5-2021

The Influence of Peer Irrigators on the Extensive and Intensive Margin of Irrigation Techniques

Victoria Bailey
University of Arkansas, Fayetteville

The Influence of Peer Irrigators on the Extensive and Intensive Margin of Irrigation Techniques

A thesis submitted in partial fulfillment
of the requirements for the degree of
Master of Science in Agricultural Economics

by

Victoria Bailey
College of the Ozarks
Bachelor of Science in Animal Science and Agricultural Business, 2019

May 2021
University of Arkansas

This thesis is approved for recommendation to the Graduate Council.

____
Kent F. Kovacs, Ph.D.
Thesis Director

____
Qiuqiong Huang, Ph.D.
Committee Member

____
Christopher G. Henry, Ph.D.
Committee Member

Abstract

We examine how irrigation techniques in use by family and friends influence the use and share of land utilizing different irrigation techniques by Arkansas producers. A bivariate sample selection model simultaneously estimates how farm characteristics determine the use and explain the share of a farm that utilizes an irrigation technique. We find that the irrigation techniques in use by family and friends do affect the irrigation techniques a producer uses and the share of acres utilizing different irrigation techniques. A producer with a family or friend that uses end-blocking irrigation is 41% more likely to use end-blocking themselves. Having a family or friend who uses pivot irrigation technology tends to decrease the share of irrigated acres that utilizes end block irrigation by 0.211. We also find that when the irrigation techniques in use by family and friends interact with variables like location and participation in a regional conservation partnership program, the effects on the producer's decision vary. The share of irrigated acres that use cutback irrigation decreases by 0.21 for a producer who has a peer that uses irrigation scheduling. However, if the producer lives along Crowley's Ridge and has a peer that uses irrigation scheduling, the share of irrigated acres that use cutback irrigation decreases by an additional 0.54.

Table of Contents

List of Tables

Introduction

Increasing demands of water for fibers, biofuels, and other products driven by population and economic growth, have highlighted the potential limitations on water supplies for agriculture (Hess and Knox, 2013). Finding ways to make irrigation more efficient is imperative to maintain production levels with fewer water resources. Analysis of adoption and diffusion patterns of irrigation technologies is the core of several empirical studies in developing and developed countries (Koundouri, Nauges, and Tzouvelekas, 2006). Many studies provide clear evidence of economic factors, demographic characteristics, and environmental conditions with results explaining their influence on the use of irrigation technologies (Frisvold and Bai, 2016; Green, Sunding, and Zilberman, 1996; Schuck et al., 2005; Wheeler and Bjornlund, 2010). Many prior studies also measure the influence that friends, family, extension agents, etc. have on a producer's use of varying agriculture technologies (Genius et al., 2014; Maertens, Michelson, and Nourani, 2012; Sampson and Perry, 2018), while few studies evaluate the influence of friends and family on the use of irrigation technologies. This paper is an effort to merge these two approaches and provide additional information, to the current literature, concerning the effects of friends and family on the use of different irrigation technologies. We examine whether social interactions or relationships with family, friends, and other producers (peer network) influence the use of specific irrigation technologies; while controlling for crop choice, current irrigation systems, and demographic characteristics. We examine not only the peer effects on the use of irrigation techniques but also the share of irrigated land on each farm utilizing these techniques. We further explore heterogeneity in peer influence by considering how the peer influence depends on the sub-region in Arkansas and a producer's participation in conservation programs.

Much of the literature on peer-effects find that close proximity will increase the likelihood of adopting similar technologies, and increasing the distance lowers the likelihood (Genius et al., 2014; Maertens, Michelson, and Nourani, 2012; Sampson and Perry, 2018; Sampson and Perry, 2019). The sheer number of friends or family that use a particular technology increase the likelihood of adopting the technology; however, when the number of friends or family is greater than ten, likelihood still increases, but does so at a diminishing rate (Bandiera and Rasul, 2006; Sampson and Perry, 2018). Conley and Udry (2010) found that when a producer heard good news about a fertilizer, they were more likely to change their use and when a producer heard bad news about a fertilizer, they were less likely to change their use. The results on extension agent services in technology adoption are somewhat mixed. Genius et al. (2014) found that extension visits positively affect the adoption of new technologies. While other literature (e.g., Conley and Udry, 2010; Ward and Pede, 2014) suggests that extension agent visits or trips to the office have a negative or insignificant effect on technology choice.

Many factors influence a producer's use and intensity of use of different irrigation practices on their farm. The older a producer is, the less likely they are to adopt a different or new type of irrigation technology (Genius et al., 2014; Koundouri, Nauges, and Tzouvelekas, 2006; Pokhrel, Paudel, and Segarra, 2018). Larger farms are more likely to use precision agriculture irrigation techniques than smaller farms (Engler, Jara-Rojas, 2016; Green, Sunding, and Zilberman, 1996; Gopalakrishnan, 1993; Schuck et al., 2005). In addition to this, Genius (2014) found that while larger farms are more likely to adopt, they do so at a slower rate. A higher on-farm income increases the likelihood of adopting different irrigation technologies (Frisvold and Bai, 2016; Koundouri, Nauges, and Tzouvelekas, 2006; Schuck et al., 2005; Wheeler and Bjornlund, 2010). Green, Sunding, and Zilberman (1996) find that having access to surface water decreases the adoption of furrow irrigation by 11%, decreases the adoption of sprinkler irrigation by 12%, and increases the adoption of drip irrigation by 23%. The greater certainty of water supply with surface water makes risk-averse producers more confident about earning sufficient profit to repay expensive on-farm irrigation investments (Green, Sunding, and Zilberman,1996; Schoengold and Sunding, 2014). Although many studies evaluate how peer networks affect the adoption of new agriculture technology and how physical characteristics affect irrigation technique adoption, there is basically no information on how peer networks affect the use of irrigation technologies. Our study should help bridge the gap and fill in the missing information.

The Alluvial Aquifer lies along the lower portion of the Mississippi River Delta. It is closer to the surface than other surrounding aquifers and is primarily used for irrigation. The average depth is 50 feet deep; it can reach up to 150 feet deep in some areas, and there are roughly 19,000 square miles of groundwater in Arkansas (West et al., 2017). Rice, soybeans, and cotton are in the top five agriculture products based on revenue generated in these areas. It is important for producers to utilize efficient irrigation practices, to continue to irrigate their crop without depleting the water source. There are 4,246,491 acres irrigated in Arkansas as of 2018. This is lower than the number of acres in 2012, which was 4,803,902 acres being irrigated (NASSa, 2018; NASS, 2017). This decrease in the number of irrigated acres could be attributed to an increase in rainfall. The United States drought monitor observed a moderate to exceptional drought widespread throughout Arkansas that lasted 101 weeks in 2010-2012, with an exceptional drought affecting 53% of the state in August of 2012 (NIDIS, 2020); therefore, fields that normally go un-watered were irrigated.

Field management practices include zero grade leveling, end blocking, deep tillage, warped surface leveling, precision grade leveling, cover crops and gypsum. Water flow control technologies consist of alternative wetting and drying, multiple inlet irrigation, surge irrigation, flowmeters, computerized hole selection, border irrigation, border irrigation, and cut-back irrigation. The water recovery or storage technologies include tail-water recovery and reservoirs, while the supplemental irrigation technology is computerized irrigation scheduling. Our sprinkler irrigation only consists of pivot irrigation. In Arkansas, 16% of irrigated farms use tail-water recovery or alternative row irrigation, 20% of irrigated farms use precision leveling, 5% of irrigated farms use shorter furrow lengths, 1% of irrigated farms use surge flow, 72% of irrigated farms use a form of poly pipe irrigation, 6% of irrigated farms use other drip irrigation systems, 84% of irrigated farms use gravity irrigation systems, and 23% use sprinkler irrigation systems (NASSd, 2018; NASSe, 2018; NASSf, 2018). The top three barriers to making improvements that conserve water was reported as the producer cannot finance the improvements (30.5%), the landlord will not share the cost (30%), or the improvements will not reduce the cost enough to cover the installation costs (25.8%) (NASSc, 2018). There are some programs enacted to assist in irrigation or drainage improvements. The USDA has programs like Environmental Quality Incentives, Regional Conservation Partnership, and Conservation Innovation Grants for water conservation and Conservation Stewardship, Conservation Reserve, Wetlands Reserve, and Grassland Reserve Stewardship; these programs have 78% and 53% of the eligible farms in Arkansas participating respectively (NASSb, 2018). This is better than the United States as a whole; 52% of the eligible farms participated in water conservation programs, and 12% of eligible farms participated in stewardship programs as of 2018 (NASSb, 2018).

Understanding how peer networks affect a producer's decision to use new or different irrigation practices could help policymakers form programs and regulations that could steer the use of specific practices. Policymakers interested in reducing erosion might distribute information pamphlets about gypsum to producers participating in regional conservation programs. The reason for this is that our findings reveal that producers in the regional conservation program have a predisposition to use a larger share of farmland with gypsum. Extension agents could also target producers more receptive to an irrigation practice. For example, producers living in the South Delta might have a larger share of farmland utilizing warped surface leveling, except our finding show in areas where flow meter use is common. If an extension agent then wants to increase the share of farmland using warped surface leveling, they would send agents to South Delta but avoid areas with greater flow meter use.

In the next section, we provide a brief insight into literature that is similar to the study we are conducting. The first portion covers articles evaluating how physical variables influence the use of particular irrigation technologies, and the second portion covers articles evaluating how social networks influence the use of different technologies. Following that, we provide insight on a bivariate sample selection regression and explain how we apply it for this study; there is also a section to describe the variables being used. We then describe the data and present the results. Following the results section, we draw conclusions as to what influenced the results. The paper concludes with a brief discussion.

Literature Review

While there is much research on how social networks can affect someone's choices and what affects the choice of irrigation techniques, few have taken into consideration how social networks affect the choice of irrigation practices. In the first part of this literature review, we will discuss how the distance between peers, the number of adopters, and how good or bad news spread by peers can affect the decision to adopt new technologies. Next, we will discuss how external influences, like extension agents, can affect the decision to adopt new technologies. The last topic we will discuss is how farm and producer characteristics such as age, farm size, income, water, and land affect a producer's decision on what type of irrigation technologies and techniques to use.

The distance between peers impacts the level of influence the peer network has. Peers that live close have a greater influence on the decisions a producer makes than peers that live further away (Genius et al., 2014; Maertens, Michelson, and Nourani, 2012; Sampson and Perry, 2018; Sampson and Perry, 2019). For every additional kilometer between olive farm producers in Crete, new irrigation technology's adoption time increases by about 63 days (Genius et al., 2014). Similarly, Maertens, Michelson, and Nourani (2012) found that simply living in the same neighborhood increases the likelihood of adopting a neighbor's practice by 6%. Evaluating three villages in India reveals that producers with a progressive neighbor's field close to their own increases the likelihood of adopting a neighbor's practice by 19.9%, 33.4%, and 16.3% (Maertens, Michelson, and Nourani, 2012). In Kansas, it was found that for every additional kilometer of distance, the probability of a peer influencing the producer's decision to use groundwater for irrigation drops by 10% (Sampson and Perry, 2018). When a peer adopter that lives within 1 kilometer adds a low energy precise application device to reduce energy and water consumption, the observed producer's odds of adopting the same technology increases by 0.26%, but if that peer lives within 5-10 kilometers, the odds of adopting the technology only increases by 0.02% and is weakly significant (Sampson and Perry, 2019). A study conducted in South Dakota evaluating spatially mediated peer effects found that a unit increase in the percentage of adopters in a 30-mile radius increases the likelihood of adopting conservation tillage by 0.003 and diverse crop rotation by 0.002 (Kolady, Zhang, Wang, and Ulrich-Schad, 2020). Conservative tillage is knowledge-intensive, and a larger number of adopters might reduce learning or mistake costs associated with the practice. They determined that the peer effects are important in the adoption of conservation tillage and diverse crop rotation though they are not substantial in magnitude. Ultimately the study suggests that spatially mediated peer effects should be included in future studies even if they are not statistically significant because they affect the statistical significance level of other variables and reduces biased estimates (Kolady, Zhang, Wang, and Ulrich-Schad, 2020).

The more friends and family that use a particular technology seems to encourage adoption of the technology, but after so many, the returns start diminishing (Bandiera and Rasul, 2006; Oster and Thornton, 2012; Sampson and Perry, 2018). A one-unit increase in the stock of adopters from the previous year increases the probability of adopting groundwater by 0.25% when evaluating at the 13 nearest neighbor level (Sampson and Perry, 2018), but these returns do eventually diminish. Sampson and Perry (2019) found that with each additional adopter within 0.5 miles, the chance of adopting increases by 4.3%. Bandiera and Rasul (2006) find a producer with 1-5 adopters among their family or friends are 0.271 more likely to adopt sunflower seeds, a producer with 6-10 adopters among their family or friends are 0.577 more likely to adopt, and a producer with 10+ adopters among their family or friends is 0.300 more likely to adopt. These results suggest that the relationship between the number of family or friend adopters and actual adoption is an inverse-U shape. Similarly, Oster and Thornton (2012) found that in the early months of the trial, for every friend who was using a cup, the observed girl was 18.6% more likely to adopt the cup as well. However, by the eighth month, every friend that was using a cup only increased the likelihood by 4.8%. Every friend that did not use the cup decreased the total likelihood of adoption by 4.9%, and the effects on the decision to not adopt decreased as time went on (Oster and Thornton, 2012). This study also evaluates the strength of a friendship. Each girl was asked to list their top friends, and if both girls mentioned each other's name, it is considered a strong friendship, but if only one girl mentions the other's name, it is considered a weak friendship. The findings show that a strong friendship can influence the decision to adopt by 26% in the first few months and by 30% almost a year later; yet weak friendships only influence the decision to adopt by 14% in the first few months and go to non-significant almost a year later (Oster and Thornton, 2012).

Conversations are a simple yet efficient way for information to spread, and the ideas and experiences of those closest to us shape the way we think ourselves. Conley and Udry (2010) found that a one standard deviation increase in a pineapple producer's observation of bad news, from their geographical neighbors, at their previous level of inputs increases the likelihood of changing their level of inputs by 15%. Producers who receive bad news at the alternative input level are 9% less likely to change their input level. Good news also affects whether producers decide to change their input level or not, but the magnitude of these changes is smaller (Conley and Udry, 2010). These results suggest that bad news is weighted heavier than good news for pineapple producers in Ghana.

