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Using and Improving Irrigation Systems: Producer Perceptions and Possibilities

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ABSTRACT

Frost, drought, and other sources of crop stress may be reduced through irrigation. A random sample of Alabama crop, tree, and vegetable producers was surveyed about the nature and extent of irrigation practices and problems. The study assesses needs for technical assistance relative to irrigation use and improvement. Results profile farmers' personal characteristics, irrigation practices, equipment, and water sources to identify barriers to adoption of improved irrigation. Findings suggest that being innovative encourages irrigation adoption, improvement, and expansion. Irrigation growth in information-transfer and collective learning may not have reached their potential for the Alabama farmer. Finding ways to support less innovative farmers may be vital to encourage greater irrigation use among those who need it most. Financial circumstances influenced farmers' decisions to irrigate. Cost-sharing and other financial incentives could be key parts of efforts to advance irrigation use.

Keywords: *Irrigation, Adoption, Diffusion, Innovation, Water, Barriers.*

Introduction

Irrigation transports water to crops to increase yield, keep crops cool under excessive heat conditions, and prevent freezing. Less than 15 percent of U.S. cropland is irrigated, although irrigation is essential for crop production in some of the most productive areas of the nation (Berardy and Chester 2017; Caswell et al. 2001).

The need to irrigate is usually driven by the necessity to meet the water needs of the crop from year to year (some areas of the country simply receive too little rainfall during the growing season to support economical crop growth). In other situations, irrigation is viewed as insurance against occasional drought. Lenders often require irrigation to protect their investment before making crop loans, since accurate irrigation scheduling in cotton can increase yields (Bajwa et al. 2007). Over the long-term, adoption decisions are influenced by changes in technology, farming practices, and climate (Bai 2008; Green et al. 1996; USGS 2010; Brown 1981; 1990; Lynne et al. 1995).

This study profiles farmer operator's irrigation practices, as well as their equipment and water sources, with the purpose of identifying barriers to the adoption and improvement of irrigation. Using data from a statewide survey, we identify assess barriers to irrigation adoption and elucidate some of the ways irrigation adoption is manifested in a representative sample of farms.

Climate Change and Irrigation

Rainfall is plentiful in Alabama, annually averaging 1400mm + / - across the state, but with great inter-annual and seasonal variability. Nonetheless, projections suggest that in the coming decades, Alabama will become warmer, and the state will probably experience more severe floods and drought (Hutson et al. 2009). Unlike most of the nation, Alabama has not become warmer during the last 50 years. But soils have become drier, annual rainfall has increased in most of the state, more rain arrives in heavy downpours, and sea level is rising about one inch every eight years (USEPA 2016). Thus, irrigation is one response to increased climate variability (Ghebreslassie 2001).

Irrigation can bring benefits by reducing risk of disease, frost damage, and other crop stressors, which can provide income stability (Jimenez et al. 2019). Other benefits include: improving crop quality (most noticeably for vegetable crops), significantly increasing crop yields, particularly on sandy soils (as in parts of Alabama) which have low moisture-holding capacities, increasing opportunities for double cropping (such as planting soybeans after wheat in the same year), and providing a means for liquid fertilizer application (National Research Council 2010).

Although Alabama receives ample amounts of rainfall, this moisture sometimes is not available when crops need it most. Increased usage of irrigation in Alabama may increase yields and reduce production risks, but also raise concerns about water quality (Albiac and Dinar 2013). As climate variability increases, droughts increase in frequency and intensity. Irrigation is an insurance policy even in a region of abundant annual rainfall (Carey and Zilberman 2002; Griliches 1957).

Barriers to Adoption of Irrigation Systems

Knowing the best irrigation method is not simple, as the Southeast experiences dry periods with irregular rainfall during the growing season and yearly weather varies from dry to wet (Langcuster 2007). As irrigation remains integral to crop production, the trial and adoption of irrigation technologies and innovations is often necessary for successful and abundant crop yields (Bajwa et al. 2007). Though rainfall amounts may seem large, rain may not always come when needed most. Other sources of crop stress may be reduced through the use of irrigation (Branch and Poremba 1990; USDA 2009).

Irrigation adoption can increase farmers' yields by minimizing disease and frost damage and by promoting early plant growth (Whittenbury and Davidson 2009). For example, as efficient, sustainable, and water-saving irrigation methods are developed, there are innovative, improved irrigation techniques available for farmers to adopt; the adoption of such technologies may allow farmers to water their crops in more efficient and environmentally friendly ways. This reflects a relatively new emphasis on more innovative water-conserving irrigation techniques in the state of Alabama (Bajwa et al. 2007; Casey et al. 1999).

