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Adoption and Continued Use of Irrigation Management Practices in Arkansas

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Abstract

The paper assesses row crop producers continued use of irrigation management practices, namely the decision to continue rather than stop the use of irrigation practices, using a probit with a sample selection model. To better explain and increase user acceptance, we must understand why producers adopt and continue using irrigation management practices. Past studies have researched the adoption of management practices. However, it is also essential to consider what factors influence continued use and why producers discontinue irrigation practices after adoption. This is the first study to investigate factors influencing the continued use of irrigation management practices in Arkansas. Producers in Arkansas have adopted irrigation management practices; however, a few years later, they were abandoned. Irrigation management practices adopted by a relatively higher proportion of producers in Arkansas include Water flow meters, Multiple-Inlet with Poly-Pipe irrigation rice, and Computerized pipe-hole-selection. Factors such as hours of in-depth training, knowing producers that used the same practice, and the percentage of countywide producers in agricultural conservation programs significantly impacted adoption. However, the likelihood of continuing to use a practice increases with the number of people a producer knows who have already used a practice, the percentage of farmland leased or rented, and the practice associated with less labor and pumping time.

KEYWORDS

continued use, groundwater, irrigation management practices, water use

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May God richly bless you.

Dedication

This write-up is dedicated to the Almighty God for how far he has brought me and for His Abundant Grace and Mercy bestowed on my life. It is also dedicated to my parents, Mr. and Mrs. Osei, and siblings.

Table of Contents

List of Tables

List of Figures

Adoption and Continued Use of Irrigation Management Practices in Arkansas

1| INTRODUCTION

Water scarcity, a pressing challenge for agriculture in the United States, significantly affects crop production (Marshall et al., 2015; Nian et al., 2020). Both surface water and groundwater are essential for agricultural production (Ruess et al., 2023). Water scarcity emanates from several factors, including climate change, increasing water demand, and over-extraction of groundwater (Brown et al., 2019; Marshall et al., 2015; Pringle & Triska, 2000; Ruess et al., 2023). Moreover, changing weather patterns and increasing prolonged droughts affect different regions of the United States (Zhang et al., 2021). The overuse of groundwater for farming has led to declines in the water table, reducing water availability for agriculture (Mall & Herman, 2019). Notably, this over-extraction is prevalent in areas with high levels of agricultural activity (Famiglietti, 2014; Mall & Herman, 2019).

The growing regions have varying water demands (Ruess et al., 2023). Regions like the Southern part of the Central Valley Aquifer, specifically the Tulare Basin in California and the Southern High Plains in Texas, face the unsustainable pumping of water (Ruess et al., 2023). Moreover, the Ogallala Aquifer is experiencing rapid groundwater depletion at 10,000 times faster than natural recharge, causing annual declines in groundwater levels up to one meter and concurrent drying of some central United States rivers (Pringle & Triska, 2000). California is often hailed as the nation's "fruit and vegetable basket" due to its plentiful production (Ruess et al., 2023), but it grapples with securing reliable water. Although irrigated land has decreased in California and Texas, states like Nebraska, Arkansas, and Idaho have witnessed an increase in irrigated lands in the 2017 census. These five states, accounting for approximately 50% of the total irrigated acres nationally, USDA (2017), play a pivotal role in agricultural production in the country. To address the growing water needs, it is crucial to implement demand management options, including adopting water-saving technology (Brown et al., 2019). Notably, in the 2018 irrigation and water management survey in Arkansas, around 36% of farms and 40% of irrigated acres utilized at least a water management practice (USDA, 2019).

The role of irrigation in agriculture has changed significantly in the United States. Starting with just 3 million acres of irrigated lands in the 1890s, it grew to approximately 58 million in 2017 (USDA ESR, 2023). This expansion can be attributed to advancements in groundwater pumping technology. However, not just the quantity of irrigated land has evolved; the intensity, determined by the national average water use per irrigated acre, has also changed (USDA ESR, 2023).

Arkansas has witnessed a significant increase in irrigated land, which, combined with higher production intensity and diversification of crops, has made the state increasingly reliant on water. Between 1997 and 2017, Arkansas added over 1 million acres of irrigated land (USDA ESR, 2023). The 2017 Census of Agriculture records that rice, soybean, corn, and cotton cultivation has increased, with most harvests from irrigated lands (USDA, 2018). Most row crops are grown in eastern Arkansas. Arkansas's irrigation relies on surface water and groundwater to support agricultural production. Irrigation accounted for approximately 84% (13,000 out of 15,500 thousand acre-feet per year) of the state's total water withdrawals in 2015, Dieter (2018), making it the largest consumer of water. The primary source of water for irrigation is the Mississippi River Valley Alluvial Aquifer (MRVAA) (UADA, 2017). However, this heavy reliance on groundwater has led to declining water levels and potential long-term sustainability challenges. This highlights the pressing need to address water management and conservation to ensure a sustainable future of irrigation in Arkansas.

The Arkansas water plan offers conservation strategies to address the anticipated groundwater supply deficit. These strategies focus on promoting and advancing irrigation water use efficiency through integrated irrigation water management and conservation practices (ANRC, 2014). Investing in more efficient on-farm irrigation technologies or practices can increase productivity while reducing the need for land and water inputs to achieve a specific yield level (Schaible & Aillery 2012). It also leads to lower on-farm water applications, ultimately reducing cost (Evans & Sadler, 2008; Geerts & Raes, 2009), bringing water quality and environmental benefits (Huffaker, 2010; Schaible & Aillery, 2003). Furthermore, government-sponsored initiatives are important in incentivizing producers to embrace essential conservation measures. Agricultural conservation programs, such as the Conservation Stewardship Program (CSP), Conservation Reserve Enhancement Program (CREP), and Environmental Quality Incentives Program (EQIP), provide cost-sharing or incentive payments to encourage farmers to adopt critical conservation practices voluntarily (Howard et al., 2022).

Extensive literature examines the adoption of irrigation management practices (IMPs), with multiple studies shedding light on this vital topic (Adams & Kovacs, 2019; Bjornlund et al., 2009; Nian et al., 2020; Quintana-Ashwell et al., 2020; Soh et al., 2023). Quintana-Ashwell et al. (2020) emphasize that, aside from increasing profits and reducing risks, various factors associated with farmers and their surrounding ecosystems shape their selection of agricultural practices. Soh et al. (2023) found that higher education, relatively higher income, farm experience, large farm acres, and growers with organic production experience positively affected adoption. Similarly, Nian et al. (2020) discovered a positive association with practice adoption, including the quantity of irrigated acreage, years of education, perception of a groundwater problem, and participation in conservation programs. Adams and Kovacs (2019) found that the adoption rate of Irrigation Management Practices affects groundwater overdrafts. Slow adoption can increase depletion with a shift to irrigation-intensive crops, while fast adoption conserves the aquifer because most crops are more efficient with water use. Bjornlund et al. (2009) analyze factors associated with the development, emergence, expansion, or contraction of irrigation and other Agricultural Water Management projects and conclude that biophysical and socioeconomic factors are important to consider at all stages.

A primary policy focus over the years has been encouraging producer adoption of irrigation technologies that improve farm-level irrigation efficiency (Schaible & Aillery, 2012). However, it needs to consider what is influencing continued use of practices and, if producers turn to discontinue use, what are the reasons. This study, therefore, fills the gap by identifying the factors that influence adoption and investigating factors that affect the continued use of irrigation management practices.

A few studies have investigated reasons why farmers discontinue using technologies like non-traditional agro exports Carletto et al. (1999), cover crops, Neill & Lee (2001), stone terraces, Aklilu and Graaf (2007). However, only a few deal with Irrigation Management Practices (IMPs), but it falls short to consider continued use. It also does not consider the effect on labor and pumping time. Our study includes a component on farmer estimated labor and pumping time-saving due to using IMP.

Understanding the dynamics of continued use is paramount to identifying challenges producers face in maintaining irrigation practices. While several studies have often centered on the initial adoption of innovative practices, delving into continuous use is equally vital. As Shaw et al. (2018) highlighted, investigating continued use allows us to better understand the technology and practice usage habits, which can hinder or support behavioral change. Producers may initially adopt a practice only to discontinue its use at a later stage. Solely focusing on adopting a practice can provide an incomplete view of its long-term effectiveness and sustainability. The shift from adoption to discontinuation (discontinued used) raises crucial questions about the impact of these innovations. After a producer adopts a practice, he also considers the additional benefits to gain from the use of the practice. This study also looks at the labor time and pumping time post-adoption.

Consequently, examining the factors and challenges influencing continued and discontinued use is imperative, as this is essential for devising strategies that ensure the enduring benefits of agricultural practices. By focusing on continued use, researchers can gain deeper insight into the complexities of technology uptake, resource conservation, and sustainable farming systems. This knowledge contributes to formulating more effective and enduring agricultural policies and practices, ultimately benefiting the farming community and the environment.

The study's main objective is to assess the current adoption and continued use of Irrigation Management Practices in Arkansas. The Specific Objectives are to describe the current situation regarding Irrigation Management Practices in Arkansas; determine the effect of producer, farm, and water characteristics on adopting and continued use of Irrigation Management Practices; and assess the factors influencing labor and pumping time reduction post-adoption.

Adoption

Pratt et al. 2021 state five stages by which a person adopts an innovation. These include “awareness” of the need for an innovation, “persuasion” through using information to reduce uncertainty, “decision to adopt” (or reject) the innovation, “initial use” of the innovation to test it, and “continued use” of the innovation. Our study focuses on the “decision to adopt” and “continued use” as they are critical in understanding how individuals integrate new practices into their farm activities. The decision to adopt sheds light on barriers and facilitators of adoption. Identifying and understanding these factors can inform strategies to enhance the adoption rate. Continued use is also crucial for realizing the long-term impact of technological advancement. In our study, respondents were asked questions: “Have you ever used a practice, do not include when you were just trying it out,” “In which year did you first use practice?” “Do you still use it?” and “In which year did you stop?” to capture adoption and continued use.

The next sections of the study are outlined as follows. Section 2 introduces the study area. Section 3 provides the survey description. Section 4 presents the descriptive analysis. Section 5 presents the theoretical framework and empirical strategy. Section 6 presents the empirical models and results. Conclusions are drawn in Section 7.

2| **STUDY AREA**

The climate of Arkansas is humid sub-tropical and characterized by long summers and significant variations in temperatures (ANRC, 2014). The average annual precipitation ranges from 36 to 72 inches between 1990 and 2022 (National Oceanic and Atmospheric Administration National Centers for Environmental Information [NOAA NCEI]). Even though rainfall occurs all year round, the wettest months (late spring and late fall) do not cover much of the typical cropping season, from planting in March/ April to harvesting in August/September/October (UADA, 2023). Extremes in temperature in summer can climb above 100 degrees Fahrenheit (NOAA NCEI). Summer is also the driest period. The combination of high temperatures and dry periods sometimes resulted in severe droughts during crop seasons, the most recent being the 2011-2012 drought (Bradley, 2012).

Arkansas is heavily dependent on irrigated crop production. The state currently ranks third in irrigated acres nationwide, after only California and Nebraska (USDA ERS, 2023). The state is the first in rice production (ADA, 2023). It also ranks fourth in cotton production, eleventh in soybean production, and twentieth in corn production (ADA, 2023). In 2017, the percentage of land irrigated was 100% for rice, 90.9% for cotton, 85.7% for corn, and 79.2% for soybean (USDA, 2018). Most row crop production occurs in the eastern part of the state, which overlays the Mississippi River Valley Alluvial Aquifer (MRVAA) and is adjacent to the Mississippi River (ADA, 2023). Nearly 97% of all groundwater withdrawals (10400 out of 10700 thousand acre-feet per year) were used for irrigation in the 2015 water use data (Dieter, 2018). Arkansas ranks second, after California, in the volume of groundwater pumped for CROP irrigation (UADA, 2023).

Arkansas faces a potential water challenge, especially in the agriculture sector. Since MRVAA is mainly recharged by precipitation, the recharge varies with the precipitation level from year to year (Kresse et al., 2014). The estimated recharge rates are much lower than precipitation (ANRC, 2014; Kresse et al., 2014; Kresse & Clark, 2008). For example, rates of recharge estimated by Kresse and Clark (2008) ranged from 0.07 to 7.8 inches (less than 15% of total precipitation) in their study areas. Moreover, withdrawals from the alluvial aquifer often exceed natural recharge rates (Czarnecki et al., 2002). For example, simulations from Clark et al. (2013) show that sustainable yields were only 45-50% of the total withdrawal in 2013. In areas of heavy pumping, groundwater levels have been declining at alarming rates. When the depth-to-water in an aquifer increases by more than one foot or more annually for a minimum of five years or when its saturated thickness has reduced by half, the Arkansas Department of Agriculture Natural Resources Division (ADANRD) (formally the Arkansas Natural Resources Commission) may declare it a critical groundwater area (Rice Production Handbook, 2001). So far, 20 Arkansas counties have been designated "Critical Groundwater Areas" (ADANRD, 2023). The trend of diminishing groundwater resources continues. For example, the depth-to-water in some Arkansas County and Lee County wells has increased by more than 20 feet from 2012 through 2022 (ADANRD 2023). An annual gap in groundwater as large as 7 million acre-feet is projected for 2050, with most of the expected shortfall attributed to agriculture (UADA, 2017).

The Arkansas Water Plan (AWP) 2014 Update outlines some recommendations to address the water shortage problem (ANRC, 2014). One suggestion is to store surface water during months with abundant water for use during the summer irrigation season when surface water is limited. Another recommendation is improving irrigation water use efficiency through integrated water management and conservation practices. Irrigation Best Management Practices are considered important tools for conserving groundwater.

Arkansas producers can access a range of federal, regional, and state programs for financial and technical assistance in adopting irrigation best management practices that could help mitigate water shortage. The flagship conservation program of the Natural Resources Conservation Service (NRCS), the Environmental Quality Incentives Program (EQIP), provides financial and technical assistance for the implementation of conservation practices (www.ar.nrcs.usda.gov). Conservation Stewardship Program (CSP), also an NRCS program, provides for maintaining the existing level of conservation (USDA NRCS, 2023). NRCS also established the Arkansas Groundwater Initiative (AGWI) with EQIP funds for the specific purpose of addressing the declines in groundwater quantity in “Critical Groundwater Areas” (USDA NRCS, 2019). In the Regional Conservation Partnership Program (RCPP), NRCS collaborates with state governments and non-governmental groups through matching funds and other investments (Stubbs, 2019). Another example of a partnership between NRCS and private partners is the Rice Stewardship Partnership (RSP) established by USA Rice in 2013, which provided rice farmers additional access to funds for conserving water (USARice, 2018). At the state level, under the Groundwater Conservation Tax Credit Program, Arkansas producers can claim up to $35,000 tax credit for conversion to surface water or land leveling (Arkansas Department of Agriculture, 2023).

3| **SURVEY DESCRIPTION**

The dataset from the 2022-2023 Arkansas Irrigated Producers Phone (AIPP) Survey was used for the study. The AIPP survey was conducted by the authors from October 19th, 2022, to March 3rd, 2023. We obtained phone numbers of 10,064 Arkansas producers and water users. The primary source (about 63%) is the water user database collected under Arkansas's Water-use Registration Program. Arkansas Act 81 of 1957 mandates that any non-domestic user of groundwater that has the potential to withdraw at least 50,000 gallons a day or any user of surface water that draws one acre-foot or more annually must register their withdrawals to the Arkansas Natural Resources Commission (ANRC), which is Arkansas's water resources planning and management agency. More than 6,000 agricultural water users were identified. Phone numbers of Arkansas producers were also purchased from Farm Journal (22%), Dunn & Bradstreet (9%), and Data Informatix (5%). Of the 10,064 phone numbers (81.4%) are disconnected or unreachable (no answer or busy signal). Of the remaining 1,871 phone numbers, 912 are ineligible. Some had retired from farming (395). The ineligible contacts were businesses not involved in crop growing (194), deceased, or had health problems preventing them from participating in the survey (142). Some were excluded because they were landowners only (not farmland operators) or had less than 100 irrigated acres (144). Some numbers belong to the same respondent who completed the survey (37). Out of the 959 eligible producers, 275 producers completed their interviews, which marks the response rate of the AIPP survey as about 28.7% (275/959). After excluding one response that we classified as invalid due to missing responses, we conducted our analysis with 274 responses. From the 2017 census of agriculture in Arkansas, there were a total of 71,771 producers. Accounting for all the producers in Arkansas, as reported in the 2017 census of agriculture, the margin of error for the survey was calculated to be 5% with a 90% confidence interval. A pretest was completed in August 2022 during the Arkansas Rice Field Day with ten producers to test the questionnaire thoroughly. The survey pretest findings were used to revise the survey instrument.

The main blocks of the survey collected information on 11 irrigation practices used in Arkansas. Although improving irrigation efficiency often means switching from gravity irrigation to center pivot in other states, such as California, the use of center pivot in Arkansas usually runs into problems such as nozzle clogging and wheels getting stuck in mud (Quintana-Ashwell et al., 2020). Therefore, irrigation practices that can improve the performance of existing gravity irrigation systems are more commonly used to boost irrigation efficiency. The AIPP survey collected information on several practices designed for furrow irrigation. *Computerized-Pipe-Hole-Selection* (CHS) is a computer software application that calculates the optimal size and location of holes punched on flexible poly-pipes based on factors such as pipe friction loss, elevation, flow rate, and pressure (UADA, 2023). Using CHS enhances down-row uniformity, which has the potential to achieve up to 25% water savings (UADA, 2023). *Surge Irrigation* (Surge) uses a surge valve to oscillate water flows from one side of the valve to the other at decided time intervals and irrigate two lateral furrows intermittently, causing an intermittent wetting and soaking cycle in the irrigated furrows (Henry et al., 2020). By pulsing or surging, water advances down the furrow faster, thus improving the uniformity of irrigation application.

The AIPP survey also collected information on several practices that can be used in all irrigation systems. *Soil Moisture Sensors* (SMS) measure soil moisture within crop root zone (UADA, 2023). In addition to canvasing crop conditions, *unmanned aerial vehicles* (drones) are increasingly used to monitor irrigation progress (Shew et al., 2022). *Water flow meters* (Flow

Meters) are often required in NRCS conservation contracts (Soh et al., 2023). Flow meters are also required to provide water flow information in CHS. *Pump timers* automatically or remotely control the time and/or amount of water at which a pump is shut off (Rice Production Handbook, 2001; Soh et al., 2023).

The AIPP survey also collected information on three practices that could improve rice irrigation. *Multiple-inlet with Poly-Pipe Irrigated Rice* (Minlet) uses gated pipes or holes placed on the pipe to deliver water to each paddy (area between levees) concurrently instead of letting the water cascade down from higher paddies (Rice Production Handbook, 2001). *Alternate wetting-and-drying rice* (AWD) reduces water use by intermittently flooding a field and allowing the flood to naturally subside via infiltration and evapotranspiration before reflooding (Henry et al., 2017). Multiple inlet irrigation is required when implementing AWD. *Furrow-irrigated rice*, also known as row rice, has the potential for water savings. Still, the main advantages come from savings in labor required for constructing and removing levees in flood irrigation and building furrows for soybeans in rice-soybean rotation (Hardke and Chlapecka, 2020).

