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EXPANSION OF IRRIGATION IN THE MID SOUTH UNITED STATES: WATER ALLOCATION AND RESEARCH ISSUES

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ABSTRACT

Irrigated lands in the Lower Mississippi River Valley (LMRV) surpassed 6.5 million acres (2.6 million ha) in 1997 and are increasing at a rate of 189,000 acres (77,000 ha) per year. Arkansas is experiencing the most rapid increase in irrigation and had more than 4 million acres (1.62 million ha) under irrigation in 1997, making it the fourth ranking irrigated state. Annual farm gate receipts in the four most heavily irrigated LMRV states, Arkansas, Missouri, Mississippi, and Louisiana, exceed $8 billion. Despite annual rainfall greater than 40 inches (100 cm), periodic summertime drought makes irrigation necessary to avoid crop failure. Little of the irrigated land is within organized irrigation districts. Rather, irrigation is mainly from wells on individual farm tracts. The increase in groundwater pumping has resulted in aquifer overdraft, particularly in eastern Arkansas, resulting in a need for surface water diversion to replace well pumping. Currently, ten irrigation projects are in the planning or construction phases in Arkansas. However, lack of scientific data about water quality, management efficiency, and environmental impacts in humid region irrigation schemes is a major impediment to project design and public acceptance, not only in Arkansas but in other Delta states. An assessment of current LMRV irrigation research activities was conducted. Over 40 research needs were identified, grouped into seven research topics, and presented.

INTRODUCTION

The USDA Agricultural Research Service (ARS) and Natural Resource Conservation Service (NRCS) collaborated on an investigation of irrigation expansion and research needs in the Lower Mississippi River Valley (LMRV) in the states of Arkansas, Kentucky, Louisiana, Mississippi, Missouri, and Tennessee. These lands are current and former flood plains of the Mississippi River and its tributaries, which are characterized by low slopes, fertile silt loam to

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clay soils, and often poor drainage. Drainage districts were the first formal organizations for farm water management. Since 1950, irrigation has increased rapidly in the LMRV, with the combined irrigated area surpassing 6.5 million acres (2.6 million ha) in 1997, almost none of it in fully functioning formal irrigation districts with surface water distribution systems. The overall rate of increase is 189,000 acres (77,000 ha) per year, most of it in Arkansas, but with steady increases in Mississippi and Missouri as well. To a large extent, the increase in irrigated area is not tied to development of irrigation districts, but is rather due to individual farm operators putting in wells for irrigation.

Farm gate receipts in the most heavily irrigated states (Arkansas, Mississippi, Missouri and Louisiana) exceed $8 billion annually. In eastern Arkansas, irrigation now covers more than 4 million acres, making it the fourth ranking irrigated state. Irrigation from wells on individual farm tracts accounts for 85% of water removed from the Alluvial and Sparta aquifers (the major eastern Arkansas aquifers); and increased pumping has resulted in aquifer overdraft. Large areas of eastern Arkansas are now designated as critical ground water zones. Despite yearly rainfall of greater than 40 inches (100 cm), droughty periods make irrigation requisite for an economically viable agriculture, which contributes >$3 billion annually to the Arkansas economy. Stream flows in the region are more than adequate to replace well water with surface diversions, but require the formation of irrigation districts to manage water distribution. Ten irrigation project areas have been identified and some planning done. Four of these are in some stage of completion through cooperative actions of local, state, and federal agencies. However, lack of scientific data is a major impediment to project design and public acceptance, not only in Arkansas but in other Delta states.