The influence of extension agents has mixed effects. According to Genius et al. (2014), exposure to extension agents has a strong positive effect on the adoption rate of irrigation technology and reducing the time to adopt by almost 16 weeks. The distance from extension outlets has a negative marginal effect on the mean adoption time of 7 weeks. This counterintuitive result can best be explained by the fact that extension agents target producers in rural areas (Genius et al., 2014). On the other hand, Conley and Udry's (2010) estimate indicates that when a producer received advice from an extension agent, their chance of adjusting the amount of fertilizer applied to their field is significantly less. For extension advice in Bangladesh, both visits from agents and visits to the office had little effect adopting hybrid rice, and the effects were insignificant (Ward and Pede, 2014). His interpretation of this phenomenon is that the experience of peers still dominates a producer's decision to switch technologies. Neighbors have more interactions with each other than with extension agents; therefore, they are more likely to trust the information that comes from their peers (Ward and Pede, 2014).

A producer's age generally tends to have a negative effect on the adoption of new technology (Genius et al., 2014; Koundouri, Nauges, and Tzouvelekas, 2006; Pokhrel, Paudel, and Segarra, 2018). In primary cotton production regions of the United States, a one-year increase in a producer's age increases the acres using furrow irrigation by 0.03%. However, age has no statistically significant effect on the other types of irrigation (Pokhrel, Paudel, and Segarra, 2018). Koundouri, Nauges, and Tzouvelekas (2006) show that in the presence of production uncertainty, producers around the age of 36 are more likely to adopt more efficient irrigation practices than producers around the age of 56. Likewise, a study conducted by Genuis (2014) in Crete found that an additional year of age delays the adoption of drip irrigation by 3.65 days. However, Wheeler and Bjornlund (2010) find that older producers do adopt new irrigation techniques. An additional year in the age of a producer using wheel irrigation increases a likelihood of a switch to pivot irrigation by 0.02% (Wheeler and Bjornlund, 2010). Wheeler and Bjornlund (2010) suggest that the producers require less labor-intensive practices as they get older.

Engler and Jara-Rojas (2016) find that when vineyards grow in size from small to medium, the probability of adopting new irrigation technology increases by 13%; furthermore, vineyards that grow from medium to large have a probability of adoption that increases by 28%. Schuck et al. (2005) determine that the proportion of a farm that utilizes sprinkler systems increases by 11% for every additional 100 irrigated acres a producer owns as a response to drought. According to Genius et al. (2014), for every additional 10 acres a producer owns, drip irrigation adoption rate is delayed by 25 days. In contrast, when a farm in California faces water price uncertainty, every 1000 acres owned reduces the chance of adopting precision irrigation techniques by 1.9% (Schoengold and Sunding, 2014). Schoengold and Sunding's (2014) findings also show the field size estimates are insignificant; therefore, in this case, there are no economies of scale in this scenario. For every one percent change in acres of field, a California citrus producer is 0.19% less likely to use furrow irrigation, 0.15% more likely to use drip irrigation, and 0.34% more likely to use sprinkler irrigation (Green, Sunding, and Zilberman). Similarly, Gopalakrishnan (1993) noted that in Hawaii, furrow irrigated fields are 30% smaller than drip-irrigated fields. Larger farms are more likely to use precision agriculture irrigation techniques than smaller farms (Engler, Jara-Rojas, 2016; Green, Sunding, and Zilberman, 1996; Gopalakrishnan, 1993).

A higher on-farm income increases the likelihood of using newer or precision irrigation technology, while a higher off-farm income decreases the likelihood of new technology adoption (Frisvold and Bai, 2016; Koundouri, Nauges, and Tzouvelekas, 2006; Schuck et al., 2005; Wheeler and Bjornlund, 2010). For every additional dollar of on-farm income in drought conditions that a producer generates, they utilize significantly lower gated pipe irrigation proportions (Schuck et al., 2005). Frisvold and Bai (2016), on the other hand, evaluated current wage levels and lagged wage levels and found that for every one percent increase in income, the use of sprinkler systems increased by 0.184%; however, these estimates were statistically insignificant. When evaluating the effects of having an off-farm income, the likelihood of new irrigation adoption reduces by 4.3% (Koundouri, Nauges, and Tzouvelekas, 2006). However, this estimate is insignificant. Wheeler and Bjornlund (2010) find that if a family member has an off-farm job, then the farm is 0.76% more likely to switch from wheel irrigation to pivot irrigation. Every 1% increase in off-farm income reduces the chance of switching from surface irrigation to wheel irrigation and switching from wheel irrigation to pivot irrigation by 0.01%. The results suggest that having other work encourages the producer to use more efficient technology. While a higher percentage of off-farm income, the lower priority farming and can lead to smaller investments.

In times of high-water prices, producers are more likely to adopt sprinkler or drip irrigation systems (Frisvold and Bai, 2016; Green, Sunding, and Zilberman, 1996; Schoengold and Sunding, 2014). For every dollar per acre-foot increase, the adoption of drip or sprinkler irrigation rises by 0.4% in California (Schoengold and Sunding et al., 2014), and the adoption of sprinkler irrigation rises by 0.45% in the western part of the United States (Frisvold and Bai, 2016). Likewise, Green, Sunding, and Zilberman (1996) find that for every percent increase in the dollar per acre-foot, the likelihood of furrow irrigation adoption lowers by 0.24%, the likelihood of sprinkler adoption lowers by 0.84% lower, and the likelihood of drip irrigation increases by 0.96%. Surface water availability has a situation-specific influence on irrigation technology use. In the western United States, where the reliance on low-cost off-farm surface water is significant, the adoption of sprinkler irrigation using groundwater as a source is low (Frisvold and Bai, 2016). Schoengold and Sunding (2014) argue the opposite that the greater certainty of water supply with surface water makes risk-averse producers more confident about earning sufficient profit to repay expensive on-farm irrigation investments. Surface water availability in California increases the adoption rate of sprinkler or drip irrigation systems by 9.3%. Green, Sunding, and Zilberman (1996) find that having access to surface water decreases the adoption of furrow irrigation by 11%, decreases the adoption of sprinkler irrigation by 12%, and increases the adoption of drip irrigation by 23%.

Farm fields have different slopes, soil properties, and crop types that influence irrigation technology choice. According to Schoengold and Sunding (2014), for every percent increase in a field's grade, a producer is 9.8% more likely to adopt precision irrigation technology. For every percent increase in the grade of a field, the adoption of furrow irrigation decreases by 0.32%, the adoption of sprinkler irrigation increases by 0.01%, and the adoption of drip irrigation increases by 0.23% (Green, Sunding, and Zilberman, 1996). Gopalakrishnan's (1993) findings indicate that soils with relatively good properties and high fertility are 0.81% more likely to utilize drip irrigation, yet soils with good properties but poor fertility are 2.85% more likely to utilize drip irrigation. Genius et al. (2014) shows that for every percent of land with sandy limestone soil, the adoption rate of drip irrigation slows by eight hours and forty-five minutes. Citrus trees, deciduous trees, and grapevines are more likely to use drip irrigation systems and less likely to use sprinkler irrigation systems (Green, Sunding, and Zilberman, 1996).

Method

A bivariate sample selection model is used to find the factors correlated between using irrigation techniques and explaining the share of acres using each technique. This model allows the maximum likelihood of each independent variable having an impact on the dependent variables. It also better explains the influence that producers' choices have on the use and share of acres under an irrigation technique. Each bivariate sample selection model is composed of participation and an outcome equation. The participation equation's dependent variables are binary to specify the use of an irrigation technique. The outcome equation's dependent variables are the share of acres of each technique if that land is used.

The dependent variable in the participation equation, y_1, is an incompletely observed value of a latent dependent variable y_1^*, where the observation rule is

$$y_1 = \begin{cases} 1 \ if \ y_1^* > 0, \\ 0 \ if y_1^* \leq 0 \end{cases}$$

and a resultant outcome equation such that

$$y_2 = \begin{cases} y_2^* \ if \ y_1^* > 0 \\ - \quad if \ y_1^* \leq 0. \end{cases}$$

This model indicates that y_2 is observed when $y_1^* > 0$, and y_2 does not take on a value when $y_1^* \leq 0$. The latent variables y_1^* and y_2^* specify that the use and percentage of land from each technique are not observed for the population as a whole. This then specifies a linear model with additive errors for the latent variables, so

$$y_1^* = x_1'\beta_1 + \varepsilon_1,$$

$$y_2^* = x_2'\beta_2 + \varepsilon_2.$$

Problems from this will arise in estimating β_2 if $\varepsilon_1$and ε_2 are correlated.

We estimate using maximum likelihood, which is asymptotically efficient, and uses the additional assumption that the correlated errors are joint normally distributed and homoscedastic with

$$\left[\frac{\varepsilon_1}{\varepsilon_2}\right] \sim \aleph \left[\left[\frac{0}{0}\right], \begin{bmatrix} 1 & \sigma_{12} \\ \sigma_{12} & \sigma_2^2 \end{bmatrix}\right].$$

The bivariate sample selection model uses the likelihood function

$$L = \prod_{i=1}^{n} \{Pr[y_{1i}^* \leq 0]\}^{1-y_{1i}} \{f(y_{2i} \mid y_{1i}^* > 0) \times Pr[y_{1i}^* > 0]\}^{y_{1i}}$$

where the first term is the participation equation when $y_{1i}^* = 0$, and the second term is thus the outcome equation when $y_{1i}^* > 0$.

The participation equation's marginal effects show the change in the probability of participation in response to a one-unit increase in the explanatory variables. The marginal effects in the outcome equation are the expected change in y_2 for a change in an explanatory variable, dependent on participation and use of the irrigation technique. If an independent variable appears only in the outcome equation, its marginal effect is equal to its coefficient. If the independent variable appears only in the participation equation, a change in the explanatory variable in the participation equation affects the expected value of the error term in the participation equation, which through correlation of the error terms in both equations, leads to an expected change in y_2. If the independent variable appears in both the participation and outcome equations, there is an expected change in y_2 from a direct effect from the explanatory variable in the outcome equation and an indirect effect from the explanatory variable in the participation equation because of the correlation of the error terms in both equations. The maximum likelihood estimation occurs through the models available in Stata® version 13.1.

Data

The data is from the Arkansas Irrigation Use Survey, which was completed in October 2016. The survey was conducted through a collaboration of state irrigation specialists at the University of Arkansas, Mississippi State University, University of Missouri, and Louisiana State University with funding from the United Soybean Promotion Board and Arkansas Soybean Promotion Board (Henry et al. 2020). The Mississippi State University Social Science Research Center administered the survey via phone interviews. The prospective survey respondents were found in the water user database managed by the ANRC, with the commercial crop growers identified by Dun & Bradstreet records for the state of Arkansas. There were 3712 eligible participants contacted: 842 were disabled numbers, 1321 were not answered and had a busy signal or went to voice mail, and 925 contacts were ineligible due to illness or language barriers, which leads to 624 accessible contacts were eligible to complete the survey. During the follow-up call of the 255 contacts who declined to participate, 7 did not complete the survey although they scheduled callbacks, and 171 discontinued the survey. In the end, 199 producers completed the survey in full; therefore, this survey's response rate was between 6.87% and 32.25%. The questionnaire has close to 150 questions and took respondents an average of 30 to 40 minutes to finish via phone.

The dependent variables used in the participation and outcome equations are described in Table 1. The first portion gives the variables used in the participation equation. These are binary variables that equal to 1 if used and 0 otherwise. Precision Grade Leveling (PrecisionGrade) is the most common irrigation practice, with 84% of respondents indicating that they use precision grade leveling on their farm. 13% of respondents use border irrigation systems (Border), 25% of the respondents reported using end block irrigation systems (Endblock), and 8% of the respondent's farms reported using cutback irrigation systems (Cutback). Those who use warped surface leveling (WarpedSurface) form 25% of the data set, cover crops (CoverCrop) also account for 25% of the respondents, and 35% of respondents use deep tillage (DeepTillage). The least common practice that the respondents reported using was gypsum (Gypsum), with only 6%.

The dependent variables for the outcome equation are described in the second portion. These are continuous variables that indicate the percentage of land using a particular practice. Precision grade leveling (Percent_PrecisionGrade) and border irrigation (Percent_Border) systems are reported by participants to be used on the largest portions of irrigated land, that is 56% and 53%, respectively. 47% of irrigated land utilizes cover crops (Percent_CoverCrop). Cut back irrigation (Percent_CutBack) use accounts for 45% of irrigated land, end block irrigation (Percent_EndBlock) use accounts for 43% of irrigated land, gypsum (Percent_Gypsum) use is reported to account for 36% of irrigated land, and deep tillage (Percent_DeepTillage) accounts for 36% of irrigated land. The irrigation practice with the smallest percentage of the irrigated land is warped surface leveling (Percent_WarpedSurface) and accounts for 22%.

This study's explanatory variables are divided into three categories in Table 2: *Farm and Irrigation Characteristics*, *Socioeconomic Characteristics*, and *Peer Network*. *Land use and Irrigation Characteristics* include binary variables that indicate the kind of irrigated crop grown by a farmer. 59% of the producers grow irrigated rice (IrrRice), and 80% have irrigated soybeans (IrrSoy). The other binary variables included in this category describe the type of irrigation practices used on the farms. Soil moisture to schedule irrigation on a farm is reported to be used by 10% of the producers (SoilSensor), 35% own any flow meters (FlowMeter), and 86% use diesel pumps (DieselPump) on the farm. While 6% use computerized scheduling to schedule irrigation on the farm (ComputerSched), only 3% use Et or atmometers to schedule irrigation times (ETAtmometer). Tail-water recovery systems (TWR) are used on 45% of farms according to the participating producers, 38% use center-pivot irrigation (PivotRow) for row crops, 33% of the producers use computerized hole selection (ComputerizedHole), and surge irrigation (Surge) is only used by 16%. The third set of binary variables relates to the county of the respondent. The Delta was broken into five categories to group the farms in similar locations. 31% of respondents lived in a county in Crowley's Ridge (Ridge), 23% lived in a county along the Mississippi River (River), 19% lived in a county in the Grand Prairie (GP), 13% lived in a county in the North Delta and not in the previously described areas (ND), and 7% lived in a county in the South Delta and not in the previously described areas (SD). The next set of binary variables include financial capital considerations. 3% of the participating producers paid for tail-water recovery systems or reservoirs through a state tax credit system (TaxCredStorage). The fifth set of binary variables relate to a farmer's participation in conservation programs. The percentage of farmers participating in a conservation reserve program (PartCRP), environmental quality incentives program (PartEQIP), or other conservation programs (PartOther) is 43%, 45%, and 14%, respectively. The final set of binary variables relate to why a producer decides to use or decide not to use precision leveling. 19% of producers use precision grade leveling to make irrigation easier (PrecisionLevelEasy); however, 6% of the producers do not use precision grade leveling because the cost is too high (NoPrecisionLevelCost).