Finally, the AIPP survey also included two practices used to store water on farms. A *tailwater recovery system* uses pickup ditches, sumps, pits, pumps, or pipelines to collect, store, and transport irrigation tailwater for reuse (Rice Production Handbook, 2001). On-farm storage reservoirs are constructed to capture and store surface water from stream runoff or rainwater for crop irrigation (Rice Production Handbook, 2001). On-farm storage reservoirs are often used with tail-water recovery systems (Rice Production Handbook, 2001).

All 11 practices studied were identified in the 2014 Water Plan Update as conservation measures. Most practices are also on the practices supported by various NRCS programs (Reba et al., 2017; Rice Production Handbook, 2001). In the AIPP survey, for each practice, producers reported the first year of use, the share of irrigated acres applied, hours of in-depth training, how many producers personally know that have already started using the practice, and changes in labor use and pumping time. If producers stopped using a practice, they were asked when and why. Other information, such as the characteristics of producers, farms, and water resources, was also collected and will be described in more detail in Table 4.

4| **DESCRIPTIVE ANALYSIS**

The irrigation practices included in our study started in Arkansas at different times (Figure 1). The two storage practices in Figure 1, panel b, became prevalent after the Arkansas Drought of 1930-1931 (Wiener et al., 2016), predating all panels a and c practices. Other practices are a more recent phenomenon. For example, producers only started to use drones in 2010. For most practices, the shares of sample producers that used a practice over time follow the S-shaped diffusion curves commonly found for many new technologies (Dearing, 2009; Rogers et al., 2014). Until 1990, few producers had used some practices plotted in panel a of Figure 1 (flow meters and SMS). After 1990, the number of users slowly rose and started to accelerate. The diffusion rate of flow meters accelerated in the early 2000s, while those of other practices in panel a started around 2012.

Similarly, after a slow rise in the 1990s, the use of Minlet accelerated in the 2000s (panel c). The use of furrow-irrigated rice and AWD started to take off around 2016. The use rates of the two storage practices (panel b) have been steadily ticking up over time.

By 2022, irrigation practices exhibited different adoption rates (Table 1). About 73% of sample producers had adopted flow meters at some point. This is followed by Minlet (71%), CHS (63%), row rice (56%), tailwater (51%) and SMS (46%). Others have remained in the low range. Despite its long history of use, only 37% of the sample producers had ever used on-farm reservoirs. The low adoption rate of drones (32%) may be because they are still in the early diffusion stage. However, the low adoption rates for others, such as surge irrigation (25%) and pump timers (17%), can only be explained by factors other than time.

There are also some disparities in the retention rates among practices. About 70% of producers used SMS and row rice after adoption. The retention rates are over 90% for CHS, pump timers, tailwater, and reservoirs. A look at reasons for discontinued use shows that aspects other than costs and benefits may play essential roles, too (Table 2). During the survey, producers who had stopped using a practice were asked to report the most important reasons for abandoning the practice. The top reasons for surge valve and furrow-irrigated rice (columns 2 and 10) are related to benefits and costs. However, for most other practices, including CHS, SMS, pump timer, drone, and AWD (columns 1, 3, 5, 6, and 11), technical aspects of the practices are cited: the difficulty of operation/maintenance, high time/labor required, the misfit between a practice and field or crop conditions. For flow meters, 24% of the adopters had only used flow meters once or twice to determine the well yields and did not use flow meters every year. The main reasons for discontinuing tailwater recovery systems and on-farm storage reservoirs are retirement from farming or changes in crop mix (columns 7 and 8).

Our data show that decisions to use different irrigation practices are correlated. None of the correlation coefficients is more than 0.4 in absolute values, suggesting weak practice associations (Table 3). This is not surprising because the use of a practice may be affected by many factors besides the use of other practices. However, many associations are statistically significant, suggesting producers often use several practices together. Since surge value and CHS are commonly used with lay flat irrigation pipes (Henry et al., 2020), their statistically significant correlation is unsurprising (Column 1). Tailwater recovery systems and/or on-farm reservoirs are associated with all three rice irrigation practices (Column 7). This makes sense since these on-farm storage structures often capture runoff from rice irrigation. Of all practices, drone is the only practice not statistically associated with most other practices.

5| MODELING ADOPTION AND CONTINUED USE OF IRRIGATION PRACTICES

5.1. Theoretical Framework

In economic literature, random utility models developed by McFadden (1981) are routinely used to explain adoption decisions. A utility-maximizing producer *i* will adopt an irrigation practice *p* if the utility from using it (U_{ip}) is greater than the utility of not adopting it (U_{iNp}). The net benefit of using a practice is $y^*_{ip} = U_{ip} - U_{iNp} > 0$. Since these utilities (U_{ip} and U_{iNp}) are unobservable, y^*_{ip} is also a latent variable. What can be observed is whether a producer decides to adopt a practice. Denote the adoption decision as y_{ip} and y_{ip} equals one for an adopter. The observable binary variable y_{ip} is related to the latent variable y^*_{ip} as $y_{ip} = 1$ if $y^*_{ip} > 0$ and $y_{ip} = 0$ otherwise.

The random utility model can also explain an adopter's decision to abandon or continue to use a practice. The adopters, denoted as $i \in \{y^*_{ip} > 0\}$, will continue to use an irrigation practice *p* if the utility (U_{ipC}) of doing so is greater than the utility of abandoning it (U_{ipNC}). That is, the net benefit of continuing a practice, $y^*_{ipC} = U_{ipC} - U_{ipNC\,p} > 0$.

5.2. Empirical Strategies

The decision to adopt irrigation practice alone has been the interest of many previous studies (e.g., Huang et al., 2017; Knapp and Huang, 2017; Nian et al., 2020). All 11 irrigation practices included in the AIPP survey are accessible to Arkansas producers. Our data show statistically significant correlations among various irrigation practices (Table 3). Therefore, we use a multivariate probit model to estimate the adoption decisions regarding irrigation practices (Greene, 2012). The model can be expressed as:

$$y_{ip} = \begin{cases} 1 \text{ if } y^*_{ip} = \mathbf{x}'_{ip}\boldsymbol{\beta}_p + \varepsilon_{ip} > 0 \\ 0 \text{ otherwise} \end{cases} \quad (1)$$

In (1), the vector, $\mathbf{x}_{ip}$, includes a set of observable producer, farm, and water resource characteristics that may influence adoption decisions. The error terms, ε_{ip}s, are distributed as multivariate normal with mean zeros. Since Minlet, row-rice, and AWD are for rice irrigation only, these three practices are put together in one specification of (1). In another specification of (1), all other practices are combined. A simulated Maximum Likelihood Estimator (MLE) is used to estimate equation (1) with the STATA command **mvprobit** developed by Cappellari and Jenkins (2003), where the Geweke–Hajivassiliou–Keane (GHK) smooth recursive conditioning simulator is used to evaluate the multivariate normal distribution functions. The marginal effect of a variable in $\mathbf{x}_{ip}$ on the probability to adopt, $\partial \Pr(y_{ip} = 1)/\partial x_{ip}$, is imputed using the postestimation command **margins** in STATA.

Estimating equations for the sequential decisions of adopting and continuing/abandoning can be described similarly to those for sample selection models. For each practice, the latent variable representing the net benefit of continuing practice, y^*_{ipC}, is only observed for adopters. This is described by the selection equation below:

$$y^*_{ipC} \begin{cases} = \mathbf{z}'_{ip}\boldsymbol{\theta}_p + v_{ip} & \text{if } y^*_{ip} = \mathbf{x}'_{ip}\boldsymbol{\beta}_p + \varepsilon_{ip} > 0 \\ \text{unobserved} & \text{if } y^*_{ip} < 0 \end{cases} \quad (2)$$

The error term, v_{ip}, is also assumed to be normally distributed. Note that equation (1) is implicitly embedded in equation (2). The binary outcome, y_{ipC}, which equals one for continuing practice p and zero otherwise, is only observed among adopters whose $i \in \{y^*_{ip} > 0\}$. The outcome equation is expressed as:

$$y_{ipC} = \quad 1 \text{ if } y^*_{ipC} > 0 \quad (3)$$

$\{\quad 0$ otherwise

Equations (2) and (3) can be estimated using the log-likelihood function:

$$\begin{aligned} \ln L = & \sum_{i \in \{y^*_{ip} < 0\}} \ln[1-\Phi(\mathbf{x}'_{ip}\boldsymbol{\beta}_p)] \\ & + \sum_{i \in \{y^*_{ip} > 0 \ \& \ y^*_{ipC} > 0\}} \ln[\Phi_2(\mathbf{x}'_{ip}\boldsymbol{\beta}_p, \mathbf{z}'_{ip}\boldsymbol{\theta}_p, \rho)] \\ & + \sum_{i \in \{y^*_{ip} > 0 \ \& \ y^*_{ipC} < 0\}} \ln[\Phi_2(\mathbf{x}'_{ip}\boldsymbol{\beta}_p, -\mathbf{z}'_{ip}\boldsymbol{\theta}_p, -\rho)] \end{aligned} \quad (4)$$

Where Φ is the Cumulative distribution function (CDF) for the normal distribution of ε_{ip}, Φ_2 is the CDF for the bivariate normal distribution between v_{ip} and ε_{ip}, and ρ is the correlation between v_{ip} and ε_{ip}. In (4), the first term is for non-adopters, the second term is for adopters that continue to use practice p, and the third term is for adopters that abandoned practice p. This setup is similar to the standard Heckman model (Heckman, 1979) except that the outcome variable is binary. The STATA command **heckprobit** is used to carry out the maximum likelihood estimation. Some variables, such as years of farming experience, may explain the adoption and continued use of irrigation practices. These variables will be included in both $\mathbf{x}_{ip}$ in (1) and $\mathbf{z}_{ip}$ in (2). Some variables, such as the performance of the irrigation practice post-adoption, will only affect y^*_{ipC}, not y^*_{ip}. These variables will only be included in $\mathbf{z}_{ip}$ in (2). For identification purposes, the exclusion restriction requires at least one variable in $\mathbf{x}_{ip}$ that is not included in the $\mathbf{z}_{ip}$. The marginal effect of a variable in $\mathbf{z}_{ip}$ on the probability of continuing practice, $\partial \Pr(y_{ipC} = 1 | y_{ip} = 1)/\partial z_{ip}$, is imputed using STATA post estimation command **margins**.

5.3. Variable Description

Previous studies' findings on adopting agricultural technologies and management practices guide the selection of variables in $\mathbf{x}_{ip}$ and $\mathbf{z}_{ip}$ (e.g., Green et al., 1996; Caswell et al., 2001). Table 4 lists the variables included and their definitions. The first group of variables measures producer characteristics, including their human capital. These variables can be proxies for a producer's ability to acquire and apply information about new agricultural production practices. The dummy variable Bachelor takes the value of one if a producer has obtained a degree at the level of Bachelor or higher. About 51% of the sample producers have a bachelor's degree or above (Bachelor) (Table 4). Farming experience is measured by how many years a producer has been farming (*YRS_Farming*). The average years of farming are about 27 years. Producers were also asked how many generations their families have been farming in the area. Their answers are used to construct a generation dummy (*Gen3More*) that equals one for producers with three or more generations of farming and zero otherwise. Farming experience may affect the adoption of new technologies or practices in multiple ways. More experienced producers may be more capable of incorporating new technologies and practices into their farming production (Caswell et al., 2001). The same producers, however, may also be more resistant to switching away from practices they have been using for a long time (Caswell et al. 2001). Since years of farming experience are also highly correlated with age, more experienced producers have shorter planning periods. Only technologies or practices that can quickly generate returns will attract them (Caswell et al., 2001).

Since most new agricultural technologies/practices have uncertainties regarding their effects on yields and inputs (e.g., water savings), producers' risk attitude is a relevant factor in adoption decisions. The producers were asked to rate their risk attitude on a scale from zero to ten, with zero meaning "not at all willing to take the risk, looking for the safest income, even though the resulting income may be low" and ten being very willing to take the risk. Answers to this question are used to construct the degree of risk-seeking. Standardized values are used for easier interpreting (*Risk_std*). Access to information plays a crucial role in adoption decisions since it increases producers' awareness of newly available practices, funding opportunities, and "how-to" knowledge (Campenhout, 2021). In Arkansas, most extension agents use Twitter (now X) as the primary social media to reach out to producers in their counties. Therefore, we measure producers' access to information with a dummy variable that equals one if they have an active Twitter account (*Twitter*).

The second set of variables measures farm characteristics. Since adopting a practice, especially one with high upfront costs is an investment, land tenure matters (Feder et al., 1985). Caswell et al. (2001) argue that farmers who own the land are often better at preserving natural resources associated with the long-term productive capacity of agricultural land. A dummy variable is used to indicate that a producer owns part or all of the farmland they operate (*Landowner*). Since many producers also rent or lease land, the percent of farmland leased or rented (*PT_rent*) is also included. On average, the sample producers hired or rented 70% of their farmland.

Farm size and total income were not directly asked during the survey because producers often refuse to provide information they consider sensitive. Two variables are used to gauge farm size. Irrigated acres are totaled across all crops (*Ir_Acres*). On average, the annual irrigated acres were about 2,700 for the periods between 2013 and 2017, which rose to about 3,000 for the periods between 2018 and 2022. Producers were asked which category their 2021 gross sale of irrigated crops was in less than \$50,000, \$50,000 to under \$100,000, \$100,000 to under \$250,000, \$250,000 to under \$500,000, \$500,000 to one million, one million or under two million, two million or more. A dummy variable is used to indicate producers whose gross sales totaled more than one million (*More1Mill*). Most previous studies have found a positive relationship between farm size and technology adoption (e.g., Green et al. 1996). Larger farms can easily overcome the financial hurdles of practice adoption (Soh et al., 2023). Caswell et al. (2001) state that a scale bias benefits larger farms with new agricultural technologies. Producers with higher gross sales may have higher opportunity costs of their time and, therefore, be more motivated to adopt practices that generate labor savings (Nian 2020).

Producers were asked what percent of irrigation water came from groundwater in 2021 (*PT_GW*). The sources of irrigation water supply (groundwater or surface water) can influence the advantages of certain practices. For instance, storage practices like tailwater recovery systems and on-farm storage reservoirs redistribute water temporally. Farms relying on year-round groundwater irrigation would benefit relatively less from these temporal redistribution mechanisms (Nian et al., 2020). Crop mix is also an essential factor. Rice grown in Arkansas is 100% irrigated. A producer's share of rice cultivated (*PT_Rice_1822*) could influence the practices used, as rice requires consistent irrigation throughout the entire growing season to thrive. Farmers usually rotate rice with soybeans. The percentage of soybeans cultivated (*PT_Rice_1822*) by a producer was also enquired about. The proportion may affect the applicability and effectiveness of certain practices. Producers in the study area recorded 27.2% of irrigated acres of rice averaged between 2018-2022, whereas 47.7% of irrigated soybean acres were cultivated for the period.

A third category of variables measures the groundwater characteristics. Producers were asked how great or small of a risk groundwater shortage is to their farm operation. Responses were categorized as no/low risk, moderate risk, or high risk. Moderate (*GW_Modrisk*) and high risk (*GW_Highrisk*) are used as opposed to no/low risk. A dummy variable was also used for farms located in groundwater critical areas (*Critical_GW*). This variable is expected to have a positive effect on adoption. Producers in these areas would more likely use management practices as groundwater is a concern in these counties. A dummy variable was also used to capture the depth-to-water increase (*D2W_Increase*). About 16% of producers felt that water levels increased. In the 2015 mid-south irrigation survey, 14% of Arkansas producers felt it was increasing (Henry et al., 2020).

A fourth set of variables of interest is on agricultural policies. The county percent of producers who participated in a program in the past five years is measured. Program enrollment is used to capture policy factors. Farmers learn about new technologies when they enroll in programs. Farmers could receive technical and financial support from the programs they enrolled in. This could influence producers' profitability using a set of management practices and alter the incentives for adoption (Caswell et al., 2001). The programs included the Environmental Quality Incentives Program, the Arkansas Groundwater Initiative, and the Regional Conservation Tax Credit Program.

Another category of variables measures the hours of in-depth training (*HR*) received by a producer and social influence. These are specific to individual practices. In-depth training means one-on-one or small group instructions. The government, as well as the state, provides technical training on irrigation practices for farmers. An example is the Irrigation School organized by the University of Arkansas. Another is the training from equipment dealers. The producers with such training would likely be more knowledgeable and adopt these irrigation practices.

Social influence (*N6up*) is measured as a dummy variable. Producers were asked to recall the number of producers they know that have already adopted a practice. A value of 1 is assigned if the highest number of producers a producer knows is six or more (i.e., between 6 and 10 producers and more than 10), and a value of zero is assigned to producers who know less than six producers that use a practice. Shahzad et al. (2022) state that social influence affects adopting new practices and technologies.

Years of use of each practice (*YRS_use*) are also measured. The start year and the end year of use of practice by a producer were asked. A positive effect is expected. How long a producer farm operation has used practice could positively influence the reduction of labor and pumping time. The effect of the use of all practices on yield was also captured. The farmers were asked how the use of the practices affected their crop yields.

6| RESULTS

6.1. Decision to Adopt a Practice

The results across the multivariate probit models indicate some commonalities when adopting some production practices (Table 5). The marginal effects of in-depth training (*HR*) hours are positive and statistically significant for most practices except for Minlet and AWD. Training provides farmers with the technical knowledge required to understand irrigation practices, and this knowledge transfer is essential for making informed decisions. Haghjou et al. 2014 stated that participation in soil conservation training is positive and significant with adoption as it increases farmers' knowledge about soil erosion.

The marginal effects of knowing six or more producers that used the same practice *(N6up*) are also positive and statistically significant for most practices except for Minlet. This is consistent with Wollni and Andersson 2014, who revealed a positive relationship with adopting organic farming, implying that a farmer is more likely to adopt if neighboring farmers are also adopters. Shahzad et al. (2022) state that social influence affects adopting new practices and technologies.

Among the groundwater characteristics, when groundwater shortage is considered a moderate risk (as opposed to no or low risk) over the next ten years (*GW_Modrisk*), it is positive and significant for CHS only. Groundwater shortage being considered a high risk (as opposed to no or low risk) over the next ten years (*GW_Highrisk*) is positive and significant for Minlet but negative and statistically significant for Row rice. Producers with a farm in a critical groundwater area (Critical_GW) are likelier to adopt the storage practices (tailwater recovery system and/or reservoir) and Minlet.