In the 1978 to 1997 period, irrigated acreage in the western states declined by 0.6%, while in the southeastern states, irrigated acreage increased by 70% or 3.8 million acres (1.5 million ha) (Fig. 1). For this analysis, the states of Louisiana, Arkansas, Missouri, and points east are considered southeastern states. Since 1978, irrigation expansion has occurred entirely without large federal or state projects, and has been the responsibility of individual farm operators who obtain water from wells drilled on their property or water that they divert from adjacent stream or drainage flows. In contrast to the large federally funded projects in the West, which were supported historically by a strong university, USDA-ARS, and USDA-NRCS research and extension effort, irrigation expansion in the last 25 years has largely occurred without strong research and extension efforts in the affected states, with the exception of Nebraska. This view is supported by the fact that roughly three quarters of the ARS irrigation research scientists are located in the western states. Just five ARS water management research scientists are located in the LMRV and four of those are dedicated almost entirely to drainage research, although they had previously done research on sub-irrigation. The sub-irrigation practice has been adopted fairly widely in Florida and North Carolina, with some use in South Carolina (Fouss, 2002).

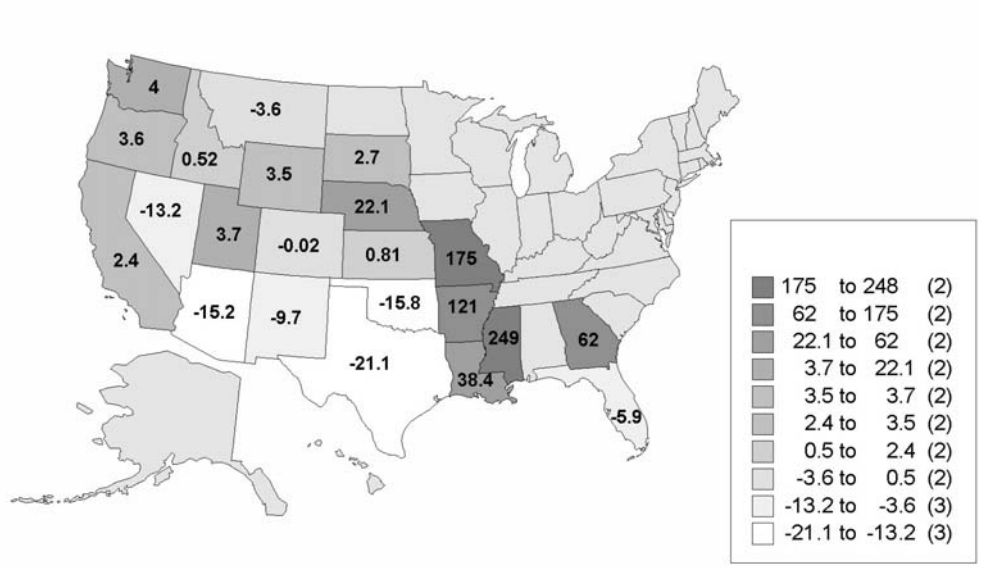

Figure 1. Percent change in irrigated area from 1978 to 1997 for the 22 highest ranking irrigated states.

IRRIGATION IN THE LOWER MISSISSIPPI RIVER VALLEY

Until recently, drainage districts were the only formal water management organizations in the Lower Mississippi River Valley. Both the French and Spanish recognized drainage as an essential water management practice in Louisiana, and tied the granting of lands to individuals to the establishment of a drainage system. However, the federal interest in drainage came much later with the Swamp Land Grants of 1849 and 1850 (Harrison, 1961). Under these federal acts, Arkansas and Louisiana received 9 and 12 million acres (3.6 and 4.9 million ha), respectively, to be sold with the proceeds to be used for land reclamation. Most of these funds were used to build levees along the Mississippi River. Organized drainage enterprises began in Arkansas in 1869 when a state statute provided that special improvement districts could be organized for drainage purposes (Harrison, 1961). However, drainage only became practical after 1900 when flooding by the Mississippi had been adequately controlled. Hundreds of drainage districts had been formed in the LMRV and 8.6 million acres (3.5 million ha) were drained by 1960 (Harrrison, 1961). The drainage districts allowed farming to flourish. Irrigation began increasing rapidly after World War II due to the drought of the 1950s, the increasing mechanization of agriculture, and the frequent occurrence of droughty summer periods. In 1997, some 6.5 million acres (2.6 million ha) of land were irrigated in the LMRV using 9.1 million acre-feet (1.1×10^{10} m^3) of water yearly, 85% of which was from groundwater (Solley et al., 1998). The major irrigation types were sprinkler (21.5%) and surface irrigation (71.4%) (Solley et al., 1998). Since 1974, irrigation in Arkansas, Mississippi and Missouri has increased linearly at an aggregate rate of 189,000 acres (76,500 ha) per year, despite increasing aquifer overdraft in some of the older irrigated areas. There is no reason to expect that farmers will not continue to exercise their right to drill wells or pump from streams to support new irrigation systems.

