Factors influencing the adoption of irrigation measurement tools in the Arkansas Delta

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Selected Paper (or Poster) prepared for presentation at the Southern Agricultural Economics Association SAEA) Annual Meeting, Jacksonville, Florida, 2-6 February 2018.

Abstract

We address factors which may influence the adoption of flow meters and/or certain irrigation scheduling practices. Measuring irrigation flow enhances management of irrigation, which improve profits. It also serves as a useful tool in evaluating which conservation measures for irrigation to adopt. This enhanced management can come in the form of scheduling. While less sophisticated versions of it exist, newer, more scientific forms can lead to better efficiency of irrigation events. As groundwater supplies become more limited, the use of flow meters and/or efficient scheduling techniques will allow farmers to better manage water resources.

Keywords: Irrigation, Groundwater conservation, Surface water delivery

JEL Classifications: Q15, Q24, Q25

Introduction

Diminishing groundwater resources are threatening the security of nearly half of the world's drinking water supply and 43% of the world's irrigation water supply (van der Gun 2012). One common solution policymakers have relied on to reduce groundwater use is to improve irrigation efficiency. However, several recent empirical studies have shown that using more efficient irrigation technologies may increase total farm-level water use (e.g., Pfeiffer and Lin, 2014). Finding ways to increase efficiency and reduce groundwater use are especially important in the state of Arkansas since its producers greatly rely on irrigation relative to other states (West, et al 2016). The foundation for improving irrigation efficiency is measuring how much water is applied to the field through the use of flow meters and when to best apply the water with irrigation scheduling. This paper examines what factors influence Arkansas producers' use of one or both of these foundational tools for irrigation efficiency.

As of 2012, Arkansas has the third most irrigated farm acres, totaling 4.8 million acres. Between 2007 and 2012, the state's irrigated base expanded by 343,220 acres; with only Mississippi having a higher percentage increase. For more perspective, of the 55.8 million acres of farmland under irrigation in the United States in 2012, about 8.6% of it was in Arkansas, and about three out of five cropland acres in Arkansas are being irrigated (West, et al 2012).

With these figures in mind, we want to determine which factors could influence Arkansas producers to adopt scientific irrigation scheduling and/or flowemeters on their farms. Both are the bases of improving irrigation efficiency (Schiable, et al, pg. 437, 2010). Scientific scheduling practices, which is an umbrella term we use for computerized scheduling, soil sensors, Woodruff charts, atmometers, and canopy temperature sensors, improve irrigation efficiency (Schiable, et al, pg. 437, 2010), but less than 10% of irrigated farms use scientific scheduling techniques

(Schiable, et al, pg. iv, 2012). However, not every farm is alike, so exact changes in irrigation efficiency are not uniform. To track these changes, flowmeters should be used. Unfortunately, irrigation water is rarely measured, so efficiency is hard to determine (Schiable, et al, pg. 29, 2012). While much of the irrigation literature is concerned with its engineering and outcomes, a relatively small amount draws attention to its adoption, let alone factors which help explain techniques as specific as scientific scheduling or the use of flowmeters. Additionally, many previous studies in this realm, although self-described as studying adoption rates, solely provide correlations.

A 2014 study by Margarita Genius on irrigation adoption in Greece influenced our use of categories and focus on social learning/peer networks. The study separated the variables into four categories: economic, farm organizational & demographic, environment, and social learning (Genius, et al 2014). Before this, Glenn Schaible and Marcel Aillery used those first three categories mentioned to describe variables in their 2012 USDA report on irrigation trends (Schaible, et al 2012). In fact, many studies prior to Genius' used similar variables which, although not explicitly categorized, could fit into the categories described above (Green, et al 1996; Schuck, et al 2005; Koundouri, et al 2006; Schoengold, et al 2014).

We share similar variables across these studies. Genius and Koundouri found that the producer's age had an inverse correlation with the (rate of) adoption of new irrigation technology (Koundouri, et al 2006; Genius, et al 2014). Both also found that education level increased the (rate of) adoption of new irrigation technology, while Schuck found an inverse correlation between the two (Shuck, et al 2005; Koundouri, et al 2006; Genius, et al 2014). It is important to note, however, that the education variables in those papers are not specific to agricultural education, as is the case in our study. Genius' study revealed a negative correlation between farm size and rate of adoption, while Green, Schoengold, and Schuck observed the opposite effect (Green, et al 1996; Schuck, et al 2005; Genius, et al 2014; Schoengold, et al 2014). In regards to peer networks and/or social learning, Koundouri and Genius were the two papers to include that information. Koundouri's variables were extension visits and active information. She found positive correlations for both (Koundouri, et al 2006). Genius used distance between adopters, exposure to extension outlets, and distance from extension outlets. Greater distance between adopters decreased the rate of adoption of irrigation technology, while the latter two increased the rate of adoption (Genius, et al 2014). Our study uses similar variables overall, but our variables are specific to irrigation practices found in the Arkansas delta and uses knowledge of the practices of peers to stand in for social learning variables. Since peer networks seem to play an important role, especially in Genius' study, we strive to specify the type of peer network, as opposed to a general knowledge of or exposure to extension outlets.