For the variable, which represents the percentage of countywide producers that participated in a subsidized water-saving agricultural program in the past five years, the marginal effects of the Environmental Quality Incentive Program (*CT_EQIP*) are positive and statistically significant for the flowmeter and pump timer. Flow control practices such as the flow meter and the pump timer qualify for funding from EQIP. The marginal effects of the percent of countywide producers that participated in the Regional Conservation Partnership Program in the past five years *(CT_Partnership*) are positive and statistically significant for the storage practices (tailwater recovery system and/or reservoir) but negative and significant for Surge.

The marginal effects of the other factors are more practice-specific. The likelihood of adopting CHS is positively associated with having an active Twitter account (*Twitter*) and a higher share of rented land (*PT_rent*). More experienced and risk-seeking producers may be less likely to use surge irrigation. Risk-seeking is negatively associated with adopting a surge valve since the marginal effects of the two variables that measure the degree of risk-seeking, standardized risk-seeking score, and its squared term *(Risk_std* and *Risksq*) are both negative. The marginal effects of years of farming *(YRS_Farming*) and being a third-or-more-generation farmer *(Gen3More*) are negative for most practices (except for the pump timer). The marginal effect of *YRS_Farming* is only statistically significant for surge irrigation, and that of *Gen3More* is only statistically significant for AWD. The likelihood of adopting SMS increases with the degree of risk-seeking, after which the relationship becomes negative and statistically significant. Producers with an active Twitter account and a relatively lower percentage of rice average between 2013 and 2017 (*PT_Rice1317*) are likelier to adopt SMS.

The likelihood of adopting a drone and tailwater recovery and/or reservoir is positively associated with a gross sale of more than one million dollars (*More1Mil*). Larger farms have higher gross sales of irrigated crops and are likelier to adopt storage tools and drone technologies. A producer may instead use a drone to monitor crops for potential problems rather than manually walk the field. They can trade off farmland for the storage reservoir or the tailwater recovery as this practice takes land out of production and has a large capital investment for construction (Rice Production Handbook, 2001). In addition, producers with Twitter accounts (*Twitter*) and a higher percentage of irrigation water from groundwater (*PT_GW*) may be less likely to use the storage practices (tailwater recovery system and/or reservoir). However, producers with a relatively higher percentage of rice average between 2013 and 2017 (*PT_Rice1317*) are more likely to adopt the storage practices.

The likelihood of adopting row rice is negatively associated with the percentage of rice average between 2013 and 2017 (*PT_Rice1317*). The likelihood of adopting AWD is positively associated with a higher share of rented land (*PT_rent*) but negatively associated with the percent irrigation water from groundwater (*PT_GW*).

6.2. Decision to Continue to use a practice

Table 6 shows the Heckman probit model for six of the practices. These practices were chosen because they had enough observations for producers that discontinue the use of the practices. The effect of producer characteristics was an important determinant of adopting management practices, but the effect in the Heckman probit analysis varied. From Table 6, the decision to continue to use practice is not likely to increase with hours of in-depth training. The marginal effects of in-depth training *(HR*) are negative and statistically significant for CHS and Minlet. The marginal effects of knowing six or more producers that used the same practice *(N6up*) are positive and statistically significant for all practices except for flow meter and row rice. Pratt et al., 2021 highlight that networks influence consumer preferences and demand for agricultural innovations. The marginal effects of less labor (*LLess*) are positive for most practices, with CHS, SMS, and Minlet being statistically significant. The marginal effects for less pumping time (*PumpHR_Less*) are positive and statistically significant for all practices but AWD. AWD is the only practice that does not have a statistically significant association with labor and pumping time.

The marginal effect of other factors varies for specific practices. The marginal effects of Depth-to-water increased in the last five years (*D2W_Increase*) for wells on farms and farms located in groundwater critical areas (*Critical_GW*) are negative for most practices. The marginal effect for *Critical_GW* is only statistically significant for CHS and row rice. The marginal effect for D2W_Increase is only statistically significant for SMS. This means that the producers who continue to use the SMS are less likely to feel that water levels are dropping. Producers with a gross sale of more than one million dollars may be more likely to use SMS. The likelihood of continued use of flow meter is positively associated with higher years of farming (*YRS_Farming*), increasing percent of rice average between 2018 and 2022 (PT_Rice1822), percent irrigation water from groundwater (*PT_GW*), groundwater shortage being considered a moderate risk (GW_Modrisk) or High risk (*GW_Highrisk*) (as opposed to no or low risk) over the next ten years.

The likelihood of continued use of row rice increases with a higher level of school completed (*Bachelor*), a higher share of rented land (*PT_rent*), and groundwater shortage being considered high risk (as opposed to no or low risk) over the next ten years (*GW_Highrisk*).

The likelihood of adopting AWD is positively associated with a higher share of rented land (PT_rent), annual irrigated acres averaged between 2018 and 2022 (*IrAcres_1822*), increasing percent of rice average between 2018 and 2022 (*PT_Rice1822*), growing soybean percent average between 2018 and 2022 (*PT_Soybean1822*), and groundwater shortage being considered a moderate risk (as opposed to no or low risk) to farm operation over the next ten years (*GW_Modrisk*).

6.3. Labor Time and Pumping Time Reduction

Table 7 presents the changes in labor and pumping time post-adoption. Among the practices used by producers in the study areas, a relatively higher proportion that used row rice (61%), pump timer (43%), and CHS (41%) mentioned that irrigation labor decreased because of using the practice. About pumping time, 73% of producers that use CHS and 72% that used Minlet said that the practice reduced pumping time, whereas 29% of row rice and 22% of pump timer users reported that using the practice increased pumping time. A relatively higher proportion (70% and 64%) of producers said that the pumping time stayed the same with drone and flow meters.

A bivariate probit model of labor time and pumping time reduction is presented in Table 8. The results from the bivariate probit model show that varied factors affect labor time and pumping time reduction for non-rice-specific practices. The marginal effect of years of use of practice (*YRS_USE*) is positive for the CHS, Surge, and SMS. It shows that the more years of practice use, the more experienced producers become, and the likelihood of reducing labor and pumping time for the CHS, Surge, and SMS is better.

The marginal effect of in-depth training (*HR*) hours is positive and statistically significant for pumping time reduction in only CHS and statistically significant for labor time reduction for only surge. Producers who complement one practice with another tend to have reduced labor and pumping time for some practices. The use of CHS with Minlet is associated with labor time reduction. The use of SMS with CHS is also associated with labor time reduction. However, using a flow meter with CHS is associated with pumping time reduction.

When groundwater shortage is considered a moderate risk (as opposed to no or low risk) over the next ten years (*GW_Modrisk*), it has a significant positive association with labor reduction for CHS. More experienced producers and third or more-generation farmers may be less likely to reduce labor using CHS. Producers with the highest degree completed as a bachelor or higher (*Bachelor*) are likelier to reduce pumping time with CHS. However, it is less likely when the producer is a landowner with a higher share of rented land and a gross sale of more than one million dollars (*More1Mil*) to reduce pumping time with CHS.

The likelihood of reducing labor with the use of surge valve is positively associated with knowing six or more producers that used the same practice (N6up), having an active Twitter account (*Twitter*), and groundwater shortage being considered a moderate risk (as opposed to no or low risk) to farm operation over the next ten years (*GW_Modrisk*). The likelihood of pumping time reduction with the use of a surge valve is positively associated with higher years of farming, having a Twitter account, being risk-seeking, percent irrigation water from groundwater, groundwater shortage being considered a moderate risk (as opposed to no or low risk) to farm operation over the next ten years and/or farm located in groundwater critical areas.

With the use of SMS, the likelihood of labor time reduction is positively associated with risk-seeking and an increasing percentage of the rice average between 2018 and 2022 (*PT_Rice1822*). The likelihood of labor time reduction flow meter is positively associated with increasing percent of land rented (*PT_Rent*) and groundwater being a high risk. Labor and pumping time for drones have a positive and significant association with groundwater shortage being considered a moderate risk.

The bivariate probit models of labor time and pumping time reduction for rice-specific practices are presented in Table 9. The marginal effect of years of use of practice (*YRS_USE*) is positive and statistically significant for labor time reduction with Minlet and row rice and for pumping time reduction for row rice only. The in-depth training (HR) hours are less likely to reduce labor time with Minlet and pumping time with row rice. The marginal effect of knowing six or more producers that used the same practice *(N_6up*) is statistically significant for pumping time reduction with only Minlet. The likelihood of reducing pumping time using Minlet is positively associated with using CHS or row rice.

There is an observed reduction in labor and pumping time when practices are used together. The likelihood of reducing labor time using row rice has a positive and significant association with using Minlet. The use of AWD and row rice has a positive and significant association with labor and pumping time reduction. AWD with Minlet is statistically significant and associated with pumping time reduction only.

Experienced producers are more likely to be associated with reduced pumping time when using AWD. The likelihood of reduced pumping time with AWD is positive and significantly associated with having an active Twitter account (*Twitter*), annual irrigated acres average between 2018 and 2022 (*IrAcres_1822*), the percent of rice average between 2018 and 2022 (*PT_Rice1822*), and the percent of soybean average between 2018 and 2022 (*PT_Soybean1822*). The share of rented land (*PT_rent*), having a gross income of more than 1 million (*More1Mil*), and being in a critical groundwater area (*Critical_GW*) is less likely to be associated with reduced pump labor for AWD.

Being a third-or-more-generation farmer (*Gen3More*), risk-seeking is significant and negatively associated with labor time reduction when using row rice. The likelihood of reducing labor and pumping time with row rice is negatively associated with an active Twitter account (*Twitter*).

7| CONCLUSION

This study develops a time-based adoption history of practices using the farmer-provided start date. The shape of the adoption rate curve provides information on the history of existing irrigation practices and the adoption rate over time.

It also analyses factors influencing the adoption and continued use of varied irrigation management practices in Arkansas. The study revealed that different factors affect the adoption and continued use of the practices. Our analysis indicates that in-depth training hours are positively associated with the decision to adopt a practice. This suggests that efforts to promote sustainable water management could prioritize training programs to enhance the adoption of practices. Stakeholders, including government agencies and educational institutions, can allocate resources to develop and implement in-depth training programs focused on water management practices.

Knowing producers who use the same practice and the decision to adopt and continue to use practices emphasizes the importance of social networks and peer influence in shaping individuals' decisions. Community networks can provide a platform for communication and knowledge sharing among producers. Peer mentoring programs can also create a knowledge transfer cycle as best practices and lessons learned can be shared.

When groundwater shortage is considered a risk over the next ten years, producers in the study areas did not see that as a significant risk. This implies that groundwater may not pose a considerable risk at the individual farm level because producers consider groundwater as a public good. There should be public awareness campaigns and educational programs to inform producers of the state's concern regarding groundwater. The importance of sustainable water management practices and individuals' role in preserving groundwater resources should be understood.

There are limitations to our study, too. Future research should collect information on the practices producers switched to when they stopped using a practice or whether they stopped altogether.

REFERENCES

Arkansas Department of Agriculture's Natural Resources Division. "Arkansas Ground-Water Protection and Management Report for 2022." (2023). Available at https://www.agriculture.arkansas.gov/wp-content/uploads/2022-Groundwater-Report-Final.pdf (Accessed September 10, 2023).

Arkansas Department of Agriculture, Groundwater Conservation Tax Credit Program. (2023). https://www.agriculture.arkansas.gov/natural-resources/divisions/water-management/tax-credits/#:~:text=Maximum%20tax%20credit%20amount%20for%20land%20leveling%20is%20%2435%2C000.,contact%20your%20local%20conservation%20district (Accessed November 7, 2023).

Arkansas Department of Agriculture Natural Resources Division, Program Overview and Summary of Registration Data. Available at https://www.agriculture.arkansas.gov/wp-content/uploads/2022/11/10-27-2022-Water-use-Reg-Overview.pdf (Accessed October 4, 2023).

Arkansas Department of Agriculture official website. Arkansas crops. (2023) Available at https://www.agriculture.arkansas.gov/partners/ar-crops/ (Accessed September 21, 2023).

Arkansas Natural Resource Commission. "Arkansas water plan: Update 2014." *Little Rock, AR: ANRC* (2014). Available at https://www.agriculture.arkansas.gov/natural-resources/divisions/water-management/arkansas-water-plan/arkansas-water-plan-2014/arkansas-water-plan-2014-update/ (Accessed September 21, 2023).

Arkansas Natural Resource Commission. "Arkansas water plan: Update 2014." *Little Rock, AR: ANRC* (2014). Available at https://www.agriculture.arkansas.gov/wp-content/uploads/2020/05/App-I_2014-11-19-Physical-Description-of-State.pdf (Accessed September 21, 2023).

Adams, Kerr, and Kent Kovacs. "The adoption rate of efficient irrigation practices and the consequences for aquifer depletion and further adoption." *Journal of Hydrology* 571 (2019): 244-253.

Amsalu, Aklilu, and Jan De Graaff. "Determinants of adoption and continued use of stone terraces for soil and water conservation in an Ethiopian highland watershed." *Ecological economics* 61, no. 2-3 (2007): 294-302.

Bjornlund, Henning, Lorraine Nicol, and K. K. Klein. "The adoption of improved irrigation technology and management practices—A study of two irrigation districts in Alberta, Canada." *Agricultural water management* 96, no. 1 (2009): 121-131.

Brown, Thomas C., Vinod Mahat, and Jorge A. Ramirez. "Adaptation to future water shortages in the United States caused by population growth and climate change." *Earth's Future* 7, no. 3 (2019): 219-234.

Campenhout, Bjorn Van. "The role of information in agricultural technology adoption: Experimental evidence from rice farmers in Uganda." *Economic Development and Cultural Change* 69, no. 3 (2021): 1239-1272. https://doi.org/10.1086/703868

Canning, Patrick, Sarah Rehkamp, Claudia Hitaj, and Christian Peters. "Resource Requirements of Food Demand in the United States." (2020).

Cappellari, Lorenzo, and Stephen P. Jenkins. "Multivariate probit regression using simulated maximum likelihood." *The STATA journal* 3, no. 3 (2003): 278-294. DOI https://doi.org/10.1177/1536867x0300300305

Carletto, Calogero, Alain De Janvry, and Elisabeth Sadoulet. "Sustainability in the diffusion of innovations: Smallholder nontraditional agro-exports in Guatemala." *Economic Development and Cultural Change* 47, no. 2 (1999): 345-369.

Caswell, Margriet, Keith O. Fuglie, Cassandra Ingram, Sharon Jans, and Catherine Kascak. *Adoption of agricultural production practices: lessons learned from the US Department of Agriculture Area Studies Project*. No. 1473-2016-120785. 2001.

Clark, Brian R., Drew A. Westerman, and D. Todd Fugitt. *Enhancements to the Mississippi Embayment Regional Aquifer Study (MERAS) groundwater-flow model and simulations of sustainable water-level scenarios*. US Department of the Interior, US Geological Survey, 2013.

Czarnecki, John B., Phillip D. Hays, and Paul W. McKee. *The Mississippi River Valley Alluvial Aquifer in Arkansas: A Sustainable Water Resource?* No. 041-02. 2002. Available at https://www.forrestcitywater.com/FCWUWebsite/information_links/2002.MississippiRiverValley.pdf

Dearing, James W. "Applying diffusion of innovation theory to intervention development." *Research on social work practice* 19, no. 5 (2009): 503-518.

Dieter, Cheryl A., Molly A. Maupin, Rodney R. Caldwell, Melissa A. Harris, Tamara I. Ivahnenko, John K. Lovelace, Nancy L. Barber, and Kristin S. Linsey. *Estimated use of water in the United States in 2015*. No. 1441. US Geological Survey, 2018.

Evans, Robert G., and E. John Sadler. "Methods and technologies to improve the efficiency of water use." *Water resources research* 44, no. 7 (2008).

Famiglietti, James S. "The global groundwater crisis." *Nature Climate Change* 4, no. 11 (2014): 945-948.

Green, Gareth, David Sunding, David Zilberman, and Doug Parker. "Explaining irrigation technology choices: a microparameter approach." *American Journal of Agricultural Economics* 78, no. 4 (1996): 1064-1072.

Geerts, Sam, and Dirk Raes. "Deficit irrigation as an on-farm strategy to maximize crop water productivity in dry areas." *Agricultural water management* 96, no. 9 (2009): 1275-1284.

Greene, William. "H.(2012): Econometric analysis." *Journal of Boston: Pearson Education* (2012): 803-806.

Hardke, J. T., and J. L. Chlapecka. "Arkansas furrow-irrigated rice handbook." *Little Rock: University of Arkansas Division of Agriculture, Arkansas Cooperative Extension Service* (2020).

Heckman, James J. "Sample selection bias as a specification error." *Econometrica: Journal of the econometric society* (1979): 153-161.

Henry, Christopher G., L. Jason Krutz, and Drew M. Gholson. *Surge Irrigation*. Publication FSA60. University of Arkansas Division of Agriculture, Little Rock, Arkansas. (2020). Available at https://www.uaex.uada.edu/publications/pdf/FSA60.pdf (Accessed October 8, 2023).

Henry, C. G., L. J. Krutz, J. Henggeler, R. Levy, Q. Q. Huang, and K. Kovacs. "A Survey of 2015 Mid-South Irrigation Practices: Report to the Mid-South Soybean Board and dataset. Mid-South Soybean Board. University of Arkansas System Division of Agriculture." *AAES Research Series* 677 (2020).

Henry, C., J. Massey, J. Hardke, J. Krutz, M. L. Reba, and A. A. Adviento-Borbe. "Using alternate wetting & drying (AWD) rice flooding management." *Arkansas Experiment Station Research Series* (2017): 1-5.

Howard, Gregory, Wendong Zhang, Adriana Valcu-Lisman, and Philip W. Gassman. "Evaluating the tradeoff between cost effectiveness and participation in agricultural conservation programs." *American Journal of Agricultural Economics* (2023).

Huang, Qiuqiong, Ying Xu, Kent Kovacs, and Grant West. "Analysis of factors that influence the use of irrigation technologies and water management practices in Arkansas." *Journal of Agricultural and Applied Economics* 49, no. 2 (2017): 159-185.

Huffaker, Ray. "Impacts of biofuels on water supply: proposed cures may worsen the disease." *Choices* 25, no. 3 (2010).

Knapp, Tyler, and Qiuqiong Huang. "Do climate factors matter for producers' irrigation practices decisions?." *Journal of Hydrology* 552 (2017): 81-91.

Kresse, Timothy M., and Brian R. Clark. *Occurrence, distribution, sources, and trends of elevated chloride concentrations in the Mississippi River Valley alluvial aquifer in southeastern Arkansas*. No. 2008-5193. US Geological Survey, 2008. Available at https://pubs.usgs.gov/publication/sir20085193

Kresse, Timothy M., Phillip D. Hays, Katherine R. Merriman, Jonathan A. Gillip, D. Todd Fugitt, Jane L. Spellman, Anna M. Nottmeier, Drew A. Westerman, Joshua M. Blackstock, and James L. Battreal. *Aquifers of Arkansas: protection, management, and hydrologic and geochemical characteristics of groundwater resources in Arkansas*. No.

