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Opinions on Irrigation Water Management Tools and Alternative Irrigation Sources by Farmers from the Delta Region of Mississippi

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Abstract: Water withdrawals for irrigation at an unsustainable rate resulted in a decline in the groundwater levels in the Mississippi River Valley Alluvial Aquifer (MRVAA) in the central southern USA. This drawdown of groundwater threatens agricultural production in the Mississippi Delta, an important agricultural region in the state of Mississippi, USA. Effective and efficient use of available resources is important to sustain and enhance agricultural productivity in this area. This study assessed the opinions of farmers on water conservation management practices and technologies that improve irrigation management and save water in the Mississippi Delta region based on data collected in an irrigation survey conducted in 2012. Most landowners believed that water conservation practices were effective in reducing irrigation water use without reducing maximum crop yields and have a positive return on investment. Land forming, tailwater recovery system, on-farm storage, instream weirs to pond surface water, computerized hole selection for furrow irrigation, short irrigation runs, and irrigation scheduling were considered efficient water conservation technologies by landowners. Perceptions about use of different practices also depend upon the crops produced by the respondents. About 20 to 24% and 14.9 to 86% of survey respondents thought that on-farm storage and center pivot, respectively, were inefficient water conservation practices for irrigating crops in the Mississippi Delta. The adoption of these practices may be increased if the landowners know the economic returns of implementing them.

Keywords: *computerized hole selection, center pivot, irrigation scheduling, land forming, on-farm water storage, tailwater recovery, water meters*

Groundwater is critically important for human society, as it provides an estimated 42% of agricultural water use globally (Konikov and Kendy 2005; Döll 2009; Döll et al. 2012) and in the United States (USGS 2015). The demand for water supply for agriculture is expected to increase by approximately 20% by 2050 to meet the increasing demand for food production (Vörösmarty et al. 2000; Konikow and Kendy 2005). In Mississippi, the main source of water for agricultural irrigation is groundwater extracted from the Mississippi River Valley Alluvial Aquifer (MRVAA). The MRVAA underlies 82,879 km^2 of the states Kentucky, Missouri, Tennessee, Louisiana, Arkansas, and Mississippi in the USA. These states had more than 3.9 million hectares (ha) of irrigated land in 2017 (USDA NASS Cropland Data Layer 2017). The MRVAA supplies approximately 370 million cubic meters of water per year and irrigates over 700,000 ha of row crops in the Mississippi Delta region (Wax et al. 2008; Massey 2010). Irrigated cropland has increased by 92% in 20 years from 1988 (306,000 ha) to 2008 (588,000 ha) in Mississippi (Vories and Evett

Research Implications

- Groundwater levels are declining in the Mississippi River Valley Alluvial Aquifer.
- Survey results showed a need for better farmer/landowner understanding of available water conservation practices as a means to reduce irrigation water use.
- Adoption of water conservation practices depends upon the economic returns from their implementation.

2014). Groundwater from the MRVAA contributes to over 90% of the irrigation water applied, whereas only 6 to 7% of the irrigation water is provided from surface water (Reba and Massey 2020). There has been a decline in water levels in the MRVAA due to withdrawals for irrigation that exceed its recharge rate (Wax et al. 2008). This aquifer has been reported to be declining at rates of 0.15 to more than 0.45 m per year in western Mississippi and eastern Arkansas (YMD 2013). Water withdrawals from the MRVAA are comparatively higher during the summer season, a period of high-water requirement by plants due to high evapotranspiration losses, high heat index, and low precipitation (Wax et al. 2008; Massey 2010; Kebede et al. 2014). The precipitation occurring during the remainder of the year is insufficient to recharge the aquifer and offset withdrawals (Wax et al. 2008), resulting in net declining water levels in the MRVAA. Therefore, it is important to implement better irrigation methods and technologies and agronomic management practices in this region that will increase water application and use efficiencies and reverse the current trend of declining water levels in the MRVAA.

