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FARM SIZE, IRRIGATION PRACTICES, AND CONSERVATION PROGRAM PARTICIPATION IN THE US SOUTHWEST[†]

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ABSTRACT

The US Department of Agriculture's Farm and Ranch Irrigation Survey collects the most detailed and comprehensive data on US irrigation practices. Yet, because the data are only easily available in cross-tab form, data are rarely used for statistical analysis of irrigator behavior. Using data from Arizona and New Mexico, this study illustrates how statistical measures of association can be used test hypotheses about how farm size (measured by sales class) affects (i) use of water management information, (ii) investment in irrigation improvements, and (iii) participation in conservation programs. Parametric (Cochran–Armitage trend test) and nonparametric (Goodman–Kruskall gamma) methods yielded similar results. Reliance on low-cost, general information was common among all size classes, while larger operations relied more on private, tailored information. Larger operations were more likely to use directly provided data (e.g. media and Internet reports) than smaller operators, who relied more on information provided by intermediaries. Smaller farms were less likely to investigate irrigation improvements, use management-intensive methods for irrigation scheduling, or participate in cost-share programs to encourage adoption of improved irrigation practices. Adoption of scientific irrigation scheduling methods was low for all groups, but especially low for small-scale irrigators. There appear to be significant barriers to information acquisition, use of management-intensive irrigation practices, and participation in conservation programs among smaller-scale irrigators. Copyright © 2012 John Wiley & Sons, Ltd.

KEY WORDS: farm size; information; investment; conservation programs

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RÉSUMÉ

Le département américain de l'agriculture organise un recensement sur l'irrigation dans les ranches et exploitations agricoles et dispose des données les plus détaillées et les plus complètes sur les pratiques d'irrigation aux États-Unis. Pourtant les données sont rarement utilisés pour l'analyse statistique du comportement des irrigants, parce qu'elles ne sont facilement disponibles dans des formats de tableaux croisés. En utilisant les données de l'Arizona et du Nouveau Mexique, cette étude illustre comment les mesures statistiques par association peuvent être utilisées pour vérifier des hypothèses sur la façon dont la taille des exploitations (mesurée par catégorie de ventes) affecte (i) l'utilisation des informations de gestion de l'eau, (ii) l'investissement pour l'amélioration de l'irrigation, et (iii) la participation à des programmes de conservation. Des méthodes paramétriques (test de tendance de Cochran–Armitage) et non paramétriques (Kruskall–Goodman gamma) ont donné des résultats similaires. La confiance dans les informations générales et peu couteuses était courante parmi toutes les classes de taille, alors que les grandes opérations ont compté davantage sur des renseignements personnels et sur mesure. Les grandes opérations étaient plus susceptibles d'utiliser les données fournies directement (par exemple les médias et les rapports Internet) que les petits opérateurs, qui comptaient plus sur les informations fournies par les intermédiaires. Les petites fermes étaient moins susceptibles d'étudier les améliorations d'irrigation, d'utiliser les méthodes de gestion intensives de planification de l'irrigation, ou de participer des programmes à coûts partagés d'adoption de pratiques d'irrigation améliorées. L'adoption de méthodes scientifiques de planification d'irrigation est faible pour tous les groupes,

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mais particulièrement faible pour les petits irrigants. Il semble y avoir des obstacles importants à l'acquisition de l'information, l'utilisation de pratiques de gestion intensives de l'irrigation, et à la participation aux programmes de conservation entre les irrigants à plus petite échelle. Copyright © 2012 John Wiley & Sons, Ltd.

