuring straw decomposition reported increases from holding winter water but, at the same time, recognized there would be cost trade-offs between straw management and water management. If fields must be pumped to maintain winter water there will be additional costs. In parts of the United States where heavy winter rains are common, one can consistently achieve adequate winter flooding without pumping.

Fall field preparation aims at straw reduction and seedbed preparation for following plant season

Nutrient benefits from winter water management are closely tied to the amount of plant material remaining in the field and how the subsequent crop is managed. There is strong evidence that keeping rice straw in the field and holding a winter flood will result in increased nitrogen (N) for the subsequent rice crop. These results were obtained after three years of straw management in a continuous rice rotation. Such benefits may not be expected from areas where rice is grown in rotation with soybeans or corn. Recent research suggests that N uptake in the subsequent rice crop might be reduced when rice straw remains on the fields and they are flooded throughout the year. There is a need to better understand the process involved and to develop ways to manage flooded fields to maximize nutrient benefits.

Impoundment of water combined with maintaining straw has been shown to improve the quality of runoff waters. This represents significant ecological and sociological benefits, and producers should make known the improved quality of water moving off winter-managed ricelands into lakes, rivers, and streams. Also, producers that maintain winter water on no-till ricelands will not need to change management practices to comply with potential future regulations for water quality.

Considerable evidence exists that waterfowl feeding in flooded ricelands will significantly reduce weed seeds. However, there is little evidence to suggest that producers recover this benefit via reduced herbicide applications. There are perceived benefits from waterfowl foraging in areas where red rice is a significant weed problem, but there has been no specific research to test this possibility.

Economics play the biggest role in determining the agronomic feasibility of managing ricelands for winter wetlands and waterfowl habitat. Rice-producing areas where winter flooding is a common practice are under legal constraints that prohibit straw burning or offer producers substantial benefits from hunting leases. This carrot-or-stick scenario illustrates the challenges in influencing rice producers to expand winter wetland and waterfowl management to widespread practice. Changes in agronomic practices necessary to create winter wetlands oftentimes represent a whole system change rather than a component change. Benefits to the farmer for making these changes are not always evident and may not be present in the immediate future. Relatively few specific recommendations exist on how producers can maximize the research-identified agronomic benefits of managing ricelands for wetland and waterfowl habitat. This deficiency must be corrected if long-term sustainability in ricelands managed for winter wetlands and waterfowl habitat is desired.

INTRODUCTION

In North America, rice production is concentrated in areas that have historically provided wetland habitat for wildlife. Over time agriculture activity has significantly altered area hydrology and wetland habitat (Reinecke et al. 1989) and reduced its ability to support wetland wildlife. By 1978, an estimated 80% of the 10 million ha (25 million acres) of bottomland hardwood forest in the Mississippi Alluvial Valley (MAV) had been cleared for agriculture production (Forsythe 1985, Reinecke et al. 1989). A similar situation exists in the Central Valley of California, where rice production is concentrated in an area important to wetland wildlife. In 1986, the North American Waterfowl Management Plan (NAWMP) put forward the goal of restoring and maintaining continental waterfowl populations at their 1970s levels. Among the original Joint Ventures (JVs) established to implement these goals, three focused specifically on providing habitat for wintering waterfowl. The Lower Mississippi Valley Joint Venture (LMVJV), the Gulf Coast Joint Venture (GCJV), and the Central Valley Habitat Joint Venture (CVHJV) in California overlapped considerably with key rice-growing regions in North America. Accordingly, success in achieving the goals of the NAWMP is closely tied to rice production. A producer's decision to adopt management practices that provide waterfowl habitat is largely dependent on agronomic and subsequent economic results.

Rice cultivation in North America was first established in the mid-seventeenth century (Dethloff 2003). Carolina Gold, a rice variety from Madagascar, was introduced to South Carolina in 1698, resulting in the export of 4.5 metric tons (Mg) (Littlefield 1981). Early production was confined to the river and costal areas of South Carolina. Improvements in water management and milling resulted in annual exports of 16,364 Mg from South Carolina and Georgia at the onset of the American Revolution (Dethloff 2003). Westward movement and the Civil War caused production shifts from South Carolina and Georgia to the Delta of Louisiana (Babineaux 1967). Railroads extended production into Texas while new producers bought land in Louisiana and expanded production to approximately 741,300 ha (183,175 acres) by 1895.

A robust export market and corresponding increases in land values forced producers to relocate. Arkansas farmer W. H. Fuller first planted rice on his farm in Carlisle in 1897. By 1904 the first successful commercial crop was produced. Production rose in the eastern prairies of Arkansas, increasing from 6.3 Mg in 1899 to 25,500 Mg in 1909 (Dethloft 2003).

The first experimental plantings of long-grain rice were made on the California Agricultural Experiment Station from 1893–96. In 1906, William W. Mackie discovered a short-grain Japanese rice variety from Hawaii that was suitable for production (Dethloff 2003). By 1914 California represented 3.8% of the total U.S. production.

During World War I rice production throughout the United States increased tremendously, yet that trend reversed at the end of the war. Collapsing prices during the Great Depression led to passage of the Agricultural Adjustment Act of 1933 that created the Agricultural Adjustment Administration (AAA). This agency allowed rice producers to enter into voluntary agreements to reduce production and abide by acreage allotments and marketing quotas. They, in turn, would receive support prices on rice at a predetermined parity level (Perkins 1969). Between 1946 and 1954 the area of rice planted in the United States rose from 0.6 million ha to 1.0 million ha (1.5–2.5 million acres) due to increased production along the lower Mississippi River (Reid and Gaines 1974). After 1950 rice production was influenced by fluctuating world demand and a series of farm programs. Rice area remained relatively constant between 1950 and 1970 (Figure 1). Between 1970 and 2002 there was a significant increase in rice acreage in Arkansas and Missouri. At the same time acreage in Texas declined, mostly as a result of competition for water.