Multiple technologies are available to farmers for better water management and higher irrigation water-use efficiency, such as computerized hole selection (CHS) (e.g., PHAUCET: Pipe Hole and Universal Crown Elevation Tool or Pipe Planner), surge valve flow irrigation (SURGE), tailwater recovery systems (TWS), on-farm water storage, sprinkler irrigation systems, and sensor-based irrigation scheduling. Computerized hole selection technology computes the flow and pressures along the length of lay-flat polyethylene tubing and selects optimal hole sizes to improve down-row uniformity across the irrigation set regardless of furrow length (Bryant et al. 2017; Spencer et al. 2019). Sensor thresholds for irrigation scheduling for soybean (*Glycine max* L.), cotton (*Gossypium hirsutum* L.), corn (*Zea mays* L.), and peanuts (*Arachis hypogaea*) have been developed by Mississippi State University researchers (Williams et al. 2018; Leininger et al. 2019). In the Mississippi Delta region, irrigation water management (IWM) practices, including those mentioned previously, reduced soybean irrigation water use and increased irrigation water use efficiency by 21 and 36%, respectively, compared to a conventional continuous-flow delivery system that utilized lay-flat polyethylene tubing attached to the well or riser head and then laid perpendicular to the furrows at the upper end of the field (Bryant et al. 2017). Integrated systems of CHS, SURGE, and sensor-based technologies improved on-farm profitability by as much as $198 per ha (Bryant et al. 2017; Spencer et al. 2019). Despite these available technologies, furrow irrigation practice has low application efficiency. Approximately 80% of the irrigated land in Mississippi is furrow irrigated, and the remaining 20% is under sprinkler or other irrigation systems. Irrigation application efficiency can be increased with the use of sprinkler systems compared to furrow irrigation methods (Sammis 1980; Cetin and Bilgel 2002). Additionally, TWS and on-farm water storage can help to conserve groundwater by facilitating the capture and re-use of precipitation and irrigation runoff (Omer et al. 2018).

Although conservation technologies exist for improved IWM, and water conservation and water quality education and extension programs are available for producers, adoption rates for IWM practices are low (Adams et al. 2013; Reba and Massey 2020). However, the impact of education programs depends on water user's attitudes, perceptions, and behavior (Adams et al. 2013). Therefore, it is important to know and understand the perceptions of farmers toward water-related issues and irrigation management practices. Surveys are one of the tools that can be used for generating information about farmers' perceptions on irrigation management practices. The objective of this paper was to assess the opinions of farmers on water conservation management practices and technologies for better irrigation management and water savings in the Mississippi Delta region, based on unpublished data from the 2012 Mississippi Irrigation Survey. Results from this study can be used for designing and implementing future research and extension programs in the state of Mississippi for better conservation of water resources for irrigation.

Materials and Methods

Mississippi State University's Survey Research laboratory conducted a survey in 2012 to evaluate farmers' opinions on IWM tools and alternative irrigation sources in the Mississippi Delta. The survey focused on all permit holders, landowners, and operators (producers) who withdraw water (surface and groundwater) for agricultural irrigation in the Yazoo-Mississippi Delta region, a region formed between the Mississippi and Yazoo Rivers in western Mississippi (Massey et al. 2017). The survey contact list was obtained from the Permit Database at the Office of Land and Water, Mississippi Department of Environmental Quality. Potential respondents identified from the Permit Database records, believed to own or hold permits for irrigation water withdrawals in the Yazoo-Mississippi Delta, totaled 1877, but only 1789 of the 1877 farmland owners and operators were used for the survey. Excluded respondents (88) were not selected because of duplicate entries or missing contact information. The survey was conducted by calling valid phone numbers. The survey was completed by 460 of the 1789 respondents, but 120 refused to complete the survey, 14 were not available at the time of the survey, 314 did not answer the phone call, 26 had issues with communication or language, 68 were either deceased or unable to speak due to health problems, and 606 had disconnected telephone numbers. Because they no longer held a permit for an agricultural irrigation well, 133 potential respondents were not included in the survey. The percentage of completed surveys based on the sum of completed responses and refusals was 79.3%.

The survey questionnaire was developed by the Mississippi State University's scientists and members of the Delta Farmers Advocating Resource Management (Delta F.A.R.M.). The Delta F.A.R.M. is an association of the growers and landowners working to conserve and restore the environment of Northwest Mississippi (https://Deltafarm.org/). The survey consisted of 13 overarching questions, most of which included additional follow-up questions. The portion of the survey questionnaire related to water conservation management is discussed in this article (Appendix 1).