Albrecht and Ladewig (2019) conclude that the single more important determinant of irrigation adoption in the Texas High Plains is farm size. Contextual factors also shape irrigation decisions. Pumping costs vary depending on the depth of wells, or distance to a pond, river, or stream water source. Electricity costs vary by locality, contract, and provider; some farmers may not have three-way electric service to their well site. Diesel pumping is substantially more expensive (Morata et al. 2019).

Fan and McCann (2020) examined a multilevel model of irrigation adoption using data from the national survey. They found adoption to increases with larger acreage, groundwater use, information sources other than neighbors, and recent higher temperatures. Adoption was lower with on-farm surface water and barriers related to increased costs, limited management time, and shorter time horizons. In contrast, Australian fruit growers changed irrigation practices in order to save time irrigating, to improve the scope for managerial flexibility in the orchard, or when redeveloping their orchard for a closer planting design (Kaine et al. 2005; Montagu et al. 2006).

Kulshreshtha and Brown (1993) suggest that adopters' attitudes, particularly with respect to economic and environmental effects of irrigation, were significant determinants of their decision to proceed with adoption of irrigation. Rodriguez et al. (2008) examined barriers to the adoption of sustainable agricultural practices, such as subsurface drip irrigation (SDI). For Alabama farmers, challenges to implementing new irrigation techniques (such as building off-stream reservoirs to store water from streams during periods of high rainfall). Cost-sharing, loans, and grants--not just farmer motivation and extension expertise--may be necessary to enable farmers to feasibly implement irrigation practices (Camp 1998; Negri and Brooks 1990; Carr 1999).

Bjornlund et al. (2008) argue that the major drivers of irrigation adoption are ensuring security of water supply during drought, increasing quantity and quality of crops, and saving costs. Thus, lack of access to water (and therefore lack of irrigation) may be because the cumulative barriers to accessing capital investment and technology have kept minority farmers from building on their investments (Rijsberman 2004; Molnar et al. 2001; Hsiao et al. 2007; Wilkinson 1989).

Method

Sample and Data Collection

This study examines survey data from a statewide sample of Alabama farm operators to explore the barriers to the adoption of irrigation. The survey adapted questions from the 2003 U.S. National Agricultural Statistics Service (NASS 2007; 2008). Census of Agriculture Farm and Ranch Irrigation Survey. The target population was all row crop, fruit-tree, vegetable, and horticulture producers across the state of Alabama. The sampling frame was the NASS list of agricultural row crop, vegetable, and fruit-tree crop farmers in Alabama. This list is continually updated by obtaining current information from a variety of local and state sources. A random sample of farmers was contacted through mailings administered by the NASS survey unit.

Data were collected from July 2009 through September 2009. The initial surveys were distributed in July 2009. Each mail packet included only the twelve-page questionnaire and a return envelope as the cover letter was part of the survey. After two weeks, a reminder was sent out to the same list (Dillman et al. 2009). Another questionnaire was sent two weeks later, making a total of three contacts to the sample (Dillman 2000; Dillman et al. 2009). The net mail response rate from all mailings was 18.4 percent. Of usable returns, 189 of the 794 respondents (approximately 24 percent) indicated that they currently irrigate.

Figure1. *Major topographical zones in Alabama*

Measures of Irrigation Adoption

Irrigated Last Year

There are five measures of irrigation adoption used in this study. The first measure is a dichotomous variable that contrasts farmers that have irrigation with those that did not, coded 1 = "No," 2 = "Yes."

Irrigation Extent Index

A second measure of irrigation adoption is the sums of responses to three items. Respondents were asked: what percent of your land is used for the following purposes was irrigated? The items were: (1) row crops, (2) fruit, vegetable, horticulture, or specialty crops, and (3) pasture or hay land. The response framework was: "None" = 1, "Some" = 2 (1-50%), and 3 = "Most" (greater than 50%). This measure is the sum of these items.

Irrigation Purpose Index

A third measure of irrigation adoption counts the number of secondary purposes for the irrigation system beyond providing water for plant growth. Respondents were asked if they used irrigation for a series of five secondary uses: (1) crop cooling to delay early budding, blooming, or to reduce heat stress, (2) to prevent freeze damage, (3) used to apply chemical fertilizers, (4) used to apply pesticides, and (5) other uses such as land disposal of liquid livestock waste, etc. The indicator is a count of the "yes" responses to the six items and was not specific to crop type.