Successful early introduction of long-grain varieties to the eastern United States resulted in a focus on these varieties. Much of the genetic background found in today's long-grain varieties can be traced to tropical Japonica cultivars from Southeast Asia (Mackill and McKenzie 2003). The tropical nature of these varieties contributed to their failure in early trials conducted in California. Success of the short-grain cultivars in California was followed by a focus on developing high-quality medium-grain varieties within temperate Japonica characteristics. The first semi-dwarf rice variety (Calrose 76) was released in California and remains typical of California cultivars (Rutger and Peterson 1976). There has been a steady increase in all yields, and many of the new varieties mature much earlier than their predecessors.

Rice production in California is continuous in fields that have been leveled and had permanent levees installed. This allows for continuous rice production and better control of water resources. In contrast, rice culture in much of the MAV and Gulf Coast is rotated with soybeans, corn, and pasture. Any changes in winter ricefield management that alters spring moisture, soil nutrient availability, or crop residue decomposition will potentially result in a different impact on the subsequent rotation crop.

The primary weed throughout much of the MAV and Gulf Coast is red rice (*O. sativa var.*), a conspecific weed that cannot be easily controlled with standard herbicides. The presence of this weed is a primary reason producers do not grow continuous rice. Red rice is also regarded as a food source for migrating waterfowl. This weed was widespread in California during 1930–40s, prior to the introduction of certified seed. It has not been a significant problem in recent years but remains a potential concern for the future.

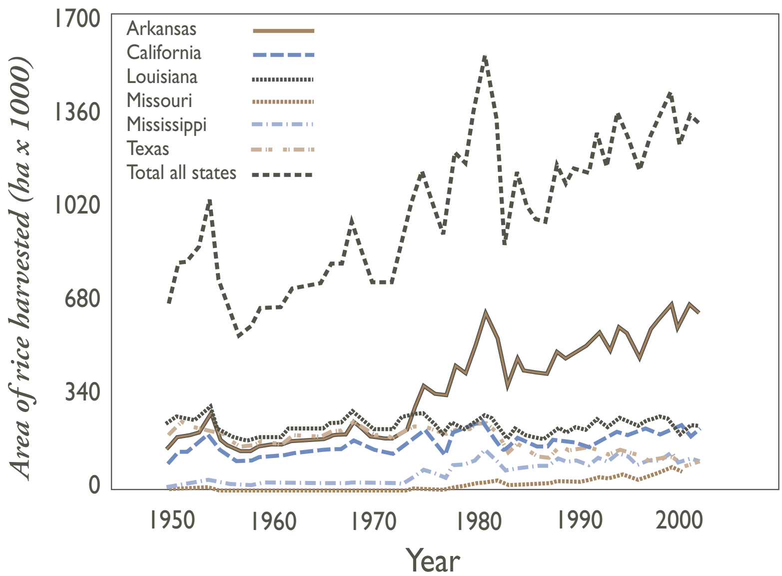
California rice growers aerially sow pregerminated seed into flooded fields, while most of the rice grown in the MAV and Gulf Coast is dry seeded with a grain drill. California growers inject fertilizer into the ground prior to seeding in order to reduce fertilizer losses. Outside California, fields are generally tilled in the fall and spring with phosphorus and potassium applied and incorporated into the soil prior to sowing. Nitrogen is aerially applied prior to the growing season flood and at intervals during plant growth. Nearly all U.S. rice is grown under flooded conditions with an 8–10 cm (3–4 inches) flood maintained throughout the growing season. It is this high demand for water that has resulted in declining rice production in Texas. Water rights, availability, and quality are issues that are present across all rice-growing regions and will impact future trends in rice production.

Historically, rice producers have focused on spring and fall field operations and were not concerned about how their fields were managed during the winter months. The abundance of waterfowl in rice-producing areas was regarded as detrimental, with yield losses attributed to waterfowl and other wildlife species (Neale 1918, Ellis 1940, Jones 1940, Frith 1957, Lane et al. 1998, Post et al. 1998). Perceptions have shifted, and waterfowl are now viewed as a resource that has economic potential (Hill 1999). This shift has provided a stimulus for producers to manage ricelands as winter wetlands and waterfowl habitat. Significant revenues from leasing hunting rights and a personal interest in wildlife have resulted in a substantial number of ricelands being flooded during the winter months. Independent, but relevant to this trend, was passage of California legislation (AB 1378) that sought to reduce the burning of rice straw over a 10-year period. Under this legislation conditional burns are allowed on up to 25% of the total rice-growing area, with an estimated 13% actually burned between 2000 and 2006. This legislation has resulted in a significant increase in holding winter water on ricelands as a means of facilitating straw decomposition in California.

Outside California, hunting revenues and interest in wildlife have largely driven interest in winter management. Implementation of the Environmental Protection Agency (EPA) regulations regarding nonpoint source (NPS) pollution encouraged producers to control runoff from ricelands. Closely tied to this legislation is the Farm Security and Rural Investment Act of 2002 (Farm Bill), which contained provisions to provide economic incentives for rice producers willing to invest in management practices that result in improved waterfowl habitat.

Regardless of the outcome of this legislation it is clear that to achieve the goals laid out in the NAWMP there will need to be a significant number of rice producers adopting conservation approaches that benefit lands managed for waterfowl. To achieve this goal, producers will need to have a full understanding of the agronomic impacts of winter water management and how this may benefit, or at least be neutral to, sustainable production and farm income.

FIGURE 1 Hectares of rice harvested in major rice-producing states and U.S. total rice area harvested from 1960 to 2002. (USDA NASS 2002).