The continuous variables in this category relate to the acreage devoted to each crop and the expected yield (in hundreds of bushels) from the crops. The total average acreage under irrigation (IrrAcres) is 2,325. The average acreage of irrigated cotton land (IrrCottonAcres) is 112 acres, and 645 irrigated acres in rice production (IrrRiceAcres). On average, the expected yield of corn (YieldCorn) is 85.9 bushels. The total average number of irrigated acres using a precision grade system on a farm (PrecisonGrade) is 1047. There are also continuous variables in this section that describes the number of irrigated acres using different irrigation techniques. The number of irrigated acres using zero grade system (ZeroGrade) is 49, end block irrigation (EndBlock) was utilized for an average of 285 acres, the number of irrigated acres that are contour levee fields using multiple inlet irrigation (Multi-Inlet) is 157, Alternative wetting and drying (AltWetDry) was utilized for an average of 54 irrigated acres of rice, 186 acres on average use warped surface leveling (WarpedSurface), and the number of irrigated acres where cover crops (CoverCrop) are planted is 18.

The last section of continuous variables is physical characteristics. According to the SSURGO database, on average 23% of land in the county of the producer's residence has a PH greater than 6.0 (PH>60) and 23% of the land has a root zone between 0 to 59 inches with available water storage (AWS) (Soil Survey Staff, 2021). The prism climate group states that 2013 had 27.11inches of growing season precipitation (PPT2013), yet 2015 only has 26.71 inches of growing season precipitation (PPT2015) (Oregon State University, 2021). It was also reported that there were 2396 degree days between 50 and 89 Fahrenheit in 2013 (GDD2013), which is degrees*days, while there were 2362 degree days between 50 and 89 Fahrenheit in 2014 (GDD2014) (Oregon State University, 2021). The SSURGO database indicates that 14% of land in the county of the producer's residence has a clay (Clay) component in the soil, 6% has loam (Loam), 63% has silt (Silt), and 9% has sand (Sand) (Soil Survey Staff, 2021). According to the national hydrology dataset a county has an average of 29 miles of flow length through streams, rivers, lakes, and any other open water (OpenWater). A county has an average of 138 miles length of stream or rivers (StreamRiver); these variables give the availability of surface water in the area that could influence irrigation choices (Arkansas GIS, 2021). We also collect three variables to gage the level of irrigation infrastructure in a county (BarrierPipe, CanalDitch, and AqueductPipe) from the national hydrology dataset. A county has 0.07 miles of pipeline that connect waterbodies separated by dams, weirs, and other artificial barriers (BarrierPipe), and the average producer has 34 miles of canals and ditches in their county of residence (CanalDitch). There are 0.01 mile of closed conduits with pumps, valves, and control devices for conveying fluids (AqueductPipe) (Arkansas GIS, 2021).

In the Socioeconomic Characteristics category, the highest education attained by producers in our sample varies considerably. 56% report having an agricultural education background (AgEdu), 42% reported earning a bachelor's degree (Bach), and 9% reported earning higher than a bachelor's degree (AdvEdu). 15% have an income higher than $200K (IncHigh), and 23% did not report any income (IncNA).

The social learning category is primarily on peer networks and information sharing. Binary variables are used to solicit a response from this question: "Please tell me if one or more of your close family members, friends, or neighbor producers has used this practice in the past 10 years?" 87% of respondents know someone who has used precision leveling (PeerPLevel), 66% know someone who has a tail-water recovery system (PeerTWR), and 67% know someone who uses a center pivot (PeerPivot). 71% know someone who uses zero grade leveling (PeerZeroGrade), 60% know someone who has reservoir storage (PeerRes), and 34% know someone who uses surge irrigation (PeerSurge). 52% know someone who uses computerized hole selection (PeerCHS), 62% know someone who owns and uses flow meters (PeerFlowMeter), 50% know someone who uses end-blocking, and cutback irrigation, or furrow diking in irrigation (PeerEndBlock). 49% know someone who uses irrigation scheduling

(PeerSchedule), 65% know someone who uses multiple-inlet rice irrigation (PeerMultiInlet), and 33% know someone who uses alternate wetting and drying for rice irrigation (PeerAltWetDry). These responses do not imply respondents use any of these aforementioned practices but rather sought to determine if there is contact with extension offices they have, and ultimately how belonging to these different peer networks affects the adoption of irrigation measurement tools.

The final set of social learning variables are interaction variables to examine the relationship between participating in a conservation program, using practices promoted by extension personnel, or geographic location with a farmer's peer network. 22% of the producers live along Crowley's Ridge and have a peer that uses center pivot (PeerPivot*Ridge). 12% of producers live in the North Delta and know someone using tail-water recovery (PeerTWR*ND) and 10% of producers live along the Mississippi River and know someone using tail-water recovery (PeerTWR*River). 17% of the producers live in the Grand Prairie and know someone using reservoirs for storage (PeerRes*GP). 3% of producers use computerized hole selection and live in the South Delta (PeerCHS*SD), while 25% of producers use computerized hole selection and participate in conservation reserve programs (PeerCHS*CRP). Producers with peers using surge irrigation and the irrigator raised money for tail-water recovery or reservoir through a federal cost-share program for on-farm reservoirs (PeerSurge*Fed) is 8% of the sample. 15% of the producers have peers using surge irrigation and computerized hole selection (PeerSurge*CHS), while 7% have peers using surge irrigation while participating in a regional conservation partnership program (PeerSurge*RegCon). 17% of producers have peers using flow meters and live on Crowley's Ridge (PeerFlowmeter*Ridge), while 16% have peers using flow meters and live in the Grand Prairie (PeerFlowmeter*GP). 18% of the producers have peers that use flow meters and participation in a federal cost-share program for on-farm reservoirs

(PeerFlowmeter*Fed), but 10% of the producers have peers that use flow meters and participated in regional conservation partnership program (PeerFlowmeter*RegCon). 15% participate in another conservation reserve program and know someone using end block irrigation (PeerEndBlock*PartOther), but 9% participate in a regional conservation partnership program and know someone using end block irrigation (PeerEndBlock*RegCon). 15% live along Crowley's Ridge and know someone using irrigation scheduling (PeerScheduling*Ridge), 4% of producers live in the South Delta and have peers using irrigation scheduling (PeerScheduling*SD), and 26% participate in conservation reserves program and have peers use irrigation scheduling (PeerScheduling*CRP). Producers that have peers that use multiple inlet irrigation rice irrigation and live along Crowley's Ridge (PeerMultiInlet*Ridge), live in the Grand Prairie (PeerMultiInlet*GP), participate in regional conservation partnership program (PeerMultiInlet*RegCon), participate in other conservation programs (PeerMultiInlet*PartOther), or participate in a federal cost-share program for on-farm reservoirs (PeerMultiInlet*Fed) make up 18%, 16%, 10%, 17%, and 18% of the sample respectively. 4% of the producers have peers using wetting and drying for rice irrigation and live in the North Delta (PeerAltWetDry*ND). 3% of the producers have peers using wetting and drying for rice irrigation and live in the South Delta (PeerAltWetDry*SD). Lastly, 8% of the producers have peers using alternating wetting and drying for rice irrigation and participate in other conservation programs (PeerAltWetDry*PartOther), participate in a federal cost-share program for on-farm reservoirs (PeerAltWetDry*Fed).

Results

Marginal effects for explaining whether a producer uses a particular irrigation practice appear in Tables 3 and 4. The marginal effects for the explanatory variables representing the irrigation practices in use by peers are in Table 3. All the other predictors for the use of an irrigation practice appear in Table 4. The use of border irrigation is influenced by whether an irrigator's peers use computerized hole selection, surge irrigation, and zero grade leveling. A producer with a peer that uses computerized hole selection (PeerCHS) has a likelihood of using border irrigation that decreases by 14.3%. If a peer uses surge irrigation and participates in a federal cost-share program for on-farm reservoirs (PeerSurge*Fed), the likelihood of border irrigation use by 22.7%. The 22.7% increase is the addition of the 2.5% increase and the 20.2% increase if the irrigator raised money for tail-water recovery or reservoir through a federal cost-share program (PeerSurge*Fed). Having a peer that uses zero grade irrigation increases the chance of using border irrigation by 7.7% (PeerZeroGrade).

The use of precision grade leveling is primarily influenced by peers that use pivot irrigation. If a producer has a peer that uses pivot irrigation, precision grade leveling increases by a not statistically significant 2.2%. However, if that producer lives along Crowley's Ridge, the likelihood decreases by a statistically significant 11.0% (2.2%+ -13.2%) (PeerPivot*Ridge). Warped surface leveling correlates with several peer variables. If a producer knows someone that uses flow meters (PeerFlowmeter), the likelihood that they will use warped surface leveling increases by about 10%. On the other hand, if a producer knows someone that uses multiple inlet irrigation (PeerMulti-Inlet), the likelihood of using warped surface irrigation decreases by 37.4%. This decrease in use holds for producers that live along Crowley's Ridge, but not for producers who live in the Grand Prairie where the likelihood increases by 13.4% (-37.4% +

50.8%) (PeerMulti-Inlet*GP) or the North Delta where the likelihood increases by 12.8% (-37.4% + 50.2%) (PeerMulti-Inlet*ND). Knowing someone that uses alternating wetting and drying (PeerAltWetDry) as an irrigation practice decreases the likelihood of using warped surface leveling decreases by 14.3%, unless they live in the South Delta (PeerAltWetDry*SD), then the use of warped surface leveling increases by 19.1% (-14.3%+ 33.4%). Similarly, a producer is 31.6% (-0.6% + -31.0%) less likely to use cover crops if they participate in programs other than a prominent federal cost-share program[1] and have a peer that uses alternative wetting and drying (PeerAltWetDry*PartOther).

A producer is 41.3% more likely to use end block irrigation if they know someone who also uses end-blocking irrigation (PeerEndBlock). A producer that lives along Crowley's Ridge and has a peer that uses flow meters (PeerFlowMeter*Ridge) is 34.0% (-2.2% + -31.8%) less likely to use end-blocking irrigation on their farm. Having a peer that uses multiple inlet irrigation (PeerMulti-Inlet) decreases the use of end-blocking irrigation by 20.4%. This is reinforced by producers who also participate in a federal cost-share program for on-farm reservoirs because the likelihood of end block irrigation use is reduced by 63.1% (-20.4% + -42.7%) (PeerMulti-Inlet*Fed).

[1] A conservation program other than the Conservation Reserve Program, Environmental Quality Incentives Program, and the Regional Conservation Partnership Program.

If a producer lives in the South Delta or participates in the conservation reserve program and has a peer that utilizes computerized hole selection (PeerCHS*SD and PeerCHS*CRP), they are 75.5% (24.4 + -99.9%) and 12.9% (24.4 + -37.3%) less likely to use deep tillage respectively. Others that have peers using computerized hole selection are 24.4% more likely to use deep tillage (PeerCHS). Living along Crowley's Ridge and having a peer that uses computerized hole selection increases the likelihood of using deep tillage by 45.7% (24.4% + 21.3%). Having a peer that uses irrigation scheduling (PeerScheduling) decreases the likelihood of deep tillage by 0.6%; however, living in the North Delta or South Delta and knowing someone that schedules irrigation (PeerScheduling*ND and PeerScheduling*SD) decreases the likelihood of using deep tillage by 52% and 78% respectively. Also, having a peer that uses scheduling and participates in a conservation reserve program (PeerScheduling*CRP) is 42.5% (0.6% + 41.9%) more likely to use deep tillage on their farm.

Table 4 has the marginal effects for the explanatory farm, irrigation, and socioeconomic variables that influence the irrigation technique choice. For example, producers that live along the Mississippi River (River) are 16.6% less likely to use border irrigation. Also, having irrigated soybeans (IrrSoy) reduces the likelihood of using border irrigation by 8.4%. The singular socioeconomic variable that affected the use of precision grade leveling, with any magnitude, is having a root zone between 0 to 59 inches with available water storage (AWS). It reduced the likelihood using of precision grade leveling by 2.7%. The number of degree days between 50 and 89 Fahrenheit in 2013 (GDD2013), which is degrees*days, reduces the likelihood of using precision grade leveling by 0.1%. The likelihood that warped surface leveling use increases by at least 37% if a producer lives in the South Delta region (SD), has irrigated soybeans (IrrSoy), or utilizes atmometers (ETAmometer). If a producer has irrigated rice (IrrRice) or participates in a conservation program other than a prominent federal cost-share program (PartOther), then the likelihood of using warped surface leveling increases. The only variable that reduces the use of warped surface leveling is soil sensors (SoilSensor). If a producer uses soil sensors, they are 25.2% less likely to use warped surface leveling.

Only tail-water recovery systems seem to influence the use of end block irrigation with any magnitude. The use of tail-water recovery increases the chance of using end block irrigation by 17.8% (TWR). The expected yield of corn (YieldCorn) and the growing season precipitation of 2014 (PPT2014) increases the chance of using end block irrigation by 0.1%. Producers are less likely to use deep tillage on their farm if they have formal agricultural education or have an advanced degree (AgEdu and AdvEdu). If a producer uses soil sensors, then they are 28.9% less likely to utilize deep tillage. When a producer uses atmometers or has irrigated soybeans, they are more likely to use deep tillage. Using precision leveling because it is more profitable also increases the likelihood of using deep tillage on their farm by 29.2%. The number of degree days between 10 and 32 Celsius in 2013, which is degrees*days, increases the likelihood of using deep tillage by 0.2%. Cover crop usage can change based on many different socioeconomic variables; like location, if a producer lives in the North Delta (ND), they are 16.5% more likely to use cover crops. Yet, if a producer lives in the South Delta (SD), they are 43.6% less likely to use cover crops. Irrigated rice (IrrRice) and pivot row irrigation (PivotRow) hurt the use of cover crops. When a producer reports having an income higher than $200,000, the producer is 14.8% less likely to use cover crops. The variables that have a positive effect on the use of cover crops are computerized scheduling with an additional 27% (ComputerSchedule), corn yield with an additional 0.4% (YieldCorn), located in the North Delta (ND) with an additional 16%, and the use of cover crops with an additional 45% (CoverCrop).

Marginal effects for explaining the share of acres that utilize each practice appear in Tables 5 and 6. Previously we considered why producers use particular practices, but now, conditional on the decision to use the practice, we are looking at the percent of irrigated acres in each practice. The marginal effects in Table 5 are for the explanatory variables that relate to the producer's peer network of fellow irrigators.