Land owners in Arkansas have riparian water rights and rights to groundwater based on common law (Harper, 1956). Historically, the situation was much the same in the other LMRV states. However, in Mississippi, recent state law has reserved surface water rights for the State. Consequently, surface water distribution and irrigation projects in Mississippi will be organized at the state level by the Yazoo Mississippi Delta Joint Water Management District, which was formed in 1989 (YMD, 2002). Most irrigation expansion in the LMRV has been on individual farm tracts that acquire water from wells, and from adjacent drainage channels and streams where available. Irrigation districts for the distribution of surface water were virtually unknown in the region until recently. Nonetheless, the growth of irrigation has been rapid since World War II in the LMRV, particularly in Arkansas, which currently has more than four million irrigated acres, and to a lesser degree in Mississippi and Missouri, which have 1.08 And 0.88 million irrigated acres, respectively (Fig. 2). The recent formation of irrigation districts, particularly in Arkansas, is occurring largely in areas already heavily irrigated by individual farm operators, and represents an attempt to address groundwater decline problems by a combination of two approaches: (i) water conservation and management using on-farm storage reservoirs, tail water recovery systems, replacement of open ditches with underground pipelines, and improvements in irrigation methods; and (ii) replacement of well water sources with surface water sources.

Irrigated acreage in Kentucky and Tennessee totaled 58 and 46 thousand acres in 1997, respectively (NASS, 1998c). However, Kentucky has only a small irrigated area in the LMRV. In Tennessee, there are about 30,000 acres (12,000 ha) of irrigated land in the LMRV, most of it irrigated by center pivot sprinklers (Buchanan, 2002). Although of local economic importance, these acreages do not have significant regional economic impact.

Missouri, in 1997, had more than 800,000 acres (324,000 ha) of irrigated land, 93% of it in the southeastern Bootheel, 41% of it under center pivot sprinklers, and most of the rest in furrow irrigation. In the Bootheel, 42% of irrigated fields are laser leveled or graded. The Bootheel of Missouri has soils and terrain similar to those elsewhere in the LMRV. In 1997, corn occupied 33% of irrigated land, followed by soybean on 31%, cotton on 16%, and rice on 13% (NASS, 1998e). In Missouri, rice is entirely irrigated, and 35% of cotton, 12% of corn, and 6% of soybean acreage is irrigated. The market value of all crops in Missouri was $5.37 billion in 1997. Henggeler (2000) estimated that $95 million of market value was lost due to yields of irrigated crops being below attainable yields. He recommended support for research on irrigation scheduling because correct scheduling had the most potential for improving yields. On corn, cotton and fullseason soybean, irrigation amounts and number of applications are approximately one half of what they should be for yield goals of 190 bu/ac (11,900 kg/ha) of corn, 1000 lbs/ac (1120 kg/ha) of cotton, and 60 bu/ac (3800 kg/ha) of soybean (Henggeler, 2000). These are conservative yield goals.