MOTS CLÉS: taille des exploitations; information; investissement; programmes de conservation

INTRODUCTION

In the 11 westernmost contiguous US states, irrigation accounts for 84% of freshwater withdrawals (Hutson *et al.*, 2005). Small changes in irrigator behavior have important implications for availability of water for other uses. A 10% reduction in irrigation water use would increase water available for all other uses by 52%. As the primary user of western water, irrigation is a primary contributor to nonpoint-source water pollution (Council for Agricultural Science and Technology (CAST), 1992; US Environmental Protection Agency (EPA), 1998). In the western states, irrigation accounts for 89% of river and 40% of lake pollution from sediment and chemical runoff (National Research Council (NRC), 1996). Irrigation is also a main contributor to salinity problems (CAST, 1992). Irrigation management will continue to be central to debates over western water allocation and pollution control. Improving irrigation efficiency is seen as key to reducing water pollution and easing competition for scarce water in the west (Caswell and Zilberman, 1985; Dinar *et al.*, 1992; Green *et al.*, 1996) and as a means to adapt to climate change (Parry *et al.*, 1998; Mendelsohn and Dinar, 2003).

Despite the importance of irrigation management, federal agencies do not collect comprehensive, annual data about irrigator behavior. The US Geological Survey (USGS) has published *Water Use in the United States* at 5-year intervals. Data are published by state and county on area irrigated and water withdrawn by method (flood, sprinkler, or micro) and source (groundwater vs surface water). USGS reports these data with long time lags. Their 2005 report first became available in October 2009.

As part of the Census of Agriculture, the US Department of Agriculture (USDA) conducts a Farm and Ranch Irrigation Survey (FRIS) roughly every 5 years, the most recent in 2008. The FRIS provides the most detailed, comprehensive picture of irrigation practices and water use at the national and state level. While FRIS data are often used for descriptive, outreach publications, they have been used rarely in statistical analyses of irrigator behavior. The USDA publishes FRIS data as cross-tabs emphasizing relationships between two variables, such as water use intensity by crop or by method of irrigation. Because the tables focus on 2×2 relationships, they do not lend themselves to standard multivariate analysis. To protect respondent confidentiality, access to raw survey data is restricted. For this reason, rigorous research using FRIS data is limited to a few studies conducted by USDA economists (and collaborators) who have easier access to the farm-level data (Negri and Brooks, 1990; Schaible *et al.*, 1991; Moore *et al.*, 1993, 1994; Schaible, 1997; Schaible and Aillery, 2003; Negri *et al.*, 2005). These studies offer important insights into irrigator behavior, but are few given the scope of the FRIS data.

Using data from Arizona and New Mexico, this study demonstrates that it is possible to use publicly available FRIS data to test economic hypotheses concerning irrigator behavior. One can move beyond merely describing differences in behavior to determining what factors account for those differences and whether those differences are significant. We examine the relationship between farm size and (i) sources and uses of water management information, (ii) barriers to improving irrigation systems for water or energy conservation, and (iii) participation in government conservation programs.

We focus on the role of farm size for two reasons. First, the ERS tabulations stratify the FRIS data by farm size. That is the data we have. Second, economic theory and previous empirical findings suggest there are systematic relationships between scale of operation and use of water management information. Leib *et al.* (2002) found significant positive relationships between farm size and adoption of scientific irrigation scheduling methods (use of crop evapotranspiration data and soil moisture testing) among Washington state farmers. Skaggs and Samani (2005) in a study of New Mexico's Elephant Butte Irrigation District found a 'lack of interest in making improvements to current irrigation systems or methods on the smallest farms'. Comparing irrigation districts in Alberta, Canada, Bjornlund *et al.* (2009) found evidence of greater adoption of information-intensive irrigation management in areas with larger farms.

Value of water management information—a conceptual framework

The value of water management information is the increase in farm returns from using the information minus any costs entailed in processing the information to make it useful. Information only has positive value if it alters an operator's choice of inputs, technology, or practices. This approach is similar to Feder and Slade (1984) (who considered active information acquisition and technology adoption generally), Johnson and Holt (1997) (who examined the value of weather information), and Parker and Zilberman (1996) (who examined use of the California Irrigation Management Information System (CIMIS)).