Results

Importance and Opinions on Water Conservation Practices

Of the survey respondents, 52% thought the primary cause of groundwater depletion was agricultural irrigation water use, whereas 30.7% of respondents disagreed or strongly disagreed. To understand farmers' opinions on water management and conservation practices, survey respondents were asked if: a) water conservation practices are effective in reducing irrigation water use, and b) water conservation practices can reduce maximum crop yields. Respondents were given the following options to choose from: strongly disagree, disagree, neither disagree nor agree, agree, or strongly agree. Out of 460 respondents, 420 respondents (91.3%) believed that water conservation practices are effective in reducing irrigation water use, whereas only 17 respondents disagreed or strongly disagreed with the statement. About 211 respondents (45.8%) disagreed or strongly disagreed that water conservation practices can reduce maximum crop yields, whereas 186 respondents (40.5%) agreed or strongly agreed that crop yields will be reduced if water conservation practices are adopted. A total of 423 out of 460 respondents (91.9%) believed that using water conservation practices saves money, whereas only 7.4% disagreed with the statement (Figure 1). Over 47% of the respondents believed that adopting conservation practices alone could take care of the water problems in the Mississippi Delta, but 41.5% of them disagreed, and 7.2% were undecided. Respondents were asked to comment on the statement: "you can implement water conservation practices and not effectively manage water." To which 70% of respondents agreed, and 21.5% did not agree. Based on 230 valid responses, 15.2% thought it is important to

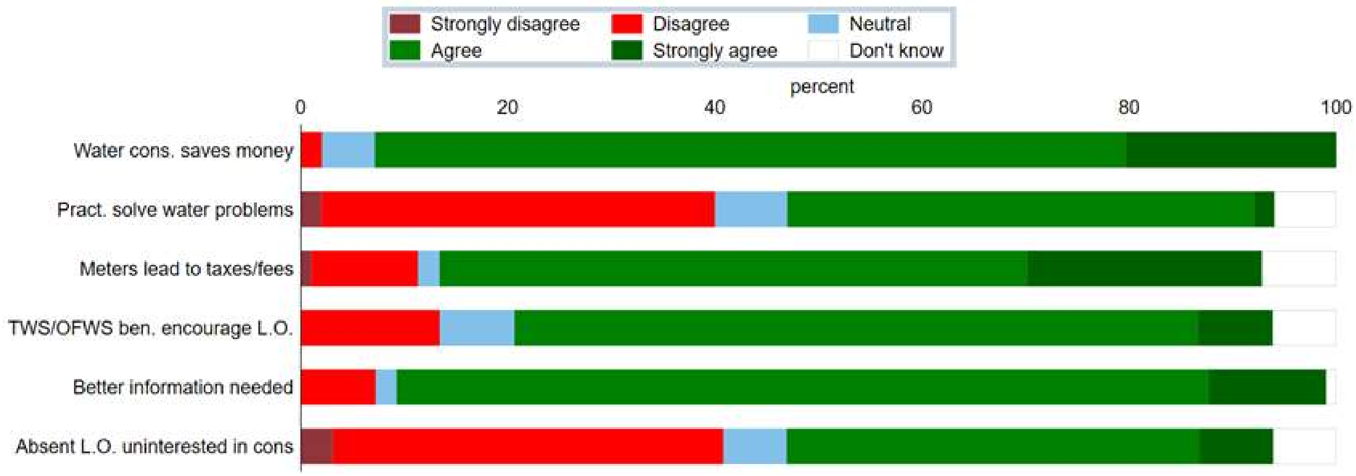

Figure 1. Survey responses to questions related to the water conservation practices in the Mississippi Delta. (Abbreviations: Pract., practices; TWS, tailwater recovery systems; OFWS, on-farm water storage systems; ben., benefits; L.O., landowners; cons., conservation practices).

have better estimates of water use efficiencies for different water conservation practices.

Respondents were also asked if it is important to know the amount of water used by each crop for effective irrigation practices. Out of 460 respondents, 75.3% agreed or strongly agreed that is the case, whereas 13.1% disagreed. When asked about the need for better information on the effectiveness of water conservation practices, 406 (88.2%) thought that there is such a need. Over 89% of respondents agreed that they were doing everything they could to conserve water. At the same time, 76.3% of respondents believed that more water supplies are needed in the Delta to sustain agriculture, whereas 11.1% disagreed. One of the reasons for the low level of adoption of the water conservation management practices might be less financial support by absentee landowners. Out of 460 respondents, 214 (46.5%) believed that absentee landowners are not interested in paying for water conservation on their land, whereas 40.7% disagreed.