2014-5149. US Geological Survey, 2014. Available at https://pubs.usgs.gov/sir/2014/5149/pdf/sir2014-5149.pdf

Mall, Natalie K., and Jonathan D. Herman. "Water shortage risks from perennial crop expansion in California's Central Valley." *Environmental Research Letters* 14, no. 10 (2019): 104014.

Marshall, Elizabeth, Marcel Aillery, Scott Malcolm, and Ryan Williams. *Climate change, water scarcity, and adaptation in the US fieldcrop sector*. No. 1477-2017-3969. 2015.

McFadden, Daniel. "Econometric models of probabilistic choice." *Structural analysis of discrete data with econometric applications* 198272 (1981).

Neill, Sean P., and David R. Lee. "Explaining the adoption and disadoption of sustainable agriculture: the case of cover crops in northern Honduras." *Economic development and cultural change* 49, no. 4 (2001): 793-820.

Nian, Yefan, Qiuqiong Huang, Kent F. Kovacs, Christopher Henry, and Jason Krutz. "Water management practices: Use patterns, related factors, and correlations with irrigated acres." *Water Resources Research* 56, no. 3 (2020): e2019WR025360.

NOAA National Centers for Environmental Information, Climate at a Glance: Statewide Time Series. Available at https://www.ncei.noaa.gov/access/monitoring/climate-at-a-glance/statewide/time-series

Pratt, Bryan, Sophia Tanner, and Suzanne Thornsbury. "Behavioral factors in the adoption and diffusion of USDA innovations." US Department of Agriculture (2021).

Pringle, C. M., and Frank J. Triska. "Emergent biological patterns and surface-subsurface interactions at landscape scales." (2000): 167-193.

Quintana-Ashwell, Nicolas, Drew M. Gholson, L. Jason Krutz, Christopher G. Henry, and Trey Cooke. "Adoption of water-conserving irrigation practices among row-crop growers in Mississippi, USA." *Agronomy* 10, no. 8 (2020): 1083.

Reba, Michele L., J. Hl Massey, M. A. Adviento-Borbe, D. Leslie, M. A. Yaeger, M. Anders, and Jerry Farris. "Aquifer depletion in the lower Mississippi River Basin: Challenges and solutions." *Journal of Contemporary Water Research & Education* 162, no. 1 (2017): 128-139.

Rice Production Handbook. "University of Arkansas Division of Agriculture Cooperative Extension Service Handbook MP192: University of Arkansas, Fayetteville." (2001). Chapter 10. Water Management. Available at https://www.uaex.uada.edu/publications/pdf/mp192/chapter-10.pdf

Rogers, Everett M., Arvind Singhal, and Margaret M. Quinlan. "Diffusion of innovations." In *An integrated approach to communication theory and research*, pp. 432-448. Routledge, 2014.

Ruess, P. J., M. Konar, N. Wanders, and M. Bierkens. "Irrigation by crop in the Continental United States from 2008 to 2020." *Water Resources Research* 59, no. 2 (2023): e2022WR032804.

Schaible, Glenn D., and Marcel P. Aillery. "Irrigation technology transitions in the mid-plains states: Implications for water conservation/water quality goals and institutional changes." *International Journal of Water Resources Development* 19, no. 1 (2003): 67-88.

Schaible, Glenn, and Marcel Aillery. "Water conservation in irrigated agriculture: Trends and challenges in the face of emerging demands." *USDA-ERS Economic Information Bulletin* 99 (2012).

Shahzad, Khuram, Qingyu Zhang, Muhammad Kaleem Khan, Muhammad Ashfaq, and Muhammad Hafeez. "The acceptance and continued use of blockchain technology in supply chain management: a unified model from supply chain professional's stance." *International Journal of Emerging Markets* ahead-of-print (2022).

Shaw, Heather, David A. Ellis, and Fenja V. Ziegler. "The Technology Integration Model (TIM). Predicting the continued use of technology." *Computers in Human Behavior* 83 (2018): 204-214.

Shew, Aaron Michael, and Kylie Meredith. *An Introduction to Small Unmanned Aircraft Systems (sUAS)*. Cooperative Extension Service, University of Arkansas, 2020. Available at https://www.uaex.uada.edu/publications/pdf/FSA6154.pdf Accessed October 9, 2023.

Soh, Moonwon, Tara Wade, Kelly Grogan, and Lauriane S. Yehouenou. "Factors affecting the bundled adoption of irrigation and nutrient best management practices for improving water quality and quantity in Florida." *Journal of the Agricultural and Applied Economics Association* 2, no. 3 (2023): 531-550.

Stubbs, Megan. "Agricultural conservation in the 2018 Farm Bill." *CRS Report, Congressional Research Service, Washington, DC* (2019).

University of Arkansas Division of Agriculture. Arkansas Water Primer Series: Water Basics. FSPPC100. Public Policy Center. (2017). Available at https://www.uaex.uada.edu/publications/pdf/FSPPC100.pdf

University of Arkansas Division of Agriculture. Cooperate Extension Service. Crops and commercial horticulture. (2023). Available at https://www.uaex.uada.edu/farm-ranch/crops-commercial-horticulture/rice/

University of Arkansas Division of Agriculture. Cooperate Extension Service. Arkansas Crop Irrigation. (2023). Available at https://www.uaex.uada.edu/environment-nature/water/agriculture-irrigation/

University of Arkansas Division of Agriculture (2023). Cooperate Extension Service. Agriculture Irrigation. Available at https://www.uaex.uada.edu/environment-nature/water/agriculture-irrigation/computerized-hole-selection.aspx Accessed October 8, 2023

United States Department of Agriculture, Economic Research Service. (2023). Available at https://www.ers.usda.gov/topics/farm-practices-management/irrigation-water-use/ (accessed September 18, 2023).

United States Department of Agriculture, Natural Resources Conservation Service. (2023) Available at https://www.nrcs.usda.gov/programs-initiatives/csp-conservation-stewardship-program/arkansas/conservation-stewardship-program (accessed September 18, 2023).

United States Department of Agriculture, Natural Resources Conservation Services. Arkansas Groundwater Initiative (AGWI) Fact Sheets. (2019) Available at https://www.nrcs.usda.gov/wps/cmis_proxy/https/ecm.nrcs.usda.gov%3A443/fncmis/resources/WEBP/ContentStream/idd_A0EB756B-0000-C213-BCAB-79BBFE893CD3/0/AGWI+Fact+Sheet.pdf (Accessed November 7, 2023).

United States Department of Agriculture. " United States 2017 Census of Agriculture." *US Department of Agriculture: Washington, DC, USA* (2019).

United States Department of Agriculture. "USDA Census of Agriculture: 2018 Irrigation and Water Management Survey (2019). Available at https://www.nass.usda.gov/Publications/AgCensus/2017/Online_Resources/Farm_and_Ranch_Irrigation_Survey/FRIS.txt (accessed 28th November 2023).

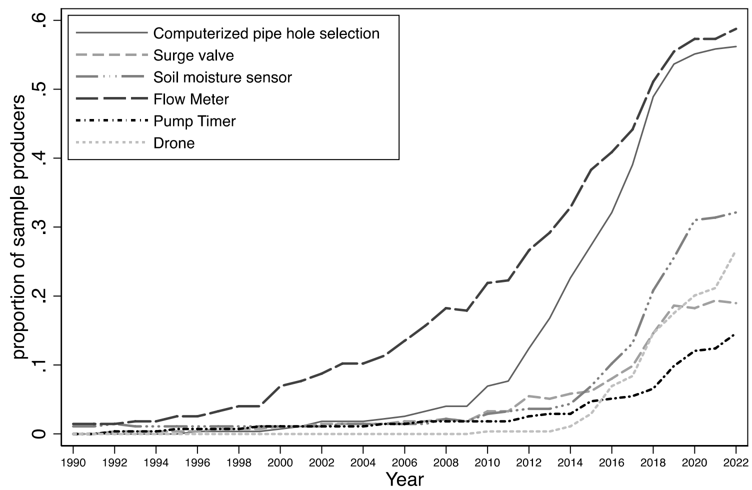
United States Department of Agriculture (USDA). 2017 US census of agriculture. (2018).

USARice. (2018). Rice Stewardship Partnership. Arlington, VA. Available at https://www.usarice.com/sustainability/ricestewardship

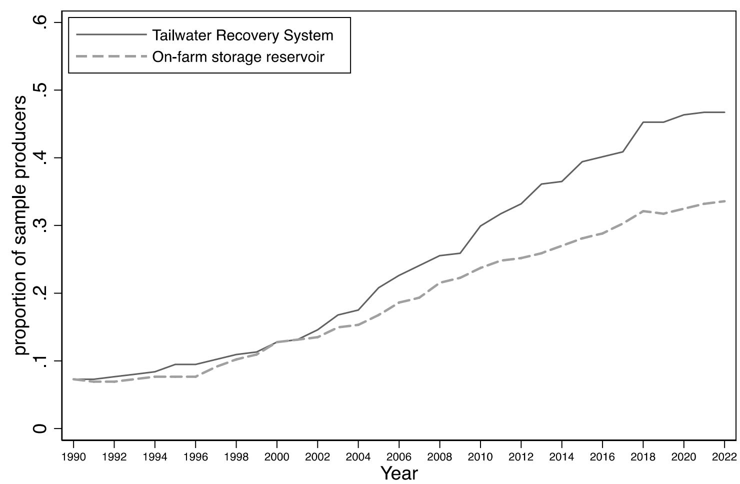
Wollni, Meike, and Camilla Andersson. "Spatial patterns of organic agriculture adoption: Evidence from Honduras." *Ecological Economics* 97 (2014): 120-128.

Wiener, John D., Roger S. Pulwarty, and David Ware. "Bite without bark: How the socioeconomic context of the 1950s US drought minimized responses to a multiyear extreme climate event." *Weather and climate extremes* 11 (2016): 80-94.

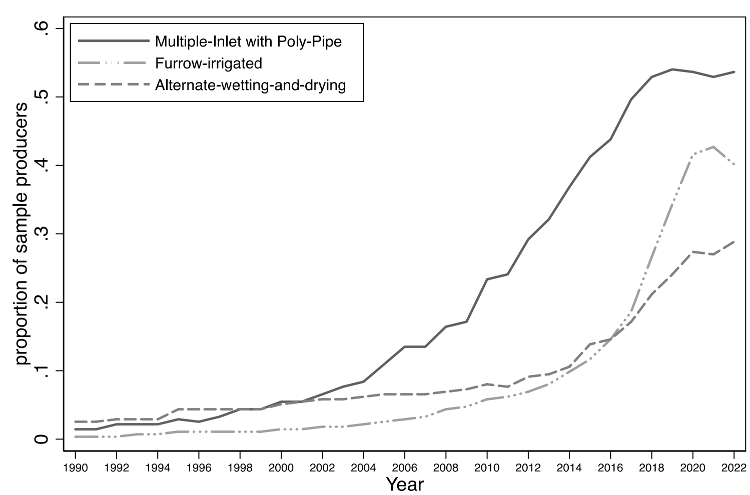
Zhang, Fangyue, Joel A. Biederman, Matthew P. Dannenberg, Dong Yan, Sasha C. Reed, and William K. Smith. "Five decades of observed daily precipitation reveal longer and more variable drought events across much of the western United States." *Geophysical Research Letters* 48, no. 7 (2021): e2020GL092293.



Panel a. Water flow control practices



Panel b. Water storage practices



Panel c. Rice irrigation practices

Figure 1 The use of irrigation practices over time.

Table 1 Number of sample producers by practice and use status in 2022.

Status of use	(1) CHS[3]	(2) Surge[4]	(3) SMS[5]	(4) Flow Meter	(5) Pump Timer	(6) Drone	(7) Tailwater[6]	(8) Reservoir[7]	(9) Minlet[8]	(10) Row Rice[9]	(11) AWD[10]
Adopted[1]	172 (63%)	69 (25%)	127 (46%)	201 (73%)	46 (17%)	89 (32%)	141 (51%)	102 (37%)	195 (71%)	153 (56%)	100 (36%)
First-year use	1996	1992	1980	1980	1978	2010	1940	1990	1980	1978	1979
Continued use[2]	157 (91%)	52 (75%)	90 (71%)	162 (81%)	42 (91%)	73 (82%)	131 (93%)	94 (92%)	146 (75%)	110 (72%)	80 (80%)
Discontinued use[2]	15 (9%)	17 (25%)	37 (29%)	39 (19%)	4 (9%)	16 (18%)	10 (7%)	8 (8%)	49 (25%)	43 (28%)	20 (20%)
Average number of years before abandon	2	1.2	2.2	3.0	3.3	2.1	7.6	8.6	4.4	1.8	3.1
Never used[1]	102 (37%)	205 (75%)	147 (54%)	73 (27%)	228 (83%)	185 (68%)	133 (49%)	172 (63%)	79 (29%)	121 (44%)	174 (64%)

1. The shares of "Adopted" and "Never used" out of all sample producers are reported in parentheses.
2. The numbers of producers under "Continued use" and "Discontinued use" add up to those under "Adopted." The shares of "Continued use" and "Discontinued use" out of producers that adopted a practice are reported in parentheses.
3. CHS is an abbreviation for Computerized-Pipe-Hole-Selection.
4. Surge is an abbreviation for Surge Valve Irrigation.
5. SMS is an abbreviation for Soil Moisture Sensor.
6. Tailwater is an abbreviation for Tailwater Recovery System
7. Reservoir is an abbreviation for On-farm Storage Reservoir.
8. Minlet is an abbreviation for Multiple-Inlet with Poly-Pipe Rice Irrigation.
9. Row rice is an abbreviation for Furrow-irrigated Rice.
10. AWD is an abbreviation for Alternate-Wetting-and-Drying Rice Irrigation.

Table 2 Number of producers by reasons for discontinued use and by practice.

	Reasons	(1) CHS	(2) Surge	(3) SMS	(4) Flow Meter	(5) Pump Timer	(6) Drone	(7) Tailwater	(8) Reservoir	(9) Minlet	(10) Row Rice	(11) AWD
Benefit	Did not save irrigation cost or bring other benefits	3 (16%)	5 (26%)	3 (7%)	6 (12%)		2 (11%)	1 (10%)	1 (9%)	2 (3%)	8 (13%)	3 (18%)
	Didn't improve profit	1 (5%)	1 (5%)		3 (6%)		1 (5%)		1 (9%)	3 (5%)	7 (11%)	
	Did not improve crop yields			4 (9%)	5 (10%)		1 (5%)			2 (3%)	24 (39%)	4 (24%)
Cost	Costly		4 (21%)	4 (9%)	3 (6%)		1 (5%)			3 (5%)		
	Government assistance such as cost-share programs ended		1 (5%)	5 (11%)	2 (4%)		1 (5%)					
Technical	Difficult to operate and maintain	5 (26%)	2 (11%)	12 (26%)	7 (14%)	3 (75%)	6 (32%)		1 (9%)	13 (21%)	1 (2%)	3 (18%)
	Too much time or labor required	6 (32%)	3 (16%)	10 (22%)	5 (10%)	1 (25%)	5 (26%)		1 (9%)	5 (8%)	3 (5%)	2 (12%)
	Did not fit the physical field or crop conditions	2 (11%)	1 (5%)	4 (9%)	2 (4%)		1 (5%)	2 (20%)	1 (9%)	6 (10%)	10 (16%)	4 (24%)
Other	Other irrigation practices better			4 (9%)	2 (4%)					10 (16%)	3 (5%)	
	No longer farm or crop mix change	1 (5%)			3 (6%)			7 (70%)	6 (55%)	18 (29%)	6 (10%)	1 (6%)
	Occasional use	1 (5%)	2 (11%)		12 (24%)		1 (5%)					

Abbreviations of practices in the first row are explained in the footnotes of Table 1.

Table 3 Correlations among different practices.

	(1) CHS	(2) Surge	(3) SMS	(4) Flow Meter	(5) Pump Timer	(6) Drone	(7) Tail_Res	(8) Minlet	(9) Row Rice
Surge	0.290***								
SMS	0.368***	0.270***							
Flowmeter	0.356***	0.216***	0.196**						
Pump Timer	0.043	0.167**	0.111	0.072					
Drone	0.163**	0.082	0.059	0.118	0.085				
Tail_Res	-0.149*	-0.153*	-0.029	0.087	-0.026	-0.016			
Minlet	0.143*	-0.039	0.092	0.108	0.006	0.046	0.203***		
Row Rice	0.045	0.008	0.016	0.229***	0.124*	0.099	0.173**	0.343***	
AWD	0.145*	0.102	0.025	0.165**	0.025	0.008	0.227***	0.315***	0.369***

Asterisks indicate levels of statistical significance. *** means the *p*-value is 1% or lower, ** means the *p*-value is 5% or lower, and * means the *p*-value is 10% or lower.

Table 4 Variable definitions and descriptive statistics.