Methods

To find which factors are correlated with the adoption of irrigation measurement tools, a multinomial logit regression will be conducted. This will be to maximize the likelihood of each independent variable having an impact on the dependent variables. This will allow for a better understanding of what variables are influencing producer's choice when it comes to adopting scientific scheduling, flowmeters, or both. For the multinomial logit model there will be four dependent variables which are assigned a whole value of 0 or 1. The dependent variables will include: producers that use neither scientific scheduling nor flowmeters, producers that use scientific scheduling only, producers that use flowmeters only, and producers that use both scientific scheduling and flowmeters.

This multinomial model is described below where m represents the alternative choice options and y is the dependent variable which takes the value of j if the j^{th} alternative is taken, j = 1,…m. We can define the probability that alternative j is chosen as:

$$p_j = \Pr[\, y = j],\ \ j = 1,\dots,\text{m}. \qquad (1.1)$$

Where p and Pr is the probability. This introduces m binary variables for each observation y,

$$yj = \begin{cases} 1 \text{ if } y = j, \\ 0 \text{ if } y \neq j, \end{cases} \qquad (1.2)$$

We can see that yj is equal to one if alternative j is the observed outcome and the remaining y_k are equal to zero, meaning that for each observation of y, one of $y_1, y_2,\dots, y_m$ will be nonzero.

For the likelihood function we use a sample of N independent observations as:

$$L_N = \prod_{i=1}^{N} \prod_{j=1}^{M} p_{ij}^{yij} \ ,$$

where i represents the i^{th} of N individuals and j represents the j^{th} of M alternatives. The log-likelihood function is therefore:

$$\Lambda = InL_N \ = \ \sum_{i=1}^{N} \sum_{j=1}^{m} y_{ij} \ In\, p_{ij,} \qquad (1.3)$$

As our regressors do not vary over alternatives, we use a multinomial logit model, otherwise known as MNL:

$$p_{ij} = \frac{e^{x'_{ij}\beta_j}}{\sum_{l=1}^{m} e^{x'_{ij}\beta_j}}, \qquad j \ = 1, \dots, m \qquad (1.4)$$

Because $\sum_{j=1}^{m} pij$ = 1, a constraint is needed to ensure the model identification and the usual restriction of $\beta_1 = \ 0$.

The coefficients in our model will be represented in terms of relative risk. For the MNL model we draw a comparison from the base category, which is also known at the alternative which is normalized to have a coefficient of zero. This is explained in (1.4) where it is implied that the probability of observing alternative *j* given that either alternative *j* or *k* or *r* or *s* is observed is

$$\Pr[y = j \mid j \text{ or } k \text{ or } r \text{ or } s] = \frac{p_j}{p_j + p_k + p_r + p_s}$$

$$= \frac{e^{x'\beta_j}}{e^{x'\beta_j} + e^{x'\beta_k} + e^{x'\beta_r} + e^{x'\beta_s}} \qquad (1.5)$$

$$= \frac{e^{x'(\beta_j - \beta_s)}}{1 + e^{x'(\beta_j - \beta_s)} + e^{x'(\beta_k - \beta_s)} + e^{x'(\beta_r - \beta_s)}}$$

which represents a logit model with the coefficient ($\beta_j - \beta_s$). We then simplify to reach a second equality. Supposing that normalization is attributed to base alternative s, meaning $\beta_s = 0$. Then

$$\Pr[y_i = j \mid y_i = j \text{ } or \text{ } k \text{ } or \text{ } r] = \frac{e^{x_{ij}'\beta_j}}{1 + e^{x_{ij}'\beta_j} + e^{x'\beta_k} + e^{x'\beta_r}} \qquad (1.6)$$

β_j can carry the same interpretation as logit model coefficient binary choice alternatives *j* and 1. Likewise, it can be interpreted using relative risk of choosing alternative *j* rather than alternative s, this is shown as

$$\frac{\Pr[y_i = j]}{\Pr[y_i = s]} = e^{x_{ij}'\beta_j} \qquad (1.7)$$

meaning e^{β_j} explains the proportionate change in relative risk when x_{ir} changes by one unit. We will output our results of the model using the relative risk values.