Irrigators with larger baseline sales revenues will receive greater benefits from processing information. Percent increases in yield or reductions in costs can be spread over more potential production. There is an area effect and a revenue per hectare (price) effect. Producers growing high-value crops may have limited area, but still be 'large' in terms of revenue. The benefits from accessing information increase with farm 'size' where hectares, value of crop, or both, contribute to size. In many cases, processing information may be relatively independent of scale. An irrigator may process information that can be applied to 200, 500 ha, or more, at little or no additional cost. If the cost of processing information is independent of scale, while the benefits increase with scale, larger-scale irrigators will process more information.

If irrigators with more technical capacity can process information at lower cost and if this capacity is positively correlated with sales revenue, then we will observe larger irrigators processing more information or using technical sources of information. If the cost of processing information increases with the amount of information or the number of sources accessed, smaller-scale irrigators will seek information from fewer sources. Information acquisition is a choice variable; irrigators can obtain more information, but at increasing cost. Because size limits benefits of information, operations below some critical size may not acquire information (Feder and Slade, 1984).

Consider a case where irrigators can access two types of information. The USDA or extension provides low-cost, but general, information. Private consultants provide specific information. Consultants tailor this higher-cost information to particular operational conditions and needs. In this case, both large and small operators rely on low-cost, public information while large irrigators are more likely to seek tailored information from private sources. Feder and Slade (1984) characterized information obtained from other farmers as passive and relatively costless. Here, one would expect high use of information from neighbors and that smaller irrigators would rely on their neighbors (relative to other more costly sources) more than larger irrigators would. Thus, adoption of low-cost information would be broad; adoption of tailored, private information would be concentrated among larger irrigators. We hypothesize that larger irrigators will use more information sources than will small irrigators.

Smaller farms may adopt fewer management-intensive practices such as scheduling irrigation based on soil-moisture or plant-moisture sensing devices, commercial irrigation scheduling services, or computer simulation models because they work more off-farm. Studies have found off-farm work discourages management-intensive practices such as integrated pest management (Fernandez-Cornejo, 1998), acquiring information for livestock feeding practices (Wozniack, 1993), and precision farming (Hoppe, 2001; Fernandez-Cornejo, 2007). Hoppe noted that smaller operators worked off-farm more. In Arizona and New Mexico, only 55% of small operators reported farming as their principal occupation. More than 87% of operators in the larger farm size classes report farming as their principal occupation (US Department of Agriculture, National Agricultural Statistical. Service (USDA, NASS) (2004)).

Our framework suggests farm size may affect information acquisition for irrigation management through multiple pathways. It also suggests farm size may be a proxy for other important factors such as technical capacity or off-farm work.

The foregoing suggests testable hypotheses about irrigator information use:

H1. The probability that an irrigator accesses any given source of information increases with farm size (with size measured in terms of hectares, sales, or both).

H2. Both small and large irrigators will rely on low-cost sources of information (e.g. government, extension, neighbors). Reliance on private, tailored sources of information (e.g. from private consultants) will increase with farm size.

H3. Following directly from H2, larger irrigators will access a greater total number of information sources.

H4. Use of management-intensive methods to schedule irrigation will increase with farm size.

Data and study setting

Data come from special tabulations of the 1998 Farm and Ranch Irrigation Survey made available by USDA's Economic Research Service (USDA, ERS, 2004). Data, available in cross-tab form, contain several categorical variables related to farmer and rancher irrigation practices. These data include several 'yes–no' responses about use of information, technology, investments to conserve water or energy, and participation in conservation programs. While the regular FRIS report does not report detailed data by farm sales class, the ERS tabulation breaks down responses by four farm sales classes:

- Small farms with sales < US$100 000;
- Medium farms with sales from US$100 000 to US $249 999;
- Large farms with sales from US$250 000 to US$499 999;
- Very large farms with sales ≥ US$500 000.

We use data from 1998 instead of the more recent 2003 or 2008 surveys because data stratified by farm size are not available for recent survey years. Efforts are underway to update the ERS special tabulation, but these data are not yet available.