Variable Name	Variable Description	Mean	Std. Dev.	Min	Max
Producer Characteristics					
Bachelor	Highest degree or level of school completed is bachelor’s or higher	0.51	0.50	0.00	1.00
YRS_Farming	Years of farming experiences	26.72	13.49	2.00	65.00
GEN_Farming	Generations family have been farming	3.34	1.17	1.00	8.00
Gen3More	Generations family have been farming for is 3 or more	0.82	0.38	0.00	1.00
Risk_std	Standardized Risk Seeking measure	0.00	1.00	-2.88	1.74
Risksq	Squared Standardized Risk Seeking	1.00	1.51	0.01	8.30
Twitter	Have an active Twitter account	0.29	0.46	0.00	1.00
Farm characteristics					
Landowner	Producer owns the Land	0.73	0.44	0.00	1.00
PT_rent	Percent farmland leased or rent	69.84	32.45	0.00	100.00
N_all	Number of Irrigation Management Practices used	4.77	2.16	0.00	10.00
IrAcres_1822	Annual irrigated acres average between 2013-2017 in 1000 acres	3.06	2.37	0.11	13.50
IrAcres_1317	Annual irrigated acres average between 2018-2022 in 1000 acres	2.70	2.22	0.00	13.50
More1Mil	Gross sales more than 1 million	0.58	0.49	0.00	1.00
PT_GW	% irrigation water from Groundwater	79.59	26.43	0.00	100.00
PT_Rice1822	% irrigated acres in Rice 2018-2022	27.20	21.10	0.00	100.00
PT_Rice1317	% irrigated acres in Rice 2013-2017	28.25	21.55	0.00	100.00
PT_Soybean1822	% irrigated acres in Soybean 2018-2022	47.71	20.11	0.00	100.00
PT_Soybean1317	% irrigated acres in Soybean 2013-2017	48.98	21.56	0.00	100.00
Water characteristics					
GW_Modrisk	Groundwater shortage poses a high risk in 10 years	0.26	0.44	0.00	1.00
GW_Highrisk	Groundwater shortage poses a moderate risk in 10 years	0.20	0.40	0.00	1.00
Critical_GW	Farms located in groundwater critical areas	0.64	0.48	0.00	1.00
D2W_Increase	Depth-to-water increased in the last five years	0.16	0.37	0.00	1.00

Variable Name	Variable Description	Mean	Std. Dev.	Min	Max
Agricultural policies					
CT_EQIP	Participated in Environmental Quality Incentive Program in last five years	0.51	0.17	0.00	1.00
CT_Initiative	Participated in Arkansas Groundwater Initiative in last five years	0.09	0.10	0.00	0.50
CT_Partnership	Participated in Regional Conservation Partnership Program in last five years	0.18	0.11	0.00	1.00
Knowing six or more producers that used the same practice (Dummy)					
N6up_CHS	knowing six or more producers that used the CHS	0.46	0.50	0.00	1.00
N6up_Surge	knowing six or more producers that used the Surge	0.10	0.30	0.00	1.00
N6up_Minlet	knowing six or more producers that used the Minlet	0.58	0.49	0.00	1.00
N6up_Sensor	knowing six or more producers that used the Sensor	0.17	0.38	0.00	1.00
N6up_AWDR	knowing six or more producers that used the AWDR	0.15	0.36	0.00	1.00
N6up_Tailwater	knowing six or more producers that used the Tailwater	0.39	0.49	0.00	1.00
N6up_Reservoir	knowing six or more producers that used the Reservoir	0.35	0.48	0.00	1.00
N6up_Tail_water	knowing six or more producers that used the Tailwater and/or Reservoir	0.45	0.50	0.00	1.00
N6up_Flowmeter	knowing six or more producers that used the Flowmeter	0.32	0.47	0.00	1.00
N6up_Pumptimer	knowing six or more producers that used the Pump timer	0.08	0.27	0.00	1.00
N6up_FurrowIrri	*knowing six or more producers that used the* Furrow Irrigation	0.58	0.49	0.00	1.00
N6up_Drone	*knowing six or more producers that used the same practice*	0.08	0.28	0.00	1.00
Hours of in-depth training (HR) (Dummy)					
HR_CHS	hours of in-depth training (HR) for CHS	3.57	9.66	0.00	100.00
HR_Surge	hours of in-depth training (HR) Surge	1.48	7.52	0.00	100.00
HR_Minlet	hours of in-depth training (HR) Minlet	3.50	16.85	0.00	250.00
HR_Sensor	hours of in-depth training (HR) Sensor	2.74	9.93	0.00	100.00
HR_AWDR	hours of in-depth training (HR) AWDR	1.95	6.57	0.00	50.00
HR_Tailwater	hours of in-depth training (HR) Tailwater	2.04	8.45	0.00	100.00

Variable Name	Variable Description	Mean	Std. Dev.	Min	Max
HR_Reservoir	hours of in-depth training (HR) Reservoir	2.35	14.26	0.00	200.00
HR_Flowmeter	hours of in-depth training (HR) Flowmeter	2.03	5.82	0.00	60.00
HR_Pumptimer	hours of in-depth training (HR) Pumptimer	0.46	2.16	0.00	20.00
HR_FurrowIrri	hours of in-depth training (HR) FurrowIrri	4.70	18.97	0.00	200.00
HR_Drone	hours of in-depth training (HR) Drone	1.58	6.53	0.00	65.00
HR_Tail_Res	hours of in-depth training (HR) on Tailwater and/or Reservoir	2.04	8.45	0.00	100.00
Years of use of practice					
YRS_USE_CHS	Years of use of CHS	6.54	4.38	0.00	26.00
YRS_USE_Surge	Years of use of Surge	5.54	5.91	0.00	30.00
YRS_USE_Minlet	Years of use of Minlet	8.93	7.08	0.00	42.00
YRS_USE_Sensor	Years of use of Sensor	4.26	6.01	0.00	42.00
YRS_USE_AWDR	Years of use of AWDR	8.51	10.73	0.00	43.00
YRS_USE_Tailwater	Years of use of Tailwater	16.56	13.20	0.00	82.00
YRS_USE_Reservoir	Years of use of Reservoir	18.66	14.78	0.00	87.00
YRS_USE_Tail_Res	Years of use of Tailwater and/or Reservoir	19.41	15.47	0.00	87.00
YRS_USE_Flowmeter	Years of use of Flowmeter	8.84	8.05	0.00	42.00
YRS_USE_Pumptimer	Years of use of Pump timer	5.45	6.70	0.00	30.00
YRS_USE_FurrowIrri	Years of use of Furrow Irrigation	4.69	5.29	0.00	32.00
YRS_USE_Drone	Years of use of Drone	2.90	2.29	0.00	8.00

Table 5 Multivariate Probit model of the decision to adopt a practice (Marginal effects).

	CHS	Surge	SMS	Flow Meter	Pump Timer	Drone	Tail_Res	Minlet	Row Rice	AWD
HR	0.255***	0.100***	0.383***	0.277***	0.196**	0.059**	0.079**	0.540	0.056**	0.049
N6up	1.080***	1.057***	0.765***	1.212***	1.388***	0.954***	0.550**	0.049	0.671***	1.676***
YRS_Farming	0.005	-0.013*	0.007	-0.010	0.010	-0.009	-0.008	-0.003	-0.011	-0.010
Gen3More	-0.391	0.206	-0.181	-0.014	0.167	-0.027	-0.236	-0.027	-0.090	-0.492**
Bachelor	0.254	0.238	0.201	0.043	0.067	-0.163	-0.242	0.061	0.151	0.142
Twitter	0.586**	0.266	0.402*	0.323	0.102	-0.061	-0.387*	0.274	0.061	0.113
Risk_std	0.155	-0.008	0.100	0.019	0.025	-0.015	0.086	-0.071	-0.020	-0.097
Risksq	-0.089	-0.186***	-0.103*	-0.058	0.015	0.014	-0.106	0.015	-0.050	-0.010
Landowner	0.318	0.688***	-0.020	0.239	0.514	-0.097	-0.099	0.253	-0.005	-0.043
PT_rent	0.007**	0.005*	-0.003	0.003	0.002	0.001	-0.003	0.000	0.001	0.008**
More1Mil	0.119	0.202	-0.005	0.183	0.181	0.459**	0.608***	0.135	0.287	0.240
IrAcres_1317	-0.053	-0.024	0.053	0.006	0.013	0.050	0.040	0.092	0.083	0.002
PT_Rice1317	-0.003	-0.012***	-0.013**	0.003	-0.007	-0.005	0.015***	0.006	-0.011**	0.007
PT_GW	0.004	0.004	0.002	-0.006	0.001	-0.003	-0.034***	-0.001	-0.003	-0.011***
GW_Modrisk	0.473*	0.299	0.196	0.067	-0.032	-0.257	0.049	0.058	-0.221	0.129
GW_Highrisk	0.353	0.098	0.301	-0.067	-0.400	-0.348	-0.261	1.233***	-0.452*	-0.092
Critical_GW	-0.121	0.051	0.100	-0.068	0.394	0.108	0.501**	0.468*	0.364	0.318
CT_EQIP	0.268	0.810	0.030	0.984*	1.104*	0.523	0.249	0.068	0.530	0.398
CT_Initiative	-0.475	0.342	-0.297	-0.108	0.360	0.569	1.197	-1.147	1.478	-0.221
CT_Partnership	-0.519	-1.413*	-0.521	-0.030	-0.372	-1.428	1.638*	-1.005	0.075	-1.626
N	274	274	274	274	274	274	274	229	229	229

To save space, standard errors are not reported. Asterisks indicate levels of statistical significance. *** means the *p*-value is 1% or lower, ** means the *p*-value is 5% or lower, and * means the *p*-value is 10% or lower.

Table 6 Logit models of the decision to continue to use a practice (Marginal effects).

	CHS	SMS	Flow Meter	Minlet	Row rice	AWD
HR	-0.002**	0.002	0.017	-0.003*	0.001	0.009
N6up	0.097**	0.253**	0.103	0.129**	-0.010	0.408**
LLess	0.086*	0.272**	-0.076	0.252***	0.113	0.015
PumpHR_Less	0.118**	0.162**	0.307***	0.100*	0.141**	-0.032
BMP_Yld_stable	0.016	0.136	0.053	-0.146	0.095	0.085
N_all	-0.005	0.023	0.010	0.020	-0.009	0.004
D2W_Increase	-0.040	-0.204*	-0.090	0.004	-0.130	-0.023
YRS_Farming	0.001	0.001	0.004*	-0.002	0.003	0.001
Gen3More	0.038	-0.067	0.075	-0.038	-0.030	-0.168
Bachelor	-0.004	-0.047	0.054	0.028	0.134*	0.054
Twitter	0.041	0.021	0.040	0.016	-0.019	0.036
Risk_std	0.012	0.049	0.020	0.017	0.017	0.049
Risksq	0.008	-0.016	-0.011	0.022	-0.008	0.073
Landowner	0.030	-0.097	0.013	-0.046	-0.026	-0.009
PT_rent	0.000	-0.000	-0.000	-0.001	0.003**	0.003**
More1Mil	0.049	0.170*	0.037	0.020	-0.008	-0.079
IrAcres_1822	-0.004	-0.010	0.000	-0.006	0.010	0.034**
PT_Rice1822	0.000	0.001	0.003***	0.004	0.004	0.008**
PT_Soybean1822	0.001	-0.001	0.002	0.001	-0.003	0.009***
PT_GW	-0.000	-0.002	0.002*	0.001	-0.002	-0.004
GW_Modrisk	-0.012	-0.069	0.097*	-0.083	0.033	0.259**
GW_Highrisk	-0.019	-0.116	0.218**	-0.084	0.231**	0.101
Critical_GW	-0.112*	-0.007	-0.032	-0.000	-0.208**	0.088
IMR	-0.120	-0.088	-0.838	-0.981	-1.038	1.480**
N	172	127	201	195	153	100

To save space, standard errors are not reported. Asterisks indicate levels of statistical significance. *** means the *p*-value is 1% or lower, ** means the *p*-value is 5% or lower, and * means the *p*-value is 10% or lower.

Table 7 Changes in labor and pumping time post-adoption.

	% producers that reported				Average change in pumping time (%)	
	Irrigation labor decreased	Pumping time			among producers that reported an increase	among producers that reported a decrease
		decreased	stayed the same	increased		
CHS	41	73	13	15	11	22
Surge	30	49	36	14	14	24
SMS	19	55	30	15	7	17
Flow Meter	14	25	64	11	3	14
Pump Timer	43	50	28	22	16	16
Drone	36	22	70	8	2	11
Tail_Res	13	56	37	7	13	23
Minlet	37	72	14	14	3	23
Row rice	61	50	20	29	12	21
AWD	27	65	15	20	5	19

Table 8 Bivariate probit models of labor time and pumping time reduction, non-rice-specific practices (Marginal effects on Marginal probabilities).

	CHS		Surge		SMS		Flow Meter		Drone		Tail_Res	
	Labor	Pumping	Labor	Pumping	Labor	Pumping	Labor	Pumping	Labor	Pumping	Labor	Pumping
YRS_USE	0.025***	0.014*	0.011***	0.040***	0.004	0.015***	0.000	0.003	0.002	0.004	-0.000	0.001
HR	0.006	0.010*	0.034***	0.016	-0.000	0.000	0.000	-0.001	-0.003	-0.009	-0.000	0.000
N6up	-0.001	0.129	0.552***	-0.494**	-0.222***	-0.021	0.078**	0.041	0.358	-0.192	-0.049	0.087
CHS			-0.238**	-0.052	0.240**	0.037	0.063	0.258***				
Surge	0.083	0.091			0.065	0.001	0.017	0.055				
SMS	-0.049	-0.197***	-0.134	0.263								
Tail_Res												
Flow Meter	-0.004	0.086	-0.004	-0.150								
Pump Timer			-0.273***	-0.220								
Drone												
Minlet	0.322**	0.104									0.037	0.054
Row Rice							0.006	0.065			-0.015	-0.123
AWD											-0.017	0.129*
YRS_Farming	-0.006***	0.006	0.005	0.015***	-0.007**	-0.009***	-0.002	-0.001	-0.005	0.001	0.004	0.001
Gen3More	-0.138*	-0.025	-0.074	0.124	-0.055	-0.081	0.105	0.173	-0.088	-0.009	-0.023	0.002
Bachelor	-0.019	0.138**	0.036	-0.211**	0.004	0.055	0.064	0.081	0.145	0.074	-0.088	-0.029
Twitter	-0.083	0.081	0.245***	0.358***	0.040	0.084	-0.060	-0.081	-0.006	0.019	-0.219***	-0.256***
Risk_std	-0.009	0.098***	-0.018	0.138**	0.030	-0.079	-0.017	0.013	-0.037	0.051	0.026	0.100***
Risksq	0.010	-0.070**	-0.198***	0.026	0.053*	0.020	-0.001	-0.000	-0.051	-0.020	-0.087***	-0.064**
Landowner	0.047	-0.206**	0.245*	0.673***	-0.063	0.058	0.081	-0.003	0.276*	-0.084	0.112	-0.021
PT_rent	0.000	-0.003*	-0.002	-0.002	-0.000	-0.001	0.002**	0.001	0.001	0.001	0.000	0.000
More1Mil	-0.003	-0.172*	-0.208	-0.309***	-0.019	-0.160	0.042	-0.006	0.055	-0.135	-0.056	-0.158*
IrAcres_1822	-0.023	-0.005	-0.024	-0.062***	-0.007	0.022	-0.003	-0.007	-0.013	-0.005	-0.002	-0.003
PT_Rice1822	0.001	-0.003	-0.004*	-0.002	0.004**	0.002	-0.002*	-0.002	-0.000	0.000	-0.002	0.000
PT_Soybean1822	-0.000	0.001	-0.004	-0.009***	0.001	0.002	0.001	0.001	0.002	-0.003*	0.001	-0.000
PT_GW	-0.002	0.002	-0.001	0.014***	0.000	-0.002*	-0.001*	-0.000	0.001	-0.002	-0.003**	-0.003
GW_Modrisk	0.176*	-0.061	0.305**	0.476***	0.048	-0.055	-0.014	-0.164**	0.182	-0.125	0.101**	-0.095
GW_Highrisk	0.083	0.049	-0.139	-0.433***	-0.176**	-0.234**	0.140**	-0.069	0.251*	0.246***	0.099	-0.201**
Critical_GW	-0.281***	0.032	0.076	0.262***	-0.043	0.029	-0.087	-0.114*	-0.050	0.137	-0.149**	0.108
IMR	-0.588	0.505	0.963	-1.685*	-0.628**	-0.471	-0.147	-0.350	-0.419	-1.550*	-0.243	0.951
N	140		68		124		168		89		138	

To save space, standard errors are not reported. Asterisks indicate levels of statistical significance. *** means the *p*-value is 1% or lower, ** means the *p*-value is 5% or lower, and * means the *p*-value is 10% or lower.

Table 9 Bivariate probit models of labor time and pumping time reduction, rice-specific practices (Marginal effects on Marginal probabilities).

	Minlet		Row rice		AWD	
	Labor	Pumping	Labor	Pumping	Labor	Pumping
YRS_USE	0.010**	0.002	0.016***	0.034***	0.001	0.001
HR	-0.002*	0.000	-0.000	-0.001*	0.002	0.003
N6up	0.040	0.167***	-0.149	-0.042	0.188	0.267
CHS	0.097	0.242***				
Tail_Res	0.004	-0.075			-0.110	0.099
Flow Meter			-0.005	0.123		
Minlet			0.205**	0.159	-0.104	0.255**
Row rice	0.049	0.114*			0.212**	0.353***
AWD	-0.012	0.030	-0.082	0.020		
YRS_Farming	0.003	0.001	0.000	0.000	-0.001	0.006*
Gen3More	0.117	0.061	-0.131*	-0.083	0.138	-0.103
Bachelor	-0.066	-0.006	0.025	-0.047	-0.141	-0.056
Twitter	-0.070	-0.021	-0.144*	-0.209**	-0.113	0.179*
Risk_std	-0.022	-0.075***	-0.091***	0.000	-0.015	-0.011
Risksq	-0.046	0.001	-0.042**	0.027	0.001	0.037*
Landowner	0.005	-0.072	0.020	-0.075	0.213**	0.103
PT_rent	-0.001	-0.001	0.002	0.001	-0.002**	0.001
More1Mil	-0.107	0.020	-0.094	0.012	-0.315***	-0.351***
IrAcres_1822	0.010	-0.016	-0.024	-0.030**	0.013	0.076***
PT_Rice1822	-0.002	0.001	-0.002	0.003	-0.005	0.010***
PT_Soybean1822	-0.003	-0.001	-0.001	0.001	-0.005*	0.009***
PT_GW	-0.003	-0.000	0.001	0.003*	-0.002	-0.002
GW_Modrisk	0.008	-0.178**	0.285***	0.155	-0.019	0.094
GW_Highrisk	0.034	-0.139	-0.010	-0.134**	0.272***	-0.181*
Critical_GW	0.176**	0.090	-0.091	-0.131	-0.161*	-0.189**
IMR	-0.305	-2.145**	-1.304**	-1.368***	-0.060	1.456
N	183		150		97	

APPENDIX

Appendix TABLE A1 Total acres harvested and irrigated acres harvested in Arkansas, 2017.