Irrigation Outlay Index

A fourth measure of irrigation adoption reflects the relative amount spent for irrigation equipment repairs in the previous year. Respondents rated their spending on items: (1) building or improving permanent storage and distribution systems (dams, ponds, reservoirs, ditches, etc.), (2) land clearing and leveling for irrigation purposes, (3) new well construction or deepening of existing wells, and (4) purchasing new or replacing irrigation equipment and machinery. The response framework was: 1 = "None," 2 = "Some," 3 = "Major Outlay". The indicator reflects the sum of the four ratings.

Irrigation Improvement Index

A fifth measure of irrigation adoption counts the number of irrigation improvements made by the respondent. Respondents were asked to check from a list of eight possible irrigation improvements indicators: (1) adding moisture instrumentation, (2) adopting irrigation scheduling as a management practice, (3) changing energy source for pumping, (4) expanding acres covered by irrigation, (5) making irrigation changes that decreased energy costs, (6) making irrigation changes that improved crop yield or quality, (7) making irrigation changes that reduced water requirements, and (8) retrofitting sprinkler system for a low pressure operation. This index counts the number of indicated improvements.

Predictors of Irrigation Adoption

Farm Size

A measure of farm size is the sum of responses to six items. Respondents were asked to summarize their farms' land use and indicate the number of acres for six separate usages. The measure is the sum of acres reported. [1]

Attitudes toward Risk

Farmers were asked to rate a selection of possible barriers to implementing an irrigation system or to improving the one already in existence. In order to assess risk attitudes, producers were then asked if they felt that irrigation system operating costs are too risky. They rated this as 1 = "Not a possible barrier," 2 = "Some," or 3 = "Great barrier."

Individual Innovativeness

To measure innovative proneness, farmers were asked, in terms of using new farming practices and technologies, how would you describe yourself? They were scored based on the selection they chose: 1 = "An innovator, often trying new approaches before anyone else," 2 = "An Early Adopter of new practices," 3 = "Not the first, but part of the Early Majority of users," 4 = "Part of the Later Majority of users of new ideas," or 5 = "Often one of the Last to try new things." The ordinal measure is scored one to five.

Social Networking and Influence

There are three measures of social networking among producers. One such measure elicits responses to the statement, no other farmers around here irrigate, as a potential barrier to implementing irrigation systems and a measure of social influence on irrigation practices. Producers matched each as 1 = "Not a barrier," 2 = "Some," or 3 = "Great barrier." A second measure had producers rate whether "Having neighbors object to irrigation operation" as 1 = "Not a reason for neglecting to irrigate," 2 = "Some," or 3 = "Major reason for not irrigating." The third measure asked farmers how helpful were other farmers with irrigation? They were rated as 1 = "Not helpful," 2 = "Somewhat helpful," or 3 = "Very helpful."

[1]The six included: (1) cropland harvested, including all land from which crops were harvested or hay was cut, and all land in orchards, citrus groves, or vineyards, (2) cropland used only for pasture or grazing, including rotation pasture and grazing land that could have been used for crops without additional improvements, (3) other cropland used for cover crops, cropland on which all crops failed, in cultivated summer fallow, and idle cropland, (4) woodland, (5) other pastureland and range-land, (6) and all other land, including land in farmsteads, buildings, livestock facilities, ponds, roads, wasteland, and so forth.

Age

Producers were asked an open-ended question to measure their age: "What is your age?" They responded by recording their actual age in years.

Education

The measure for education counted the highest level of education respondents completed. They were asked, which category best describes your level of education? Respondents ranked their education: 1 = "Some high school or less," 2 = "Graduated high school," 3 = "Some college /technical school," 4 = "College graduate," 5 = "Some graduate school," and 6 = "Master's degree or more."

Technical Assistance

Producers were asked, how helpful are each of the following sources of information about implementing or improving irrigation? The respondents ranked nine sources of technical assistance as 1 = "Not helpful," 2 = "Somewhat helpful," or 3 = "Very helpful." [2]

Need for Technical Training

To measure the influence of technical assistance on irrigation adoption, producers rated their level of agreement or disagreement with the statement: "I need more training and technical assistance to implement or expand irrigation on my operation." They were scored accordingly: 5 = "Strongly Agree," 4 = "Agree," 3 = "Undecided," 2 = "Disagree," 1 = "Strongly Disagree."