Data for Arizona and New Mexico reveal a small share of irrigators account for a large share of water applied (Table I). In Arizona, small farms account for 64% of farms, but only 4% of the water applied. Small, medium, and large farms combined account for 82% of irrigators, but only 23% of water applied. In New Mexico, small farms account for 88% of irrigators, but 26% of water used. In contrast, very large farms account for 18% of irrigators and 77% of water used in Arizona and 4% of irrigators and nearly half of the water used in New Mexico.

New Mexico farm operations are more numerous and smaller on average than in Arizona (Table I). One reason for this difference is New Mexico's tradition of small-scale production, and community-based water management organizations called *acequias*. This system of small-scale, community water management relies on earthen canals for gravity-flow irrigation. It dates back to institutions established during Spanish colonization (Rivera, 1998). The *acequia* system took hold more significantly in New Mexico than elsewhere in the US Southwest and continues today.

METHODS: MEASURES OF ASSOCIATION

Data from the FRIS tabulations can be arranged as a set of 4×2 contingency tables with four rows for each farm size class and two columns, one representing a 'no' response to a survey question and the other a 'yes' response. It would be useful to have a method for measuring the strength of the association between farm size and different yes–no responses. The commonly used Pearson correlation coefficient is not appropriate because it assumes two variables have a bivariate normal distribution and are measured numerically. The variables in the tables, however, are categorical (farm size and yes/no).

One could also treat the variables as ordinal. This is easy to see for farm size classes, moving from small to larger classes. The yes–no responses are binary with zero for no and one for yes. One can give an economic interpretation to binary responses so that one considers 'yes' 'higher' than the category 'no'. For example, farmers would seek out a particular source of water management information if the expected benefit were positive and zero otherwise. The 'yes' response would indicate a positive expected benefit to information use; a 'no' response would indicate zero or negative expected benefit.

A common test of association for contingency tables is the chi-squared test. The test's null hypothesis is that there is independence (no association) between two variables represented in a contingency table. Gibbons (1993) points out problems with the chi-squared test. First, even for large sample sizes, the test statistic's distribution is only approximately chi-squared. The true distribution is unknown. Second, the chi-squared test does not allow for testing a particular *type* of association (e.g. positive or negative). Third, when some cells have few observations relative to the total, the test statistic becomes inflated. Here, Gibbons (1993) warns, 'the test almost always leads to rejection of the null if the sample size is large'.

An alternative to the chi-squared test is the Goodman–Kruskal gamma (γ) coefficient (Goodman and Kruskal, 1980; Gibbons,

Table I. Distribution of farms and irrigation water applied by farm sales class

(a) Arizona	Small	Medium	Large	Very large
Percent of farms	64	8	11	18
Percent of water applied	4	7	12	77
Cumulative percent of farms	64	72	82	100
Cumulative percent of water applied	4	11	23	100
All farms				
Total number of farms	2 637			
Total water applied (Mm^3)	5 079			
Mm^3 applied/farm	1.93			
(b) New Mexico				
	Small	Medium	Large	Very large
Percent of farms	88	5	3	4
Percent of water applied	26	12	15	48
Cumulative percent of farms	88	93	96	100
Cumulative percent of water applied	26	38	52	100
All farms				
Total number of farms	6 035			
Total water applied (Mm^3)	2 134			
Mm^3 applied/farm	0.35			

1993). The γ coefficient is a nonparametric measure of association between two ordinal variables. As with the correlation coefficient, values range from +1 (for positive association) to -1 (for negative association). For complete independence, $\gamma = 0$, but γ can also equal 0 for U-shaped or inverted U-shaped relationships between variables. One can interpret γ in terms of proportionate reduction in error (Garson, 2012). If $\gamma = 0.82$, this means that knowing the rank of the row reduces our error in predicting the rank of the column by 82%. Exact tests of the significance level of γ require special tables (Goodman and Kruskal, 1980), but Gibbons (1993) provides an approximate, normally distributed test statistic, z.