If a producer knows someone that uses flow meters (PeerFlowMeter), the share of irrigated land in border irrigation decreases 0.136. Having a peer that uses flow meters and participates in a federal cost-share program for on-farm reservoirs is estimated to use a substantially larger share of border irrigation, 0.346 (-0.136 + 0.482) to be exact (PeerFlowmeter*Fed). Producers living in the Grand Prairie and know someone who uses flow meters (PeerFlowmeter*GP) have 0.815 (-0.136 + -0.679) fewer shares of irrigated land that utilizes border irrigation. The share of irrigated land that uses precision grade leveling also decreases if a producer has a peer that uses flow meters (PeerFlowmeter). Knowing someone that uses tail-water recovery systems (PeerTWR) will decrease the share of irrigated land estimated to use precision grade leveling by 0.173; unless you live along the Mississippi River (PeerTWR*River), then the estimated share of land only decreases by 0.020 (-0.175 + 0.155). Producers with a peer that utilizes end block irrigation (PeerEndBlock) increase the share of irrigated land using precision grade leveling by 0.173. Producers with peers that use end block irrigation and participate in regional conservation programs (PeerEndBlock*RegCon) are estimated to use 0.049 less (0.173 + -0.223) shares of land using precision grade leveling. Having a peer that uses alternative wetting and drying (PeerAltWetDry) increases the share of land that likely uses precision grade leveling by 0.184. Plus, participating in a federal cost-share program for on-farm reservoirs and having a peer that uses alternating wetting and drying

(PeerAltWetDry*Fed) also positively affects the estimated share of acres using precision grade leveling. If a producer has a peer that utilizes surge irrigation (PeerSurge), decreases the share of acres utilizing precision grade leveling by 0.105, unless the producer also uses computerized hole selection (PeerSurge*CHS), then the likelihood increases by 0.064 (-0.105 + 0.169). Producers participating in a federal cost-share program for on-farm reservoirs and have a peer that uses surge irrigation (PeerSurge*Fed) the share of land using precision grade leveling decreases by 0.318 (-0.105 + -0.213).

If a producer lives in the Grand Prairie and knows someone using reservoirs (PeerRes*GP), they are estimated to have 0.030 (-0.152 + 0.183) more shares that utilize warped surface leveling, but in the other regions having a peer that uses reservoirs (PeerRes) decreases the share of land utilizing warped surface leveling by 0.152. On a different note, producers that know someone using end block irrigation are likely to use 0.082 of the irrigated land of end-blocking irrigation instead of the average 0.430. A producer that participates in regional conservation programs or other programs and has a peer that uses end block irrigation will likely have 0.073 (-0.348 + 0.275) and 0.563 (-0.348 + -0.215) fewer shares of land using end block. Producers with a peer that uses center-pivot irrigation (PeerPivot) are likely to have 0.211 less irrigated land that utilizes end block irrigation. Participating in a regional conservation program and having a peer that uses flow meters (PeerFlowmeter*RegCon) will increase the share of irrigated land that utilizes end block irrigation yet having a peer that uses multiple inlet irrigation (PeerMultiInlet*RegCon) decreases the share of land. Producers that live along Crawley's Ridge having a peer that uses a flow meter (PeerFlowmeter*Ridge) increases the share of land using end block irrigation by 0.179 (-0.041 + 0.221)). Knowing someone that uses alternative wetting and drying (PeerAltWetDry) decreases the share of land using end block irrigation unless the farm is located in the North Delta (PeerAltWetDry*ND) or participates in other conservation programs (PeerAltWetDry*PartOther).

Living in the North Delta and having a peer that uses tail-water recovery (PeerTWR*ND) decreases the share of estimated land that utilizes deep tillage-at the same time, having a peer that uses tail-water recovery and living elsewhere increases the share of acres that utilizes deep tillage. Knowing someone who uses computerized hole selection (PeerCHS) decreases the share of irrigated land that uses deep tillage by 0.226. Having a peer that uses scheduling (PeerScheduling) or alternative wetting and drying (PeerAltWetDry) decreases the share of irrigated land that uses deep tillage by a little more than 0.100. Lastly, having a peer that uses multiple inlet irrigation (PeerMultiInlet) increases irrigated land shares that uses deep tillage by 0.282. Knowing someone that uses precision leveling (PeerPLevel) increases the share of estimated irrigated cover-crop land by 0.237. If a producer has a peer that uses alternative wetting and drying and participates in another conservation program (PeerAltWetDry*PartOther), then the share of irrigated land that utilizes cover crops increases by 0.327 (0.029 + 0.298).

If a producer has a peer that uses surge irrigation (PeerSurge), they will likely have more irrigated land that uses cutback irrigation, especially if they also participate in a regional conservation program (PeerSurge*RegCon). Producers that live along Crowley's Ridge and know someone who uses flow meters (PeerFlowmeter*Ridge) will likely have 0.496 (0.269 +0.227) more shares of irrigated land that uses cut back irrigation. In comparison, producers in other regions with peers using flow meters (PeerFlowMeter) will likely only have 0.269 more shares of irrigated land. Knowing someone that uses end block irrigation (PeerEndBlock) increases the estimated share of land that utilizes cutback irrigation by 0.223. Knowing someone that uses a form of scheduling (PeerScheduling) decreases the share of irrigated land that utilizes cutback irrigation by 0.213; when the farm is also located along Crowley's Ridge, it is estimated to decrease by an additional 0.539 for a total decrease of 0.753. (PeerScheduling*Ridge). Having a peer that uses multiple inlet irrigation (PeerMultiInlet) decreases the share of irrigated land that uses cutback irrigation unless the producer also participates in other conservation programs (PeerMultiInlet*PartOther). Having a peer that uses reservoirs (PeerRes) decreases the irrigated land share utilizing cutback irrigation by an estimated 0.128. Also, having a peer with a reservoir (PeerRes) or using computerized hole selection (PeerCHS) decreases the share of irrigated land that uses gypsum. If a producer uses pivot irrigation (PeerPivot), they will have more land that uses gypsum; this is particularly true if the producer lives along Crawley's Ridge, with about 0.430 more shares of irrigated land than producers in other regions (PeerPivot*Ridge). Having a peer that uses tail-water recovery (PeerTWR) increases the estimated share of land that uses gypsum by 0.359. A producer who knows someone who uses a form of scheduling (PeerScheduling) should have a higher percentage of land that uses gypsum. It is even more so if they also participate in a conservation reserve program (PeerScheduling*CRP). Producers participating in regional conservation programs and know someone that uses multiple inlet irrigation (PeerMultiInlet*RegCon) are likely to have 0.208 (0.248 + -0.456) fewer shares using gypsum.

Table 6 has the marginal effects for the explanatory farm, irrigation, and socioeconomic variables that influence the share of land that uses a particular practice. Using end block irrigation (EndBlock), having sandy soil (Sand), and knowing the estimated corn yield (YieldCorn) has a negative effect on the share of land in border irrigation, while warped surface leveling, has a positive effect. When looking at education, having a bachelor's degree (Bach) decreases irrigated acres' share that uses border irrigation to 0.257. Producers that use barrier pipes are likely to have 1.76 more shares of land that use border irrigation.

If a producer reported using precision leveling on their farm because it makes things easier (PrecisionLevelEasy), then the share of irrigated land that uses precision grade leveling increases by 0.099. Producers with an advanced education (AdvEdu) are estimated to have 0.202 more shares of irrigated land that utilize precision grade leveling. Producers with loamy soils (Loam) will likely have a larger share of acres utilizing precision grade leveling. A farm's location has a rather significant impact on the share of land that uses warped surface leveling. The producers that live along the Mississippi River (River) and Crowley's Ridge (Ridge) are expected to have a higher share of acres that use warped surface leveling. If a producer uses atmometers or other similar technologies (ETAtmometer), it is estimated that the farm will have 0.271 more shares of irrigated land that uses warped surface leveling. Producers that grow irrigated soybeans (IrrSoy) will likely have a share of irrigated land using warped surface leveling that is 0.174 larger. Unlike warped surface leveling, if a producer has irrigated soybeans (IrrSoy), they are estimated to have 0.192 fewer shares of irrigated land using end block irrigation. Having a master's degree (AdvEdu) increases the share of irrigated land that uses end block irrigation to 0.862. The use of tail-water recovery systems (TWR) reduces the share of irrigated land that uses end block irrigation. While having a root zone between 0 to 59 inches with available water storage (AWS) and loamy soils (Loam) increases the share of irrigated acres that uses end-blocking irrigation.

Participation in a conservation reserve program (PartCRP) reduces the share of irrigated acres utilizing deep tillage by 0.193. In contrast, participation in the environmental quality incentive program (PartEQIP) increases the share of deep tillage irrigated land by 0.229. Computerized hole selection (ComputerHole), precision grade leveling (PrecisionGrade), loamy soils (Loam), and multiple inlet irrigation (MultiInlet) increase the share of land using deep tillage. Producers that do not use precision leveling (NoPrecisionLevelCost) because it is too expensive will likely reduce the share of deep tillage land by 0.176. For every year that a producer uses precision leveling (PrecisionLevelAge), they are likely to have a higher share of irrigated land using deep tillage. The producers that did not report their income (IncNA) will likely have a lower share of irrigated land that uses deep tillage by 0.117. Other variables that will slightly reduce the share of land that uses deep tillage include zero grade leveling (ZeroGrade), artificial paths (ArtificalPath), canal ditches (CanalDitch), and the amount of growing season precipitation (PPT2013). When it comes to the share of land using cover crops, having a bachelor's degree (Bach) likely reduces the amount of land by 0.220. If a producer lives in the North Delta (ND), they will likely have a 0.358 less share of irrigated acres that utilize cover crops. Yet, if a producer lives in the South Delta (SD), they will probably have 0.265 more shares of irrigated land that utilize cover crops. When a producer uses pivot irrigation, the share of irrigated land that uses cover crops tends to increase by 0.148. The use of computerized scheduling (ComputerSchedule), the use of computerized hole selection (ComputerHole), or the type of cover crop type (CoverCropType) indicates a reduction in the share of acres that uses cover crops by at least 0.133. When a farm is composed of loamy soils (Loam), the producer is more likely to use cover crops. Lastly, if a producer participated in another conservation program (PartOther), the share of cover crop irrigated acres increases by 0.206.

If a producer has some agriculture education, then the producer is likely to use cutback irrigation for 0.101 more shares of irrigated land. Producers with bachelor's degrees (Bach) will likely decrease the shares of irrigated land in cutback irrigation by 0.443, while producers with a master's degree or higher (AdvEdu) should increase the share of cutback irrigated land by 0.684. The amount of land using gypsum on a farm is influenced by a completely different set of variables. If a producer participates in conservation reserve programs (PartCRP) or reported high income (IncHigh), they will have a smaller share of irrigated land that uses gypsum. However, producers that participate in a regional conservation program (PartRegCon) have a larger share of irrigated land that uses gypsum.

Discussion

The irrigation choices of peers have more influence on producers' use of field management practices than an influence on border irrigation; however, the irrigation choices of peers have about the same influence on the share of land using field management practices and the share of border irrigation. Border irrigation is influenced by three peer variables. Other than end-blocking, the field management practice shows an average number of two significant peer variables that influence the use. All of the irrigation techniques that we evaluated have at least one peer variable that is significant, but deep tillage has the most peer variables with large magnitudes. The likelihood of end-block irrigation from peer influence ranges from - 42% for a peer that uses multiple inlet irrigation and participates in a federal cost share program to 41% for a peer that uses end-block irrigation.

Producers that have peers using end block irrigation are more likely to use end block irrigation themselves; this is especially true if the producer also participates in a federal cost-share program for on-farm reservoirs. Interacting the participation in a federal cost-share program for on-farm reservoirs with having a peer that also uses end block irrigation increases the likelihood of use by an additional 37%. The same can be said for producers that have peers using precision grade leveling; they are more likely to use it themselves and even more so if they participate in a federal cost-share program for on-farm reservoirs. However, the end-blocking peer use magnitude is about five times larger than the magnitude of precision grade leveling peer use. Federal programs offer cost-share funding for irrigation practices the producers use, so the availability of money could be a plausible explanation for the additional increase in likelihood. Producers participating in these cost-share programs could simply have a heightened awareness of conservation practices in general, which could also be a plausible explanation for the additional increase in likelihood.

The results reveal a complementary or substitution relationship between these techniques based on the peer effects. Producers are less likely to use border irrigation if they have a peer using computerized hole selection, suggesting those practices are substitutes. Yet, producers are more likely to use deep tillage if they have a peer that uses computerized hole selection, suggesting those practices are used together. Having a peer that uses pivot irrigation increases the use of precision grade leveling by 2%. If a producer has a peer that uses multiple inlet irrigation, they will probably not use end block irrigation or warped surface leveling. Producers that have peers using water storage or recovery technology they are likely to use field management practices on a smaller share of land, which suggests that water storage or recovery is a substitute for field management. Multiple inlet irrigation is likely used instead of either of these techniques, so it could be considered a substitute. Having a peer that uses multiple inlet irrigation and participation in a federal cost-share program for on-farm reservoirs is 63% less likely to use end block irrigation. Warped surface leveling and alternating wetting and drying are also substitutes 14% of the time. In general, water flow control technologies seem to be substitutes for field management practices, when looking at the likelihood of use. This hold true for all practices except deep tillage and computerized hole selection, which is likely due to the idea that both practices are used to improve water penetration in the soil.

The interaction variables reveal homogeneous peer effects by location and program participation for border irrigation, end block irrigation, and cover crops. Having a peer that uses surge irrigation has a positive effect on the use of border irrigation. Having a peer that uses surge irrigation while participating in a federal cost-share program for on-farm reservoirs also has a positive effect on the use of border irrigation. When looking at end block irrigation, having peers that use flow meters or multiple inlet irrigation reduces the likelihood of use, and this is even more so when interacted with location and participation in a federal cost-share program for on-farm reservoirs, respectively. Peers that use alternative wetting and drying decrease the use of cover crops, but when interacted with participation in other programs, the magnitude of influence increases dramatically. Interacting different locations and peer use of multiple inlet irrigation vary the use of deep tillage. Peer use of computerized hole selection increases the use of deep tillage, and it does even more so along Crowley's Ridge and Grand Prairie, but it decreases the use of deep tillage in the South Delta. All of the significant location interactions with peer use of scheduling increase the use of deep tillage. The use of precision grade leveling increases if a peer uses pivot irrigation, except for the producers that live along Crowley's Ridge. Warped surface leveling is negatively influenced by having a peer that uses multiple inlet irrigation, but when it interacts with the locations Crowley's Ridge, the Grand Prairie, or the North Delta positively influences the use. Multiple inlet irrigations effect on warped surface leveling varies with location more than any other variable in this model.

Producers that live along the Mississippi river are less likely to use border irrigation in their farm. However, producers that live in the South Delta are 50% more likely to use warped surface leveling. Cover crops are more likely to be used by producers that live in the North Delta, but South Delta's producers are less likely. Along with location, the type of crops can also influence a producer's choice to use a particular practice or not. Planting an irrigated field with soybeans or rice increases the likelihood of using warped surface leveling; however, irrigated rice decreases the likelihood of planting cover crops. Producers with advanced education are not likely to deep till their fields, and producers with some agriculture education are even less likely to deep till their fields. This could be attributed to a heightened awareness of the long-term environmental impacts, like erosion, emphasized in many agriculture educational programs. Lastly, if a producer reported an income of $200,000 or higher, they are 14% less likely to use cover crops.