Annual Household Income

An eighth variable that potentially influences irrigation adoption is annual household income level. A measure of income level reflects the total amount earned per household over the course of a year. Respondents were asked to check from a list of eight possible income brackets: 1 = "Less than $20,000," 2 = "$20,000 to $29,000," 3 = "$30,000 to $39,000," 4 = "$40,000 to $59,000," 5 = "$60,000 to $99,999," 6 ="$100,000 or more."

Level of Farming Operation Debt

To measure current debt level for their farming operations, respondents were asked to check

[2]The sources of information included: the Alabama Office of Water Resources, Auburn University specialists or researchers, county or regional extension agents, specialists from the USDA-Natural Resources Conservation Service, Internet websites, irrigation equipment dealers, media reports or information from the press, other farmers with irrigation, and private irrigation specialists or consultants.

from a list of four possible debt groups: 1= "No debt," 2 = "Very little debt," 3 = "Moderate debt," 4 = "Heavy debt." The responses indicate the respondents' perception of their debt level, rather than their actual level of debt.

Availability of Resources

The availability of resources may influence the implementation of irrigation adoption. Respondents were asked how hard it is to get replacement parts when needed and rated the difficulty of accessing resources for equipment and parts as: 1 = "Not a barrier," 2 = "Some," or a 3 = "Great barrier" to implementing or improving irrigation.

Access to Information

Another predicted influence on irrigation adoption is farmers' access to media and Internet, or more broadly speaking, to technical information. To measure this, producers were asked: "Do you have Internet access?" They responded by checking either "No" = 1, "Dial-up only" =2, or "Cable or DSL" = 3.

Information Sources

Respondents were asked how helpful a number of information sources were in regards to implementing or improving irrigation. Respondents checked whether these resources were: 1 = "Not helpful," 2 = "Somewhat helpful," or 3 = "Very helpful." The indicator counts the number of information sources used and/or found helpful. [3]

Ethnicity

To measure ethnicity, respondents were asked: What is your ethnicity? They responded by checking one of six possible options: Two dummy variables are employed: White, nonwhite, and Black, nonblack respondents.

Gender

To measure gender, respondents were asked: "What is your gender?" Respondents checked either 1 = "Male" or 2 = "Female."

RESULTS

As is shown in Table 1, 30 percent use ground water on or near their farm, which was the highest water source used on or near farm. Sixty-seven percent of respondents reported that they have to pay for most of their irrigation water, and another 16 percent indicated paying for at least some of this water.

Table1. *Sources of Irrigation Water Used, Alabama Farm Operators, 2009*

Sources of Irrigation Water (N = 192)	Some	Main Source
Ground water from well located on farm or another farm	21	30
On-farm flowing surface supply (stream, spring, or river)	22	25
On-farm standing water body surface supply (lake, pond, or reservoir)	20	21
Off-farm water suppliers (commercial company, municipal or community water system	3	7
Did you have to pay for water for irrigation?	16	67

As shown in Table 2, various types of irrigation techniques are adopted to provide the necessary amount of water to meet plant needs, which differ in respect to how water is obtained from the sources and how it is distributed. Center pivot irrigation (including high, medium, and low pressures) was the most highly used irrigation technique, with a total of 57 percent.

Table2. *Types of Irrigation Used, Alabama Farm Operators, 2009*

Type of Irrigation System (N=192)	Percent Using System
Center pivot	55
Drip, low flow, or trickle irrigation	33
Hose tow	13
Sprinkler irrigation	12
Gravity irrigation down rows or furrows	5
Cable tow	4
Linear and wheel move systems	3
Solid set and permanent systems	3
Hand move	2
Irrigated acres that have been laser leveled	0

Table 3 lists potential reasons for not irrigating and shows the percentages that farmers reported these reasons to be somewhat of a barrier or a major barrier to irrigating. The main reason reported for not irrigating, was that farmers could not afford the investment. The next two major reasons were due to shortage of surface water, which may force farmers to look for water elsewhere and pay for water, and because irrigation is uneconomical due to high energy costs. Thus,

[3]Information resources included the Alabama Office of Water Resources, Auburn University specialists or researchers, county or regional extension agents, specialists from the USDA Natural Resources Conservation Service, Internet websites, irrigation equipment dealers, media reports or information from the press, other farmers with irrigation, and private irrigation specialists or consultants.

finances appear to be a major factor for not irrigating.