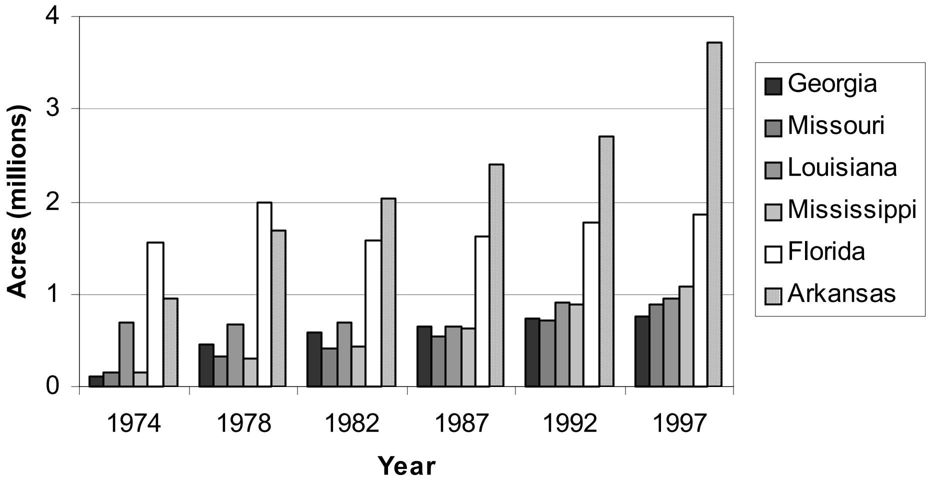

Figure 2. Irrigated acreage in the six highest ranking irrigated eastern states, which includes four of the Lower Mississippi River Valley states (Source NASS, 1998a). Data from the 2002 census are not yet available.

In Mississippi, irrigated acreage grew from 161,000 acres (65,000 ha) in 1974 to 1,076,000 acres (436,000 ha) in 1997, most of it in the LMRV of western Mississippi, including the Yazoo and Mississippi river drainages (NASS, 1998a). In 1997, soybeans occupied 41% of irrigated land, followed by cotton on 28%, rice on 22%, and corn on 8%. The major crops in Mississippi are cotton, corn, and soybean in order of decreasing economic importance. About 24% of corn acreage, 29% of cotton acreage, 24% of soybean acreage, and all rice acreage is irrigated. The market value of all crops was $1.29 billion in 1997. Most irrigation uses water pumped from the Alluvial Aquifer, which underlies about 7,000 square miles (18,000 km^2) in 19 counties of western Mississippi. Water pumped from the aquifer has increased from 745 million gallons (2.8 million m^3) per day in 1975 to approximately 2 billion gallons (7.6 million m^3) per day in 1994, and is expected to increase with rapid increases in irrigation for rice and row crops, and with increases in catfish production and industrial use (Arthur and Strom, 1996). There is concern that Mississippi will experience the aquifer declines already evident in Arkansas; and the Alluvial Aquifer is being closely monitored cooperatively by the USGS and the YMD Joint Water Management District (Pennington, 2002). To date, irrigation pumping in Mississippi has not explored the deeper-lying Sparta Aquifer, the main source of drinking water in the region, to any great extent.

In Louisiana, irrigated acreage has not changed as rapidly and consistently as in Arkansas and Mississippi, increasing from 702,000 acres (284,000 ha) in 1974 to just 943,000 acres (382,000 ha) in 1997 (NASS, 1998a). Rice is planted on 61% of irrigated land, cotton on 17%, corn on 9.7%, and soybean on 8.6% (NASS, 1998d). Sugar cane is almost entirely non-irrigated; but surface drainage is practiced on most sugar cane fields. Drainage here involves a combination of precision graded fields, shallow drainage ditches, and "quarter drains" formed annually to divert runoff across rows to the closest ditch. Sugar cane acreage was 396,000 acres (160,000 ha) in 1997, up from 356,000 acres (148,000 ha) in 1992. The market value of all crops in Louisiana was $1.41 billion in 1997. While all rice is irrigated, just 22% of corn, 25% of cotton, and 6.4% of soybean are irrigated (NASS, 1998d). This leaves the potential for more irrigation, particularly in the Mississippi River Valley of northern Louisiana (Fouss, 2002); but there is little sign of rapid increases in irrigated acreage there.