The irrigation techniques of peers have 19 different influences on producers' use of field management practices, while the irrigation techniques of peers only have 9 influences on producers' use of alternative irrigation approaches. Physical characteristics of a farm can be a strong contributor to the techniques a producer uses, but we found interactions with peers are the strongest contributors. When evaluating what proportion of land a producer will use cover crops for, all of the peer variables have a positive effect. Peers using precision grade leveling or alternative wetting and drying, the share of land using cover crops are larger. Having a peer that uses alternative wetting and drying or multiple inlet irrigation negatively influences the portion of land for end-blocking and deep tillage and positively for precision grade leveling and cover crops. A peer that uses multiple inlet irrigation has a negative effect on cutback irrigation, with a positive effect on end-blocking, deep tillage, and gypsum. Having a peer that uses reservoirs reduced the portion of irrigated land using gypsum by 0.42, which is the largest magnitude effect.

Producers that have peers using end block irrigation likely have a larger share of land using end block irrigation; however, this is untrue if the producer also participates in regional conservation programs or other programs. When having a peer that uses end-blocking is interacted with participation in regional conservation, the negative effect is on the share of land is lessened, but if it interacts with participation in other programs, the negative effect is strengthened. Having a peer using precision leveling increases the proportion of land using precision leveling at the 10-40 percentile. The magnitude of the peer precision grade leveling effects is small; it also increases the amount of land by less than one percent, while the magnitude of having peers using end block irrigation decreases the portion of land by 7 – 56%. Producers with peers using pivot irrigation are more likely to use gypsum on a slightly larger portion of their farm, and this amount is increased by 0.43 when interacted with Crowley's ridge location.

Having a peer that uses surge irrigation reduces the share of land using border irrigation and precision grade leveling by about 0.10, suggesting these techniques are weak substitutes. The share of land that uses cutback irrigation increases suggesting that surge irrigation is a compliment, and previously surge irrigation was suggested to be a substitute. End block irrigation has the most substitutes when evaluating the influence on the share of irrigated land. This list includes peers that use pivot irrigation with -0.21, peers that use flow meters with -0.04, and peers that use alternating wetting and drying with -0.21. Yet end block irrigation and cutback irrigation are complements, since having a peer the uses end block irrigation increases the share of land using cutback irrigation. Having a peer who uses flow meters decreases the amount of land using border irrigation especially producers that live in the Grand Prairie or participate in a federal cost-share program for on-farm reservoirs, making them a substitute. The interaction of living in the Grand Prairie and having a peer that uses flow meters has the largest magnitude effect in this model, with a 0.81 reduction in the amount of land using border irrigation. Precision grade leveling complements end-blocking irrigation and alternative wetting and drying but substitutes with surge irrigation and flow meters.

The peer effects are heterogeneous for cover crops and cutback irrigation. It appears as though all the practices have significant interaction terms. Having a peer that uses precision grade leveling or alternative wetting and drying increases the share of land using cover crops. This increase in the shares is reinforced by an additional 0.29 when participation in other programs interacts with peers using alternative wetting and drying. This finding is similar to the outcome of interacting alternating wetting and drying with participation in a federal cost-share program for on-farm reservoirs because this interaction increases the amount of land utilizing precision grading by an additional 0.29. Cutback irrigation is used on a larger portion of land if the producer has a peer that uses surge irrigation and even more so if the producer also participates in a regional conservation program. The portion of land using cutback irrigation is reduced if they have a peer using a scheduling form, especially if the producers live along Crowley's Ridge. The peer effects of scheduling irrigation time for the portion of land using gypsum and cutback irrigation are homogeneous, but the peer effects for multiple inlet irrigation are not.

Producers living along the ridge or by the river are likely to have more land using warped surface leveling than other locations; but producers in the North Delta will likely have cover crops on a smaller portion of land, while in the South Delta, they will have cover crops on a larger portion of land. However, if a producer's farm has loamy soils, the share of land using deep tillage is higher than other soil types. The level of education a producer has influences the share of land utilizing border irrigation, precision grade leveling, end block irrigation, cover crops, and cutback irrigation. Producers with a bachelor's degree are shown to have a smaller share of land using water flow control technology. However, a producer with at least a master's degree is more likely to use cutback irrigation, end-blocking irrigation, and precision grade leveling. The miles of barrier pipe (BarrierPipe) that connect waterbodies separated by dams, weirs, and other artificial barriers has the largest magnitude effect on the proportion of land using border than any other variable. A producer's participation in government programs influences the share of land utilizing gypsum, cover crops, and deep tillage. Producers use gypsum and deep tillage on a smaller share of land if they participate in a conservation reserve program. Participation in an environmental quality incentives program increases the amount of land using deep tillage. Participation in a regional conservation program increases the amount of land gypsum is used, and participation in other programs increases the amount of land that cover-crops are planted on.

Conclusion

Producers should try and utilize efficient irrigation practices, to continue irrigating their crop without depleting the water source; therefore, factors influencing the use of irrigation practices are worthwhile to investigate since there have been significant groundwater depletions within the state. Many past studies have analyzed how physical factors have influenced the use or adoption of different irrigation practices and technologies. Other studies analyze how friends, family, and their interactions influence the adoption or use of different technologies. We examine how these peer networks interact with location and participation in programs change the initial effects. For example, a producer that has a peer using multiple inlet irrigation is 37% less likely to use warped surface leveling; however, if the producer has a peer that uses multiple inlet irrigation and lives in the Grand Prairie, the likelihood of using warped surface leveling increases by 13% (-37% + 50%). Producers that reported having loamy soil tended to use field management practices on a slightly larger share of their land. The irrigation technologies choices of producer's peers influence their choices to use particular irrigation technologies and the percentage of irrigated land that uses those technologies. Having a peer that uses multiple inlet irrigation reduces the likelihood a producer uses end-blocking irrigation on their farm by 20%; however, if a producer has a peer that uses multiple inlet irrigation, they are likely to use end block irrigation on 0.183 more shares of irrigated land.

When evaluating the model as a whole, the largest average magnitude effect occurs if the irrigation techniques interact with the various locations. The average magnitude effect is 0.38. Similarly, the interactions of irrigation techniques and participation in the various programs have more positive impacts on the share of irrigated land than interactions with the various locations. Warped surface leveling use is negatively influenced by having a peer that uses multiple inlet irrigation (-37%), but when it interacts with the locations Crowley's Ridge (-2%), the Grand Prairie (13%), or the North Delta (12%) the use is positively influenced. Warped surface leveling is influenced by interactions with location more than the other technologies in the model. When a producer participates in any conservation programs, it affects the share of land using field management practices more than it affects the share of land using water flow control technologies. For example, the interaction of peer effects and participation in the regional conservation partnership program is -0.45 shares for gypsum, while the effects of participation in the regional conservation partnership program on cutback irrigation or border irrigation are smaller or nonexistent. We find that location can not only reinforce an outcome but can even go as far as reversing the initial peer effect. The likelihood that a producer uses deep tillage on their farm decreases if they live in the South or North Delta, regardless of the variable it is interacted with; therefore, we see that deep tillage is a more common practice in the middle of Arkansas. End block irrigation has the most substitutes when evaluating the influence on the share of irrigated land. The list of peer variables influencing the share of land using end-blocking irrigation is a peer using pivot irrigation with -0.21, peers that use flow meters with -0.04, and peers that use alternating wetting and drying with -0.21 as well. We likely see the decrease of end blocking based on peers using pivot irrigation because end blocking is for furrow irrigation, while center pivot irrigation is a sprinkler irrigation system. With this point, having peers that use end block irrigation increases the likelihood that a producer uses end block irrigation by 43%, yet it reduces the share of land that a producer has using end block irrigation by 0.34. If a producer has someone sharing knowledge, asking questions, or sharing equipment with them, it makes sense that they use the technologies. Physical characteristics of a farm can be a strong contributor to the techniques a producer uses, but we found interactions with peers are the strongest contributors. A majority of the physical variables are not significant when looking at the use and share of land using a particular technique. The type of soil, number of growing degree days, and growing season precipitation between the counties are similar and that is likely the reason all of these variables were insignificant. Greater variation in the physical variables could reveal significance in the results.

Producers with advanced education are not likely to use deep tillage on their farms, and producers some agriculture education are even less likely to deep till their fields. While deep tillage helps water reach the crop roots efficiently, producers with education would likely be aware of the long-term erosion effects as well. We find varying education levels can significantly increase or decrease a producer use of particular irrigation technologies, which is dramatically different for some of the other similar studies. Wheeler and Bjornlund's (2010) study indicated that education did play a part in a producer's decision to switch irrigation technologies, but the effects are minimal and insignificant. Engler and Jara-Rojas (2016) found for every additional year of education, the chances of adopting irrigation scheduling decreases, but it is also insignificant at the 10^{th} percentile. According to Genius et al. (2014), if a producer had more than nine years of education, they adopt drip irrigation quicker than producers with less education. Our study contrasts these findings to a degree. However, we find the share of land that utilizes cutback irrigation increases with agriculture education and advanced education, but a bachelor's degree decreases the share of land. Maertens, Michelson, and Nourani (2012) find that education can increase or decrease the adoption of a new technology depending on what village they live in. Not all of the values are significant. These results resemble the interactions between peer influences and location in our study. Another outcome is the interaction of living in the Grand Prairie with having a peer that uses flow meters on the use of border irrigation, with the largest magnitude effect in this model; it reduces the amount of irrigated land using border irrigation by 0.81. While this data supports the idea that flowmeters are considered an improvement over border irrigation, it is only reported to be used by 13% of the producers. Since this practice is used by so few, skewed results could be contributed to the small sample size.

Maertens, Michelson, and Nourani (2012) found that living in the same neighborhood could increase the likelihood of a learning link by an average of 13%. Our study indicates that interactions with payment for the irrigation technology coming from a federal cost-share program for on-farm reservoirs averages a 12% increase in the use of various technologies. We also find that the magnitude for use of field management practices is larger with peer variables than with farm, irrigation, and socioeconomics variables. On that same note, Bandiera and Rasul (2006) prove that having more peers that use a particular technology increases the chance of adopting the same technology. Producers in Northern Mozambique with a social network containing 1-5 adopters increases the propensity to adopt sunflower seeds by 0.27, while having a social network containing 6-10 adopters increases the propensity by 0.58 (Bandiera and Rasul, 2006). Girls with more friends using the technology adopt it faster, although by the end of the study, usage rates between all the girls with friends using the technology are fairly similar (Oster and Thornton, 2012). For the 13 nearest neighbor peer definition, additional peer adopters increase the probability of adoption; until the number of peer adopters reaches 9, then an additional peer adopter does not make much difference (Sampson, 2018). All of these studies indicate, in different aspects, that having a peer using the technology positively affects their choice and use of the technology. Like studies, we find that having a peer who uses the same irrigation technologies makes a producer more likely to use them as well, even as much as 43%. The conservation programs have an influence through the peer effects that is sometimes positive and other times negative. When looking at the share of land using field management practices, the interactions with participation in a regional conservation partnership program and peer variables the sign of the affect is opposite of just the peer variable. For example, having a peer that uses end blocking shows a 0.17 increase in the share of land using precision leveling, but having a peer that uses end blocking and the producer participated in a regional conservation partnership program the share of land using precision grade leveling shows a 0.22 decrease in the share of land. These results suggest that participation in this program changes the way a producer thinks, and they don't rely as much on peers as producers not in this program.

These results extend the literature on variables and peer networks that influence the use and share of irrigated acres in specific techniques in the Arkansas Delta. It helps bridge the gap between literature evaluating irrigation technologies and literature evaluating the effects of peer networks. Further research is needed to account for the potential differences of peer effects in different regions in the United States. Also, studies with additional peer information the number of peers, type or length of relationships, and frequency of their interactions could provide additional insight on how peer networks influence irrigation technology uses. Lastly, examining how these same variables and interactions influence other irrigation technologies.

References

1. AgWeb Staff. "Irrigation: Yield Enhancer or Farmland Destroyer?" *AgWeb:FarmJournal*, 11 July 2011, www.agweb.com/irrigation-yield-enhancer-or-farmland-destroyer.

2. Arkansas GIS. "Water." *Arkansas GIS Office*, Arkansas Department of Transformation and Shared Services, 2021, gis.arkansas.gov/product-category/data/water/.

3. O. Bandiera, I. Rasul. 2006. Social Networks and Technology Adoption in Northern Mozambique. *The Economic Journal,*116(514), 869-902.

4. T. Conley, C. Udry. 2010. Learning About a New Technology: Pineapple in Ghana. *American Economic Review*, 100(1), 35-69.

5. A. Engler, R. Jara-Rojas. 2016. Efficient use of Water Resources in Vineyards: A Recursive Joint Estimation for the Adoption of Irrigation Technology and Scheduling. *Water Resources Management,* 30(14), 5369-5383.

6. G. Frisvold, T. Bai. 2016. Irrigation Technology Choice as Adaptation to Climate Change in the Western United States. *Journal of Contemporary Water Research and Education,* 158(1), 62-77.

7. M. Genius, P. Koundouri, C. Nauges, and V. Tzouvelekas. 2014. Information Transmission in Irrigation Technology Adoption and Diffusion: Social Learning, Extension Services, and Spatial Effects. *American Journal of Agriculture Economics,* 96(1), 344-382.

8. G. Green, D. Sunding, D. Zilberman. 1996. Explaining Irrigation Technology Choices: A Microparameter Approach. *American Journal of Agricultural Economics,* 78(4), 1064-1072.

9. C. Gopalakrishnan. 1993. Adoption and Diffusion of Drip Irrigation Technology: An Econometric Analysis. E*conomic Development and Cultural Change,* 41(2), 407-418.

10. C. Henry, L. Krutz, J. Henggeler, R. Levy, Q.Q. Huang, and K. Kovacs. 2020. A Survey of 2015 Mid-South Irrigation Practices: Report to the Mid-South Soybean Board and dataset. Mid-South Soybean Board. University of Arkansas Division of Agriculture.

11. T. Hess, J. Knox. 2013. Water savings in irrigated agriculture: A framework for assessing technology and management options to reduce water losses. *Outlook on Agriculture,* 42(2), 85–91. www.scopus.com/inward/record.url?partnerID=HzOxMe3b&scp=84880630068&origin=inward.

12. D. Kolady, W. Zhang, T. Wang, and J. Ulrich-Schad. 2020. Spatially Mediated Peer Effects in the Adoption of Conservation Agriculture Practices. *Journal of Agricultural and Applied Economics,* (2020), 1-20.