Water Conservation Practices

Water Meters. About 52.4% of respondents believed that installing water meters is the best way to measure irrigation water use, but 28% did not agree. Respondents were also asked if meters will save water and whether installing meters on wells will lead to taxes or fees on water use (Figure 1). Nearly 47% of respondents believed that using meters as irrigation practices can save water, but 78.3% (360) of respondents thought that installing meters on wells will ultimately lead to taxes or fees on water use. Related to this, respondents were also asked about who should pay for the purchase and installation of the water meters. Approximately one-third or 151 respondents thought the federal government should shoulder the cost, while 15.4% of respondents thought the state government should do so. Out of 460, only 62 respondents thought farmers or producers should pay for the water meters.

Land Forming. Out of 455 respondents, 94.4% responded that land forming is an effective water conservation practice for all crops (Figure 2). Respondents were also asked about the efficiency of the different water conservation practices for irrigating corn, soybean, cotton, and rice (Table 1). They were provided the following responses to choose from: highly efficient, efficient, inefficient, don't know/not sure, and refused. Out of the valid responses (highly efficient, efficient, inefficient) from 460 respondents, 99.6% of the respondents believed that land forming is an efficient or highly efficient practice for corn and soybean (Table 1). For cotton, only 1.4% of respondents thought it was not efficient. For rice, 375 respondents provided a valid response to the question concerning the efficacy of zero grade land forming as an effective water conservation practice, and 66.5% agreed or strongly agreed that it is effective, while 11.8%

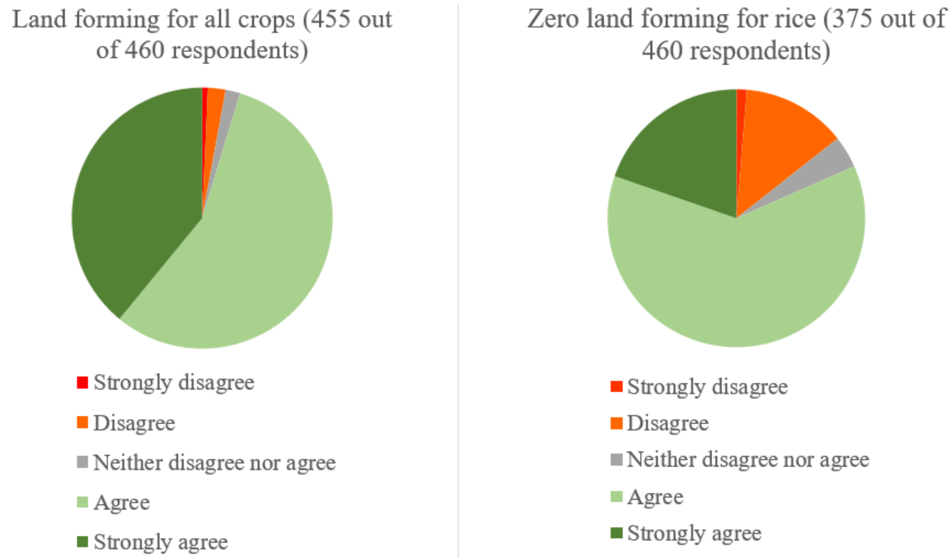

Figure 2. Survey responses to questions related to the effectiveness of the land forming in the Mississippi Delta.

disagreed (Figure 2). About 8.6% respondents thought it an inefficient practice.

Tailwater Recovery Systems. Valid responses received for TWS efficiency for irrigating corn, soybean, and cotton were 234, 256, and 133, respectively, out of the 460 respondents (Table 1). From the valid responses, only 11.1, 10.9, and 12.8% of the respondents believed it an inefficient practice for irrigating corn, soybean, and cotton, respectively.