	Total	Irrigated	Total
Corn	594,773	509,819 (*85.7%*)	488,581
Cotton	439,582	399,559 (*90.9%*)	216,670
Soybean	3,498,157	2,770,211 (*79.2%*)	1,250,093
Rice	1,103,773	1,103,733 (*100%*)	397,653
All crops	7,098,672	4,843,849 (*68.2%*)	3,314,955

[a.] Shares of total acres harvested irrigated are reported in parentheses.
[b.] Source: 2017 Census of Agriculture (USDA, 2018)

Appendix Table A2 Summary statistics by the status of CHS use

CHS	Never Used	Continued use	Abandoned
% irrigation water from Groundwater	75	83.0**	77.5
% irrigation water from farm reservoirs/tailwater recovery systems/both	16	10.3*	9.2
% irrigation water from surface water	14	8.7**	14.5
% irrigation water irrigation water bought from an irrigation district	0	0.3	0.7
% under centre pivot 2013-2017	6	12.3**	2.7+
% under centre pivot 2018-2022	6	11.7**	2.1+
Annual irrigated acres 2013-2017 in 1000 acres	2	2.9	2.6
Annual irrigated acres 2018-2022 in 1000 acres	3	3.3**	3.3
Depth-to-water increased in the last five years	0	0.2	0.3
Doesn't know any peer producers	0	0.0***	0.1**
Farms located in groundwater critical areas	1	0.6	0.9++
Generations family have been farming	3	3.4	2.7**++
Generations family have been farming for is 3 or more	1	0.8	0.7
Gross sales more than 1 million	1	0.6**	0.5
Groundwater shortage poses a high risk in 10 years	0	0.2	0.2
Groundwater shortage poses a moderate risk in 10 years	0	0.3	0.3
Have an active Twitter account	0	0.4***	0.2
Highest degree or level of school completed is bachelor’s or higher	0	0.6**	0.6
Hours of in-depth training	0	5.6***	4.4***
Irrigated Corn Acres average between 2013 and 2017	0	0.3	0.4
Irrigated Corn Acres average between 2018 and 2022	0	0.5	0.7**
Irrigated Cotton Acres average between 2013 and 2017	0	0.3**	0.1
Irrigated Cotton Acres average between 2018 and 2022	0	0.4**	0.2
Irrigated Rice Acres average between 2013 and 2017	1	0.8	0.8
Irrigated Rice Acres average between 2018 and 2022	1	0.8	1.0
Irrigated Soybean Acres average between 2013 and 2017	1	1.4	1.3
Irrigated Soybean Acres average between 2018 and 2022	1	1.6**	1.3
Knows ten or fewer peer producers	1	0.5	0.8**++
Knows five or fewer peer producers	0	0.3***	0.7**+++
Knows more than ten peer producers	0	0.4***	0.1++
Knows more than six peer producers	0	0.7***	0.2+++
Ownership of Land	1	0.8	0.7
Participated in Arkansas Groundwater Initiative in last five years	0	0.1	0.1+
Participated in Environmental Quality Incentive Program in last five years	1	0.5	0.5
Participated in Regional Conservation Partnership Program in last five years	0	0.2	0.2

CHS	Never Used	Continued use	Abandoned
Percent farmland leased or rent	66	71.8	74.1
Squared Standardized Risk Seeking	1	0.9	0.7
Standardized Risk Seeking measure	0	0.1**	-0.3
Use social networks once a week or more	1	0.6*	0.7
Years of farming experiences	27	27.2	22.3

The difference between groups is based on the t-test. Asterisk (*) denotes the significance between "never used" and "continued use" or "discontinued use". The plus (+) indicates significance between "continued use" and "discontinued use".

Note:
ttest of mean between producers that Never use, Continue and Discontinue use (* = 0.1, ** = 0.05, *** = 0.01)
ttest of mean between producers that Continue use and Discontinue use (+ = 0.1, ++ = 0.05, +++ = 0.01)

Appendix Table A3 Summary statistics by the status of Surge use

Surge	Never Used	Continued use	Abandoned
% irrigation water from Groundwater	78	88.8***	76.4+
% irrigation water from farm reservoirs/tailwater recovery systems/both	14	7.2*	7.9
% irrigation water from surface water	12	4.9**	15.5++
% irrigation water irrigation water bought from an irrigation district	0	0.0	1.2+
% under centre pivot 2013-2017	8	14.7**	7.8
% under centre pivot 2018-2022	8	11.7	11.2
Annual irrigated acres 2013-2017 in 1000 acres	3	3.0	2.6
Annual irrigated acres 2018-2022 in 1000 acres	3	3.7**	3.1
Depth-to-water increased in the last five years	0	0.1	0.1
Doesn't know any peer producers	1	0.1***	0.4+++
Farms located in groundwater critical areas	1	0.5	0.7
Generations family have been farming	3	3.4	3.3
Generations family have been farming for is 3 or more	1	0.8	0.8
Gross sales of more than 1 million	1	0.6	0.7
Groundwater shortage poses a high risk in 10 years	0	0.2	0.1
Groundwater shortage poses a moderate risk in 10 years	0	0.2	0.5*+
Have an active Twitter account	0	0.4*	0.5**
Highest degree or level of school completed is bachelor’s or higher	0	0.6	0.5
Hours of in-depth training	0	5.6***	1.2
Irrigated Corn Acres average between 2013 and 2017	0	0.4	0.4
Irrigated Corn Acres average between 2018 and 2022	0	0.6	0.5
Irrigated Cotton Acres average between 2013 and 2017	0	0.6***	0.1
Irrigated Cotton Acres average between 2018 and 2022	0	0.8***	0.1+
Irrigated Rice Acres average between 2013 and 2017	1	0.7	0.6
Irrigated Rice Acres average between 2018 and 2022	1	0.8	0.7
Irrigated Soybean Acres average between 2013 and 2017	1	1.3	1.6
Irrigated Soybean Acres average between 2018 and 2022	1	1.4	1.7
Knows ten or fewer peer producers	0	0.8***	0.6
Knows five or fewer peer producers	0	0.6***	0.4
Knows more than ten peer producers	0	0.1***	0.0
Knows more than six peer producers	0	0.3***	0.2**
Ownership of Land	1	0.8	0.8
Participated in Arkansas Groundwater Initiative in last five years	0	0.1	0.1
Participated in Environmental Quality Incentive Program in last five years	0	0.6**	0.5
Participated in Regional Conservation Partnership Program in last five years	0	0.2*	0.2

Surge	Never Used	Continued use	Abandoned
Percent farmland leased or rent	69	73.6	74.4
Squared Standardized Risk Seeking	1	0.6*	1.0
Standardized Risk Seeking measure	0	0.0	-0.2
Use social networks once a week or more	1	0.6	0.6
Years of farming experiences	27	26.4	22.8

Appendix Table A4 Summary statistics by the status of Minlet use

Multiple Inlet	Never Used	Continued use	Abandoned
% irrigation water from Groundwater	86	75.7***	80.5
% irrigation water from farm reservoirs/tailwater recovery systems/both	8	15.2**	10.9
% irrigation water from surface water	8	12.7	11.2
% irrigation water irrigation water bought from an irrigation district	0	0.4	0.3
% under centre pivot 2013-2017	17	4.8***	10.6++
% under centre pivot 2018-2022	17	4.6***	8.7**+
Annual irrigated acres 2013-2017 in 1000 acres	2	2.8*	2.9
Annual irrigated acres 2018-2022 in 1000 acres	3	3.3**	3.0
Depth-to-water increased in the last five years	0	0.2**	0.2*
Doesn't know any peer producers	0	0.0***	0.0***
Farms located in groundwater critical areas	1	0.7***	0.6
Generations family have been farming	3	3.4	3.3
Generations family have been farming for is 3 or more	1	0.8	0.8
Gross sales more than 1 million	0	0.7***	0.6
Groundwater shortage poses a high risk in 10 years	0	0.2**	0.2
Groundwater shortage poses a moderate risk in 10 years	0	0.3	0.3
Have an active Twitter account	0	0.3	0.2
Highest degree or level of school completed is bachelor’s or higher	0	0.5	0.5
Hours of in-depth training	1	3.7***	7.4
Irrigated Corn Acres average between 2013 and 2017	0	0.3	0.4++
Irrigated Corn Acres average between 2018 and 2022	0	0.5	0.5
Irrigated Cotton Acres average between 2013 and 2017	0	0.1***	0.2
Irrigated Cotton Acres average between 2018 and 2022	1	0.2***	0.3
Irrigated Rice Acres average between 2013 and 2017	0	1.0***	0.8***
Irrigated Rice Acres average between 2018 and 2022	0	1.1***	0.7**+++
Irrigated Soybean Acres average between 2013 and 2017	1	1.4***	1.5**
Irrigated Soybean Acres average between 2018 and 2022	1	1.5***	1.6**
Knows ten or fewer peer producers	1	0.4***	0.7++
Knows five or fewer peer producers	1	0.2***	0.4+++
Knows more than ten peer producers	0	0.5***	0.3***+++

Multiple Inlet	Never Used	Continued use	Abandoned
Knows more than six peer producers	0	0.8***	0.5***+++
Ownership of Land	1	0.8	0.8
Participated in Arkansas Groundwater Initiative in last five years	0	0.1	0.1
Participated in Environmental Quality Incentive Program in last five years	1	0.5***	0.5
Participated in Regional Conservation Partnership Program in last five years	0	0.2	0.2
Percent farmland leased or rent	72	68.7	70.4
Squared Standardized Risk Seeking	1	0.9	0.9
Standardized Risk Seeking measure	0	0.1	-0.1
Use social networks once a week or more	1	0.6	0.6
Years of farming experiences	27	25.9	28.7

Appendix Table A5 Summary statistics by the status of SMS use

Sensor	Never Used	Continued use	Abandoned
% irrigation water from Groundwater	77	80.6	86.6*
% irrigation water from farm reservoirs/tailwater recovery systems/both	13	12.7	8.9
% irrigation water from surface water	14	7.7**	9.1
% irrigation water irrigation water bought from an irrigation district	0	0.0	0.6++
% under centre pivot 2013-2017	7	15.1***	6.9+
% under centre pivot 2018-2022	7	13.7***	7.1
Annual irrigated acres 2013-2017 in 1000 acres	2	3.2***	2.8
Annual irrigated acres 2018-2022 in 1000 acres	3	3.5***	3.3
Depth-to-water increased in the last five years	0	0.2	0.3**+
Doesn't know any peer producers	0	0.1***	0.2*++
Farms located in groundwater critical areas	1	0.6	0.6
Generations family have been farming	3	3.4	3.3
Generations family have been farming for is 3 or more	1	0.8	0.8
Gross sales more than 1 million	1	0.6	0.6
Groundwater shortage poses a high risk in 10 years	0	0.2	0.3
Groundwater shortage poses a moderate risk in 10 years	0	0.3	0.3
Have an active Twitter account	0	0.4***	0.3
Highest degree or level of school completed is bachelor’s or higher	0	0.6**	0.6*
Hours of in-depth training	0	6.9***	2.6***
Irrigated Corn Acres average between 2013 and 2017	0	0.4	0.4
Irrigated Corn Acres average between 2018 and 2022	0	0.5*	0.6*
Irrigated Cotton Acres average between 2013 and 2017	0	0.4**	0.1+
Irrigated Cotton Acres average between 2018 and 2022	0	0.5***	0.2
Irrigated Rice Acres average between 2013 and 2017	1	0.8	0.8
Irrigated Rice Acres average between 2018 and 2022	1	0.8	0.8
Irrigated Soybean Acres average between 2013 and 2017	1	1.6***	1.5
Irrigated Soybean Acres average between 2018 and 2022	1	1.7***	1.7**
Knows ten or fewer peer producers	1	0.8**	0.8*
Knows five or fewer peer producers	1	0.6	0.6

Sensor	Never Used	Continued use	Abandoned
Knows more than ten peer producers	0	0.2***	0.0++
Knows more than six peer producers	0	0.3***	0.1++
Ownership of Land	1	0.8	0.8
Participated in Arkansas Groundwater Initiative in last five years	0	0.1	0.1+
Participated in Environmental Quality Incentive Program in last five years	1	0.5	0.5
Participated in Regional Conservation Partnership Program in last five years	0	0.2	0.2
Percent farmland leased or rent	71	68.7	67.9
Squared Standardized Risk Seeking	1	0.9	0.9
Standardized Risk Seeking measure	0	0.1	-0.1
Use social networks once a week or more	1	0.7	0.5
Years of farming experiences	27	26.1	28.2

Appendix Table A6 Summary statistics by the status of AWD use

AWDR	Never Used	Continued use	Abandoned
% irrigation water from Groundwater	84	69.5***	83.8++
% irrigation water from farm reservoirs/tailwater recovery systems/both	10	18.1***	12.4
% irrigation water from surface water	9	16.4***	6.2++
% irrigation water irrigation water bought from an irrigation district	0	0.7**	0.0
% under centre pivot 2013-2017	13	2.5***	6.8+
% under centre pivot 2018-2022	12	1.9***	8.6+++
Annual irrigated acres 2013-2017 in 1000 acres	3	3.1**	2.7
Annual irrigated acres 2018-2022 in 1000 acres	3	3.5**	3.3
Depth-to-water increased in the last five years	0	0.2	0.2
Doesn't know any peer producers	0	0.0	0.0
Farms located in groundwater critical areas	1	0.7*	0.6
Generations family have been farming	3	3.5	2.9+
Generations family have been farming for is 3 or more	1	0.8	0.7
Gross sales more than 1 million	1	0.7**	0.6
Groundwater shortage poses a high risk in 10 years	0	0.2	0.1
Groundwater shortage poses a moderate risk in 10 years	0	0.4***	0.1++
Have an active Twitter account	0	0.3	0.3
Highest degree or level of school completed is bachelor’s or higher	0	0.6**	0.4
Hours of in-depth training	1	3.9***	3.0*
Irrigated Corn Acres average between 2013 and 2017	0	0.3	0.2
Irrigated Corn Acres average between 2018 and 2022	0	0.5	0.6
Irrigated Cotton Acres average between 2013 and 2017	0	0.2	0.3
Irrigated Cotton Acres average between 2018 and 2022	0	0.2	0.4
Irrigated Rice Acres average between 2013 and 2017	1	1.1***	1.0*
Irrigated Rice Acres average between 2018 and 2022	1	1.1***	1.0*
Irrigated Soybean Acres average between 2013 and 2017	1	1.5*	1.4
Irrigated Soybean Acres average between 2018 and 2022	1	1.7**	1.5
Knows ten or fewer peer producers	0	0.7***	0.8***
Knows five or fewer peer producers	0	0.5***	0.7***+
Knows more than ten peer producers	0	0.2***	0.1***

AWDR	Never Used	Continued use	Abandoned
Knows more than six peer producers	0	0.4***	0.2***
Ownership of Land	1	0.7	0.8
Participated in Arkansas Groundwater Initiative in last five years	0	0.1	0.1
Participated in Environmental Quality Incentive Program in last five years	1	0.5	0.5
Participated in Regional Conservation Partnership Program in last five years	0	0.2	0.2
Percent farmland leased or rent	67	74.6*	73.8
Squared Standardized Risk Seeking	1	1.1	0.5
Standardized Risk Seeking measure	0	0.0	-0.1
Use social networks once a week or more	1	0.6	0.5
Years of farming experiences	27	26.3	23.0

Appendix Table A7 Summary statistics by the status of Tailwater use

Tailwater	Never Used	Continued use	Abandoned
% irrigation water from Groundwater	94	63.3***	96.0+++
% irrigation water from farm reservoirs/tailwater recovery systems/both	1	24.8***	0.0++
% irrigation water from surface water	5	18.1***	4.0+
% irrigation water irrigation water bought from an irrigation district	0	0.4	0.0
% under centre pivot 2013-2017	16	2.6***	5.6
% under centre pivot 2018-2022	15	2.4***	13.3+++
Annual irrigated acres 2013-2017 in 1000 acres	3	2.9	1.6+
Annual irrigated acres 2018-2022 in 1000 acres	3	3.4**	1.7++
Depth-to-water increased in the last five years	0	0.2**	0.0+
Doesn't know any peer producers	0	0.1***	0.0**
Farms located in groundwater critical areas	1	0.7***	0.8*
Generations family have been farming	3	3.4	2.6*++
Generations family have been farming for is 3 or more	1	0.9	0.5**+++
Gross sales more than 1 million	1	0.7***	0.1**+++
Groundwater shortage poses a high risk in 10 years	0	0.2*	0.2
Groundwater shortage poses a moderate risk in 10 years	0	0.3*	0.4
Have an active Twitter account	0	0.3	0.1
Highest degree or level of school completed is bachelor's or higher	1	0.5	0.3
Hours of in-depth training	1	3.6***	0.5
Irrigated Corn Acres average between 2013 and 2017	0	0.3	0.3
Irrigated Corn Acres average between 2018 and 2022	0	0.5	0.3
Irrigated Cotton Acres average between 2013 and 2017	0	0.1***	0.0
Irrigated Cotton Acres average between 2018 and 2022	0	0.1***	0.0
Irrigated Rice Acres average between 2013 and 2017	1	1.0***	0.5+
Irrigated Rice Acres average between 2018 and 2022	1	1.1***	0.4++
Irrigated Soybean Acres average between 2013 and 2017	1	1.4	0.8+

Tailwater	Never Used	Continued use	Abandoned
Irrigated Soybean Acres average between 2018 and 2022	1	1.6**	1.0
Knows ten or fewer peer producers	1	0.4	1.0***+++
Knows five or fewer peer producers	0	0.2***	0.8*+++
Knows more than ten peer producers	0	0.5***	0.0+++
Knows more than six peer producers	0	0.7***	0.2+++
Ownership of Land	1	0.7	0.7
Participated in Arkansas Groundwater Initiative in last five years	0	0.1	0.1*
Participated in Environmental Quality Incentive Program in last five years	1	0.5**	0.5
Participated in Regional Conservation Partnership Program in last five years	0	0.2	0.2
Percent farmland leased or rent	73	66.5*	64.5
Squared Standardized Risk Seeking	1	0.9	0.9
Standardized Risk Seeking measure	0	0.1**	0.3
Use social networks once a week or more	1	0.6	0.5
Years of farming experiences	27	26.9	26.1

Appendix Table A8 Summary statistics by the status of Reservoir use

Reservoir	Never Used	Continued use	Abandoned
% irrigation water from Groundwater	90	60.1***	80.0++
% irrigation water from farm reservoirs/tailwater recovery systems/both	2	31.4***	6.7*++
% irrigation water from surface water	8	16.1***	15.0
% irrigation water irrigation water bought from an irrigation district	0	0.5	0.0
% under centre pivot 2013-2017	14	1.4***	0.6
% under centre pivot 2018-2022	13	1.6***	0.6
Annual irrigated acres 2013-2017 in 1000 acres	3	2.7	1.9
Annual irrigated acres 2018-2022 in 1000 acres	3	3.3	2.0
Depth-to-water increased in the last five years	0	0.2	0.0
Doesn't know any peer producers	0	0.0***	0.2+++
Farms located in groundwater critical areas	1	0.8***	0.5++
Generations family have been farming	3	3.5	2.8
Generations family have been farming for is 3 or more	1	0.8	0.6
Gross sales of more than 1 million	1	0.7**	0.5
Groundwater shortage poses a high risk in 10 years	0	0.3*	0.1
Groundwater shortage poses a moderate risk in 10 years	0	0.4**	0.4
Have an active Twitter account	0	0.2*	0.2
Highest degree or level of school completed is bachelor’s or higher	1	0.5	1.0***+++
Hours of in-depth training	1	5.9***	0.0
Irrigated Corn Acres average between 2013 and 2017	0	0.3	0.1
Irrigated Corn Acres average between 2018 and 2022	0	0.5	0.2
Irrigated Cotton Acres average between 2013 and 2017	0	0.1***	0.1
Irrigated Cotton Acres average between 2018 and 2022	0	0.1**	0.2
Irrigated Rice Acres average between 2013 and 2017	1	1.0***	0.6
Irrigated Rice Acres average between 2018 and 2022	1	1.1***	0.6
Irrigated Soybean Acres average between 2013 and 2017	1	1.4	1.0
Irrigated Soybean Acres average between 2018 and 2022	1	1.5	1.0