According to Harper (1956), "Irrigation began in Arkansas in 1904 near Lonoke when seventy acres (28 ha) of rice was planted". By 1915, there were 100,000 acres (40,000 ha) of rice, and by 1949, 350,000 acres (142,000 ha) of rice plus 85,000 acres (34,000 ha) of other crops irrigated in eastern Arkansas (Harper, 1956). Today, there are more than 8 million acres (3.2 million ha) of cropland in eastern Arkansas of which greater than 50% are irrigated, making Arkansas the fourth ranking state by irrigated acreage. The adoption of irrigation is motivated by risk aversion on the part of lenders and farmers. Although Arkansas receives >40 inches (100 cm) of rainfall annually, droughty periods in the summer frequently cause large yield losses. Even short droughts are problematic due to the shallow root zones and thus small water holding capacities of the many soils affected by root-limiting fragipans and tillage pans. Rice is entirely irrigated and makes up 42% of U.S. production on 1.6 million acres (650,000 ha). Farm gate receipts for all crops in eastern Arkansas exceed $3 billion. Irrigation methods include flooding (mostly on rice) on 40% of the land, sprinkler on 14% of the land (NASS, 1998c), and furrow and border irrigation on the rest. The four crops with the most irrigated acreage are rice (58%), soybean (25%), cotton (10%), and corn (3%) (NASS, 1998a). In addition, Arkansas produces >80% of the nation's bait fish, and ranks second in catfish production. Approximately 60,000 acres (24,000 ha) of aquaculture ponds produce more than $100 million in farm gate receipts and greater than $600 million in sales of processed and unprocessed products.

On average, irrigation in Arkansas uses 7.5 million acre-feet (9.3×10^9 m^3) of water yearly, 85% of it from groundwater pumping. Aquifer overdraft is on the order of 20%. Over 1.6 million acres (650,000 ha) of eastern Arkansas land is in areas designated as critical groundwater areas due to overdraft, according to the Arkansas Soil and Water Conservation Commission (Fig. 3). This area is expected to increase rapidly at current pumping rates. Also, some 580,000 acres (235,000 ha) experience high salt levels in groundwater due to salt intrusion exacerbated by aquifer overdraft. Since 1985, the USGS has cooperated with the ASWCC in measuring and modeling ground water levels to document and project areas of critical overdraft in the two major aquifers of eastern Arkansas, the

Alluvial and Sparta (Hays and Fugitt, 1999; Hays et al., 1998; Schrader, 2001; Joseph, 1999, 2000; Mahon and Poynter, 1993; USGS, 1985). Depth to water table is measured in 320 wells; and these measurements have been used for model testing and verification, resulting in reliable forecasts of water table decline.

Groundwater overdraft problems were recognized as early as 1939 (State Planning Board, 1939); but active planning for irrigation improvements began in the 1980s in response to the rapid increase in irrigated acres (Fig. 2) and resulting groundwater declines. Planning and action have involved cooperation by multiple agencies including the Arkansas Soil and Water Conservation Commission (ASWCC), USDA-NRCS, U.S. Army Corps of Engineers, and USGS. In 1987, the Eastern Arkansas Water Conservation Project quantified existing irrigation efficiency problems (USDA-SCS, 1987). Irrigation application efficiency measured on farmers' fields averaged 65% for paddy rice and 83% for sprinkler irrigation, with furrow irrigation somewhere between those values. The 1987 report was followed by the Eastern Arkansas Region Comprehensive Study (1989), which established the feasibility of surface water development to replace pumping for irrigation. The second Arkansas Water Plan assumed that demand for water would increase greatly, largely due to increases in irrigated cropland (ASWCC, 1990). It also recommended that surface water diversions be used to meet the increased demands and to reduce ground water depletion, and that regional irrigation districts be formed to manage these resources. Diversions were envisioned from the Arkansas, White, Black, Bayou de View, and L'Anguille Rivers. Irrigation water conservation improvements were also recommended.