The explanatory factors can be categorized as follows:

$$x_{ij}'\beta_j = = \beta_0 + c_i'\beta_1 + d_i'\beta_2 + p_i'\beta_3 + u_i \text{ where } i = 1, \ldots, n. \qquad (1.8)$$

The parameter β_0 is the intercept of the model. $c_i'\beta_1$ is a vector of independent variables which are associated with crop choice and irrigation conditions $d_i'\beta_2$ is a vector of independent variables which are associated with demographic and economic characteristics, and $p_i'\beta_3$ is a vector of independent variables which are associated with social learning or peer networks which include the dummy variables. The term u_i is an extreme value distributed error that represents unobserved explanatory variables.

Data

The data set comes from the Arkansas Irrigation Use Survey conducted by the authors with collaborators from Mississippi State University. The survey was completed in October 2016. Survey data were collected via telephone interviews administered by the Mississippi State University Social Science Research Center. Potential survey respondents come from the water user database managed by the ANRC and all commercial crop growers identified by Dun & Bradstreet records for the state of Arkansas. Of 3,712 attempted contacts, 842 resulted in calls to disabled numbers, resulting in a net sample size of 2,870. Of the remaining contacts, 1,321 led to no answer, busy signal or voicemail. Another 925 contacts were ineligible due to illness or language barrier or identified as non-farmer. In total, 624 contacts reached were eligible to complete the survey. Among the eligible contacts, 255 contacts declined to participate, 7 scheduled callbacks but did not complete the survey, and 171 contacts discontinued the survey. The final sample size is 199 producers that completed the survey in its entirety. Depending on how response rate is calculated, the response rate for this survey varies from 6.87% to 32.25%. The survey has nearly 150 questions and took respondents about 30 to 40 minutes to finish by phone. The survey collected a wealth of information about producers' decision about crop production and irrigation practices. The survey also collected information on a variety of socio-economic factors.

Explanatory variables in this study were divided into three categories in Table 1: *crop choice and irrigation conditions*, *demographic and economic characteristics*, and *social learning*. These categories were created to understand which types of factors play the most important roles in determining the adoption of scientific scheduling, we compare our sample to the 2012 Census of Agriculture using several variables that are collected in both surveys. The comparison indicates that our sample is comparable to that of the Census. The shares of irrigated land in rice (RiceAc) are similar between the Census of Agriculture and our sample (27.5% versus 27.51%, Table 1). The shares are also similar for soybean (SoyAc). The share of irrigated area in soybean is slightly higher in our sample (53.93%) than in the census (49.19%). Given the upward trend in irrigated soybean production in Arkansas, we believe that the difference is likely attributable to the 4-year gap between the two samples. In our sample, the years of farming experience (Exp) ranged from one to 60 years with an average of 30.91 years. This is higher than the average in the Census of Agriculture (24.47 years). Most likely this is because the Census reports years of experience as operators rather than total years of farming experience as in our survey. We believe that these two measures for years of experience are consistent.

In addition to the variables described above, several other variables are included in our analysis to control for *crop choice and irrigation conditions*. The amount of irrigated land of corn (CornAc), cotton (CottonAc), and sorghum (SorghumAc) in hundreds of acres are included, as well as dummy variables for growing rice (D_Rice), soybeans (D_Soy), corn (D_Corn), cotton (D_Cotton), and sorghum (D_Sorghum). Dummy variables were created to indicate whether producers use the following irrigation practices: computerized hole selection (D_CHS), surge irrigation (D_Surge), switched from center pivot to furrow irrigation (D_PivFur), and tailwater recovery systems (D_TWR). Of these, tailwater recovery systems were the most common (45%), and surge irrigation was the least common (16%). Additionally, the number of on-farm reservoirs were included (Res). The final variables in this category were dummies for whether the producer believed the depth-to-water increased (D_DepInc) (groundwater going down) or decreased (D_DepDec) (ground water rising) on his or her farm. 13% of respondents believed they were experiencing a reduction in groundwater, while 27% believed they were experiencing a rise in ground water.

The highest education attained by producers in our sample vary widely. 23% reported earning an associate's degree, 42% reported earning a bachelor's degree, and 9% reported earning higher than a bachelor's degree. In the final specification of the empirical analysis, we include binary variables that equals one if the producer has an agricultural education background (D_AgEdu), an associate's degree (D_EduAssoc), a bachelor's degree (D_EduBach), or an advanced degree (D_EduAdv). In addition to these *demographic and economic* variables, income levels are used: high (D_IncHigh), mid-level (D_IncMid), and unreported income (D_IncNA). Most respondents fell within the mid-level income grouping. A dummy variable for belonging to a conservation program (D_Conserv), such as Ducks Unlimited, is also in this category, with just over 50% responding in the affirmative.