Reservoir	Never Used	Continued use	Abandoned
Knows ten or fewer peer producers	0	0.3***	0.6+
Knows five or fewer peer producers	0	0.2***	0.5+
Knows more than ten peer producers	0	0.6***	0.1+++
Knows more than six peer producers	0	0.7***	0.2+++
Ownership of Land	1	0.8	0.6
Participated in Arkansas Groundwater Initiative in last five years	0	0.1	0.2***+
Participated in Environmental Quality Incentive Program in last five years	1	0.5**	0.6++
Participated in Regional Conservation Partnership Program in last five years	0	0.2	0.2
Percent farmland leased or rent	73	63.9**	78.8
Squared Standardized Risk Seeking	1	0.9	1.6
Standardized Risk Seeking measure	0	0.1	0.5
Use social networks once a week or more	1	0.6	0.6
Years of farming experiences	27	25.5	24.5

Appendix Table A9 Summary statistics by the status of Flow meter use

Flowmeter	Never Used	Continued use	Abandoned
% irrigation water from Groundwater	86	76.4**	80.7
% irrigation water from farm reservoirs/tailwater recovery systems/both	7	14.3**	14.2*
% irrigation water from surface water	10	11.5	11.2
% irrigation water irrigation water bought from an irrigation district	0	0.4	0.3
% under centre pivot 2013-2017	13	8.1*	8.2
% under centre pivot 2018-2022	12	7.4	10.4
Annual irrigated acres 2013-2017 in 1000 acres	2	2.9*	2.7
Annual irrigated acres 2018-2022 in 1000 acres	2	3.3***	3.0
Depth-to-water increased in the last five years	0	0.2	0.2*
Doesn't know any peer producers	1	0.1***	0.2***++
Farms located in groundwater critical areas	1	0.6	0.6
Generations family have been farming	3	3.4	3.2
Generations family have been farming for is 3 or more	1	0.8	0.8
Gross sales more than 1 million	0	0.7**	0.5++
Groundwater shortage poses a high risk in 10 years	0	0.2	0.1+
Groundwater shortage poses a moderate risk in 10 years	0	0.3	0.2
Have an active Twitter account	0	0.4***	0.2
Highest degree or level of school completed is bachelor’s or higher	0	0.6*	0.4+
Hours of in-depth training	0	3.2***	0.6++
Irrigated Corn Acres average between 2013 and 2017	0	0.3	0.4
Irrigated Corn Acres average between 2018 and 2022	0	0.5*	0.6**
Irrigated Cotton Acres average between 2013 and 2017	0	0.2	0.4
Irrigated Cotton Acres average between 2018 and 2022	0	0.3	0.5*
Irrigated Rice Acres average between 2013 and 2017	1	0.9**	0.7
Irrigated Rice Acres average between 2018 and 2022	1	0.9**	0.7
Irrigated Soybean Acres average between 2013 and 2017	1	1.4	1.2
Irrigated Soybean Acres average between 2018 and 2022	1	1.6**	1.2+

Flowmeter	Never Used	Continued use	Abandoned
Knows ten or fewer peer producers	0	0.6***	0.7***+
Knows five or fewer peer producers	0	0.5	0.7***+++
Knows more than ten peer producers	0	0.3***	0.1+++
Knows more than six peer producers	0	0.5***	0.1+++
Ownership of Land	1	0.8	0.6++
Participated in Arkansas Groundwater Initiative in last five years	0	0.1	0.1
Participated in Environmental Quality Incentive Program in last five years	1	0.5	0.5
Participated in Regional Conservation Partnership Program in last five years	0	0.2	0.2
Percent farmland leased or rent	66	70.4	73.7
Squared Standardized Risk Seeking	1	0.9	1.1
Standardized Risk Seeking measure	0	0.1*	-0.2
Use social networks once a week or more	1	0.6	0.5
Years of farming experiences	28	27.3	22.7*+

Appendix Table A10 Summary statistics by the status of Pump Timer use

Pump timer	Never Used	Continued use	Abandoned
% irrigation water from Groundwater	80	79.5	81.2
% irrigation water from farm reservoirs/tailwater recovery systems/both	13	9.8	0.0
% irrigation water from surface water	11	13.3	18.8
% irrigation water irrigation water bought from an irrigation district	0	0.0	0.0
% under centre pivot 2013-2017	10	9.9	2.5
% under centre pivot 2018-2022	9	7.8	2.5
Annual irrigated acres 2013-2017 in 1000 acres	3	3.4**	2.5
Annual irrigated acres 2018-2022 in 1000 acres	3	3.5	1.9
Depth-to-water increased in the last five years	0	0.1*	0.2
Doesn't know any peer producers	1	0.1***	0.2**
Farms located in groundwater critical areas	1	0.6	0.8
Generations family have been farming	3	3.3	3.8
Generations family have been farming for is 3 or more	1	0.9	1.0
Gross sales more than 1 million	1	0.7	0.5
Groundwater shortage poses a high risk in 10 years	0	0.1	0.0
Groundwater shortage poses a moderate risk in 10 years	0	0.3	0.5
Have an active Twitter account	0	0.4*	0.2
Highest degree or level of school completed is bachelor's or higher	1	0.5	0.8
Hours of in-depth training	0	2.1***	0.6
Irrigated Corn Acres average between 2013 and 2017	0	0.4	0.4
Irrigated Corn Acres average between 2018 and 2022	0	0.6	0.3
Irrigated Cotton Acres average between 2013 and 2017	0	0.5**	0.1
Irrigated Cotton Acres average between 2018 and 2022	0	0.5*	0.1
Irrigated Rice Acres average between 2013 and 2017	1	1.0	0.7
Irrigated Rice Acres average between 2018 and 2022	1	0.8	0.6
Irrigated Soybean Acres average between 2013 and 2017	1	1.6*	1.4

Pump timer	Never Used	Continued use	Abandoned
Irrigated Soybean Acres average between 2018 and 2022	1	1.6	0.9
Knows ten or fewer peer producers	0	0.7***	0.8**
Knows five or fewer peer producers	0	0.5***	0.8**
Knows more than ten peer producers	0	0.1***	0.0
Knows more than six peer producers	0	0.3***	0.0
Ownership of Land	1	0.9***	0.8
Participated in Arkansas Groundwater Initiative in last five years	0	0.1	0.1
Participated in Environmental Quality Incentive Program in last five years	1	0.5	0.5
Participated in Regional Conservation Partnership Program in last five years	0	0.2	0.3+
Percent farmland leased or rent	70	70.7	48.8
Squared Standardized Risk Seeking	1	1.1	0.9
Standardized Risk Seeking measure	0	0.1	0.1
Use social networks once a week or more	1	0.7	0.5
Years of farming experiences	26	28.8	36.2

Appendix Table A11 Summary statistics by the status of Row Rice use

Row rice	Never Used	Continued use	Abandoned
% irrigation water from Groundwater	84	75.8**	76.8
% irrigation water from farm reservoirs/tailwater recovery systems/both	10	13.4	16.4
% irrigation water from surface water	8	14.0**	11.3
% irrigation water irrigation water bought from an irrigation district	0	0.6*	0.0
% under centre pivot 2013-2017	16	5.1***	3.1***
% under centre pivot 2018-2022	15	3.7***	4.4***
Annual irrigated acres 2013-2017 in 1000 acres	2	3.2***	2.6
Annual irrigated acres 2018-2022 in 1000 acres	2	3.7***	3.0
Depth-to-water increased in the last five years	0	0.2	0.2
Doesn't know any peer producers	0	0.0***	0.0*
Farms located in groundwater critical areas	1	0.6	0.8***+++
Generations family have been farming	3	3.4	3.3
Generations family have been farming for is 3 or more	1	0.8	0.8
Gross sales more than 1 million	0	0.7***	0.6
Groundwater shortage poses a high risk in 10 years	0	0.2	0.1*
Groundwater shortage poses a moderate risk in 10 years	0	0.3	0.2
Have an active Twitter account	0	0.3**	0.3
Highest degree or level of school completed is bachelor’s or higher	0	0.6*	0.4++
Hours of in-depth training	1	9.4***	3.7***
Irrigated Corn Acres average between 2013 and 2017	0	0.4**	0.3
Irrigated Corn Acres average between 2018 and 2022	0	0.6***	0.5
Irrigated Cotton Acres average between 2013 and 2017	0	0.2	0.1*
Irrigated Cotton Acres average between 2018 and 2022	0	0.2	0.1
Irrigated Rice Acres average between 2013 and 2017	1	1.0***	0.8
Irrigated Rice Acres average between 2018 and 2022	1	1.1***	0.8++
Irrigated Soybean Acres average between 2013 and 2017	1	1.6***	1.5**
Irrigated Soybean Acres average between 2018 and 2022	1	1.8***	1.5**

Row rice	Never Used	Continued use	Abandoned
Knows ten or fewer peer producers	1	0.4***	0.6*
Knows five or fewer peer producers	1	0.2***	0.3*++
Knows more than ten peer producers	0	0.6***	0.4***
Knows more than six peer producers	0	0.8***	0.6***++
Ownership of Land	1	0.7	0.8
Participated in Arkansas Groundwater Initiative in last five years	0	0.1*	0.1
Participated in Environmental Quality Incentive Program in last five years	1	0.5	0.5
Participated in Regional Conservation Partnership Program in last five years	0	0.2	0.2
Percent farmland leased or rent	69	73.8	62.6+
Squared Standardized Risk Seeking	1	0.9	1.0
Standardized Risk Seeking measure	0	0.1	-0.1
Use social networks once a week or more	1	0.6	0.7
Years of farming experiences	29	25.0**	25.0*

Appendix Table A12 Summary statistics by the status of Drone use

Drone	Never Used	Continued use	Abandoned
% irrigation water from Groundwater	79	80.5	77.8
% irrigation water from farm reservoirs/tailwater recovery systems/both	14	9.7	4.7
% irrigation water from surface water	10	11.1	18.8
% irrigation water irrigation water bought from an irrigation district	0	0.3	0.0
% under centre pivot 2013-2017	8	11.0	14.4
% under centre pivot 2018-2022	8	9.9	12.1
Annual irrigated acres 2013-2017 in 1000 acres	2	3.2***	3.2
Annual irrigated acres 2018-2022 in 1000 acres	3	3.9***	3.3
Depth-to-water increased in the last five years	0	0.2	0.1
Doesn't know any peer producers	0	0.1***	0.3++
Farms located in groundwater critical areas	1	0.6	0.8
Generations family have been farming	3	3.4	3.6
Generations family have been farming for is 3 or more	1	0.8	0.9
Gross sales of more than 1 million	1	0.7**	0.7
Groundwater shortage poses a high risk in 10 years	0	0.2	0.2
Groundwater shortage poses a moderate risk in 10 years	0	0.2	0.2
Have an active Twitter account	0	0.3	0.4
Highest degree or level of school completed is bachelor's or higher	1	0.5	0.4
Hours of in-depth training	0	4.5***	0.8
Irrigated Corn Acres average between 2013 and 2017	0	0.4**	0.4
Irrigated Corn Acres average between 2018 and 2022	0	0.7***	0.5
Irrigated Cotton Acres average between 2013 and 2017	0	0.3	0.3
Irrigated Cotton Acres average between 2018 and 2022	0	0.4	0.4
Irrigated Rice Acres average between 2013 and 2017	1	0.9	0.5
Irrigated Rice Acres average between 2018 and 2022	1	0.9	0.6
Irrigated Soybean Acres average between 2013 and 2017	1	1.6***	1.9***
Irrigated Soybean Acres average between 2018 and 2022	1	1.7***	1.7
Knows ten or fewer peer producers	0	0.8***	0.7
Knows five or fewer peer producers	0	0.7***	0.7*
Knows more than ten peer producers	0	0.1***	0.0

Drone	Never Used	Continued use	Abandoned
Knows more than six peer producers	0	0.2***	0.0++
Ownership of Land	1	0.8	0.5**++
Participated in Arkansas Groundwater Initiative in last 5 years	0	0.1	0.1
Participated in Environmental Quality Incentive Program in last 5 years	1	0.5	0.5
Participated in Regional Conservation Partnership Program in last 5 years	0	0.2***	0.2
Percent farmland leased or rent	69	68.2	86.8**++
Squared Standardized Risk Seeking	1	1.1	0.8
Standardized Risk Seeking measure	0	0.1	-0.2
Use social networks once a week or more	1	0.7***	0.6
Years of farming experiences	28	25.5	21.6*

Appendix Table A13 Alternative specification of Table 5, with share of users in the county the year prior to adoption included

	CHS	Surge	Minlet	Sensor	AWD	Tail_Res	Flowmeter	Pumptimer	Row rice	Drone
Prev_CT_CHS	-13.421***	-0.786	-1.706	-0.479	-2.252*	-0.328	-0.800	-0.262	-0.483	-0.325
	(2.457)	(0.854)	(1.202)	(1.091)	(1.229)	(0.932)	(1.913)	(1.662)	(1.125)	(0.994)
Prev_CT_Surge	0.844	-2.862	3.386**	2.753**	-1.324	-2.462*	-3.786**	7.654***	-0.847	0.022
	(1.390)	(1.862)	(1.717)	(1.380)	(1.951)	(1.374)	(1.545)	(2.938)	(1.806)	(1.349)
Prev_CT_Minlet	-0.436	0.444	-8.139***	0.482	-1.273	-1.658	1.686	1.228	0.302	0.912
	(1.389)	(1.031)	(1.382)	(0.823)	(0.955)	(1.075)	(1.030)	(1.213)	(0.976)	(0.885)
Prev_CT_Sensor	2.487	-1.898	-3.440**	-7.979***	0.548	-2.142*	-3.298	-2.345	0.088	0.085
	(1.817)	(1.244)	(1.525)	(1.579)	(1.327)	(1.135)	(2.492)	(2.199)	(1.399)	(1.183)
Prev_CT_AWD	0.266	-1.678	-2.501	-0.344	-8.773***	4.517**	-0.262	3.699*	1.682	-1.323
	(1.607)	(1.353)	(1.561)	(1.161)	(1.915)	(1.852)	(1.670)	(1.933)	(1.399)	(1.300)
Prev_CT_Tail_Res	-0.928	-0.660	2.274*	-1.846*	3.558***	-5.242***	0.653	1.766*	2.969***	1.928*
	(1.109)	(0.995)	(1.278)	(1.011)	(1.245)	(1.472)	(1.069)	(1.056)	(0.985)	(0.997)
Prev_CT_Flowmeter	1.382	-0.285	2.755***	0.441	1.601*	1.508	-11.616***	0.296	0.978	-1.947**
	(1.047)	(0.900)	(1.037)	(0.934)	(0.945)	(1.117)	(1.988)	(1.022)	(0.909)	(0.862)
Prev_CT_Pumptimer	-2.525	0.734	3.928	-2.491	8.330***	0.327	3.802	-21.676***	6.700***	-3.689
	(2.769)	(1.933)	(2.671)	(2.077)	(2.404)	(2.438)	(3.009)	(6.508)	(2.471)	(2.543)
Prev_CT_FurrowIrri	-0.411	0.794	1.264	-0.030	0.779	2.268*	-0.625	1.985	-5.931***	-0.071
	(1.401)	(1.030)	(1.313)	(1.110)	(1.022)	(1.335)	(1.304)	(1.601)	(1.260)	(1.026)
Prev_CT_Drone	-1.397	-1.945	-0.813	0.641	-5.040***	-0.278	-5.031**	-5.986***	-2.789*	-8.836***
	(1.877)	(1.498)	(1.896)	(1.377)	(1.523)	(1.528)	(2.274)	(2.187)	(1.690)	(2.343)
HR_CHS	0.568***	0.153*	0.027	0.757***	0.141	0.091	0.561**	0.390*	0.104*	0.070**
	(0.209)	(0.081)	(0.069)	(0.242)	(0.102)	(0.067)	(0.228)	(0.225)	(0.055)	(0.031)
N6_10_CHS	3.045***	1.895***	1.912***	1.568**	2.590***	1.108*	4.051**	2.514***	0.665	0.993
	(0.927)	(0.655)	(0.474)	(0.643)	(0.602)	(0.567)	(1.740)	(0.844)	(0.557)	(0.620)
N10up_CHS	2.144***	3.418**	3.233***	1.094	0.000	0.622	1.976**	2.743**	1.732***	3.066***
	(0.639)	(1.426)	(0.588)	(0.730)	(.)	(0.611)	(0.785)	(1.306)	(0.434)	(1.141)
PT_rent	0.012	0.005	0.000	-0.006	0.022***	-0.009	0.004	-0.000	0.002	-0.001
	(0.010)	(0.005)	(0.007)	(0.005)	(0.008)	(0.007)	(0.007)	(0.008)	(0.006)	(0.006)
YRS_Farming	0.018	-0.014	0.005	0.010	0.003	-0.028*	-0.028	0.029	-0.006	-0.025*
	(0.019)	(0.015)	(0.017)	(0.013)	(0.016)	(0.015)	(0.019)	(0.018)	(0.015)	(0.014)
Gen3More	-0.941	0.357	-0.434	-0.430	-1.140**	-0.251	-0.578	-0.068	-0.417	0.003