Reasons for not Irrigating

Table3. *Reasons for Not Irrigating, Alabama Farm Operators, 2009*

Reasons for Not Irrigating (N = 794)	Some	Major
Cannot afford the investment	15	46
Shortage of surface water	17	20
Irrigation is uneconomical due to high energy costs	24	19
Shortage of ground water (wells or falling water tables)	16	17
Do not own the land that could be irrigated	13	16
Sufficient soil moisture—No irrigation needed	18	8
Plan to quit farming	9	7
Hard to get reliable information on different irrigation methods	12	4
Irrigation equipment failure	7	2
Neighbors object to irrigation operation	3	1
Pollution of water source	3	1

Irrigation Adoption

Use of Irrigation

About 76 percent reported not irrigating. Only 14 percent reported irrigating between one and 50 percent of only one type of crop. Eight percent irrigated one to 50 percent of two crops. Only two percent reported having irrigated most (greater than 50 percent) of at least one crop.

Irrigation Purposes Index

Respondents rarely used irrigation for any secondary purposes, but typically only for the sole purpose of providing water to their crops. Ninety-two percent of respondents used irrigation solely for supplying water when needed to crops. Six percent reported using irrigation for one secondary purpose and one percent for two other purposes. Less than 1 percent reported using irrigation for three extra uses, or for four or more secondary purposes.

Irrigation Outlay Index

Respondents on average made almost no expenditures on improvements or additions to their irrigation equipment in the previous year. Eighty-six percent spent no money to make improvements to their irrigation systems and equipment. However, only one percent made four improvements, and even fewer spent money to make five or more improvements to their irrigation systems. No respondent indicated making expenditures on the major outlay of all of the possible listed improvements.

Irrigation Improvement Index

Eighty-six percent of respondents made no improvements to their irrigation systems and equipment. Only six percent reported making one change, three percent made two changes, and three percent made three changes. Two percent reported making four changes, and only one percent reported making five or more changes.

Correlations

Table 4 summarizes the correlations among the dependent variables. For this study, each of the measures of irrigation adoption were strongly correlated ($p < 0.01$).

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Table4. *Correlations among Irrigation Adoption Dependent Variables, Alabama Farm Operators, 2009*

Variable	Irrigation Adoption Indictors (N=794)				
	Irrigated Last Year	Irrigation Land Index	Irrigation Use Index	Irrigation Outlay Index	Irrigation Improvement Index
Irrigated Last Year	--				
Irrigation Land Index	0.873**	--			
Irrigation Use Index	0.463**	0.466**	--		
Irrigation Outlay Index	0.590**	0.405**	0.610**	--	
Improvement Index	0.603**	0.608**	0.365**	0.628**	--
* p<0.05; ** p<0.01; *** p<0.001 (2-tailed)					

Multiple Regression

Irrigated Last Year

Table 5 gives a summary of the multivariate linear regression results for the five measures of irrigation usage as related to producer and farm characteristics. The adjusted R square for the dependent variable "irrigated last year" is 0.189, $p < 0.001$.

As shown in Table 5, attitudes towards risk had a significantly negative effect on irrigation use (beta = -0.18, $p < 0.001$). Also, producer innovativeness had a significant influence on all five dependent measures, including whether they irrigated their land or not (beta = -0.05, p < 0.05); those who reported being more innovative tended to have irrigated. Innovative proneness is reverse coded (5 = innovator, 1 = laggard). Thus, being more innovative is reflected in irrigation adoption and use.

Not having neighbors who have adopted irrigation negatively influenced respondents who irrigated (beta 0.10, p < 0.01). Also, there is no significant effect of having neighbors who object to irrigation usage on whether producers irrigated.

Regression results showed that those who reported using irrigation did not feel that they needed more training and technical assistance to implement or expand irrigation; having sufficient technical training and assistance positively influenced whether producers irrigated any of their farmland (beta = -0.07, p < 0.001).

As shown by regression results, debt level is significantly related to whether Alabama producers irrigated or not (beta = 0.05, p < 0.05). Thus, irrigating one's crops may be a great expense and cause greater debt.