The final category, *social learning*, focuses on peer networks and information sharing. First, to determine awareness of options for conversion to surface water irrigation, respondents were asked if they were aware of a state tax credit program that allow them to claim up to $9,000 tax credit for conversions to surface water or land leveling (D_AwareCredit). About 48% of the respondents were aware of this program. Respondents were also asked if they have ever participated in the Environmental Quality Incentives Program (D_EQIP). About 45% of the respondents indicated that they have participated in the EQIP. The ten other variables in the *social learning* category are dummies based off a “yes” or “no” 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?” The practices mentioned in this question were center pivot (D_PNet_CP), tailwater recovery (D_PNet_TWR), reservoirs (D_PNet_Res), computerized hole selection (D_PNet_CHS), surge irrigation (D_PNet_Surge), precision leveling (D_PNet_PL), zero grade leveling (D_PNet_ZG), end blocking (D_PNet_EB), multiple inlet irrigation (D_PNet_MI), and alternate wetting and drying (D_PNet_AltWet). The responses to this question do not reflect the producer’s practices, but are instead meant to potentially gauge where the producer lives, how much contact with extension offices he or she has, and ultimately how belonging to these different peer networks affect adoption of irrigation measurement tools.

Results

Table X shows the relative risk ratios of the variables when the dependent variable was equal to 1 (producer uses scientific scheduling i.e. Computerized Scheduler, Woodruff charts, ET or Atmometer, Canopy temperature, and Soil moisture sensors), equal to 2 (producer uses flowmeters), and equal to 3 (producer uses both scientific scheduling and flowmeters). Seven variables were significant under irrigation scheduling alternative 1, ten under flow meters alternative 2, and twenty-one under the both irrigation scheduling and flow meters alternative 3.

In alternative 1, producers growing soybeans (D_soy), more acres of cotton (CottonAc), and belonging to a peer network that uses a tailwater recovery system (D_PNet_TWR) showed decreased odds of using scientific scheduling. Those who grow corn (D_Corn), have a bachelor's degree (D_EduBach), a high income (D_IncHigh), and belong to peer network who uses computerized hole selection (D_PNet_CHS) showed an increased odds of using scientific scheduling.

In alternative 2, those with more acres of sorghum (SorghumAc), switched from pivot to furrow irrigation (D_PivFur), and belong to peer network with a tailwater recovery system (D_PNet_TWR) or surge irrigation (D_PNet_Surge) showed a decreased odds of using flowmeters. Those with more reservoirs (Res); are members in a conservation organization (D_Conserv); and belong to peer networks who uses either center pivot (D_PNet_CP), reservoirs (D_PNet_Res), multiple-inlet irrigation (D_PNet_MI), or alternate wetting and drying (D_PNet_AltWet) showed an increased odds of using flowmeters.

In alternative 3, many more explanatory variables are significant. For crops, those who grow rice (D_Rice) showed decreased odds of using the combination of scientific scheduling and flowmeters. More acres of corn (CornAc) decreases the odds, while more acres of cotton increases the odds (CottonAc). Those who used computerized hole selection (D_CHS) have lower odds while those who switched from pivot to furrow irrigation (D_PivFur), use a tailwater recovery system (D_TWR), and have higher numbers of reservoirs have higher odds (D_Res). Producers with a background in agricultural education (D_AgEdu), who are aware of the tax credit (D_AwareCredit), and have higher income (D_IncHigh) or non-reported income (D_IncNA) have greater odds of choosing the third alternative. Producers who are part of EQIP (D_EQIP) and have more farming experience (Exp) have lower odds. Producers who belong to peer networks with either tailwater recovery system (D_PNet_TWR), precision grading (D_PNet_PL), or zero-grade leveling (D_PNet_ZG) have lower odds. Those who belong to peer networks with either center pivot irrigation (D_PNet_CP), reservoirs (D_PNet_Res), computerized hole selection (D_PNet_CHS), or multiple-inlet irrigation (D_PNet_MI) have greater odds.