RICE STRAW MANAGEMENT

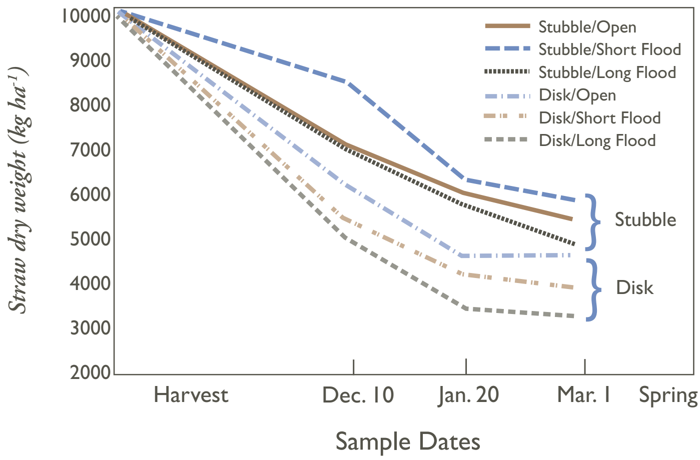
Producers view rice straw as a byproduct that incurs additional costs for removal from, or decomposition in, the field. Straw removal during winter is essential for seedbed preparation in spring and to ensure that physical barriers or biological effects do not impede germination. Traditionally, producers would burn rice straw following harvest and disk fields to incorporate the remaining crop residues into the soil. In 1991, the California Legislature passed the California Rice Straw Burning Reduction Act that sought to reduce air pollution by eliminating the burning of rice straw. Similar concerns regarding burning do not yet exist in rice-growing areas of the MAV or Gulf Coast, yet producers must contend with the large volume of straw after harvest. In both areas, partnerships between public and private conservation organizations have offered incentives to landowners to flood ricelands in winter to provide habitat for waterfowl and other wildlife, and as a result acreage flooded during the winter has increased considerably over the past decade (Baxter et al. 1996). Wildlife management in ricelands is being adopted in other areas of the MAV and Gulf Coast as a way to complement waterfowl hunting interests. A number of studies subsequently brought together the concepts of winter water management and new rice straw management approaches (Manley 1999, Bird et al. 2000, Bird et al. 2002a, van Groenigen et al. 2003, Anders et al. 2005, Manley et al. 2005). The interactions of winter water, straw decomposition, and waterfowl determine many of the agronomic outcomes of managing ricelands for wetland and waterfowl habitat.

WINTER FLOODING AND STRAW DECOMPOSITION

To provide wetland and waterfowl habitat, fields must receive and hold water after the rice crop has been harvested. This practice greatly extends the time a field is under waterlogged and potentially anaerobic conditions. A major by-product of rice production is the approximate 8–10 Mg/ha (3.5–4.5 tons/acre) of straw produced by each crop (Brouder 1993, Brandon et al. 1995, Brouder and Hill 1995, Manley et al. 2005). Where the more traditional practice of burning rice straw (Becker et al. 1994) is not possible, there has evolved a suite of management practices aimed primarily at reducing tillage problems created by the residual straw the following season. These practices incur additional expenses that may or may not be recovered by the producer. Practices such as disking aid in straw decomposition but can potentially bury rice and weed seed that would otherwise attract waterfowl (Miller et al. 1989). Removal of rice straw from the field is practical only when there is a market for the straw. This approach has been studied and pilot projects implemented, but with little success to date. In the MAV, rice stubble that is left on the soil surface following harvest must also be managed in a way such that it will not physically impede field operations in the following year. A key to expanding the area of rice production managed for wetland and waterfowl habitat is capitalizing on the agronomic benefits resulting from alternate straw management practices.

Factors that influence straw decomposition include environmental conditions, soil properties, and field management (Williams et al. 1972, Pal et al. 1975, Broadbent 1979, Manley 1999, Manley et al. 2005). As temperature and moisture levels throughout winter vary and interact, it has not been possible to accurately predict the results on rice straw decomposition. Research into winter riceland management has focused more on measuring overall reductions in straw mass and its subsequent impact on soil fertility. Manley et al. (2005) reported that flooding alone during the winter months reduced straw mass to 54%, identical to disking alone (Figure 2). In the same study, combining disking and 120-day flood treatments reduced rice straw by 68%. Cost savings from reduced field operations will be realized only if the costs of maintaining a winter flood are less than the cost of disking. Additional cost savings likely occur from enhanced straw decomposition as the result of waterfowl foraging.

FIGURE 2 Reduction in rice straw biomass in ricefields under different treatments of post-harvest treatment and winter-water management, Mississippi Alluvial Valley of Mississippi, winters 1995–97. No data were collected between harvest (September–October) and the December 10 sampling interval. Data from Manley (1999).



WATERFOWL FORAGING ACTIVITY AND STRAW DECOMPOSITION

Foraging activities of waterfowl have been thought to facilitate straw decomposition in winter (Smith 1992, Gannon 1994, Brouder and Hill 1995, Burnham 1995, Rush 1996, Bird et al. 2000). This idea has been evaluated recently in a series of studies in California. Bird et al. (2000) used experimental plots (5x5m) in which waterfowl (Mallards) were either excluded or stocked at densities comparable to those observed in the Central Valley during winter. In the plots without waterfowl, 27–41% of the residue was decomposed by spring, with the amount depending on whether the straw was rolled or not after flooding (Figure 3). However, in plots with waterfowl, the remaining residue was reduced by 72–76% (Figure 3). Carbon to nitrogen ratios (C:N) and lignin concentrations in the surface residue were also reduced in plots with duck activity, indicating an increased rate of straw decomposition (Bird et al. 2000). The presence of lignin during straw decomposition is reported to reduce nitrogen availability in a subsequent crop (Olk et al. 2004); thus reducing lignin concentrations would suggest possible gains in available N. In areas where rice straw cannot be burned, straw reductions attributable to waterfowl activity are significant in that they decrease the volume of rice straw on the field without incurring the cost of rolling. Decreased straw mass the following season can potentially reduce tillage requirements.

Results from Bird et al. (2000) were further evaluated by van Groenigen et al. (2003) across 15 farms in the Sacramento Valley. Paired plots featured one that excluded waterbirds while another was left open to foraging activities. The results confirmed Bird et al.'s (2000)

FIGURE 3 Experimental evaluation of the effect of waterfowl on rice straw decomposition. Data from Bird et al. (2000).