On-farm Storage. Valid responses received for on-farm water storage systems efficiency for irrigating corn, soybean, and cotton were 227, 248, and 127, respectively, out of the 460 respondents (Table 1). Based on valid responses, 79.7, 79, and 75.6% of the respondents believed that on-farm water storage is an efficient or highly efficient practice for irrigating corn, soybean, and cotton, respectively. For this practice, more than 20% of the respondents thought it an efficient practice.

Instream Weirs to Pond Surface Water. Based on valid responses (highly efficient, efficient, inefficient), 85.5, 88.5, and 81.9% of respondents thought that instream weirs are an efficient or highly efficient practice for irrigating corn, soybean, and cotton, respectively (Table 1).

Center Pivot Irrigation. More than 20% of the valid responses to the survey questions believed that center pivot is not an efficient practice for water conservation in corn and soybean, whereas only 15% of the respondents provided the same response for irrigating cotton. About 238, 262, and 134 respondents out of 460 provided a valid response to this question for irrigating corn, soybean, and cotton, respectively. For corn, 74.7% of the respondents agreed that center pivot is efficient or highly efficient, whereas 78.6 and 85% of the respondents responded that it is an efficient practice for soybean and cotton, respectively (Table 1). Eighty-six percent of the 143 valid responses believed that center pivot irrigation is an inefficient practice for irrigating rice.

Short Irrigation Runs. An irrigation run is defined as moving water from one end of the field to the other end. Irrigation runs that are too long can result in water loss due to deep percolation at the upper end of the field prior to the lower end receiving adequate irrigation. Only 10, 11.3, and 11.6% of the 231, 257, and 129 respondents believed that short irrigation runs are an inefficient practice for irrigating corn, soybean, and cotton, respectively, while the majority of the respondents believed that they are an efficient water conservation practice (Table 1).

Irrigation Scheduling. Irrigation scheduling determines the right amount and timing to apply water to the crop (Taghvaeian et al. 2020). Irrigation scheduling is important in this region to avoid yield losses from flash droughts that occur during the summer due to insufficient

Table 1. Survey responses to the efficiency of different water management practices and tools in the Mississippi Delta.

Water Conservation Practices	Respondents that provided valid responses (out of 460 respondents)	Highly Efficient (%)	Efficient (%)	Inefficient (%)
CORN				
Land forming	254	48	51.6	0.4
Tailwater recovery system	234	33.3	55.6	11.1
On-farm storage	227	26	53.7	20.3
Instream weirs to store surface water	206	23.8	61.7	14.6
Center pivot irrigation	238	17.6	57.1	25.2
PHAUCET program for sizing holes for furrow irrigation	210	29.5	64.3	6.2
Short irrigation runs	231	20.8	69.3	10
Irrigation scheduling	241	18.3	69.7	12
SOYBEAN				
Land forming	276	52.5	47.1	0.4
Tailwater recovery system	256	30.1	59	10.9
On-farm storage	248	25.4	53.6	21.0
Instream weirs to pond surface water	226	19.9	68.6	11.5
Center pivot irrigation	262	18.3	60.3	21.4
PHAUCET program for sizing holes for furrow irrigation	231	27.3	64.1	8.7
Short irrigation runs	257	24.1	64.6	11.3
Irrigation scheduling	268	21.6	67.5	10.8
COTTON				
Land forming	139	46.0	52.5	1.4
Tailwater recovery system	133	31.6	55.6	12.8
On-farm storage	127	30.7	44.9	24.4
Instream weirs to pond surface water	116	25.9	56.0	18.1
Center pivot irrigation	134	24.6	60.4	14.9
PHAUCET program for sizing holes for furrow irrigation	118	28.8	61.9	9.3
Short irrigation runs	129	26.4	62.0	11.6
Irrigation scheduling	131	26.0	58.8	15.3
RICE				
Zero grade land forming	162	58.0	33.3	8.6
Side-inlets	150	34.0	62.0	4.0
Center pivot irrigation	143	2.8	11.2	86.0
Irrigation scheduling	151	17.9	58.3	23.8

rainfall events. Irrigation scheduling saves water and energy and helps to improve crop yields and quality. For corn and soybean, 241 and 268 respondents, respectively, provided valid responses by indicating that the practice is highly efficient, efficient, or inefficient (Table 1). Only 131 and 151 respondents provided valid responses for the cotton and rice, respectively, when asked about irrigation scheduling (Table 1). About 88, 89, 85, and 76% of the respondents thought irrigation scheduling is an efficient or highly efficient water conservation practice for irrigating corn, soybean, cotton, and rice, respectively, in the Delta region.