Explanatory variables under *Crop Choice and Irrigation Conditions* did not show much magnitude either decreasing or increasing the odds of the alternatives. Growing soybeans (D_Soy) and having more acres of cotton (CottonAc) decrease the odds of alternative 1, while growing corn (D_Corn) increases the odds. More acres of sorghum (SorghumAc) slightly decreases the odds of alternative 2. Growing rice (D_Rice) and having more acres of corn (CornAc) decreases the odds of alternative 3, while more acres of cotton (CottonAc) slightly increases the odds. Being a producer who switched from pivot to furrow irrigation (D_PivFur) decreases the odds of alternative 2, while having more reservoirs (Res) increases the odds. Using computerized hole selection (D_CHS) decreases the odds of alternative 3; while being someone who switched from pivot to furrow irrigation (D_PivFur), has a tailwater recovery system (D_TWR), and more reservoirs (Res) increases the odds. D_PivFur and D_TWR increase the odds the most, and D_Rice decreases the odds the most for *Crop Choice and Irrigation Conditions* variables.

All *Demographic and Economic* variables increase the odds where they are significant, save for experience (Exp) under alternative 3. Having a bachelor's degree (D_EduBach), and a high income (D_IncHigh) increase the odds of alternative 1. Belonging to a conservation group (D_Conserv) increases the odds of alternative 2. Having an agricultural education background (D_AgEdu) and all income variables (D_IncHigh, D_IncMid, and D_IncNA) increase the odds of alternative 3. Almost each variable has relative the same magnitude where significant. *Demographic and Economic* explanatory variables.

All *Social Learning* explanatory variables show significance under at least one alternative. D_PNet_CHS increases the odds of alternative 1, while D_PNet_TWR decreases the odds. D_PNet_CP, D_PNet_Res, D_PNet_MI, and D_PNet_AltWet increase the odds of alternative 2; while D_PNet_TWR and D_PNet_Surge decrease the odds. D_PNet_CP, D_PNet_Res, D_PNet_CHS, D_AwareCredit, D_PNet_EB, and D_PNet_MI increase the odds of alternative 3; while D_EQIP, D_PNet_TWR, D_PNet_PL, and D_PNet_ZG decrase the odds. D_PNet_TWR decreases the odds substantially across all alternatives. D_PNet_PL decreases the odds the most under alternative 3 for the *Social Learning* variables. D_PNet_CP has a very large positive magnitude for alternative 3, but D_PNet_CHS increases the odds the most of any variable under alternative 3.

Discussion and Conclusion

The relative risk ratio values above or below one in the *Demographic and Economic* explanatory variables are intuitive relative to the other categories. Having an agricultural education background (D_AgEdu) and belonging to a conservation group (D_Conserv) should increase your knowledge of new irrigation techniques and products. Higher and mid-levels of income (D_IncHigh, D_IncMid) provide you with more of an opportunity to invest in flowmeters and/or adopt scientific scheduling techniques. More experienced farmers (Exp) are less likely to use both flowmeters and a scientific form of scheduling. This seems reasonable since an older farmer may be unlikely to change his or her style of farming.

Effect of *Crop Choice* variables on the odds of using scientific scheduling, flowmeters, or both are not as straight forward. To begin with, growing rice (D_Rice) decreases the odds of alternative 3. This is most likely because rice farmers maintain a fixed water level in the paddies, so tracking it or using more advanced scheduling techniques is not a necessary expense. Growing corn (D_Corn) shows a relatively large magnitude of increasing the odds of alternative 1, but having more acres of corn (CornAc) decreases the odds of alternative 3. Although growing corn itself leads to the use of scientific scheduling techniques, those with large corn farms are most likely located in areas where water scarcity is not a large concern. Growing soybeans (D_Soy) also decreases the odds of using scientific forms of scheduling, which is consistent with rice, as the two are often rotated. Increasing acres of cotton (CottonAc) decrease the odds of alternative 1, but increases the odds of using scientific scheduling and flowmeters. This shows producers with large cotton farms are interested in both measuring water usage and scheduling its application, but not just scheduling it. Since sorghum is not an irrigation intensive crop, it makes sense that the more acres of it a producer grows (SorghumAc), the less likely to use a flowmeter he or she is. In this way, producers may be treating sorghum as a substitute for purchasing flowmeters.

Under *Irrigation Conditions* variables, using computerized hole selection (D_CHS) decreases the odds of using flowmeters and scientific scheduling. Computerized hole selection is a popular method advocated by extension agents, and more trendy than scientific scheduling. Like sorghum, computerized hole selection may serve as a substitute for the dependent variables. Producers who have switched from pivot irrigation to furrow irrigation (D_PivFur) are inclined to use flowmeters and scientific scheduling but not just measuring the amount of water – a similar explanation as growing more acres of cotton. Using a tailwater recovery system (D_TWR) increases the odds of alternative 3, showing that those who use these systems are concerned about water usage. In a similar explanation with the tailwater recovery systems, those with increasing numbers of reservoirs on site have increased odds of using just flowmeters or in combination with scientific scheduling.