Irrigation Improvement Index

The adjusted R square for the irrigation improvement index = 0.118, p < 0.001 significance level. Producers' innovative proneness had a significant effect on the irrigation improvement index (beta = -0.138, p < 0.01), as shown by Table 5. Those who are more innovative, then, were more likely to have made improvements to their irrigation systems. Also, producers' risk attitudes significantly affected the improvement index (beta = -0.330, p < 0.001).

Those who did not feel that irrigation operating costs are too risky made greater improvements to their irrigation equipment, as well. However, total combined household income during 2008 (beta = -0.070, p < 0.05) had a significant negative effect on this dependent variable; thus, higher income households reported fewer improvements. In contrast, education level had a positive effect on the improvement index (beta = 0.072, p < 0.05).

Income had a significantly negative effect on irrigation improvements made (beta = -0.07, p < 0.05). Regression results showed that producers' level of debt had a significantly positive effect on whether they irrigated (beta = 0.05, p < 0.05). Farmers with more debt were more likely to irrigate.

Irrigation Usage Index

The regression for the irrigation usage index produced an adjusted R square value of 0.133, p < 0.001, as shown in Table 5. Five independent variables influencing this index, which measures the number of different crops that receive irrigation, are described below:

The need for more training and technical assistance to implement or expand irrigation had a negative significant effect on the irrigation land index (beta = -0.10, p < 0.01), as did producer innovative proneness (beta = -0.09, p < 0.01). Thus, producers who reported not needing further training and technical assistance and being more innovative were more likely to irrigate to a fuller extent.

Also, producers' risk attitudes had a significant negative effect on the land index (beta = -0.25, p < 0.001); those who did not feel that irrigation operating costs were too risky used irrigation more widely on a greater amount of land. Having "no other farmers around here that irrigate" negatively affected the land index (beta = -187, p < 0.01) as well. Thus, not having neighbor adopters did not appear to affect the extent to which producers irrigate. And lastly, household income level negatively and significantly affected the land index (beta = -0.05, p < 0.05).

Irrigation Outlay Index

As shown in Table 5, the adjusted R square for the irrigation outlay index = 0.105 and the F value = 4.68. These values are significant at the p < 0.001 level. Regression results showed that those who reported using irrigation did not feel that they needed more training and technical assistance to implement or expand irrigation; having sufficient technical training and assistance positively and significantly influenced whether producers made significant expenditures on their irrigation systems (beta = -0.08, p < 0.05). Also, more innovative farmers tended to spend more on their irrigation operations as well (beta = -0.121, p < 0.001). Producers with more positive risk attitudes, who did not feel that irrigation system operating costs were too risky, were more likely to spend more on irrigation (beta = -0.26, p < 0.001). None of the other predictor variables significantly affected the irrigation outlay index.

Irrigation Purpose Index

The adjusted R square value for the irrigation purpose index = 0.06, p< 0.001. Innovative proneness had a significant effect on the irrigation use index (beta = -0.04, p < 0.05). Thus, those who described themselves as being more innovative reported using irrigation for more secondary purposes than those who reported being less innovative. Risk attitudes also significantly influenced the use of irrigation for secondary uses (beta = -0.10, p < 0.01), as did ethnicity (beta = 0.29, p < 0.001). Thus, the regression results suggest that more non-white producers use irrigation for secondary purposes other than watering crops. However, the proportion of non-Caucasian ethnicities was quite low, so this particular result should be taken cautiously.

Table5. *OLS Regression of Irrigation Adoption on Selected Irrigated Farms, Alabama Farm Operators, 2009*

Independent Variable	Irrigation Adoption Indicators (standardized coefficients)				
	Irrigated Last Year	Irrigation Land Index	Irrigation Use Index	Irrigation Outlay Index	Irrigation Improvement Index
Farm Size	0.02	-0.01	0.00	0.03	0.07
Risk Attitudes	-0.18***	-0.25***	-0.10	-0.26***	-0.33***
Innovative Status	-0.05	-0.10	-0.04	-0.12***	-0.14**
Neighbor Adopter	-0.10**	-0.12***	-0.01	-0.11	-0.11
Neighbors Object	-0.10	-0.09	0.00	-0.12	-0.1
Age	0.00	0.00	0.00	0.00	0.00
Education	0.02	0.04	0.02	0.01	0.07*
Helpfulness Index	-0.01	-0.14**	0.00	0.00	0.00
Training Needed	-0.07***	-0.08*	-0.02	-0.09*	0.06
Annual Income	-0.02	-0.05	-0.02	-0.02	-.08*
Debt Level	0.05*	0.06	0.04	0.06	0.07
Resource Availability	0.02	0.08	-0.19***	0	0.07
Gender	-0.08	-0.16	-0.1	-0.13	-0.24
Ethnicity	0.14	0.27	0.29***	0.26	0.25
Adjusted R^2	0.19	0.13	0.06	0.11	0.12
F-ratio	8.30***	5.87***	2.84***	4.68***	5.20***
*p<0.05; **p<0.01; ***p<0.001 (N=794)					