13. P. Koundouri, C. Nauges, and V. Tzouvelekas. 2006. Technology Adoption Under Production Uncertainty: Theory and Application to Irrigation Technology. *American Journal of Agriculture Economics,* 88(3), 657-670.

14. A. Maertens, H. Michelson, V. Nourani. 2012. How Do Farmers Learn from Extension Services? Evidence from Malawi. *American Journal of Agriculture Economics,* 00(00), 1-27.

15. National Agricultural Statistics Service (NASSa). "Table 2: Irrigated Farms by Acres Irrigated: 2018 and 2013." *Census of Agriculture*, USDA, 2018, www.nass.usda.gov/Publications/AgCensus/2017/Online_Resources/Farm_and_Ranch_Irrigation_Survey/index.php.

16. National Agricultural Statistics Service (NASSb). "Table 24: Technical and Financial Assistance Received During the Past Five Years for Irrigation or Drainage Improvements: 2018." *Census of Agriculture*, USDA, 2018, www.nass.usda.gov/Publications/AgCensus/2017/Online_Resources/Farm_and_Ranch_Irrigation_Survey/index.php.

17. National Agricultural Statistics Service (NASSc). "Table 25: Barriers to Making Improvements to Reduce Energy Use or Conserve Water". *Census of Agriculture*, USDA, 2018, www.nass.usda.gov/Publications/AgCensus/2017/Online_Resources/Farm_and_Ranch_Irrigation_Survey/index.php.

18. National Agricultural Statistics Service (NASSd). "Table 29: Gravity Irrigation in Fields in the Open". *Census of Agriculture*, USDA, 2018, www.nass.usda.gov/Publications/AgCensus/2017/Online_Resources/Farm_and_ Ranch_Irrigation_Survey/index.php.

19. National Agricultural Statistics Service (NASSe). "Table 30: Sprinkler Irrigation in Fields in the Open". *Census of Agriculture*, USDA, 2018, www.nass.usda.gov/Publications/AgCensus/2017/Online_Resources/Farm_and_ Ranch_Irrigation_Survey/index.php.

20. National Agricultural Statistics Service (NASSf). "Table 39: Water Management Practices Used by Producers with Gravity Systems for Acres in the Open". *Census of Agriculture*, USDA, 2018, www.nass.usda.gov/Publications/AgCensus/2017/Online_Resources/Farm_and_ Ranch_Irrigation_Survey/index.php.

21. National Agricultural Statistics Service (NASS). "Table 10: Irrigation: 2017 and 2012." *Census of Agriculture*, USDA, 2017, www.nass.usda.gov/Publications/AgCensus/2017/Full_Report/Volume_1, Chapter_2_US_State_Level/.

22. NIDIS. “Arkansas.” *Arkansas | Drought.gov*, 2020, www.drought.gov/states/arkansas#:~:text=The%20U.S.%20Drought%20Monitor%20started,affected%2053.6%25%20of%20Arkansas%20land.

23. Northern Economics, Inc. Summary of Results from Survey Research Laboratory’s Arkansas Crop Irrigation Survey. Prepared for The University of Arkansas. December 2017.

24. Oregon State University. “PRISM Climate Group.” *PRISM Climate Group, Oregon State U*, USDA Risk Management Agency, 2021, prism.oregonstate.edu/.

25. E. Oster, R. Thornton. 2012. Determinants of Technology Adoption: Peer Effects in Menstrual Cup Take-Up. *Journal of the European Economic Association,* 10(6), 1263-1293.

26. OSU forage information. “Describe the Importance of Irrigation in Producing Forages.” *Forage Information System*, Oregon State University, 7 Jan. 2016, forages.oregonstate.edu/nfgc/eo/onlineforagecurriculum/instructormaterials/availabletopics/irrigation/importance.

27. B. Pokhrel, K. Paudel, and E. Segarra. 2018. Factors Affecting the Choice, Intensity, and Allocation of Irrigation Technologies by U.S. Cotton Farmers. *Multidisciplinary Digital Publishing Institute,* Water 2018, 10, 706.

28. G. Sampson, E. Perry. 2019. Peer Effects in the Diffusion of Water-Saving Agricultural Technologies. *International Association of Agricultureal Economics,* 50: 693-706.

29. G. Sampson, E. Perry. 2018.The Role of Peer Effects in Natural Resource Appropriation-The Case of Groundwater. *American Journal of Agriculture Economics,*101(1), 154-171.

30. K. Schoengold, D. Sunding. 2014. The impact of water price uncertainty on the adoption of precision irrigation systems. *Agricultural Economics,* 45(6).

31. E. Schuck, W. Frasier, R. Webb, L. Ellingson, W. Umberger. 2005. Adoption of More Technically Efficient Irrigation Systems as a Drought Response. *Water Resource Development,* 21(4), 651-662.

32. Soil Survey Staff, Natural Resources Conservation Service, United States Department of Agriculture. Soil Survey Geographic (SSURGO) Database for Arkansas. Available online. Accessed 2/2021.

33. Oregon State University. “PRISM Climate Group.” *PRISM Climate Group, Oregon State U*, USDA Risk Management Agency, 2021, prism.oregonstate.edu/explorer/.

34. U.S. Geological Survey. "Hydrography - NHD/WBD/NHDPlus HR - Data+Dictionary Report." *Welcome to Spec-X*, USGS, March 2021, usgsmrs.cr.usgs.gov/SPECX/lookup/lookupSearch?reportType=Data%2BDictionary&tnmTheme=2&layer=1&editionSpecification=1&scale=1&table=1&submit=Submit&__ncforminfo=h4OBpM3FxcWLQAJnupg6qEam1QNhwhiu9JycvLCbo_9J1awStQSWe05vJtkESt4hjoRO5W7jwgkTFx8tTCcgJa9Vs5fN2Z7SXcIqK7AWG5YMM_1RhCnb3Fs3WINxWLopWSdmMbvMB2XdSLnHP8gHMU7I63hzF6Ephn_nhDcHUa8Y3A68ypO0NNdoXlMYL5c1e4BU0FeFkSYeBZKdjwZB1vJnT3Xg0BxFx3tmdIjJIoTXERlscY2rpWhocjrA9eyqfkYfpkqT9_AB0vb7xtiEohFHouZTxG6401HBzNPpl4t0HK8_2grdA5TdDiUf95KODtDxs2QMk45HFdpq0if3VaOBsj2_qY83iy0ZwEwmzBZKtC0upMxB8m8smU1HBFKLo2sEwSKygUx4sswSJLD2FXbDH0WkKEvsH6EpacDOeEh62dcQ%3D%3D.

35. P. Ward, and V. Pede. 2014. Capturing Social Network Effects in Technology Adoption: The Spatial Diffusion of Hybrid Rice in Bangladesh. *Australian Journal of Agricultural and Resource Economics,* 59: 225-241.

36. G. West, K. Kovacs, C. Henry, I. Engram, Q. Huang. "Arkansas Irrigation." *Division Of Agriculture Research & Extension*, University of Arkansas, 2017.

37. S. Wheeler, and H. Bjornlund. 2010. Modelling the Adoption of Different Types of Irrigation Water Technology In Alberta, Canada. WIT Transactions on Ecology and the Environment, 134: 189-201.

Tables

Table 1. Dependent variables for participation equation and outcome equation					
Variable	Definition	Mean	Std Dev	10^{th} Percentile	90^{th} Percentile
Border	=1 if use border irrigation	0.13	0.333	0	1
PrecisionGrade	=1 if use precision grade/ constant slope	0.84	0.369	0	1
WarpedSurface	=1 if use warped surface/ optisurface	0.25	0.436	0	1
EndBlock	=1 if use end-blocking	0.25	0.433	0	1
CutBack	=1 if use cutback irrigation	0.08	0.270	0	1
DeepTillage	=1 if use deep tillage	0.35	0.479	0	1
Gypsum	=1 if treated with gypsum	0.06	0.240	0	1
Covercrop	=1 if cover crops are planted	0.25	0.433	0	1
Percent_Border	Percent of irrigated acres using border irrigation if border =1	53.16	40.85	0.4	100
Percent_Precision Grade	Percent of irrigated acres using precision grade/ constant slope if precision grade =1	56.69	36.69	1.08	100
Percent_Warped Surface	Percent of irrigated acres using warped surface/ optisurface if warped surface =1	22.18	21.29	1.28	100
Percent_EndBlock	Percent of irrigated acres using end-blocking if end block =1	43.01	30.21	2.27	100
Percent_CutBack	Percent of irrigated acres using cutback irrigation if cutback =1	45.35	29.69	3.33	100
Percent_Deep Tillage	Percent of irrigated acres using deep tillage if deep tillage =1	36.68	25.97	2.94	100
Percent_Gypsum	Percent of acres treated with gypsum if gypsum =1	37.52	30.99	3.12	100
Percent_Cover Crop	Percent of acres where cover crops are planted if cover crop =1	47.87	41.76	0.65	100

Table 2. Explanatory variables for irrigation technology modeling

Farm and irrigation characteristics

Variable	Definition	Proportion
IrrRice	=1 if grows rice	0.59
IrrSoy	=1 if grows irrigated soy	0.80
FlowMeter	=1 Own any flow meters	0.35
SoilSensor	=1 if use soil moisture to schedule irrigation on farm	0.10
ETAtmometer	=1 if use ET or atmometer to schedule irrigation times	0.03
ComputerizedScheduling	=1 if used computerized scheduling to schedule irrigation	0.06
DieselPump	=1 if use diesel pump on farm	0.86
Ridge	=1 if county is in Crowley's Ridge	0.31
River	=1 if county is along Mississippi River	0.23
Grand Prairie	=1 if county is in the Grand Prairie	0.19
ND	=1 if county is in the North Delta and not others	0.13
SD	=1 if county is in the South Delta and not others	0.07
TWR	=1 if use tail-water recovery system on farm	0.45
TaxCredStorage	=1 if payment for tail-water recovery system or reservoir was state tax credit program	0.03
PartCRP	=1 if participated in conservation reserve program	0.43
PartEQIP	=1 if participated in environmental quality incentives program	0.45
PartRegCon	=1 if participated in regional conservation partnership program	0.14

PartOther	=1 if participated in other conservation program	0.23	
ComputerizedHole	=1 if used computerized hole selection	0.33	
Surge	=1 if used surge irrigation	0.16	
PrecisionLevelProfit	=1 if used precision leveling to make irrigation more profitable	0.19	
NoPrecisionLevelCost	=1 if precision leveling is not used because the cost is too high	0.06	
PivotRow	=1 if used center pivot irrigation for row crops	0.38	
		Mean	Std Dev
IrrCottonAcres	Number of irrigated cotton acres (in hundreds)	112.88	458.04
IrrRiceAcres	Number of irrigated rice acres (in hundreds)	654.79	979.26
YieldCorn	Expected yield of corn (in tens of bushels per acre)	85.85	95.82
PrecisionGrade	Number of irrigated acres using precision grade system	1047.22	1537.40
PrecisionLevelAge	Year started using precision leveling	1065.18	998.85
ZeroGrade	Number of irrigated acres using zero grade system	49.07	156.62
EndBlock	Number of irrigated acres using end block irrigation	285.52	786.39
Multi-Inlet	Number of irrigated acres that are contour levee fields using multiple inlet irrigation	157.02	422.22
AltWetDry	Number of irrigated rice acres managed under alternative wetting and drying	54.10	343.57
WarpedSurface	Number of irrigated acres using warped surface leveling	186.89	769.78
CoverCrop	Number of acres where cover crops are planted	0.18	0.39
PH>6.0	Percent of land in the county of the producer's residence with a PH greater than 6.0	23.16	16.72

AWS	Root zone between 0 to 59 inches available water storage (in)	9.11	1.19
PPT2013	Growing season precipitation in 2013 (in)	27.11	4.02
PPT2014	Growing season precipitation in 2014 (in)	28.07	2.50
PPT2015	Growing season precipitation in 2015 (in)	26.71	4.49
GDD2013	Degree days between 50 and 89 Fahrenheit in 2013 (degrees*days)	2396.22	101.18
GDD2014	Degree days between 50 and 89 Fahrenheit in 2014 (degrees*days)	2362.51	84.57
Clay	Percent of land in the county of the producer’s residence with a clay component in the soil	14.71	16.61
Loam	Percent of land in the county of the producer’s residence with a loam component in the soil	6.56	6.09
Silt	Percent of land in the county of the producer’s residence with a silt component in the soil	63.36	17.77
Sand	Percent of land in the county of the producer’s residence with a sand component in the soil	9.41	8.39
OpenWater	Miles of flow length through streams, rivers, lakes, and any other open water in the county of the producer’s residence	29.30	15.88
BarrierPipe	Miles of pipeline that connect waterbodies separated by dams, weirs, and other artificial barriers in the county of the producer’s residence	0.07	0.11
CanalDitch	Miles of canals and ditches in the county of the producer’s residence	21.28	19.50
AqueductPipe	Miles of aqueduct and other closed conduits with pumps, valves, and control devices in the county of the producer’s residence	0.01	0.04
StreamRiver	Miles of streams and rivers in the county of the producer’s residence	85.69	44.06

Socioeconomic characteristics

		Proportion
AgEdu	=1 if formal education related to agriculture	0.56
Bach	=1 if completed Bachelor's degree	0.42
AdvEdu	=1 if completed education beyond a Bachelor's degree	0.09
IncHigh	=1 if household income greater than $200K	0.15
IncNA	=1 if household income not available	0.23

Peer Network

Variable	Definition	Proportion
PeerPivot	=1 if peers used center pivot	0.67
PeerTWR	=1 if peers used tail-water recovery system	0.66
PeerRes	=1 if peers used reservoir storage	0.60
PeerCHS	=1 if peers used Computerized hole selection	0.52
PeerSurge	=1 if peers used surge irrigation	0.34
PeerFlowMeter	=1 if peers used flowmeters on the wells	0.62
PeerPLevel	=1 if peers used precision leveling	0.87
PeerZeroGrade	=1 if peers used zero grade leveling	0.71
PeerEndBlock	=1 if peers used alternate end-blocking, cutback irrigation, or furrow diking in irrigation	0.50
PeerScheduling	=1 if peers used irrigation scheduling such as: soil moisture sensors, ET, and Atometer	0.49
PeerMulti-Inlet	=1 if peers used multiple-inlet rice irrigation	0.65
PeerAltWetDry	=1 if peers used wetting and drying for rice irrigation	0.33
PeerPivot*Ridge	=1 if peers used center pivot and located on Crowley's Ridge	0.22
PeerTWR*River	=1 if peers used tail-water recovery system and located along the Mississippi River	0.10