The *Social Learning* variables show the most consistent significance as well as the largest magnitudes, especially for alternative 3. Producers enrolled in EQIP (D_EQIP) primarily care about precision leveling, which in turn would not require them to be concerned with scheduling or flowmeters. Producers aware of the tax credit (D_AwareCredit) are probably connected to extension agents, so the increased odds of alternative 3 is understandable. Belonging to a peer network which uses computerized hole selection (D_PNet_CHS) suggests you are connected with extension agents – increasing the odds of using scientific scheduling, flowmeters, or both. Producers in peer network groups using center pivots (D_PNet_CP), reservoirs (D_PNet_Res), end blocking (D_PNet_EB), multiple inlet irrigation (D_PNet_MI), and alternate wetting and drying (D_PNet_AltWet) show increased odds of any single alternative or a combination of them. Producers belonging to these peer networks may be in areas where water usage is more of a concern than other areas.

Since surge irrigation is a furrow-only technique, producers belonging to peer network groups using surge irrigation (D_PNet_Surge) are in areas with less water scarcity, which explains the decrease in odds of using flowmeters. Those in peer network groups using tailwater recovery systems (D_PNet_TWR) and precision leveling (D_PNet_PL), and zero-grade leveling (D_PNet_ZG) show decreased odds across all or some of the alternatives. Producers using tailwater recovery systems or precision leveling techniques are most likely more concerned with irrigation water quality and the uniform application of irrigation water than the cost of the groundwater pumped. Those who use zero-grade leveling may be using the practice as a substitute for flowmeters, and by extension, scientific scheduling.

Overall, belonging to a peer network group has a significant impact on a producer's decision to use scientific scheduling, flowmeters, or both. One unique case is the use and/or knowledge of computerized hole selection. Belonging to a peer network of computerized hole selection users provides the largest increase in odds the producer uses both scientific scheduling and flowmeters. While using computerized hole selection (D_CHS) decreases the odds, being in a peer network of producers who use the computerized hole selection (D_PNet_CHS) greatly increases odds. This presents a key point that broader knowledge of irrigation practice implementation, along with a support network, may be more important than the use of a particular irrigation technique in explaining the use of other types of efficient irrigation practices. Some of these irrigation techniques may serve as substitutes to flowmeters or scientific scheduling as opposed to a complement.

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Table 1. Summary Statistics of Variables

Variables	Definition	Mean	Std. Dev.
Crop Choice and Irrigation Conditions			
D_Rice	=1 grows rice	0.59	0.49
D_Soy	=1 grows soybeans	0.80	0.39
D_Corn	=1 grows corn	0.39	0.49
D_Cotton	=1 grows cotton	0.10	0.30
D_Sorghum	=1 grows sorghum	0.07	0.25
CornAc	Amount of irrigated land of corn (in hundreds of acres)	2.98	9.48
CottonAc	Amount of irrigated acres of cotton	1.12	4.58
SoyAc	Amount of irrigated acres of soybeans	12.01	14.88
RiceAc	Amount of irrigated acres of rice	6.55	9.79
SorghumAc	Amount of irrigated acres of sorghum	0.34	1.77
D_CHS	=1 uses computerized hole selection	0.30	0.52
D_Surge	=1 has ever used surge irrigation	0.16	0.44
D_PivFur	=1 switched any acreage from pivot irrigation to furrow irrigation	0.18	0.38
D_TWR	=1 has a tailwater recovery system	0.45	0.50
Res	Number of reservoirs on the farm	0.77	1.74
D_DepInc	=1 depth-to-water increased (water levels dropping)	0.13	0.34
D_DepDec	=1 depth-to-water decreased (water levels rising)	0.27	0.44
Demographic and Economic			
D_AgEdu	=1 received any formal education in agriculture	0.56	0.50
Exp	Years of farming experience	32.7	15.3
D_Conserv	=1 belongs, or has belonged, to a conservation organization	0.51	0.50
D_EduAssoc	=1 has completed some college, vocational program, or associate's degree	0.23	0.42
D_EduBach	=1 has completed a bachelor's degree	0.42	0.49
D_EduAdv	=1 has completed a master's degree or beyond	0.09	0.28
D_IncMid	=1 2014 household income from all sources before taxes is ≥ $75,000 and ≤ $200,000	0.39	0.49
D_IncHigh	=1 2014 household income from all sources before taxes is > $200,000	0.15	0.36
D_IncNA	=1 unreported 2014 household income from all sources before taxes	0.23	0.42
Social Learning			
D_EQIP	=1 participant in the Environmental Quality Incentives Program in the last five years	0.45	0.50
D_AwareCredit	=1 aware of state tax credits program for conversion to surface water or land leveling	0.43	0.55
D_PNet_CP	=1 close family members, friends, or neighbor producers (peer network) has used a center pivot in the past 10 years	0.67	0.47
D_PNet_TWR	=1 close family members, friends, or neighbor producers (peer network) has used a tail-water recovery system in the past 10 years	0.66	0.47