Summary and Conclusions

This study found that the variables that propel farmers to implement irrigation practices and improve and expand irrigation systems have not changed much in relation to past studies. Irrigation is still relatively underutilized among Alabama farmers. This may indicate that growth in information transfer and collective learning, such as extension education and the Internet, has not yet reached its potential for the Alabama farmer.

Producers' attitudes towards risk significantly influenced all five dependent irrigation variables. This finding suggests that being less concerned with risk allows producers to more easily adopt, improve, and expand irrigation systems on their property. Irrigated row crops and fruit/horticulture /specialty crops were both significantly and negatively correlated with risk aversion, unlike pasture and hay land. Farmers who produce vegetables, fruit, horticulture, and specialty crops are less likely to view irrigation operating costs as risky. Instead, it may be risky for these farmers to not irrigate.

Neighbor adopters, or producers' local social networks, had a significant effect on irrigation and the extent of irrigation used (the irrigation land index). Though respondents were not affected by having no nearby irrigators, having neighbors who irrigate can encourage producers to irrigate and use irrigation on a larger portion of their crops; Rogers' theory of innovation, for example, suggests a bandwagon process where an increase in the number of irrigators creates stronger "bandwagon" pressures. Social pressures can cause increases in the number of actual adopters of irrigation. Through communication with other local irrigators, producers can develop a social network for information and technical support for one another (Morris et al. 2000; Rogers 1995).

Those with greater levels of education made larger numbers of improvements to their irrigation equipment. Thus, education may be a key factor in encouraging farmers to improve their irrigation systems and make them more efficient. Growing pressures to conserve water and reduce costs while continuing to sustain yields and reduce risk require farmers to use the most efficient irrigation techniques; this requires farmers to be aware of and understand how to use new efficient technology. Therefore, finding more ways to educate farmers outside of the traditional educational system and for educators/researchers to collaborate with producers is a possibility for future research.

Those who reported a greater debt level also tended to report having irrigated. Irrigation is a capital investment for those producers who choose to irrigate and may contribute to their debt level. This is a classic example of Cochrane's (1993) treadmill of production; farmers who adopt new technology and therefore increase productivity gain significant benefits, such as greater yield. Over time, others follow and increase supply; as supply increases, commodity's price tends to fall, which can increase debt as producers continue to irrigate and make expenditures on irrigation equipment and improvements. Increased efficiency in agricultural production, such as increased irrigation also can drive down commodity prices. This downward pressure on crop price results in "price-squeeze" and "cost-squeeze," which in effect can increase debt level aswell (Cochrane 1993).

Finding a way to make irrigation more affordable to implement and maintain may be a necessary step to encourage more Alabama producers to irrigate in the future. Sixty-seven percent of respondents reported having to pay for the majority of their irrigation water and another 16 percent reported paying for at least some of it; this cost may be a reason for not irrigating.

New technology has advanced the practice of irrigation to better meet plant needs, conserve water, and save money by reduced pumping and water costs. For example, soil sensors can be used to support irrigation scheduling decisions to monitor changes on soil moisture conditions and canopy temperature. Future research on farmer adoption of irrigation systems, management technology, and water conservation will consider the mediating role of information technologies in facilitating farmer control and operation of water distribution when and where it is need.

The main reason for not irrigating, was that farmers could not afford the investment. Cost-sharing, subsidized loans and other incentives could be key parts of efforts to advance irrigation use in Alabama. Farmers irrigate to protect yield and crop quality, but operators balance the costs of irrigation with commodity price expectations. Making irrigation water more accessible, making irrigation technology more efficient, educating farmers about efficient techniques, and making pumping more affordable are necessary changes for irrigation to be a smaller financial risk to Alabama's producers. By doing so, a larger percentage of Alabama's farmers may be more inclined to irrigate, expand their currently installed irrigation operations, and improve the efficiency of the systems already in use.

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