PeerTWR*ND	=1 if peers used tail-water recovery system and located in the North Delta	0.12
PeerRes*GP	=1 if peers used reservoir storage and located in the Grand Prairie	0.17
PeerCHS*SD	=1 if peers used computerized hole selection and located in the South Delta	0.03
PeerCHS*Ridge	=1 if peers used computerized hole selection and located along Crowley's Ridge	0.16
PeerCHS*CRP	=1 if peers used computerized hole selection and participate in conservation reserve program	0.25
PeerSurge*Fed	=1 if peers used surge irrigation and the irrigator raised money for tail-water recovery or reservoir through a federal cost-share program	0.08
PeerSurge*CHS	=1 if peers used surge irrigation and computerized hole selection	0.15
PeerSurge*RegCon	=1 if peers used surge irrigation and participated in regional conservation partnership program	0.07
PeerFlowMeter*Ridge	=1 if peers used flowmeter and located on Crowley's Ridge	0.17
PeerFlowMeter*GP	=1 if peers used flowmeter and located in the Grand Prairie	0.16
PeerFlowMeter*Fed	=1 if peers used flowmeter and the irrigator raised money for tail-water recovery or reservoir through a federal cost-share program	0.18
PeerFlowMeter*RegCon	=1 if peers used flowmeter and participated in regional conservation partnership program	0.10
PeerEndBlock*PartOther	=1 if peers used end-blocking and participate in other conservation program	0.15
PeerEndBlock*RegCon	=1 if peers used end-blocking and participated in regional conservation partnership program	0.09
PeerScheduling*Ridge	=1 if peers used irrigation scheduling and located on Crowley's Ridge	0.15
PeerScheduling*SD	=1 if peers used irrigation scheduling and located in the South Delta	0.04
PeerScheduling*ND	=1 if peers used irrigation scheduling and located in the North Delta	0.06
PeerScheduling*CRP	=1 if peers used irrigation scheduling and participated in conservation reserves program	0.26

PeerMult-Inlet*Ridge	=1 if peers used multiple-inlet rice irrigation and located on Crowley's Ridge	0.18
PeerMult-Inlet*GP	=1 if peers used multiple-inlet rice irrigation and located in the Grand Prairie	0.16
PeerMult-Inlet*ND	=1 if peers used multiple-inlet rice irrigation and located in the North Delta	0.15
PeerMult-Inlet*RegCon	=1 if peers used multiple-inlet rice irrigation and participate in regional conservation partnership program	0.10
PeerMult-Inlet*PartOther	=1 if peers used multiple-inlet rice irrigation and participate in other conservation programs	0.17
PeerMult-Inlet*Fed	=1 if peers used multiple-inlet rice irrigation and the irrigator raised money for tail-water recovery or reservoir through a federal cost-share program	0.18
PeerAltWetDry*ND	=1 if peers used wetting and drying for rice irrigation and located in the North Delta	0.04
PeerAltWetDry*SD	=1 if peers used wetting and drying for rice irrigation and located in the South Delta	0.03
PeerAltWetDry*PartOther	=1 if peers used wetting and drying for rice irrigation and participate in other conservation programs	0.08
PeerAltWetDry*Fed	=1 if peers used wetting and drying for rice irrigation and the irrigator raised money for tail-water recovery or reservoir through a federal cost-share program	0.08

Table 3. Marginal effects for the peer network variables to explain the percent use of an irrigation practice

Variable	Border Irrigation	Precision Grade Leveling	Warped Surface Leveling	End Block Irrigation	Deep Tillage	Cover Crops
PeerPivot		0.022 (0.36)				
PeerCHS	-0.143 (-3.28)[a]				0.244 (1.83)[c]	
PeerSurge	0.025 (0.62)					
PeerFlowMeter			0.112 (1.97)[b]	-0.022 (-0.27)		
PeerZeroGrade	0.077 (1.75)[c]					
PeerEndBlock				0.413 (3.82)[a]		
PeerScheduling					0.006 (0.16)	
PeerMulti-Inlet			-0.374 (-1.95)[b]	-0.204 (-2.20)[b]		
PeerAltWetDry			-0.143 (-2.37)[a]			-0.006 (-0.09)
PeerPivot*Ridge		-0.132 (-2.01)[b]				
PeerCHS*Ridge					0.213 (1.66)[c]	
PeerCHS*SD					-.999 (-2.41)[a]	
PeerCHS*CRP					-0.373 (-2.46)[a]	
PeerSurge*Fed	0.202 (2.58)[a]					
PeerFlowMeter*Ridge				-0.318 (-2.80)[a]		
PeerScheduling*ND					-0.522 (2.32)[b]	
PeerScheduling*SD					-0.738 (1.90)[b]	
PeerScheduling*CRP					0.419 (2.78)[a]	
PeerMult-Inlet*Ridge			0.346 (1.69)[c]			
PeerMult-Inlet*GP			0.508 (2.39)[a]			
PeerMult-Inlet*ND			0.502 (2.32)[b]			
PeerMult-Inlet*Fed				-0.427 (-1.71)[c]		
PeerAltWetDry*SD			0.334 (1.66)[c]			

PeerAltWetDry*Part Other						-0.310 (-2.63)[a]
Pseudo R^2	0.222	0.218	0.286	0.467	0.251	0.288
Number of observation	229	221	229	197	221	221

a – 1%, b – 5%, c–10% Significance. Z statistics from the probit model estimates in parentheses.

Table 4. Marginal effects for the farm, irrigation, and socioeconomics variables to explain the percent use of an irrigation practice

Variable	Border Irrigation	Precision Grade Leveling	Warped Surface Leveling	End Block Irrigation	Deep Tillage	Cover Crops
IrrRice			0.174 (2.64)[a]			-0.183 (-2.35)[b]
IrrSoy	-0.084 (-2.07)[b]		0.374 (3.75)[a]		0.365 (2.87)[a]	
CoverCrop						0.457 (5.78)[a]
Advanced Education					-0.314 (-2.02)[b]	
Ag. Education					-0.207 (-2.67)[a]	
IncHigh						-0.148 (-1.65)[c]
SoilSensor			-0.252 (-2.27)[b]		-0.289 (-1.99)[b]	
MultipleInlet			0.000 (1.88)[c]			
ETAtmometer			0.482 (2.68)[a]		0.488 (2.15)[b]	
ComputerSchedule						0.272 (2.51)[a]
River	-0.166 (-2.56)[b]					
ND						0.165 (1.86)[c]
SD			0.519 (2.44)[a]			-0.436 (-2.39)[a]
TWR				0.178 (2.29)[b]		
PivotRow						-0.174 (-2.59)[a]
YieldCorn				0.001 (2.46)[a]	0.001 (2.79)[a]	0.004 (3.01)[a]
PrecisionLevelProfitability					0.292 (2.43)[a]	
PrecisionLevelAge		-0.000 (-3.70)[a]				-0.000 (-1.87)[c]
ZeroGrade	0.000 (2.17)[b]					
PartOther			0.075 (1.73)[c]			
AWS		0.027 (2.13)[b]				
Clay						-0.005 (-1.68)[c]
GDD 2013		-0.001 (-2.24)[b]			0.002 (3.54)[a]	

PPT 2014			-0.031 (-2.58)[a]	0.032 (2.03)[b]		
PPT 2015			-0.017 (-1.83)[c]			
StreamRiver			-0.001 (-1.68)[c]			
Pseudo R^2	0.222	0.218	0.286	0.467	0.251	0.288
Number of observation	229	221	229	197	221	221

a – 1%, b – 5%, c–10% Significance. Z statistics from the probit model estimates in parentheses.

Table 5: Marginal effects for the peer network variables to explain the share of irrigated acres using an irrigation practice

Variable	Border Irrigation	Precision Grade Leveling	Warped Surface Leveling	End Block Irrigation	Cut Back Irrigation	Deep Tillage	Gypsum	Cover Crops
PeerPivot				-0.2113 (-2.73)[a]			0.0733 (0.80)	
PeerTWR		-0.174 (-3.06)[a]				-0.033 (0.58)	-0.358 (2.28)[b]	
PeerRes			-0.152 (-2.49)[a]		-0.127 (-2.37)[a]		-0.427 (-3.06)[a]	
PeerCHS						-0.226 (-3.42)[a]	-0.192 (-1.85)[c]	
PeerSurge	0.138 (0.93)	-0.104 (-1.59)			0.094 (1.92)[b]			
PeerFlowMeter	-0.135 (-1.55)	-0.134 (-2.13)[b]		-0.041 (-0.51)	0.269 (7.15)[a]			
PeerPLevel								0.237 (3.34)[a]
PeerEndBlock		0.173 (3.31)[a]		-0.348 (-2.09)[b]	0.223 (2.89)[a]			
PeerScheduling					-0.213 (-3.27)[a]	-0.116 (-1.71)[c]	0.073 (0.74)	
PeerMulti-Inlet				0.180 (1.90)[c]	-0.143 (-1.98)[b]	0.281 (4.77)[a]	0.247 (-1.06)	
PeerAltWetDry		0.184 (2.56)[a]		-0.215 (-1.92)[b]		-0.109 (-2.24)[b]		0.029 (0.42)
PeerPivot*Ridge							0.438 (3.86)[a]	
PeerTWR*River		0.154 (1.70)[c]						
PeerTWR*ND						-0.330 (-2.62)[a]		

PeerRes*GP			0.182 (2.10)[b]					
PeerSurge*Fed		-0.213 (-1.84)[c]						
PeerSurge*CHS		0.168 (2.03)[b]						
PeerSurge*Reg Con					0.243 (5.08)[a]			
PeerFlowMeter* Ridge				0.220 (1.93)[b]	0.226 (2.33)[b]			
PeerFlowMeter* GP	-0.679 (-4.83)[a]							
PeerFlowMeter* Fed	0.482 (3.57)[a]							
PeerFlowmeter* RegCon				0.206 (1.68)[c]				
PeerEndBlock* PartOther				-0.215 (-2.73)[a]				
PeerEndBlock* RegCon		-0.223 (-2.62)[a]		0.274 (3.02)[a]				
PeerScheduling* Ridge					-0.539 (-8.69)[a]			
PeerScheduling* CRP							0.260 (2.50)[a]	
PeerMult-Inlet*PartOther					0.157 (1.74)[c]			
PeerMult-Inlet*RegCon				-0.253 (-1.76)[c]			-0.455 (-3.30)[a]	
PeerAltWetDry* ND				0.523 (2.76)[a]				
PeerAltWetDry* PartOther				0.389 (2.59)[c]				0.297 (3.34)[a]

PeerAltWetDry* Fed		0.291 (2.62)[a]						
Pseudo R^2	0.109	0.005	0.026	0.011	0.050	0.010	0.023	0.019
LR equations: Chi squared statistics χ^2	28.27[a]	5.23[b]	52.25[a]	5.56[b]	33.01[a]	2.39	21.01[a]	40.52[a]
Number of observation	20	159	58	57	18	81	11	48

a – 1%, b – 5%, c–10% Significance. Z statistics from the bivariate sample selection model estimates in parentheses.

Table 6: Marginal effects for the farm, irrigation, and socioeconomics variables to explain the share of irrigated acres using an irrigation practice

Variable	Border Irrigation	Precision Grade Leveling	Warped Surface Leveling	End Block Irrigation	Cut Back Irrigation	Deep Tillage	Gypsum	Cover Crops
TotalIrr.Acres		-0.000 (-2.33)[b]				-0.000 (-3.51)[a]		-0.000 (-3.63)[a]
PercentCorn	0.019 (4.98)[a]				-0.008 (-3.94)[a]			0.005 (3.91)[a]
PercentSoybean							-0.003 (-2.17)[b]	0.002 (2.25)[b]
PercentRice					0.0019 (1.74)[c]		-0.007 (-3.07)[a]	0.004 (1.77)[c]
PivotRows								0.148 (2.65)[a]
WarpedSurface	0.0059 (4.72)[a]							
EndBlock	-0.009 (-6.61)[a]							
IrrSoy			0.173 (1.67)[c]	-0.191 (-1.66)[c]				
IrrigatedRice					-0.000 (-2.18)[b]			
IrrigatedCotton		0.001 (1.88)[c]						
ETAtmometer			0.271 (1.82)[c]					
Ridge			0.232 (2.74)[a]					
River			0.276 (1.98)[b]					
ND								-0.357 (-2.88)[a]

SD								0.264 (3.56)[a]
TWR				-0.228 (-2.75)[a]				
PartCRP						-0.193 (-3.90)[a]	-0.179 (-1.76)[c]	
PartEQIP						0.229 (3.87)[a]		
PartRegCon							0.211 (2.34)[b]	
PartOther								0.206 (5.51)[a]
ComputerHole						0.138 (2.44)[b]		-0.133 (2.13)[b]
Computer Schedule								-0.288 (-3.17)[a]
YieldCorn	-0.003 (-7.51)[a]			-0.000 (-1.74)[c]	-0.000 (-2.27)[b]			-0.001 (-4.25)[a]
CoverCrop								-0.271 (-3.04)[a]
PrecisionGrade						0.000 (2.21)[b]		
PrecisionLevel Easy		0.099 (1.76)[c]						
NoPrecision LevelCost						-0.175 (-1.80)[c]		
PrecisionLevel Age		-0.000 (-1.60)[c]	0.000 (3.43)[a]			0.000 (2.64)[a]		0.000 (1.95)[b]
ZeroGrade						-0.007 (-3.06)[a]		
Multi-Inlet			0.0015 (2.77)[a]			0.001 (2.14)[b]		

AgEdu					0.100 (1.82)[c]			
Bach	-0.273 (-2.76)[a]				-0.442 (-5.23)[a]			-0.220 (-4.13)[a]
AdvEdu		0.201 (2.31)[b]		0.432 (2.29)[b]	0.683 (6.26)[a]			
IncHigh							-0.234 (-3.49)[a]	
IncNA						-0.116 (-2.17)[b]		
PH60					-0.003 (-1.81)[c]			
AWS				0.159 (2.33)[b]				
PPT2013		-0.021 (-2.59)[c]				-0.020 (-2.74)[a]		
PPT2015					0.009 (2.24)[b]			
GDD2013		-0.000 (-1.74)[c]						
Loam		0.010 (2.30)[b]		0.020 (2.41)[c]		0.011 (1.95)[b]		0.024 (7.44)[a]
Silt					-0.004 (-1.65)[c]			
Sand	-0.007 (-1.70)[c]							
OpenWater						-0.003 (-2.34)[b]		
CanalDitch				-0.006 (-2.05)[b]	0.011 (7.25)[a]	-0.004 (-2.17)[b]		
BarrierPipe	1.769 (3.45)[a]							
Pseudo R^2	0.109	0.005	0.026	0.011	0.050	0.010	0.023	0.019

LR equations: Chi squared statistics χ^2	28.27[a]	5.23[b]	52.25[a]	5.56[b]	33.01[a]	2.39	21.01[a]	40.52[a]
Number of observation	20	159	58	57	18	81	11	48

a – 1%, b – 5%, c–10% Significance. Z statistics from the bivariate sample selection model estimates in parentheses.