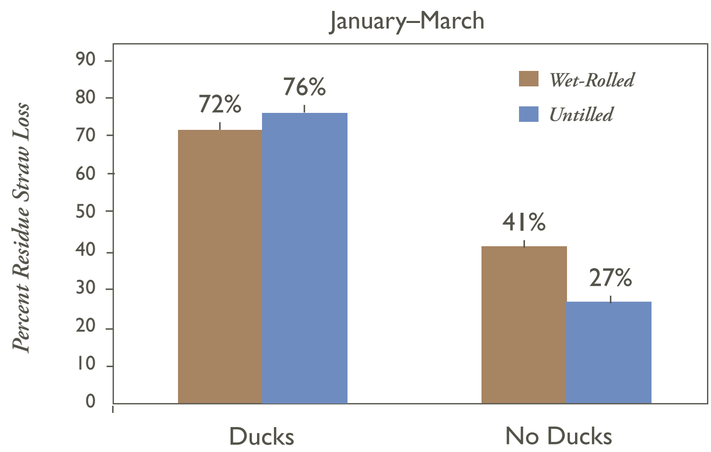
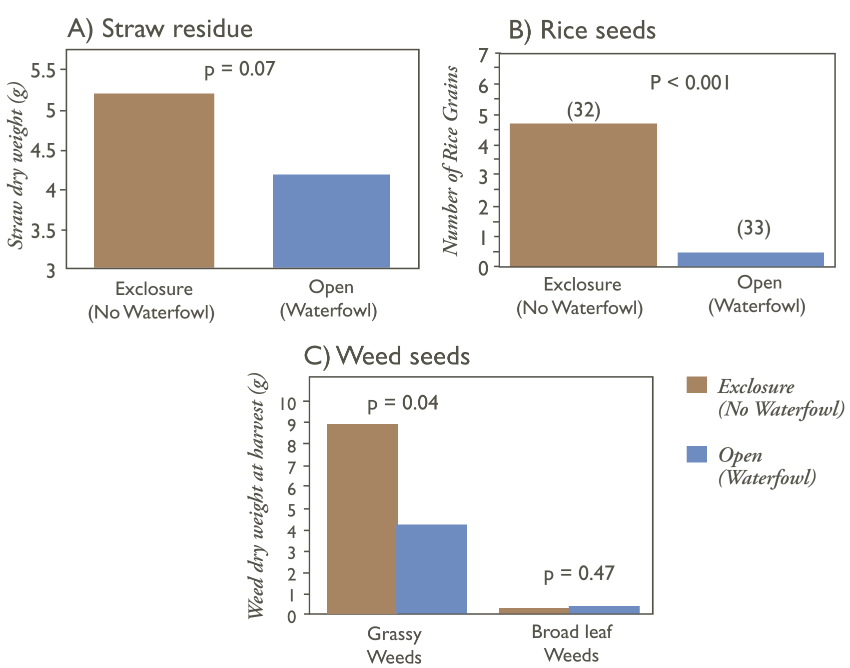


FIGURE 4 Straw residue, rice seeds, and weed seeds remaining in open (foraged) and exclosed (nonforaged) study plots. Data from van Groenigen et al. (2003).



findings. The median value in spring for straw residue remaining inside the exclosures (without waterfowl) was almost double that of the open plots (Figure 4). This effect was even greater on the sites where waterfowl densities were relatively higher (van Groenigen et al. 2003). Natural densities of waterfowl appear to be sufficient to promote significant reduction of straw residue.

In California and parts of the MAV, winter flooding to a water depth that is optimal for waterfowl habitat is possible only if there is adequate water available to augment winter rainfall. Competition for water supplies and decreasing available ground water could limit winter flooding to rainfall impoundments in some areas. These results support winter flooding as a way to manage rice straw, but do not address questions on the impact of decomposing rice straw on subsequent soil fertility.

PLANT NUTRIENT AVAILABILITY

Rice Straw and Nutrient Availablility

Rice straw has the potential of increasing soil organic matter (Verma and Bhagat 1992) and eventually increasing N mineralization (Bacon 1990, Bird et al. 2001, Bird et al. 2002b, Linquist et al. 2006). Adding large quantities of rice straw to the soil has been shown to initially reduce rice yields (Azam et al. 1991, Verma and Bhagat 1992, Eagle et al. 2000). This reduction in rice yields is attributed to N immobilization, a condition that can be corrected by additional N applications (Adachi et al. 1997). Nitrogen has been identified as the most limiting nutrient to rice yields worldwide (Cassman et al. 1996a), and reducing available N by adding straw is expected to decrease yields in a following rice crop. However, one-third of the rice plant N is in straw (Cassman et al. 1996a), returning straw to the soil will add N to the system. The time and quantity of N that results from rice straw management will influence the amount of fertilizer N required by crops planted after rice. Immobilization of N that results from adding rice straw to the system is transient and influenced by winter water (Eagle et al. 2000, Linquist et al. 2006). Compounds that inhibit N availability that are formed from anaerobic rice straw decomposition have been identified (Schmidt-Rohr et al. 2004) and their subsequent impact on a following rice crop documented (Olk et al. 2004). These results indicate a potential loss of available N when anaerobic decomposition of rice straw takes place, a problem that will need to be managed if the full benefits of returning N to the system are to be realized.

Studies suggest that over time plant available N, yield, and total N uptake are positively affected by straw incorporation (Cassman et al. 1996b, Kundu and Ladha 1999, Bird et al. 2001). In an early study, Williams et al. (1972) reported that over a five-year period there were no significant differences in a subsequent rice crop grain yield if crop residues were burned or incorporated at the end of the previous season. These results were obtained using N fertilizer rates of 0, 45, 90, and 135 kg N/ha (0, 40, 80, 120 pounds/acre), with and without a legume green manure crop, and suggest that additional N returned to the field by not burning the straw did not result in additional N being available to the following crop. There was no indication as to how the plots used in this study were treated during the winter months. A later study (Eagle et al. 2001) using ^{15}N to measure N use efficiency and crop N uptake from straw found that the aboveground biomass N contribution to the overall plant N availability in the first year after incorporation may not be as important as N derived from root decomposition. This conclusion applied regardless of straw management (burn vs. incorporate) or winter field management (flood vs. no flood). Fertilizer N use efficiency increased whenever residue was removed from the field, indicating that there was a net accumulation of N when all plant residues remained on the field. The amount and availability of this N will determine the benefits producers might expect from combining winter water with straw retention.