D_PNet_Res	=1 close family members, friends, or neighbor producers (peer network) has used a storage reservoir in the past 10 years	0.60	0.49
D_PNet_CHS	=1 close family members, friends, or neighbor producers (peer network) has used computerized hole selection in the past 10 years	0.52	0.50
D_PNet_Surge	=1 close family members, friends, or neighbor producers (peer network) has used surge irrigation in the past 10 years	0.34	0.48
D_PNet_PL	=1 close family members, friends, or neighbor producers (peer network) has used precision leveling in the past 10 years	0.87	0.33
D_PNet_ZG	=1 close family members, friends, or neighbor producers (peer network) has used zero grade leveling in the past 10 years	0.71	0.45
D_PNet_EB	=1 close family members, friends, or neighbor producers (peer network) has used end blocking in the past 10 years	0.50	0.50
D_PNet_MI	=1 close family members, friends, or neighbor producers (peer network) has used multiple-inlet rice irrigation in the past 10 years	0.65	0.48
D_PNet_AltWet	=1 close family members, friends, or neighbor producers (peer network) has used alternate wetting and drying for rice irrigation in the past 10 years	0.33	0.47

Table 2. Relative risk ratios for explanatory factors of the use of irrigation scheduling, flow meters or both

Variables	RRR 1	Std. Err.	RRR 2	Std. Err.	RRR 3	Std. Err.
Crop Choice and Irrigation Conditions						
D_Rice	0.816	0.794	1.27	0.910	0.010**	0.020
D_Soy	0.103*	0.126	2.85	2.18	0.533	0.711
D_Corn	6.89*	7.22	2.30	1.25	9.79	15.60
D_Cotton	1.18	2.11	0.301	0.359	0.218	0.445
D_Sorghum	1.72	3.36	5.00	4.96	1.22	2.40
CornAc	1.00	0.73	0.964	0.025	0.530*	0.182
CottonAc	0.676**	0.134	1.09	0.077	1.53***	0.152
SoyAc	1.03	0.060	1.03	0.026	1.04	0.056
RiceAc	0.978	0.099	0.971	0.038	1.01	0.094
SorghumAc	0.730	0.255	0.764*	0.119	0.962	0.269
D_CHS	0.249	0.358	1.78	0.745	0.171**	0.141
D_Surge	3.85	3.83	1.28	0.809	0.288	0.303
D_PivFur	0.419	0.471	0.172**	0.134	17.50**	16.21
D_TWR	5.19	5.36	2.90	1.96	26.92**	30.50
Res	0.858	0.324	2.08**	0.439	4.15***	1.32
D_DepInc	1.86	3.16	0.339	0.296	0.105	0.171
D_DepDec	0.282	0.427	1.34	0.768	0.693	0.760
Demographic and Economic						
D_AgEdu	2.34	2.21	1.42	0.734	24.46**	28.94
Exp	0.971	0.034	1.01	0.016	0.905**	0.040
D_Conserv	1.00	1.00	2.53*	1.36	0.642	0.602
D_EduAssoc	4.11	8.43	0.922	0.658	0.354	0.393
D_EduBach	11.94*	16.24	2.32	1.67	0.834	1.05
D_EduAdv	27.75	49.42	2.22	2.28	0.08	0.200
D_IncMid	3.20	4.30	0.861	0.531	13.36**	15.20
D_IncHigh	18.42**	26.61	0.440	0.366	32.25**	41.81
D_IncNA	2.77	2.45	0.492	0.356	6.18*	6.09
Social Learning						
D_EQIP	2.11	2.00	1.18	0.599	0.072**	0.077
D_PNet_CP	3.71	4.59	3.16**	1.83	1665**	4480
D_ PNet_TWR	0.073*	0.109	0.063**	0.056	1.41e-3***	2.33e-3
D_AwareCredit	1.20	0.698	1.97	1.02	648.8***	825.0
D_ PNet_Res	3.20	4.16	3.21*	2.19	9.34*	9.09
D_ PNet_CHS	16.32**	17.42	1.09	0.601	59560***	115700
D_ PNet_Surge	4.06	5.08	0.195**	0.131	0.338	0.319
D_ PNet_PL	0.131	0.233	0.827	0.818	6.45e-5**	1.82e-4
D_ PNet_ZG	0.914	1.60	0.811	0.689	0.082**	0.884
D_ PNet_EB	0.974	1.03	0.917	0.492	51.83***	56.13
D_ PNet_MI	3.59	3.58	3.34*	2.17	1525***	3126
D_ PNet_AltWet	0.385	0.376	4.08**	2.22	1.05	1.41

Note: *,**,*** represents significance at 10%, 5%, and 1% levels. A relative risk ratio (RRR) of 1.00 reflects rounding to one from a value slightly above one.