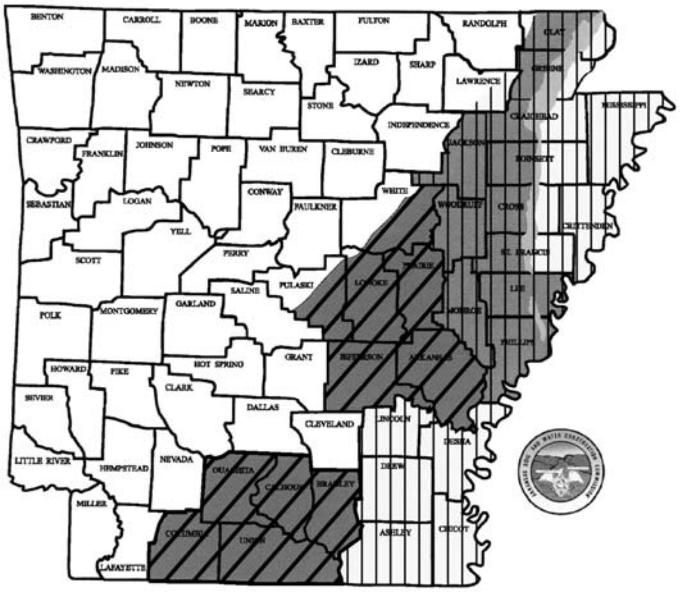

Figure 3. Arkansas critical groundwater areas (diagonal hashing) and study areas (vertical hashing) (Source: ASWCC, 2001)

To date, ten irrigation project areas have been identified (Fig. 4) covering 1.74 million acres (704,000 ha). It is estimated that without these projects >1 million acres (405,000 ha) of irrigated land will be lost by 2020. Assuming that 50% of the irrigated land lost would convert from rice to non-irrigated soybean production and that 50% of the loss would be from irrigated to non-irrigated cotton, the economic loss would exceed $200 million yearly based on average commodity prices for 2000-2002 (World Bank, 2002) and on mean irrigated and non-irrigated yields (NASS, 1998b). All of the proposed projects include plans for water conservation. Some of them are completely based on water conservation features and have no surface water distribution component.

Water conservation practices most commonly used are on-farm storage reservoirs, tail water recovery systems, and pump and pipe systems to (i) transfer water from tail water pits back to reservoirs, (ii) distribute water to fields, and (iii) re-lift water from drainage canals and bayous into reservoirs and fields. With these practices, much of the runoff from rainfall is captured for irrigation use. This is particularly important for storage of off-season rainfall. The existing drainage canals are implicitly included in these systems, serving as they do to capture diffuse runoff and re-distribute it for capture by downstream farmers. This re-use of drainage and runoff waters undoubtedly increases system-wide water use efficiency, but to an extent that is currently unknown (but, see the paper by Clemmens and Carman in these proceedings). Also, drainage waters that are re-used typically deposit sediment in farmers' fields; but the improvement in water quality engendered by this practice is also not quantified. Finally, extensive re-use of drainage waters, while increasing system-wide water use efficiency, may result in less water in bayous and wetlands, the effects of which also need study.

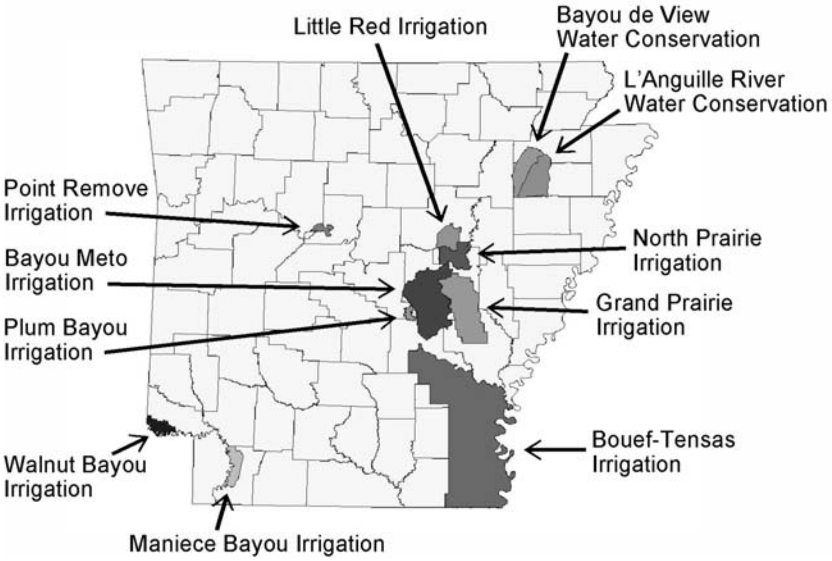

Figure 4. Irrigation project areas as of 2002. The two water conservation districts are subunits of the Northeast Arkansas irrigation area (Source: NRCS).