Another method for testing the significance of association is the Cochran–Armitage trend test. It is analogous to testing the significance of the slope coefficient β in a linear probability regression model (Agresti, 2002). Let π_i be the probability the ith farmer responds 'yes' to a question. Then, a linear probability model would be

$$\pi_i = \beta(\text{category score})_\text{i} + \varepsilon_i$$

In our case, the categories are small, medium, large, and very large farms, which would be assigned numeric scores. The null hypothesis is $\beta = 0$; there is no linear trend between the category score (farm size) and the proportion of yes responses. The Cochran–Armitage trend test has a normally distributed z-test statistic. This test is for both significance and sign of the trend. Results of the Cochran–Armitage trend test are analogous to a test of a zero slope coefficient in a logistic regression. The z-test statistics for both the Goodman–Kruskal γ and the Cochran–Armitage trend test provide critical values measuring the statistical significance of positive or negative relationships between farm size and variables of interest. The significance level = 5% for $|z| = 1.96$; = 1% for $|z| = 2.576$; and = 0.1% for $|z| = 3.291$.

Farm size and sources of irrigation information

Farmers were asked, 'What are the sources of information you rely on for guidance in reducing irrigation costs or to conserve water used to for irrigation (mark all that apply)? (USDA, NASS, 1999). Choices were not mutually exclusive; respondents could list more than one information source. Options for responses were:

1. Extension agents or university specialists;
2. Government specialists;
3. Irrigation equipment dealers;
4. Irrigation district or water supplier;
5. Media reports/press;
6. Neighboring farmers;
7. Private irrigation specialists or consultants.

One striking result is that no single information source was used by more than half of irrigators (Table II). This suggests there is no 'one-stop shopping' source of irrigation management information. For federal agencies and extension, this means that most irrigators are not accessing their directly provided information. Public entities may have to consider delivering information both directly and indirectly. Extension may need to target news media, trade journals, irrigation district managers, and input suppliers as clientele. These sources can serve as 'retail outlets' for extension messages that irrigators fail to access directly.

Results are largely consistent with our hypothesis that farms in larger sales classes are more likely to access any given source of information (H1). Based on tests of γ, there is a positive and significant association between sales class and use of most information sources (Table II). Exceptions are irrigation districts, where there is a negative association, and neighboring farmers with a negative association in New Mexico and no association in Arizona. Smaller farms are more likely to have their irrigation scheduling determined by irrigation districts, taking some water management decisions out of their hands. Smaller operations may thus be more reliant on irrigation districts for information.

Hypothesis H2 predicted both large and small operators rely on lower-cost, general, public information, while large irrigators are more likely to seek tailored information from private sources. Reliance on university/extension specialists and neighbors (sources of lower cost, general information) tends to be higher than for other sources. There is no significant relationship between sales class and reliance on extension/university specialists in New Mexico and a relatively weak positive association in Arizona. In both states, there was a relatively strong positive association between farm size and reliance on private irrigation specialists and consultants, with $\gamma = 0.81$ for Arizona and $\gamma = 0.93$ for New Mexico. While use was still relatively low for even very large farms, it was virtually nonexistent for small farms. These results conform generally to hypothesis H2, suggesting there may be barriers to accessing private, tailored information for smaller irrigators.

In Table II, the row sums of the percentages of irrigators accessing different sources of information represent an index of the number of information sources used per farm for each size class. The row sums suggest that some irrigators rely on multiples sources of information and larger farm size classes tend to rely on more information sources (consistent with hypothesis H3).