PHAUCET Program for Sizing Holes for Furrow Irrigation. Respondents were asked if the PHAUCET program should be used for every furrow irrigation system. Out of 460 respondents, 241 provided a valid answer by choosing from options including strongly disagree, disagree, neither disagree or agree, agree, strongly agree: with 113 respondents in agreement. Respondents were also asked about the efficiency of this water conservation practice for irrigating corn, soybean, and cotton. Out of the valid responses received, 93.8, 91.4, and 90.7% respondents believed that PHAUCET is an efficient or highly efficient practice for water conservation for irrigating corn, soybean, and cotton, respectively (Table 1).

Future of Irrigation and Economic Constraints

When asked about the future of irrigation management technologies in the Delta region, 270 out of 460 respondents provided a valid response (strongly disagree, disagree, neither disagree nor agree, agree, strongly agree). Of the valid responses, 68.1% agreed and 7% strongly agreed that automated irrigation metering, soil moisture probes, rain gauges, and other technology are the future of irrigation in the Delta region. However, 15.9% of the respondents disagreed whereas 1.5% strongly disagreed.

Respondents were also asked questions relating to the economic benefits of the management practices and how they might impact adoption in the Delta. About 32% of respondents thought it was important to have estimates of dollar savings associated with different conservation practices. A total of 430 valid responses were recorded for the question: "documenting the economic benefits of the tailwater recovery and on-farm storage systems would encourage more landowners to implement these practices." Of the valid responses, 76.8% thought that landowners would adopt the tailwater recovery and on-farm storage systems if they knew their economic benefits.

Similarly, the respondents were asked if they would consider implementing one or more different water conservation practices if these saved them money. Out of 254 valid responses, 30.3% of respondents said that they would implement new or different water conservation practices if it would save them \$124-\$247 per ha (\$50-\$100 per acre). For the same questions, 27.2 and 22.8% of the respondents mentioned that they would adopt the practices if their savings were in the range of \$62-\$124 per ha (\$25-\$50 per acre) and more than \$247 per ha (>\$100 per acre), respectively. About 19.7% of respondents agreed to implement new or different water conservation practices even if the savings are less than \$62 per ha (<\$25 per acre).

Respondents were also asked about who should be paying for alternative water supplies, including inter-basin transfers, or well fields near the levees. Out of 355 valid responses, 64.2% preferred that the federal government pay, whereas only 16.1% said that the state government should pay for these water supplies. Producers (7.6%) and landowners (12.1%) are the least preferred agents responsible for the payment of alternative water supplies.

Discussion

Based on the survey conducted in 2012, most of the landowners in Mississippi believed that water conservation practices are effective in reducing irrigation water use without reducing maximum crop yields, and, in return, help to save money. In agreement with the survey results, research studies conducted after year 2012 on the agronomic and water conservation practices in the Mississippi Delta have shown positive results in terms of water savings, economic returns, and yield production (Henry and Krutz 2016; Bryant et al. 2017; Wood et al. 2017; Spencer et al. 2019). Research conducted in the Mid-South USA has shown a 502 kg ha^{-1} improvement in corn yield and a 40% reduction in applied water with the implementation of water and agronomic management practices such as irrigation scheduling, surge valves, PHAUCET program for furrow irrigation, hybrid selection, population, and planting times (Henry and Krutz 2016). Depending on crop prices and actual pumping depths, the combined benefits could easily exceed $148 per ha. However, farmers and landowners have been slow to adopt these practices (Quintana-Ashwell et al. 2020), possibly because the benefits and economic returns of the practices occur over time, whereas producers must pay the cost of implementation of practices upfront at the time of adoption (Quintana-Ashwell et al. 2020). Possibly, the positive results obtained at plot-level research are not well known to farmers or not easily replicated at farm scale. Other reasons for the low adoption of water conservation practices may be the lack of interest and financial support for their implementation by absentee landowners, and limited access/understanding of information on the effectiveness of available water conservation practices. According to the survey results, most respondents indicated the need for better information on the effectiveness of conservation practices and irrigation water demands for different crops grown in the Delta region.