The White River (Grand Prairie) Irrigation District is exemplary of modern irrigation projects in Arkansas. The district is the site of the U.S. Army Corps of Engineers (COE) Grand Prairie Demonstration Project, which will affect about 240,000 irrigated acres (97,000 ha). The first stage of the project is the construction of water conservation measures, which entail on-farm storage reservoirs, tail water pits, pipelines, and pumping systems, including re-lift pumps to take diffuse runoff from drainage canals and streams and store it in reservoirs. Construction is funded 65% by the COE and 35% by individual farmers. As of early 2002, 228 contracts had been signed, including 109 reservoirs, 43 re-built reservoirs, and associated pipelines and pumps. At that time, 60 reservoirs, 81 tail water pits, and 60 miles (97 km) of pipeline had been installed. The completed and contracted construction of conservation measures in early 2002 involved about one quarter of the total project area. However, even at this level of project completion, it is becoming apparent that most of the diffuse runoff is being captured. This is a sure sign that water diversion from the White River will be necessary to deliver adequate irrigation water to the project and reduce groundwater pumping. Also, it is likely that crops other than rice are currently under-irrigated, as has been documented in the LMRV of Missouri (Henggeler, 2000). Although proper irrigation scheduling is known to increase water use efficiency (Howell, 2001), it probably will also increase water use throughout the system. The second stage of the project will involve diversion of water from the White River through a system of canals and pipelines to farm tracts. The pumping plant at the diversion point will have a maximum capacity of 1,640 cubic feet per second (46 m^3 s^{-1}). The COE estimates that without the project, irrigated cropland would decrease by 77% in 2015, resulting in a decrease of $46 million annually in farm gate receipts in the project area alone. Because farm real estate value is much less for non-irrigated land, the value of farmland in the area would decrease by >$100 million (Army Corps of Engineers, 2002).

Water quality issues have gained in importance in the 1990s. The Arkansas Governor’s Water Resources Task Force report recommended development of a water quality research plan and the identification of gaps in existing research infrastructure, along with providing support to leverage federal research funds and federal/state research partnerships (Rockefeller, 2001). Also recommended was the provision of resources to improve Arkansas’ water quality monitoring program, including development of TMDLs and implementation of non-point source reduction programs. The Arkansas Department of Environmental Quality (DEQ) currently monitors 141 stream stations monthly. The USGS monitors stream gaging and water quality stations in Arkansas and in 2000 reported on 81 surface-water gaging stations and 62 surface-water quality stations. However, funding cuts had reduced water quality stations by 136 and stream gaging stations by 43 prior to the 2000 report, leaving large areas of Arkansas with sparse data on stream flows and water quality (Porter et al., 2000). The Task Force supported completion of the Grand Prairie Demonstration Project and of the White River

Comprehensive Plan, and recommended that ASWCC be enabled to revise the State Water Plan. The Task Force also recommended a strong education effort at K-12, university, and community levels. It is notable that the education emphasis was completely on water quality, not on water quantity concerns, even though the latter are critical in Arkansas. Additional educational efforts needed include improving the public's understanding of water quantity needs and alternatives for supplies, and education of farmers in more efficient irrigation methods, management and equipment. However, much of this information must come from irrigation research that has yet to be done.