Irrigation scheduling

In the 1998 FRIS survey, growers were asked, 'how did you decide when to apply water in 1998?' Options were: (i) condition of crop by observation; (ii) feel of the soil; (iii) soil moisture sensing devices; (iv) commercial scheduling services; (v) media reports on crop water needs; (vi) water

Table II. Sources of irrigation information (values are percentage yes responses)

Arizona								
Farm size	Extension agents or university specialists	Government specialists	Irrigation equipment dealers	Irrigation district/water supplier	Media reports/ press	Neighboring farmers	Private irrigation specialists or consultants	Row sum
Arizona								
Small	31	5	7	42	3	36	0	124
Medium	45	16	3	16	14	40	1	135
Large	50	30	6	9	10	32	10	147
Very large	40	41	13	21	11	38	17	170
Gamma	0.22	0.72	0.21	−0.49	0.45	0.02	0.81	
Gamma z value	7.58	24.69	7.30	−16.72	15.37	0.61	25.61	
Cochran–Armitage z	5.59	20.55	3.99	−11.20	7.06	0.35	14.98	
New Mexico								
Small	32	19	8	22	12	49	0.2	142
Medium	23	22	29	7	20	44	16	161
Large	36	29	22	10	16	35	11	159
Very large	36	40	44	8	12	42	28	210
Gamma	−0.02	0.30	0.67	−0.52	0.15	−0.14	0.93	
Gamma z value	−1.67	22.47	49.10	−38.22	10.83	−10.46	68.68	
Cochran–Armitage z	−0.62	8.65	19.75	−7.65	1.54	−3.53	30.85	

Significance level = 5% for $|z| = 1.96$; = 1% for $|z| = 2.576$; = 0.1% for $|z| = 3.291$.

delivered in turn; (vii) calendar schedule; (viii) computer simulation models, and (ix) other practices. The ERS also tabulated an aggregate category, 'most water-management-intensive and water-conserving means to decide when to apply water'. Farms were assigned to this category if they used any one of soil-moisture sensing devices, commercial irrigation scheduling services, or computer simulation models (Table III).

Consistent with the Leib *et al*. (2002) study of Washington farmers, the dominant methods to decide irrigation timing are observation of the condition of the crop and by the 'feel of the soil'. Next in importance was calendar scheduling. Hypothesis H4 suggested larger irrigators would use relatively management-intensive techniques to schedule irrigation. There is a significant positive association between farm size and use of the most water-management-intensive and water-conserving means to decide when to apply water (Table III). The association is stronger in New Mexico ($\gamma = 0.60$) than in Arizona ($\gamma = 0.36$). Adoption rates of soil moisture testing or commercial services were relatively low for each size class. Both Arizona and New Mexico had positive and significant γ coefficients and Cochran–Armitage test statistics for soil moisture testing. In New Mexico, the γ for commercial scheduling was high (0.96), but adoption among even the very large farms was low (8%). In Arizona, the γ for commercial scheduling was weakly negative (−0.08). While significant at the 5% level for the γ test, it was insignificant under the Cochran–Armitage test. However, overall use of management-intensive methods is positively associated with farm size. This is consistent with the finding of Leib *et al*. (2002), of a positive association between farm size and use of scientific scheduling methods. In their comparison of two Canadian irrigation districts, Bjornlund *et al*. (2009) found adoption of management-intensive methods (use soil moisture monitoring devices, private consultants, etc.) was greater in the district with more large operations.

There was a negative association between having water delivered in turn and farm size. In New Mexico, 25% of small farms responded that water was delivered in turn, suggesting little discretion over when to apply water. Use of media reports is slight outside of very large farms and still low (6% for Arizona and 10% for New Mexico). Smaller farms were more likely to receive their water delivered in turn by irrigation districts and to rely on irrigation district staff for information. This suggests government and extension specialists could fruitfully target irrigation district staff for water management information. Public institutions can act as 'wholesalers' of information to irrigation district staff, while irrigation districts may transfer public information as 'retailers' of water management information.