Reduced N fertilizer rates when there is an increase in soil N from straw retention will improve fertilizer nitrogen use efficiency (FNUE) (Cassman et al. 1993) and decrease production costs. Nitrogen made available through straw retention in the first year after straw incorporation has been estimated via plant uptake to be 12–19 kg N/ha (10.7–16.9 pounds/acre) (Eagle et al. 2000). However, the total N benefit of incorporating straw on soil N supply will be larger, as a subsequent rice crop will not utilize all N from the straw. Total change in soil N supply when straw is incorporated or removed becomes clear when unfertilized rice is grown under the two conditions. The yield of unfertilized rice almost doubled when straw was incorporated (Eagle et al. 2000). Savings in fertilizer-N were estimated at 25 kg N/ha (22.3 pounds/acre) after straw had been incorporated for five years (Bird et al. 2002b). These results indicate that producers would benefit from lowering their N fertilizer application rates on a subsequent rice crop (Bird et al. 2002a, Lindquist et al. 2006).

Eagle et al. (2000) evaluated the effect of rice straw and winter water management on N uptake, yield, and N use efficiency in a five-year study at two locations in California. In this study, maintaining winter water had no significant effect on grain yield in a subsequent rice crop regardless of straw management (whether burned, chopped and incorporated with a chisel plow or disc, rolled into soil surface, or windrowed and baled). Differences in soil N and its availability to a subsequent rice crop were influenced by straw management in the third year of the study with more soil N available in treatments where the straw was retained. Increased soil N did not result in higher grain yields, but does indicate that less N would need to be applied to a subsequent rice crop to obtain similar grain yields.

Any straw or water management practices that alter nutrient availability will also be impacted by rotation. While many physical and chemical changes brought about by straw and water management will be similar across regions, the potential to capitalize on these changes will depend on what crop is planted after rice and how that crop is managed. A rotation of soybeans might explain the results reported by Manley (1999) and Anders et al. (2000) (Table 1). In a comparison of winter flooded ricelands to those not flooded, Manley (1999) reported no significant difference in available soil ammonium in the spring. An increase up to 12.5 kg/ha N (11.1 pounds/acre) in available soil ammonium and nitrate under winter flooded conditions was observed in California, and such differences in available soil N could impact rice grain yield (Bird et al. 2001). However, as fertilizer-N input rates have often not been adjusted to the new straw management practices, associated benefits are not fully realized.

TABLE 1 Summary of soybean seed yields (kg/ha) for the main effects of rice straw management, winter flooding, tillage, and irrigation from 1997 to 1999 in a study conducted at the University of Arkansas Rice Research and Extension Center, Stuttgart, Arkansas (Anders et al. 2000).

OPERATION	TREATMENT	1997	1998	1999
	Seed yield kg ha^{-1}			
	Disked	2150	-	-
Straw management	Standing	2150	2490	2490
	Rolled	2280	2550	2420
	Drained	2220	2490	2420
Winter flooding	Rainfall	2080	2690	2490
	Pumped	2220	2350	2490
	Conventional tillage	2490***	2690***	2490
Tillage	No-till	1950***	2350***	2420
	Irrigated	3090***	3430***	3960***
Irrigation	Dryland	1280***	1610***	940***

***Treatments were significantly different at the $p < 0.001$ level.

WATERBIRD USE OF FLOODED RICEFIELDS AND NUTRIENT AVAILABILITY

The large numbers of waterbirds that are attracted to flooded ricelands could further influence nutrient inputs (Have 1973, Brandvold et al. 1976, Brierley et al. 1976, Manny et al. 1994). For example, large concentrations of geese on the Bosque del Apache National Wildlife Refuge in New Mexico redistributed substantial quantities of nutrients across the landscape (Post et al. 1998). Indeed, in some cases, the level of nutrient loading was sufficient to raise concerns about potential impacts on water quality (Have 1973, Brandvold et al. 1976, Brierley et al. 1976).

Waterfowl providing fall tillage of rice straw

Waterfowl foraging could also influence nutrient availability indirectly through increased shredding and decomposition of straw (see above). Bird et al. (2000) reported that N concentrations in the above-ground straw decreased when waterfowl foraging or field tillage occurred compared to plots with no waterfowl foraging. The same study found no increases in soil C or N as a result of waterfowl foraging. Because this was a one-year study, it is not possible to determine if the effect of waterfowl foraging would have eventually improved soil N levels, or if improvement might follow a longer timeline as reported in the Eagle et al. (2000). Van Diepen et al. (2004) examined the effect of waterfowl foraging on N-cycling by experimentally excluding waterfowl from 3x3m plots along transects in a California ricefield . They used ^{15}N labeling of straw to follow the fate of labeled residue into the light and mineral N fraction of the soil. While there was no difference in total N loss between control and exclosure plots, the amount of ^{15}N lost from the labeled residue was higher when waterfowl were present (van Diepen et al. 2004). Overall, 54% of the labeled ^{15}N residue was recovered in the enclosure plots compared to 40% in the control plots. However, the increased amount of residue N lost in the control plots could not be traced to the total soil N, the light fraction or the mineral N pools, and hence it was uncertain whether producers would realize any benefit of increased N availability for the subsequent rice crop.

SOIL AND WATER CONSERVATION

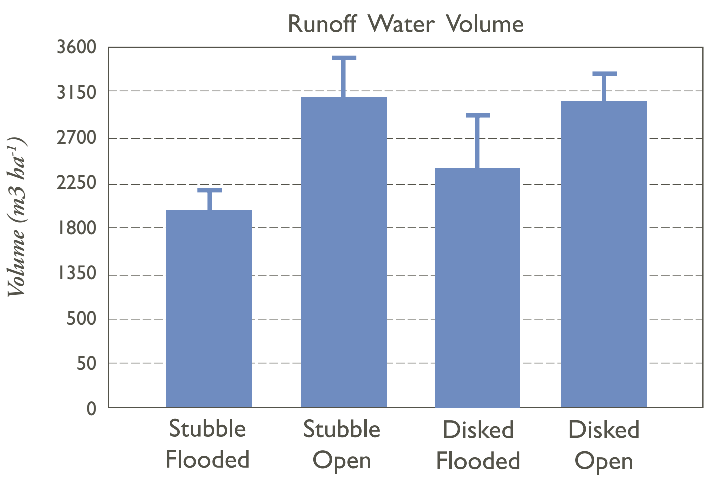
Research addressing the impact of managing ricelands for winter wetland and waterfowl habitat on soil and water conservation varies with regional needs. Soil erosion has long been a concern of agriculturalists and conservationists. With California rice producers facing increasingly restrictive legislation on water and air quality at state and local levels, there has been increased

Water will play a leading role in determining the scale of both rice production and winter wetland and waterfowl management

interest in understanding the role of winter water and rice straw management on rice production. Rice producers in the MAV and Gulf Coastal areas of Louisiana and Texas are now facing water quality and quantity problems along with possible legislation targeted to reduce water and air pollution (Scott et al. 1998).