Appendix

Appendix A

Table A1 shows the marginal effects from the probit estimation that were significant between the 10th and 40th percentile after the marginal effects were applied. These values were significant as coefficients below the 10th percentile before the marginal effects were applied.

Table A1. Marginal Effects from Probit Estimation, All variables significant between 10th and 40th percentile

Variable	Border Irrigation	Precision Grade Leveling	Warped Surface Leveling	End Block Irrigation	Deep Tillage	Cover Crops
irr_rice						
irr_soy				-0.155 (-1.29)		
IncNA			-0.059 (-0.92)			
AltWetDry				0.000 (1.25)		
FlowMeter				0.088 (1.39)		0.089 (1.31)
Ridge			0.164 (1.46)			
SD		0.171 (1.56)				
PrecisionLeveling				-0.000 (-1.37)		
WarpedSurface					-0.000 (-1.00)	
PartCRP						
PartOther				-0.209 (-1.22)		
ComputerSchedule			-0.124 (-1.09)			
ComputerHole		0.075 (1.47)				0.105 (1.59)
Surge		0.063 (1.13)			-0.136 (-1.46)	
YieldCorn						
PrecisionLevelAge				-0.000 (-1.10)		
AWS			-0.019 (-1.19)			
PH<5.5						
PH>6.0			0.003 (1.49)			
PPT2013						-0.001 (-1.52)
PPT2014						

PPT2015				0.001 (1.51)		
GDD2014				0.001 (1.08)		
Clay			-0.005 (-1.57)			
Loam			-0.009 (-1.29)			
Silt		-0.003 (-1.59)	-0.004 (-1.30)			-0.003 (-1.19)
CanalDitch						-0.001 (-1.02)
AqueductPipe						0.626 (0.94)
StreamRiver					-0.001 (-0.98)	
PeerRes						
PeerSurge						
PeerZeroGrade				-0.062 (-0.85)		
PeerEndBlock						
PeerPLevel		0.087 (1.35)				
PeerMulti-Inlet						
PeerPLevel*Fed		0.062 (1.13)				
PeerPivot*Ridge						
PeerPivot*PartOther		0.115 (1.45)				
PeerPivot*CRP		0.050 (0.85)				
PeerRes*CRP						
PeerCHS*ND					-0.252 (-1.05)	
PeerCHS*GP					0.209 (1.32)	
PeerEndBlock*Fed				0.371 (1.46)		
PeerSurge*PartOther						
PeerScheduling*CRP						
PeerFlowMeter*RegCon				-0.181 (-1.34)		
PeerZG*PartOther				-0.138 (-1.19)		
PeerZG*EQIP						
PeerZG*Fed	-0.077 (-1.48)					
PeerZG*Fin				0.145 (0.96)		
PeerMult-Inlet*River			0.189 (0.93)			
PeerMult-Inlet*RegCon				0.176 (1.49)		

Z statistics in parentheses.

Table A2 shows the marginal effects from the probit estimation that were not significant at the 40th percentile after the marginal effects were applied. These values were significant as coefficients below the 10th percentile before the marginal effects were applied.

Table A2. Marginal Effects from Probit Estimation, All variables not significant at 40th percentile

Variable	Border Irrigation	Precision Grade Leveling	Warped Surface Leveling	End Block Irrigation	Deep Tillage	Cover Crops
Irr_rice				0.061 (0.77)		
irr_soy		-0.067 (-1.05)				
AdvEdu		-0.053 (-0.73)				
WarpedSurfaceLeveling				-0.000 (-0.79)		
GDD2015				-0.001 (-0.81)		
Silt	-0.001 (-0.78)					
Loam	-0.003 (-0.76)					
StreamRiver	-0.000 (-0.73)					
PeerPivot		0.022 (0.36)				
PeerRes				-0.049 (-0.67)		
PeerSurge	0.025 (0.53)					
PeerScheduling						
PeerFlowmeter				-0.022 (-0.27)	0.088 (0.86)	
PeerZeroGrade						
PeerMulti-Inlet		-0.032 (-0.64)				
PeerAltWetDry						-0.006 (-0.09)
PeerSurge*RegCon						

Z statistics in parentheses.

Appendix B

Table B1 shows the marginal effects from the bivariate sample selection model estimation that were significant between the 10th and 40th percentile after the marginal effects were applied. These values were significant as coefficients below the 10th percentile before the marginal effects were applied.

Table B1: Marginal Effects from Bivariate Sample Selection, All variables significant between 10th and 40th percentile

Variable	Border Irrigation	Precision Grade Leveling	Warped Surface Leveling	End Block Irrigation	Cut Back Irrigation	Deep Tillage	Gypsum	Cover Crops
TotalIrr.Acres				-0.000 (-0.91)				
IrrigatedSoybean			-0.000 (-1.32)					
IrrigatedRice			-0.000 (-1.19)					
IrrCotton							-0.11 (-0.95)	
PercentCotton		-0.004 (-1.44)						
PercentSoybean		0.000 (1.43)						
PercentPeanut		0.019 (1.20)						
IrrRice			0.060 (1.51)					0.090 (1.31)
DieselPump		0.016 (0.87)						
AdvEdu	-0.128 (-1.09)		-0.117 (-0.96)					
IncHigh								0.081 (1.11)
IncNA			-0.046 (-1.30)					
SD			0.113 (1.59)					
ND			0.134 (1.24)					
CoverCropType								
PrecisionLevelAge				0.000 (1.45)				
PrecisionLevelEasier			0.095 (1.41)					
TaxCredStorage								-0.123 (-1.30)
ComputerHole								
ComputerSchedule			-0.045 (0.357)					
SoilSensor			-0.078 (-1.55)					
Flowmeter			0.0837 (1.39)					-0.075 (-1.32)
Surge		0.0281 (1.36)						
ZeroGrade								
PartOther				0.100 (0.92)				
WarpedSurface				-0.001 (-1.12)				
PartRegCon		-0.020 (-1.01)						

AltWetDry				-0.000 (-1.40)				
PH		0.059 (1.24)						
PH55		0.001 (1.55)						
PH60			-0.003 (-1.45)			0.002 (1.29)		
PPT2014	-0.000 (-1.10)			-0.000 (-1.45)				
PPT2015		0.002 (1.00)		-0.003 (-1.19)		0.004 (1.50)		
GDD2015	-0.003 (-1.07)							
Clay		0.013 (1.45)		0.017 (1.01)	0.005 (1.50)	0.003 (1.12)		-0.002 (-0.92)
Silt		-0.017 (-0.91)		-0.039 (-1.23)		0.003 (1.08)		
OpenWater		-0.000 (-1.22)		-0.001 (-1.48)				
CanalDitch								-0.001 (-1.50)
BarrierPipe		-0.204 (-1.21)						
AqueductPipe		0.639 (1.61)						
PeerRes				0.056 (0.88)				
PeerSurge		-0.104 (-1.59)						
PeerEndBlock			0.498 (1.00)					
PeerTWR						0.033 (0.58)		
PeerFlowmeter	-0.135 (-1.55)			-0.041 (-0.51)				
PeerZeroGrade				0.124 (1.27)				
PeerPLevel		0.032 (1.42)						
PeerMultiInlet			-0.046 (-1.33)				0.247 (-1.06)	0.072 (0.79)
PeerAltWetDry			-0.623 (-1.53)					0.029 (0.42)
PeerPivot*Ridge		-0.036 (-1.55)						
PeerPivot*CRP		0.020 (1.13)						
PeerPivot*PartOther		0.033 (1.26)						
PeerRes*Ridge				-0.098 (-1.05)				
PeerRes*CRP								
PeerPLevel*Fed		0.012 (0.89)						
PeerFlowMeter*CRP		0.068(1.07)						
PeerFlowMeter*Fin		-0.156 (-1.57)						
PeerSurge*Fed								
PeerEndBlock*CRP								
PeerEndBlock*Fin				0.136 (1.17)				
PeerEndBlock* RegCon			0.108 (0.98)					
PeerZeroGrade*Part Other					-0.100 (-1.07)			
PeerZeroGrade*EQIP					-0.058 (-1.39)			

PeerZeroGrade*Fin				-0.098 (-0.83)				
PeerMult-Inlet*Ridge			0.045 (1.22)					-0.116 (-1.09)
PeerMult-Inlet*GP			0.074 (1.53)					
PeerMultiInlet*Other		-0.032 (-1.24)		-0.125 (-1.01)				
PeerAltWetDry* EQIP		-0.114 (-1.28)						

Z statistics in parentheses.

Table B2 shows the marginal effects from the bivariate sample selection estimation that were not significant at the 40th percentile after the marginal effects were applied. These values were significant as coefficients below the 10th percentile before the marginal effects were applied.

Table B2: Marginal Effects from Bivariate Sample Selection, All variables not significant at 40th percentile

Variable	Border Irrigation	Precision Grade Leveling	Warped Surface Leveling	End Block Irrigation	Cut Back Irrigation	Deep Tillage	Gypsum	Cover Crops
IrrSoy	-0.023 (-0.52)				0.056 (0.62)	-0.039 (-0.57)		
YieldCorn		-0.000 (-0.91)	0.000 (0.98)			-0.000 (-0.56)		
AgEdu						0.019 (0.67)		
Bach			0.039 (0.78)					
AdvEdu						0.039 (0.58)		
PrecisionLevel Profit						-0.030 (-0.58)		
Surge						0.014 (0.59)		
WarpedSurface						0.000 (0.53)		
ZeroGrade	-0.000 (-0.51)							
ETAtmometer						-0.066 (-0.52)		
SoilSensor						0.040 (0.55)		
River	0.043 (0.52)							
SD		0.025 (0.78)						
PH55	-0.004 (-0.40)							
PH60				0.002 (0.83)				
Org_Matter						-0.019 (-0.47)		
GDD2013						-0.003 (-0.60)		
GDD2014						0.001 (0.56)		
Clay	-0.006 (-0.55)							
Loam			0.005 (0.70)					
OpenWater	0.000 (0.52)							
StreamRiver						0.000 (0.51)		
PeerPivot							0.073 (0.80)	
PeerSurge	0.138 (0.93)							
PeerScheduling							0.073 (0.74)	
PeerCHS	0.053 (0.52)							
PeerCHS*Ridge						-0.034 (-0.57)		
PeerCHS*ND						0.030 (0.53)		

PeerCHS*SD						0.100 (0.60)		
PeerCHS*GP						-0.030 (-0.54)		
PeerCHS*CRP						0.039 (0.63)		
PeerCHS*Part Other	-0.040 (-0.51)							
PeerSurge*Fed	-0.058 (-0.51)							
PeerScheduling* ND						-0.060 (-0.58)		
PeerScheduling* SD						-0.076 (-0.61)		
PeerScheduling* CRP						-0.042 (-0.63)		
PeerFlowMeter* EQIP						-0.018 (-0.56)		
PeerAltWetDry* CHS				0.097 (0.79)				

Z statistics in parentheses.

Appendix C

Table C1. Explanatory variables for irrigation water source modeling, only significant above 10th percentile

Variable	Description	Proportion
PrecisionLevelProfitability	=1 if used precision leveling to improve profitability	0.10
PeerPLevel*Fed	=1 if peers used precision leveling and the irrigator raised money for tail-water recovery or reservoir through a federal cost-share program	0.21
PeerPivot*CRP	=1 if peers used center pivot and participated in conservation reserves program	0.29
PeerRes*Ridge	=1 if peers used reservoir storage and located on Crowley's Ridge	0.18
PeerRes*CRP	=1 if peers used reservoir storage and participate in conservation reserve program	0.28
PeerCHS*Ridge	=1 if peers used computerized hole selection and located on Crowley's Ridge	0.17
PeerCHS*GP	=1 if peers used computerized hole selection and located in the Grand Prairie	0.10
PeerCHS*ND	=1 if peers used computerized hole selection and located in the North Delta	0.05
PeerCHS*EQIP	=1 if peers used computerized hole selection and participated in environmental quality incentives program	0.31
PeerEndBlock*Fed	=1 if peers used end-blocking and the irrigator raised money for tail-water recovery or reservoir through a federal cost-share program	0.14
PeerSurge*PartOther	=1 if peers used surge irrigation and participate in other conservation program	0.09
PeerScheduling*ND	=1 if peers used irrigation scheduling and located in the North Delta	0.06
PeerScheduling*EQIP	=1 if peers used irrigation scheduling and participated in environmental quality incentives program	0.28
PeerScheduling*RegCon	=1 if peers used irrigation scheduling and participated in regional conservation partnership program	0.08
PeerFlowMeter*River	=1 if peers used flowmeter and located along the Mississippi River	0.14
PeerZG*PartOther	=1 if peers used zero grade leveling and participate in other conservation program	0.20
PeerZG*EQIP	=1 if peers used zero grade leveling and participated in environmental quality incentives program	0.36
PeerZG*Fin	=1 if peers used zero grade leveling and primary reason for adoption was financial assistance	0.04
PeerZG*Fed	=1 if peers used zero grade leveling and the irrigator raised money for tail-water recovery or reservoir through a federal cost-share program	0.19
PeerEndBlock*River	=1 if peers used end-blocking and located along the Mississippi River	0.09
PeerEndBlock*ND	=1 if peers used end-blocking and located in the North Delta	0.09
PeerEndBlock*Fin	=1 if peers used end-blocking and primary reason for adoption was financial assistance	0.03
PeerEndBlock*CRP	=1 if peers used end-blocking and participated in conservation reserve program	0.25
PeerAltWetDry*CHS	=1 if peers used wetting and drying for rice irrigation and used computerized hole system	0.12

PeerAltWetDry*RegCon	=1 if peers used wetting and drying for rice irrigation and participate in regional conservation partnership program	0.05
PeerAltWetDry*Fin	=1 if peers used wetting and drying for rice irrigation and primary reason for adoption was financial assistance	0.03

Table C2. Multivariate Probit Model Coefficient of Irrigation Choices

Variables	Border Irrigation	Precision Grade Leveling	Warped Surface Leveling	End Block Irrigation	Deep Tillage
Precision Grade Leveling	-0.14 (-0.77)				
Warped Surface Leveling	-0.12 (-0.72)	0.29 (1.51)			
End Block Irrigation	-0.28 (-1.35)	0.08 (0.33)	-0.07 (-0.25)		
Deep Tillage	-0.04 (-0.16)	-0.02 (-0.1)	0.41 (2.49)[a]	0.09 (0.50)	
Cover Crops	0.36 (1.84)[b]	0.23 (1.29)	-0.34 (-1.96)[b]	-0.20 (-1.03)	-0.21 (-1.3)

a – 1%, b – 5%, c–10% Significance. Z statistics from the multivariate sample selection model estimates in parentheses.