The survey also included questions about the farmers' opinions on the efficiency of the conservation practices. Most landowners believed that land forming, TWS, on-farm storage, in-stream weirs to store pond surface water, PHAUCET program for sizing holes for furrow irrigation, short irrigation runs, and irrigation scheduling are efficient water conservation technologies. Land grade leveling creates a uniform slope that improves drainage, decreases soil erosion, facilitates furrow irrigation, and enables crop management (Massey et al. 2017). Irrigation water use by zero grade land forming for rice is 46% less than the ungraded crooked levees in Mississippi and Arkansas (Reba and Massey 2020). In Mississippi and Arkansas, combined use of CHS, soil moisture sensors for irrigation scheduling, and surge flow irrigation in soybean production fields reduced seasonal irrigation applications by an average of 21% and increased irrigation water use efficiency by 36%, compared to conventional furrow irrigation controls (Bryant et al. 2017). More than 2 million ha of cropland in the lower Mississippi River Basin is irrigated using poly-tubing and could benefit greatly from use of the PHAUCET program to improve irrigation water use efficiency (Reba et al. 2014). The on-farm water storage systems for irrigation can completely replace groundwater pumping in some years, depending upon the growing season climatic conditions, storage capacity, and farmed area (Quintana-Ashwell et al. 2020). Reba et al. (2014) mentioned that the construction of on-farm reservoirs is motivated by the depth to groundwater for a well, as observed for an increasing number of deep wells in areas such as Arkansas and Mississippi where significant groundwater declines have occurred. Adopting irrigation technologies is dependent upon the attributes of the technologies, including cost, ease of use, durability, data interpretation, and whether the technology is based on scientific research (Taghvaeian et al. 2020). In agreement, the survey results indicate that adoption of water conservation practices depends upon the economic benefits or dollar savings from the use of different conservation practices.

About 25.2, 21.4, 14.9, and 86% of the survey respondents thought center pivot systems were not an efficient water conservation practice for corn, soybean, cotton, and rice, respectively. Furrow irrigation is the predominant irrigation method in the Mississippi Delta region as it is relatively simple and comparatively inexpensive. In addition, the landscape in the Mississippi Delta is flat, with slopes ranging from 0.1 to 0.2% (Reba and Massey 2020) which enables the furrow irrigation as the preferred choice of irrigation (Henry and Krutz 2016). However, pivot irrigation systems have lower application rates compared to furrow irrigation in row crop production and can save water (Massey et al. 2017). A 12-year study by Massey et al. (2017) in Mississippi reported that irrigation applications by corn producers through center pivot sprinklers and furrow irrigation averaged around 160 ± 90 and 330 ± 200 mm, respectively. In the Mississippi Delta, most of the center pivots were installed in the 1980s, predominantly for irrigating cotton (Coblentz 2014). About 32% of the cropland was irrigated by overhead sprinklers in Mississippi, whereas 69% was under furrow irrigation in 1998 (Reba and Massey 2020). Previously installed pivot systems for cotton were not designed to meet the irrigation water demands of corn and soybean crops. Therefore, producers in the Mississippi Delta have been migrating away from the center pivot systems. A major consideration is the high cost for repairs or installation of new pivot systems in contrast to using poly pipe in furrow irrigation of row crops (Quintana-Ashwell et al. 2020). Precision land grading of the cropland has increased in the Delta region, which has also contributed to reduction in over-head sprinkler irrigation systems (Reba and Massey 2020). Other issues associated with the operation of the center pivot in the Delta region include wheels getting stuck in heavy clay soils and clogging of nozzles due to the poor quality of groundwater used for irrigation (Quintana-Ashwell et al. 2020).

Most respondents believed that installing meters on the wells is the best way to measure groundwater use, and that this practice can save water. These results are from a survey conducted in 2012; however, there have been changes in the area since then. Irrigated area has increased over time and the number of wells drilled has doubled since 1998 in Mississippi (Reba and Massey 2020). There were 14,000 wells in Mississippi drawing groundwater for irrigation needs in 2017 (Reba and Massey 2020). Flowmeters installed on these wells to measure the quantity of water pumped can facilitate tracking groundwater usage from the wells. The use of flowmeters was higher in Mississippi due to the requirement that at least 10% of the agricultural groundwater wells per county should be equipped with flowmeters by the end of 2015 (MSDEQ 2015). However, the survey respondents in 2012 thought that installing meters would result in some taxes or fees on water use, and that this might negatively impact agricultural production in the Delta.