In the MAV there is generally sufficient rainfall to fill winter wetlands. Water management can provide benefits beyond those directly related to waterfowl. In a two-year study, Manley (1999) reported a decrease in runoff of 899m^3/ha (0.3 acre feet [AF]) from controlled flooded fields when compared to open fields where rainfall was allowed to runoff after each rain event (Figure 5). This decrease represented a drop from 53% of total rainfall being discharged from the open field compared to 39% of total rainfall from flooded fields. Holding water on a field during the winter allows suspended solids to settle, thus lowering their concentration in the discharged water (Manley 1999). A combination of disking with open-field conditions resulted in suspended solid exports of 1,121 kg/ha (998 pounds/acre) as compared to only 35 kg/ha (31 pounds/acre) leaving fields with standing stubble and controlled flooding.

FIGURE 5 Total water runoff volume (m^3 ha^{-1}) from experimental ricefields in the Mississippi Alluvial Valley, Mississippi, winters 1995–97. Data from Manley (1999).



WEED CONTROL

Waterfowl consume seeds in flooded fields, including rice, red rice, millet (*Echinochloa spp.*), and other weeds (Wright 1959, Forsyth 1965, Smith and Sullivan 1980). Winter water management has been shown to decrease seed viability, and may reduce competition from spring weeds (Baskin and Baskin 1998, Buehler et al. 1998, Bird et al. 2002a, Manley et al. 2005). Many past studies indicate waterfowl foraging and winter water management reduced weed populations and could have saved the rice industry more than $290 million in 1977 (Smith et al. 1977, Hobaugh et al. 1989). Even earlier, McAtee (1923) postulated that annual savings as high as $150,000 could be realized by the founding rice producers in Arkansas by waterfowl feeding on red rice. Fontenot (1973) reported that producers in southwest Louisiana were attracting waterfowl to their ricelands in winter as a strategy to reduce red rice and other weed problems.

More recent documentation occurred in California, where holding water in winter decreased the density of watergrass (Bird et al. 2002a). It remains to be determined whether the reduction in watergrass seeds in California was a direct effect of winter water or foraging waterfowl. Research into the potential benefits of waterfowl reducing weed populations in winter-managed ricelands was initiated by Smith and Sullivan (1980), who evaluated the reduction of red rice seed from waterfowl foraging in a field heavily infested with red rice. Their study reported that the percentage reduction in red and white rice seed numbers was 97.3% and 97%, respectively. While impressive, these numbers represent a field that was heavily infested with red rice and was located adjacent to a state wildlife area that historically attracted large numbers of ducks.

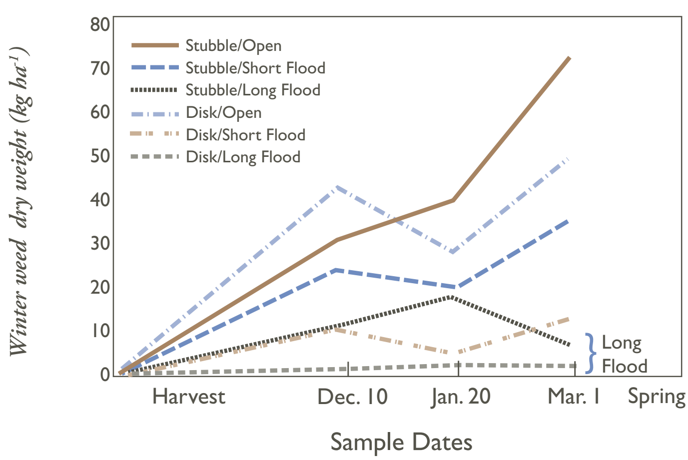
Maintaining winter water will shift the weed spectrum from terrestrial to generally less invasive aquatic species. This is particularly true in California, where winter weeds are generally not considered a problem in rice production. Manley et al. (2005) found that fields without winter water contained the highest weed biomass (50–70 kg/ha [44.5–62.3 pounds/acre] by winters end) while those fields that were flooded for an extended length of time were lowest (<8 kg/ha [7.1 pounds/acre]) (Figure 6). Disking a field prior to flooding reduced winter weeds by an average of 35% as compared to leaving stubble stand in a drained or flooded field. The same trend was not found with red rice where seed viability was reduced one year by disking and the next year by leaving seed on the soil surface. It is not clear whether the practice of disking significantly destroys or buries seed, reducing availability as a food source to waterfowl. If this were the case, disking would be counter-productive in a system that strives to provide winter feeding resources. In areas where red rice is the dominant weed problem it is unclear if any of the agronomic practices associated with winter water management for waterfowl habitat will have a significant impact in reducing seed numbers or viability.

Bird et al. (2002a) reported that after seven years of testing straw management practices, the watergrass seed bank was reduced from a maximum of 50,000 seeds/ha when straw was incorporated and the field left open to drain to almost zero when the straw was burned in the spring. Clearly, burning straw had a significant effect on reducing weed seeds.

In an effort to distinguish between the effects of winter water management and waterfowl foraging on weed seeds, van Groenigen et al. (2003) compared fall weed biomass in plots with and without previous winter foraging (waterfowl were excluded by wire cages). They reported an average decrease in weed biomass from 91 to 44 kg/ha (81 to 39 pounds/acre) in the subsequent rice crop. In fields with high waterfowl activity, weed biomass was reduced from 204 to 89 kg/ha (182 to 79 pounds/acre) (Figure 4). Despite these reductions, there were no significant yield differences between rice crops from areas that were visited by waterfowl and those where waterfowl were excluded. These results suggest that either the weed densities were not sufficient to impact yield or that producers were adequately controlling their weeds through other management approaches. This would also suggest that direct benefits from waterfowl activity might be confined to extremely weedy fields or cases where producers are not depending on herbicides for weed control. These research findings might not apply to areas where red rice is the dominant weed species.