	CHS	Surge	Minlet	Sensor	AWD	Tail_Res	Flowmeter	Pumptimer	Row rice	Drone
	(0.666)	(0.463)	(0.575)	(0.496)	(0.533)	(0.486)	(0.615)	(0.739)	(0.511)	(0.471)
Bachelor	1.177**	0.560	-0.125	0.749**	-0.001	-0.820*	0.489	0.546	-0.187	-0.500
	(0.500)	(0.365)	(0.429)	(0.348)	(0.410)	(0.430)	(0.503)	(0.476)	(0.397)	(0.346)
Twitter	1.109**	0.658*	-0.480	0.579	0.243	-0.553	1.016	0.257	0.188	-0.189
	(0.527)	(0.381)	(0.471)	(0.481)	(0.503)	(0.432)	(0.659)	(0.532)	(0.478)	(0.371)
More1Mil	0.080	0.166	-0.081	-0.227	-0.652	0.949*	0.408	0.569	0.746	0.191
	(0.629)	(0.471)	(0.502)	(0.449)	(0.475)	(0.504)	(0.684)	(0.694)	(0.480)	(0.435)
Risk0_4	0.464	-1.431**	1.189**	-0.155	-0.837	-0.720	0.106	-0.426	-0.093	0.056
	(0.677)	(0.564)	(0.563)	(0.547)	(0.812)	(0.550)	(0.559)	(0.589)	(0.637)	(0.461)
Risk9_10	-0.007	-1.942**	-0.555	-0.956**	-0.804*	0.743	-0.498	-0.715	-1.336*	-0.139
	(0.703)	(0.860)	(0.737)	(0.437)	(0.447)	(0.691)	(0.563)	(0.563)	(0.697)	(0.455)
PT_GW	0.042***	0.016*	-0.013	0.007	-0.026***	-0.077***	-0.010	0.008	-0.013	0.002
	(0.014)	(0.009)	(0.009)	(0.007)	(0.008)	(0.019)	(0.010)	(0.012)	(0.009)	(0.007)
GW_Highrisk	0.439	0.180	1.078**	0.349	0.210	-0.330	-0.319	-0.538	-0.781*	-0.001
	(0.618)	(0.453)	(0.508)	(0.488)	(0.498)	(0.540)	(0.566)	(0.625)	(0.439)	(0.432)
Critical_GW	-0.614	0.515	1.777***	0.314	1.045**	1.622***	-0.558	0.461	0.128	0.112
	(0.657)	(0.437)	(0.510)	(0.458)	(0.465)	(0.519)	(0.636)	(0.675)	(0.529)	(0.433)
CT_EQIP	4.769**	1.895	-1.483	-1.186	0.387	0.824	3.781	5.596***	-0.012	3.772**
	(2.074)	(1.220)	(2.085)	(1.170)	(1.418)	(1.363)	(2.685)	(1.759)	(1.499)	(1.725)
CT_Initiative	-3.774*	-0.214	0.101	-0.490	-0.348	1.627	-1.267	1.621	6.516***	0.404
	(2.271)	(2.077)	(2.225)	(2.032)	(1.821)	(3.074)	(2.187)	(2.295)	(2.377)	(1.759)
CT_Partnership	-3.907*	-1.569	-3.903*	1.967	-4.220*	4.482**	6.003**	0.818	-1.913	-4.571**
	(2.087)	(1.532)	(2.107)	(1.791)	(2.358)	(2.063)	(2.336)	(2.575)	(2.570)	(1.989)
IrAcres_1317	-0.002	-0.052	0.236*	0.132	0.116	0.028	-0.048	0.088	0.274	0.171**
	(0.192)	(0.096)	(0.131)	(0.105)	(0.106)	(0.103)	(0.199)	(0.157)	(0.175)	(0.082)
PT_Rice1317	0.021*	-0.018**	0.053***	-0.029**	0.014	0.037***	0.013	-0.015	-0.021**	-0.005
	(0.012)	(0.008)	(0.016)	(0.012)	(0.011)	(0.011)	(0.011)	(0.011)	(0.010)	(0.009)
_cons	-2.068	-2.273	1.674	1.137	0.901	5.764**	5.379	-7.227***	0.710	0.347
	(2.034)	(1.510)	(1.611)	(1.414)	(1.437)	(2.239)	(3.292)	(2.360)	(1.549)	(1.209)
N	274	274	274	274	212	274	274	274	229	274
AIC	195.507	279.724	226.411	272.834	236.997	238.351	194.004	194.104	241.057	299.672
BIC	303.901	388.117	334.805	381.228	334.338	346.745	302.398	302.498	344.068	408.065

Appendix Table A14 Alternative specification of Table 5, outcome as % irrigated areas that adopted the practice

	CHS	Surge	Minlet	SMS	AWD	Tail_Res	Flowmeter	Pump timer	Row rice	Drone
CHS		3.628	-0.470	9.613***	6.667	-2.878	9.534	-1.339	7.134	4.120
		(3.220)	(7.865)	(3.050)	(6.358)	(3.354)	(6.996)	(3.759)	(6.182)	(5.374)
Surge	11.236		10.514	-0.059	3.962	2.681	9.423	-0.140	1.713	-10.016
	(10.517)		(11.964)	(4.875)	(9.336)	(5.032)	(10.422)	(5.864)	(9.307)	(8.132)
Minlet	2.633	-3.317		2.578	-1.622	0.631	-12.477	-6.640	-12.764	-4.697
	(9.552)	(4.202)		(4.170)	(7.821)	(4.191)	(8.992)	(4.810)	(7.892)	(7.051)
Sensor	2.310	-2.282	2.335		-14.530**	-0.854	7.476	-0.014	-17.330***	6.680
	(7.432)	(3.258)	(8.490)		(6.946)	(3.493)	(7.515)	(3.912)	(6.462)	(5.604)
AWD	-9.034	3.570	-7.631	-2.260		-2.013	10.726	-4.484	4.173	3.526
	(8.250)	(3.665)	(8.665)	(3.616)		(3.832)	(8.128)	(4.242)	(6.957)	(6.188)
Tail_Res	-7.414	2.218	-12.704	-2.458	21.652***		-16.009*	4.128	7.459	-0.862
	(9.247)	(4.093)	(10.224)	(4.142)	(8.165)		(8.633)	(4.672)	(7.792)	(7.003)
Flowmeter	-2.241	-1.378	-17.602**	1.180	-4.186	0.222		-6.456	-10.688	4.311
	(8.130)	(3.596)	(8.724)	(3.696)	(7.063)	(3.887)		(4.185)	(6.971)	(5.766)
Pumptimer	-0.181	-2.017	6.346	-1.302	10.715	-2.987	14.017*		9.526	10.334*
	(8.401)	(3.845)	(9.175)	(3.967)	(7.558)	(3.864)	(8.478)		(7.169)	(6.082)
FurrowIrri	2.134	1.431	1.965	-3.631	8.321	4.097	3.850	6.477		-6.803
	(7.976)	(3.632)	(8.267)	(3.548)	(7.098)	(3.788)	(7.989)	(4.207)		(6.022)
Drone	3.563	1.329	-2.574	0.574	-4.440	-2.386	14.248*	12.091***	-9.227	
	(7.890)	(3.545)	(8.629)	(3.790)	(7.037)	(3.696)	(7.631)	(4.176)	(6.811)	
PT_rent	0.060	-0.037	-0.022	-0.015	0.041	-0.035	-0.056	0.022	0.016	-0.015
	(0.063)	(0.028)	(0.070)	(0.028)	(0.053)	(0.029)	(0.062)	(0.033)	(0.054)	(0.047)

	CHS	Surge	Minlet	SMS	AWD	Tail_Res	Flowmeter	Pump timer	Row rice	Drone
YRS_Farming	0.122	0.013	-0.344**	-0.122*	-0.080	-0.033	-0.059	0.004	-0.238*	-0.165
	(0.156)	(0.072)	(0.173)	(0.071)	(0.138)	(0.073)	(0.157)	(0.080)	(0.127)	(0.116)
Gen3More	-3.228	1.781	-4.966	1.322	-1.976	2.259	7.345	2.486	-9.263**	4.903
	(5.115)	(2.290)	(5.651)	(2.305)	(4.529)	(2.404)	(5.136)	(2.681)	(4.426)	(3.859)
Bachelor	5.534	0.830	6.345	-1.030	2.731	2.286	3.730	2.666	9.977***	-2.085
	(3.940)	(1.782)	(4.354)	(1.744)	(3.508)	(1.844)	(3.954)	(2.081)	(3.403)	(2.988)
Twitter	8.473*	1.244	3.286	0.557	3.675	1.674	-3.465	1.997	2.466	1.778
	(4.580)	(2.108)	(5.126)	(2.061)	(4.119)	(2.147)	(4.621)	(2.429)	(3.939)	(3.522)
More1Mil	-2.536	-2.480	6.709	-1.530	-5.668	1.190	2.452	-0.802	3.260	-0.435
	(4.688)	(2.103)	(5.202)	(2.106)	(4.240)	(2.110)	(4.690)	(2.441)	(4.030)	(3.483)
Risk0_4	0.489	-0.367	1.741	0.437	0.921	-0.923	-2.811	-4.200	1.893	1.921
	(6.138)	(2.629)	(6.471)	(2.779)	(5.389)	(2.748)	(6.002)	(3.152)	(5.180)	(4.550)
Risk9_10	2.660	-1.238	6.791	-0.746	-1.511	-4.273	14.929**	-1.551	-8.344	-2.897
	(5.745)	(2.536)	(6.566)	(2.669)	(5.166)	(2.741)	(5.869)	(3.068)	(5.135)	(4.370)
PT_GW	0.195*	0.051	-0.218*	-0.033	-0.057	-0.571***	-0.163	0.049	-0.060	-0.007
	(0.108)	(0.050)	(0.126)	(0.049)	(0.098)	(0.044)	(0.106)	(0.058)	(0.093)	(0.084)
GW_Highrisk	3.169	4.045*	-0.056	-2.181	-6.049	1.930	4.607	-0.430	-5.914	3.886
	(4.998)	(2.266)	(5.377)	(2.236)	(4.375)	(2.345)	(4.955)	(2.580)	(4.212)	(3.733)
Critical_GW	-4.669	-0.507	16.189***	-1.723	2.805	5.433***	-1.474	4.096*	-14.351***	2.380
	(4.361)	(2.005)	(5.065)	(2.003)	(3.933)	(2.043)	(4.338)	(2.289)	(3.786)	(3.289)
CT_EQIP	15.872	14.397**	7.983	-7.298	-12.227	2.698	-28.759**	21.381***	-7.428	10.608
	(11.986)	(5.719)	(13.083)	(5.345)	(10.427)	(5.581)	(12.023)	(6.799)	(10.141)	(9.188)
CT_Initiative	-30.091	-11.200	-30.259	12.619	6.776	-1.942	-18.070	-9.198	40.699**	38.312**

	CHS	Surge	Minlet	SMS	AWD	Tail_Res	Flowmeter	Pump timer	Row rice	Drone
	(20.515)	(9.365)	(22.785)	(9.368)	(18.441)	(9.453)	(20.617)	(10.833)	(17.667)	(15.447)
CT_Partnership	-28.187	-4.264	16.558	-6.296	-10.851	4.157	29.920*	1.191	-24.078	-30.276**
	(17.625)	(7.999)	(19.622)	(8.129)	(15.636)	(8.440)	(17.575)	(9.340)	(15.321)	(13.124)
IrAcres_1317	-0.310	-0.016	0.308	-0.155	0.496	-0.562	-0.199	-0.279	1.427	-1.298
	(1.095)	(0.497)	(1.213)	(0.483)	(0.978)	(0.516)	(1.097)	(0.573)	(0.911)	(0.825)
PT_Rice1317	0.030	-0.080	0.371***	-0.014	-0.117	-0.021	0.257**	-0.031	-0.133	0.050
	(0.121)	(0.054)	(0.128)	(0.053)	(0.105)	(0.054)	(0.118)	(0.063)	(0.104)	(0.092)
HR_CHS	0.171	0.245**	-0.160	0.208**	0.483*	0.000	0.060	0.248	0.070***	0.884***
	(0.204)	(0.122)	(0.127)	(0.101)	(0.287)	(0.000)	(0.058)	(0.511)	(0.026)	(0.216)
Prev_CT_CHS	-70.369***	-21.773***	-34.875***	-20.174***	-53.888***	-11.508**	-26.401***	-34.354***	-32.209***	-41.152***
	(10.346)	(6.414)	(9.624)	(6.582)	(11.652)	(4.494)	(9.152)	(11.171)	(8.326)	(12.215)
N6_10_CHS	37.139***	14.939***	19.452***	2.186	24.434***	1.721	9.496	22.759***	7.425*	32.303***
	(5.365)	(3.370)	(5.617)	(3.155)	(6.383)	(2.861)	(6.370)	(4.502)	(4.304)	(6.400)
N10up_CHS	34.180***	43.293***	24.233***	16.247***	46.188***	9.858***	20.938***	20.870***	19.861***	35.509***
	(5.224)	(5.565)	(5.357)	(3.303)	(7.357)	(2.481)	(4.718)	(6.164)	(4.204)	(8.247)
_cons	27.394	-1.582	39.337**	17.661**	25.455	57.215***	32.896*	-10.076	54.375***	12.346
	(17.675)	(7.682)	(19.246)	(8.235)	(15.513)	(7.826)	(17.117)	(8.961)	(14.803)	(13.445)
AIC	24963.286									
BIC	26047.224									

Standard errors in parentheses; * p<0.10, ** p<0.05, *** p<0.01"

Appendix Table A16 Alternative specification of Table 6, with share of users in the county the year prior to adoption included

	CHS	Minlet	SMS	AWD	Flowmeter	Row Rice
Landowner	0.998	0.056	-0.025	0.386	0.694	-0.963
	(1.726)	(0.661)	(1.218)	(1.014)	(0.725)	(0.831)
PT_rent	0.019	-0.008	0.002	0.010	-0.003	0.019**
	(0.022)	(0.007)	(0.011)	(0.015)	(0.011)	(0.010)
YRS_Farming	0.026	-0.042*	0.018	-0.004	0.041*	0.048*
	(0.037)	(0.025)	(0.025)	(0.035)	(0.024)	(0.026)
Gen3More	1.545	0.001	-0.442	-0.335	1.069	-0.120
	(1.236)	(0.620)	(0.890)	(0.910)	(0.742)	(0.784)
Bachelor	-0.078	0.362	-0.011	-0.125	0.754	1.016
	(1.175)	(0.445)	(0.626)	(0.694)	(0.576)	(0.798)
More1Mil	1.933*	0.600	0.121	-0.600	1.340	-0.562
	(1.166)	(0.601)	(0.787)	(0.947)	(0.824)	(0.767)
Risk0_4	-0.484	0.625	-0.277	0.520	-1.290	0.215
	(1.360)	(0.661)	(1.009)	(1.152)	(0.827)	(0.798)
Risk9_10	1.512	0.824	-1.661*	1.114	-0.949	0.283
	(1.398)	(0.821)	(1.008)	(1.331)	(1.397)	(0.863)
PT_GW	-0.023	0.004	-0.009	-0.029	0.030*	-0.005
	(0.035)	(0.010)	(0.014)	(0.045)	(0.016)	(0.013)
GW_Modrisk	-0.602	-0.588	-0.215	2.118**	0.919	0.770
	(1.027)	(0.520)	(0.740)	(0.963)	(0.783)	(0.893)
GW_Highrisk	-0.055	-0.332	0.086	1.393	2.912**	2.676***
	(1.176)	(0.656)	(0.770)	(0.974)	(1.249)	(0.918)
Critical_GW	-3.403*	0.440	-0.102	1.162	-2.317**	-2.368***
	(1.865)	(0.484)	(0.679)	(1.087)	(1.016)	(0.704)
PT_Rice1822	-0.002	0.035**	0.028	0.035	0.058**	0.031
	(0.018)	(0.016)	(0.017)	(0.023)	(0.024)	(0.024)
PT_Soybean1822	0.040	0.013	-0.001	0.045**	0.013	-0.014
	(0.039)	(0.015)	(0.018)	(0.020)	(0.014)	(0.018)
BMP_Yld_stable	-1.925	-0.761	1.872	1.156	1.477	2.108**
	(1.231)	(0.847)	(1.543)	(0.848)	(1.033)	(0.910)
N_all	-0.350	0.275**	-0.108	-0.038	0.229	0.115
	(0.494)	(0.131)	(0.199)	(0.224)	(0.194)	(0.224)
D2W_Increase	-2.467	-0.147	-1.887*	0.002	-1.195	-2.095**
	(1.572)	(0.678)	(1.042)	(1.211)	(0.938)	(0.898)
HR	-0.062	-0.021**	0.090	0.038	0.561**	0.005
	(0.078)	(0.008)	(0.064)	(0.060)	(0.254)	(0.017)
N5orLess	-2.495*	-2.733***	0.643	-1.529	1.676	-2.731*
	(1.447)	(1.058)	(0.667)	(1.358)	(1.020)	(1.562)

	CHS	Minlet	SMS	AWD	Flowmeter	Row Rice
N6_10	3.759	-2.547**	2.772***	1.795	4.266***	-3.478**
	(2.295)	(1.221)	(1.044)	(2.129)	(1.555)	(1.593)
N10up	-0.056	-1.937	3.743**	1.073	4.432***	-3.646**
	(1.640)	(1.188)	(1.499)	(2.135)	(1.414)	(1.531)
LLess	2.861***	1.652***	1.578	-0.334	-1.125	0.673
	(0.821)	(0.632)	(1.225)	(1.156)	(0.994)	(0.577)
PumpHR_Less	3.228**	1.020**	1.731*	0.296	4.657***	0.958*
	(1.340)	(0.445)	(0.905)	(0.789)	(1.177)	(0.570)
IMR	2.078	-4.299	7.121*	5.141	-1.401	-16.608***
	(3.583)	(2.951)	(3.882)	(7.908)	(2.557)	(5.175)
Prev_CT_Surge	0.050	0.871	-3.049	-1.597	1.615	-9.424***
	(3.011)	(1.710)	(2.731)	(2.678)	(2.093)	(2.375)
Prev_CT_Minlet	2.396		-0.769	-2.912	-0.359	2.141
	(3.771)		(1.770)	(1.957)	(1.713)	(1.404)
Prev_CT_Sensor	-2.379	3.071*		4.737	1.498	3.536*
	(3.103)	(1.790)		(3.090)	(2.711)	(1.964)
Prev_CT_AWD	2.709	0.985	-2.960		2.582	-2.880
	(6.161)	(1.631)	(2.859)		(2.181)	(2.004)
Prev_CT_Tail_Res	-0.453	-0.107	-1.255	-0.403	5.746***	-1.202
	(2.881)	(1.123)	(1.812)	(2.432)	(1.898)	(1.512)
Prev_CT_Flowmeter	-4.360	-1.616	2.374	-2.440		2.165
	(3.498)	(1.259)	(1.768)	(1.762)		(1.328)
Prev_CT_Pumptimer	5.152	-0.601	2.020	4.681	-5.386*	8.475***
	(5.702)	(2.633)	(4.800)	(4.546)	(2.896)	(3.256)
Prev_CT_FurrowIrri	-0.750	1.344	-1.583	0.550	-1.421	
	(2.916)	(1.340)	(1.643)	(2.042)	(2.229)	
Prev_CT_Drone	-1.306	-3.186*	-1.310	-2.484	-0.992	8.410***
	(5.911)	(1.656)	(3.603)	(3.191)	(2.770)	(2.592)
Prev_CT_CHS		1.231	-4.934***	-3.322	-1.089	-1.492
		(1.295)	(1.584)	(2.868)	(1.637)	(1.813)
_cons	3.163	1.731	-2.371	-2.378	-10.573***	5.916*
	(5.217)	(2.872)	(4.372)	(3.610)	(4.021)	(3.509)
N	172	195	127	100	201	153
AIC	121.251	221.355	165.738	133.759	168.182	172.778
BIC	228.266	332.637	262.441	222.335	280.495	275.813

Standard errors in parentheses; * p<0.10, ** p<0.05, *** p<0.01"

UNIVERSITY OF ARKANSAS

To:	Qiuqiong Huang
From:	Douglas J Adams, Chair IRB Expedited Review
Date:	06/27/2022
Action:	**Exemption Granted**
Action Date:	06/27/2022
Protocol #:	2102319059
Study Title:	Year 2022 Arkansas Irrigated Producers Survey

The above-referenced protocol has been determined to be exempt.

If you wish to make any modifications in the approved protocol that may affect the level of risk to your participants, you must seek approval prior to implementing those changes. All modifications must provide sufficient detail to assess the impact of the change.

If you have any questions or need any assistance from the IRB, please contact the IRB Coordinator at 109 MLKG Building, 5-2208, or irb@uark.edu.

cc: Christopher Garrett Henry, Investigator

Page 1 of 1