In this 2012 survey, about 75% of the respondents agreed that there would be increasing future use of various technologies such as automation, irrigation metering, soil moisture probes, and rain gauges. This indicates that producers were concerned about depleting groundwater levels in the aquifer and would prefer to use irrigation technologies for saving water. Use of automation in irrigation scheduling has increased over the last ten years, possibly due to advances in soil moisture sensor and telemetry technologies, increased farm size, shortage of labor, and increased research and outreach efforts for increasing awareness about water conservation and best utilization (Reba et al. 2014). Survey responses in 2012 showed that producers would implement water conservation practices on their farms if it saved them money and would use alternative water supplies if the federal government helped to pay for it.

The survey conducted in 2012 was the first survey to gather information about perceptions of the agricultural producers in the Mississippi Delta region about the status of water resources and conservation practices. The 2012 survey can be used as a baseline and can help in future follow-up surveys about water resources and management practices. A future follow-up survey in the Delta region of Mississippi can be focused on changes in opinions and perceptions of producers about water resources and conservation practices over time (from 2012 to the present), and adoption of water conservation practices.

Conclusion

Available water resources should be used efficiently and effectively to sustain agricultural productivity. The survey results discussed in this article provided important information to the scientists at the Mississippi State University, Delta F.A.R.M., United States Department of Agriculture (USDA), and other organizations concerning the opinions of producers on water conservation practices. The results from this survey provide valuable insights into farmers' thoughts on water and water conservation practices in the Mississippi Delta. These insights will help with developing research and education programs that, in turn, will help inform policymakers and other stakeholders interested in improving the adoption of water conservation practices in the Mississippi Delta.

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Appendix 1. Survey questions and their respective answer choices.

Question	Response
Are you a:	a) Landowner only b) Landowner & operator c) Operator only d) Other e) Don’t know/not sure f) Refused
Please tell me whether you grow and irrigate each of the following crops: corn, cotton, soybeans, rice, other crops	a) Yes b) No c) Don’t know/not sure d) Refused
What other crops do you grow and irrigate?	a) None b) Don’t know/not sure c) Refused
Please tell me whether you strongly disagree, disagree, neither disagree nor agree, agree, or strongly agree with the following statement: • Water conservation practices are effective in reducing irrigation water use • Water conservation practices can reduce maximum crop yields • Effective irrigation practices rely on knowing how much water is used for each crop • Water meters are the best way of measuring water use	a) Strongly disagree b) Disagree c) Neither disagree nor agree d) Agree e) Strongly agree f) Don’t know g) Refused
Next, I am going to read some statements about water conservation, for each one please tell me if you strongly disagree, disagree, neither disagree nor agree, agree, or strongly agree. • Land forming is an effective water conservation practice for all crops • Zero grade land forming is an effective water conservation practice for rice • I am currently doing everything I can to conserve water • Water conservation practices save money • Using meters as part of irrigation practices can conserve water and maximize profits • You can implement water conservation practices, and not effectively manage water • Conservation practices alone can take care of water problems in the Delta	a) Strongly disagree b) Disagree c) Neither disagree nor agree d) Agree e) Strongly agree f) Don’t know g) Refused

Appendix 1 Continued.

Question	Response
Please tell me whether you consider each of the following water conservation practices as highly efficient, efficient, or inefficient for irrigating corn, soybean, and cotton: • Land forming • Tailwater recovery system • On-farm storage • Instream weirs to pond surface water • Center pivot irrigation • PHAUCET program for sizing holes for furrow irrigation • Short irrigation runs • Irrigation scheduling	a) Highly efficient b) Efficient c) Inefficient d) Don't know/not sure e) Refused
Please tell me whether you consider each of the following water conservation practices as highly efficient, efficient, or inefficient for irrigating rice: • Zero grade land forming • Side-inlets • Center pivot irrigation • Irrigation scheduling	a) Highly efficient b) Efficient c) Inefficient d) Don't know/not sure e) Refused