Attracting large numbers of waterfowl to ricelands could have a detrimental effect on weed control if seeds are transported to fields by internal passage in the gut or on the feet and feathers of birds (Powers et al. 1978). De Vlaming and Proctor (1968) demonstrated that waterfowl can excrete seeds in a viable form. However, when Powers et al. (1978) examined the viability of seeds of 17 species of plants collected from the guts of 7 species of waterfowl, they found that only 2.5% of those seeds germinated under laboratory conditions. In a feeding experiment, none of the red rice seeds fed to captive waterfowl remained intact after passing through the intestinal tract. Germination rates of other plant species varied; no germination was recorded from voided barnyard grass seed, less than 1% of pink smartweed (*Polygonum pensylvanicum*) seeds germinated, and germination of sprangletop (*Leptochloa fascicularis*) varied between 7–57% (Powers et al. 1978). Thus waterfowl may act as dispersers of some wetland plant species, but appear unlikely to add to the weed loads for the economically important species such as red rice and barnyard grass.

FIGURE 6 Average biomass of winter weeds in ricefields under different treatments of post-harvest treatment and winter-water management, Mississippi Alluvial Valley, 1995–97. No data were collected between harvest (September–October) and the December 10 sampling date. Data from Manley (1999).



Expanding the area of ricelands managed for winter wetland and waterfowl habitat requires identifying agronomic practices that minimize costs and maximize financial returns. There must be a tangible economic benefit to producers—either reduced input costs, increased production, or income from hunting or ecotourism. Otherwise, additional benefits will be needed in the form of tax legislation or other incentives to promote and sustain management practices that provide winter wetlands and waterfowl habitat. For much of the MAV the current and historical incentive for winter water and rice straw management has come through revenues received from the hunting industry and a general interest in wildlife. In California the same was true until legislation to reduce rice straw burning was enacted and became the primary driving force for winter water management. In neither of these areas has winter wetland and waterfowl management improved agricultural economics enough to be the sole incentive for expanding the area managed. This suggests that agronomic impacts of winter wetland and waterfowl management do not clearly and easily translate into improved producer income.

The costs associated with winter wetland and waterfowl management include the expense of purchasing, moving, and holding water, and post-harvest straw management. In much of the MAV, water is pumped from underground sources with no imposed limits on the amount of water used. Water costs are low because the simple closing of water-control structures will, on average, impound plentiful rain and associated runoff (Manley 1999). However, in the Texas rice prairies, winter water is mainly available in roost or rest ponds sourced from irrigation companies or pumped from wells or adjacent creeks in early fall, at considerable cost to the landowner (Hobaugh et al. 1989). The price for pumping water from underground wells ranges $10–$35/AF, while direct purchase of water during the rice irrigation season is a minimum of $30/AF (Hobaugh et al. 1989). During wet winters, most ricelands in Texas maintain standing water, with reservoirs receiving excessive use by waterfowl during dry winters. Reduced water availability and increasing costs are of concern in this region. In California, water is purchased and there are existing restrictions on the amount of water producers can use. Water for winter wetlands is expensive, averaging $15–$20/AF in the fall. Since fields are typically flooded to an average depth of 15 cm (0.5 feet), this results in an additional expense of $43.24/ha ($17.50/acre), and with labor the amount increases to $53.13/ha ($21.50/acre) (Williams et al. 2001). Growing population demands in California and increased competition for available water supplies will likely limit water use in the near future.

Winter water management follows post-harvest management actions such as disking fields prior to flooding, rolling wet or dry straw over soil, chopping straw and post-flooding incorporation. In California, open-field burning without flooding costs an average of $6.65–$7.40/ha ($2.70–$3.00/acre), while costs of chopping, rolling, tilling, or disking can range from $74.15–$197.70/ha ($30.00–$80.00/acre) (Brouder and Hill 1995). On average, straw incorporation and winter water management costs growers in California $91.45/ha ($37.00/acre), a considerable increase over the traditional methods of burning straw residue (Horwath and van Kessel 2001).

In one of the first efforts to undertake a more comprehensive analysis of the costs and benefits of winter water management, Manley et al. (2005) indicated that winter water increased straw decomposition, reduced winter weeds, and improved soil retention and water quality in the MAV. Accordingly, they suggested that by leaving stubble in the field and holding winter water until 1 March, producers could eliminate two passes of a disk in fall at savings of $34.22/ha ($13.85/acre). In the MAV, costs of winter flooding are low, provided much of the water is impounded rainfall. But if levees have to be refurbished to retain winter precipitation, this would add $3.76/ha ($1.52/acre). Finally, if an aerial application of herbicide could be omitted, a direct savings of $28.71/ha ($11.62/acre) would be realized. Other producers in Mississippi have estimated that winter flooding has saved up to $49.42/ha ($20.00/acre) on chemical and tillage costs (Muzzi 1994).

In a three-year study that measured the effect of rice straw management and winter flooding, Anders et al. (2000) reported that all field operations involved with developing or maintaining a winter wetland resulted in additional costs that were not offset by increased soybean yields. Thus net returns from soybeans were lower (Table 2). The treatment combination that increased costs the most was pumping the field to establish an early-season flood. This practice is common for producers that sell hunting rights for specific fields. It is not known what the impact on the hunting industry would be if a much greater number of producers managed winter wetland and waterfowl habitat for the purpose of commercial hunting leases. It would appear that to remain viable there would need to be a corresponding increase in waterfowl numbers. Treatment combinations that only impounded water were less expensive and produced net returns close to those where nothing was done. These results indicate that the cost of providing winter wetland and waterfowl habitat in a rice-soybean rotation would be between $12.35–$24.70/ha ($5.00–$10.00/acre)

Studies measuring straw decomposition and fertilizer N efficiency report 12–19 kg N/ha (10.7–16.9 pounds/acre) increased N uptake from fields where straw was retained. These amounts translate to a monetary value of $2.04–$3.23/ha ($0.83–$1.31/acre) if the N source was urea priced at $160.00 Mg ($142.40/ton). These values are unlikely to interest producers in managing ricelands as winter wetland and waterfowl habitat.