STATUS OF IRRIGATION RESEARCH AND SUPPORT

Information on the current state of irrigation research and on current and future research needs was gathered during site visits to sixteen local, state, and federal organizations in Arkansas, Louisiana, Mississippi, and Missouri; and contacts made with irrigation specialists in Tennessee and Kentucky. In contrast with the rapid growth of irrigation, there is relatively little irrigation research occurring in these states. The University of Arkansas (UA) has two scientists devoted mostly to irrigation, one in research and one in extension. In addition, two UA scientists do some work on cotton and rice irrigation. Most irrigation research is devoted to agronomic considerations (row spacings, fertilization levels, scheduling of irrigation termination, no tillage, etc.), but there is some comparative work on irrigation methods, and a small program in crop water use determination. There are extension publications providing guidance for rice and soybean irrigation. Also, UA scientists have developed an irrigation scheduling computer program, the Arkansas Scheduler; but adoption by farmers is slow as has been seen for similar programs in other states. Little work is being done on water quality or quantity questions related to irrigation.

Mississippi State University has two irrigation specialists with research and extension appointments who also work on improving agronomic practices. Louisiana recently appointed its only irrigation specialist. The University of Missouri has one irrigation engineer (100% extension) in the Bootheel who has some applied research underway on irrigation scheduling methods. There is also an engineer in the Department of Biological & Agricultural Engineering at Columbia, MO, who does irrigation research. The USDA Agricultural Research Service has no irrigation researchers in Arkansas or Missouri and only one in Mississippi, where an irrigation research program began at Stoneville in 2001. The project plan for the Mississippi program is currently being written. At Baton Rouge, LA, four ARS scientists are fully committed to working on water quality and management related to drainage of sugar cane and other crops important to the region (corn, soybean); but surface irrigation work is a minor part of the work there. Key work has been completed on water table control for sub-irrigation using subsurface drainage systems with controls on the drain outlet structure.

In addition to the extension irrigation specialists in Arkansas and Missouri, the NRCS has an Irrigation & Water Quality Project Office at Dexter, MO, with four employees who develop irrigation plans and system improvements. The NRCS also has the Grand Prairie/Bayou Meto Irrigation Office in Lonoke, AR, where a nine-member interdisciplinary team composed of engineers, biologists, and conservationists develops plans for on-farm water conservation improvements, including reservoirs, tail water recovery systems, pipelines and pumps, for the 240,000-acre Grand Prairie and 276,000-acre Bayou Meto projects.

Among the locations visited, there was unanimous recognition of needs for additional irrigation research to solve problems faced by farmers, natural resource managers, and policy makers. Over 40 research questions were identified, which were condensed into seven topic areas:

- Irrigation Efficiency at Field, Farm, and Watershed Scales
- Irrigation Methods/Management, including scheduling, weather forecasting, reservoir – tail water capture systems
- Water Quality/TMDL Issues at Farm and Watershed Scales
- Social Issues, including social effects of loss of sustainability
- Soil - Irrigation Interactions
- Irrigation Project Design and Management
- Production Practices/Agronomics

IN CONCLUSION

There is strong debate in Arkansas on the wisdom of diverting surface water from rivers for irrigation. The debate centers around effects of diversion on important sport fisheries, on riparian wildlife and habitat, on maintenance of adequate stream flows during the summer months, and on water quality. This generates a demand that we demonstrate that water diverted for irrigation is used as efficiently as possible, and that environmental impacts of well designed and operated irrigation schemes are low. Irrigation water use efficiency at field, farm, and project levels; irrigation effects on water quality; and irrigation project design alternatives to improve overall water use efficiency are research topics that are of critical importance to the successful transition from groundwater to surface waters for irrigation in eastern Arkansas and the LMRV in general, and thus for the continued economic success of agriculture in the region. Because the true project-wide efficiency is influenced strongly by re-use of drainage and runoff waters at points downstream, these are also topics that require a watershed approach to irrigation research that is beyond the scope of current University research activities, which focus on agronomics, management, soils, and production practices. Because diffuse runoff from irrigated fields is a fact of life in the sub-humid Mid-South and eastern states, and because runoff goes to man made and natural drainage ways, a watershed approach to water quality research is also required.

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