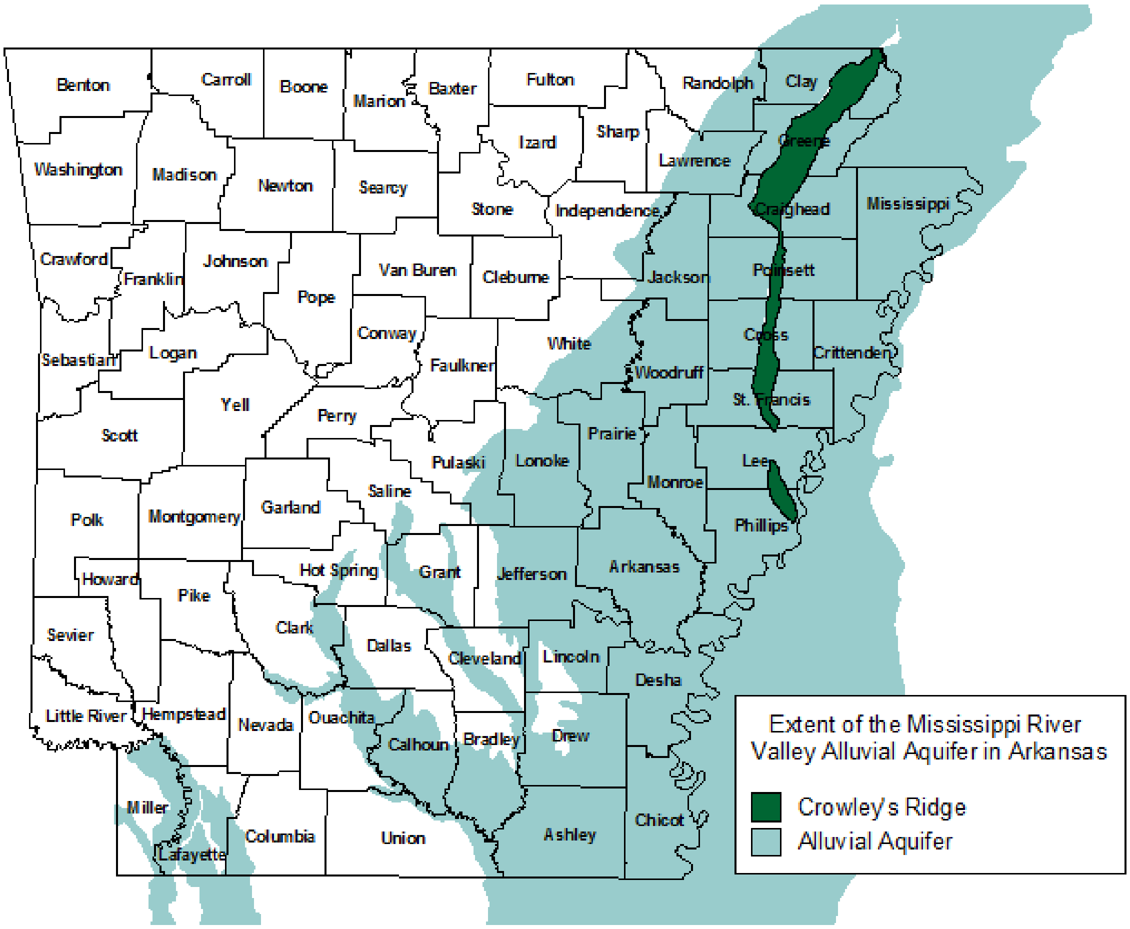

Figure 1. Extent of the Mississippi River Valley Alluvial Aquifer and Crowley's Ridge in Arkansas. The Mississippi River alluvial aquifer (MRVAA) is a critical source of irrigation water for agricultural production in the region. A defining feature of the region is Crowley's Ridge, which is generally recognized as a point of demarcation for relative groundwater abundance (to the east of Crowley's Ridge) and relative groundwater scarcity (to the west of Crowley's Ridge).