Finally, the social value of managing ricelands to enhance waterfowl habitat could likely become an issue for California producers. Much of the MAV and Gulf Coast areas receive sufficient winter rainfall to provide various levels of riceland flooding. This approach may prove to be the most cost effective for producers, but will not necessarily provide ideal waterfowl habitat through the winter season. Regardless of how each area addresses these constraints, there will be additional costs associated with winter water and straw management, and these costs must be recovered through cost savings, incentives, and recreational income.

RECOMMENDATIONS FOR RESEARCH AND EDUCATION

The following research needs are provided in order of priority.

1. A full economic understanding of the impact of managing ricelands to enhance winter wetland and waterfowl habitat.
   a. An economic assessment of the interaction between winter wetland and waterfowl habitat and the sporting industry, to include impacts if significantly larger areas were actively managed.
   b. Costs involved in developing and maintaining winter wetland and waterfowl habitat as compared to returns on that investment in a range of crop rotations and land tenure agreements.

Most lacking in the literature reviewed for this chapter was an in-depth cost analysis that provided insights on the economic benefits of managing winter wetland and waterfowl habitat as currently practiced. Such a study could take the form of surveys given to producers and hunters. This study could also quantify costs of maintaining winter wetland and waterfowl habitat along with some of the perceived benefits. A number of scientists identified potential benefits in cost savings or increased production from winter water management but did not provide in-depth economic analysis. This analysis needs to be completed either on existing studies, additional field studies, or surveys. It must take into consideration the wide range of land use agreements (owner, leaser) that exist and how winter wetland and waterfowl management impacts all parties. The selling of winter wetland management to additional producers will not be possible without some perceived benefits to both producers and society, nor will government be able to provide producers with an equitable incentive for winter wetland and waterfowl management without this knowledge.

2. Conduct a series of medium- to long-term studies that better identify processes directly impacted by winter wetland and waterfowl management.

This work would build on existing studies and provide a better understanding of how managing ricelands for wildlife would fit into a future rice industry. These studies would focus on producers' fields with supporting research station studies and would contain economic components. These studies would strengthen the important link between the rice industry and natural resource conservationists.

3. Develop a set of extension recommendations that allows producers to take full advantage of the agronomic benefits of winter wetland and waterfowl management.

The advantage of a lower weed biomass, reduced red rice, improved nitrogen dynamics, and less residual straw mass will help persuade producers to adopt winter wetland management practices. Without any guidelines on how to do this, there will be an extended time to adoption and a large number of producers will revert back to more traditional management approaches. Producers who can manage ricelands in a way that takes the full and utmost advantage of winter water will continue this best management practice with or without government subsidies.

SUMMARY

The number of studies on the agronomic effects of winter riceland management for waterfowl habitat is limited (Table 3). Managing ricelands as winter wetlands will aid in the decomposition of rice straw, a process that is enhanced when waterfowl are present. Retaining rice straw and winter water can eventually improve nitrogen uptake in a subsequent crop. This benefit may take up to three years to manifest itself and will apply to areas where rice is continuously grown. How this process might benefit areas where rice is grown in rotation with other crops has not been researched and would require a long-term approach to be properly documented. Straw retention and a controlled winter flood can significantly reduce runoff water volume along with sediments and nutrients in runoff water. Reductions in suspended and dissolved solids via runoff water will directly improve water quality in lakes, streams, and rivers. However, other water-quality issues such as dissolved organic carbon and bacteria may complicate management of rice straw and winter wetlands in the future.

Winter wetland and waterfowl management results in a lower weed biomass and reduced weed viability in the early spring. Waterfowl feed on weed seeds and may be effective in reducing red rice and other weed species. These processes and activities have the potential to benefit producers by reducing production costs or increasing crop yields. However, there is little direct proof that this is the case. There is a reasonable understanding in the scientific community of the physical and chemical processes that are altered through straw and winter water management in ricelands but little information on exactly how this will directly benefit rice producers. In order to increase the rate of adoption of winter wetland and waterfowl management, agronomic impacts must be better understood, and directly tied to producer economics through cost savings, increased production, tax legislation and financial incentives, and recreational income. This gap between practice and profit is the most important one to be filled to increase riceland management for winter wetlands and waterfowl habitat in the future.

TABLE 2 Summary of pooled net returns for the top ten treatment combinations in a study comparing soybean yields under different rice straw management, winter flooding, tillage, and irrigation from 1997 to 1999 at the University of Arkansas Rice Research and Extension Center, Stuttgart, Arkansas. Data from Anders et al. (2000).

RICE STRAW	WINTER FLOODING	TILLAGE	NET RETURNS $ ha^{-1}
standing	drained	no-till	393.52
rolled	rainfall	no-till	383.84
standing	rainfall	no-till	382.97
standing	drained	conventional	360.64
rolled	drained	conventional	321.89
standing	rainfall	conventional	303.41
standing	pumped	no-till	254.66
rolled	pumped	no-till	250.68
rolled	rainfall	conventional	232.52
standing	pumped	conventional	205.01

*Calculated at a soybean price of $222.00 t^{-1} and a 25% land cost

TABLE 3 Review of studies with treatments or measurements relevant to the agronomic impact of winter wetland and waterfowl management in ricelands.

CROP	IMPOSED VARIABLES	DATA COLLECTED	ANALYSIS	SOURCE
Soybeans	Rice straw management Winter flooding	Soybean yields Field operations	Treatment effects Net returns	Anders et al. 2000
Rice	Rice straw management Waterfowl foraging	Rice straw decomposition Soil nitrogen and carbon	Full analysis N & C	Bird et al. 2000
Rice	Rice straw management Winter flooding Nitrogen fertility	Rice yields Nitrogen uptake N use efficiency		Eagle et al. 2000
Rice	Rice straw management Winter flooding	Crop N uptake Fertilizer N use efficiency		Eagle et al. 2001
Rice	Rice straw management Winter flooding	Straw decomposition Weed biomass Red rice viability Red rice biomass	Full analysis Economic	Manley 1999
Rice	None	Red rice seed	Mean values	Smith and Sullivan 1980
Rice	Rice straw management Waterfowl foraging	Rice straw decomposition Weed biomass Rice yields	Mean values	van Groenigen et al. 2003
Rice	Rice straw management Green manure N fertilizer rates	Rice straw yield Rice grain yield N uptake	Mean values	Williams et al. 1972

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