Barriers to improvements to irrigation systems and practices

Kislev and Shchori-Bachrach (1973) and Feder and Slade (1984) have developed models where information acquisition increases farm productivity. In the Kislev and

Table III. Method to determine time to apply irrigation water (values are percentage yes responses)

Farm sizes	Condition of crop— by observation	Feel of the soil	Soil-moisture sensing devices	Commercial-scheduling services	Media reports on crop water needs	Water delivered in turn	Calendar schedule	Computer simulation models	Other practices	Water-management-intensive and water-conserving
Arizona										
Small	63	5	7	7	0	7	28	0	0	7
Medium	88	30	0	1	0	3	25	0	3	0
Large	66	27	12	--	0	--	51	0	5	12
Very large	91	50	14	8	6	5	30	1	5	20
Gamma	0.45	0.76	0.23	−0.08	1	−0.28	0.13	1	0.78	0.36
Gamma z	15.55	26.14	7.85	−2.36	34.45	−8.90	4.37	38.51	26.87	12.49
Cochran–Armitage z	10.76	23.25	4.70	−0.06	9.57	−2.94	3.40	4.49	8.86	7.86
New Mexico										
Small	61	23	5	0.07	0.20	25	31	*	2	5
Medium	91	19	8	--	--2	--2	10	*	9	9
Large	93	39	8	3	--	--	13	*	6	15
Very large	84	58	21	8	10	9	15	*	5	28
Gamma	0.66	0.34	0.48	0.96	0.90	−0.75	−0.51	*	0.55 *	0.60
Gamma z value	48.89	24.96	35.58	64.81	60.70	−50.27	−37.49	*	40.77	44.06
Cochran–Armitage z	12.65	11.73	10.36	18.51	16.12	−10.81	−8.87	*	6.04	15.18

Significance level = 5% for $|z| = 1.96$; = 1% for $|z| = 2.576$; = 0.1% for $|z| = 3.291$. *Insufficient data for publication by USDA.

Shchori-Bachrach model, farmers with more knowledge about how to use a technology are early adopters. Differences in knowledge among farmers are taken as given. Feder and Slade (1984) extend this approach by treating knowledge acquisition as a decision variable. Farmers actively acquire information about a technology at a cost. They also allow information to have different productivity effects on different inputs. In their model, actively acquired information increases returns to adopting modern technologies. In the context of our model, this formulation would imply that not only the level of inputs, x, but their productivity could be enhanced by information. It would also imply that acquiring information about new irrigation technologies or systems would be an important precursor to investments in irrigation improvements.

The 1998 FRIS survey asked producers, ‘What were barriers to implementing improvements that might reduce energy and/or conserve water in your irrigation system?’ In an earlier question, the survey instructed respondents to consider changes in equipment or management practices as improvements, considering any improvements since 1994. The survey gave respondents a choice of barriers and instructed them to mark all that applied.

Response options were:

- Have not investigated improvements (since 1994);
- Risk of reduced yield or poorer quality crop yield from not meeting water needs;
- Physical field/crop conditions limit system improvements;
- Improvements will reduce costs, but not enough to cover the installation costs;
- Cannot finance improvements, even if they reduce costs;
- Landlords will not share in the cost of improvements;
- Uncertainty about future availability of water;
- Will not be farming this place long enough to justify new improvements.

The Feder–Slade model implies smaller farms would be less likely to acquire information about improvements. Results are consistent with this prediction. Figure 1 shows results for the first response ‘have not investigated improvements’. Of small farms in Arizona, 59% responded that they had not investigated improvements, while the response was 23% among small farms in New Mexico. In both states, there was a significant negative association between farm size and a ‘no investigation’ response. The relationship was particularly strong in Arizona ($\gamma = 0.8$).

Cochran–Armitage and γ tests suggested that there was a positive association between nearly all of the barriers and farm size. This runs counter to most literature that suggests larger farms are more likely to adopt irrigation improvements. What accounts for the counter-intuitive result? One possibility is that farmers who responded that they had not investigated improvements did not mark any other barriers to adoption. This assumes that only farmers seeking to implement improvements would encounter the other barriers. There is no way of knowing if this is a reasonable assumption without access to the original raw data files. Figure 2, however, shows each farm size class’s share of the total ‘have not investigated improvement’ responses.

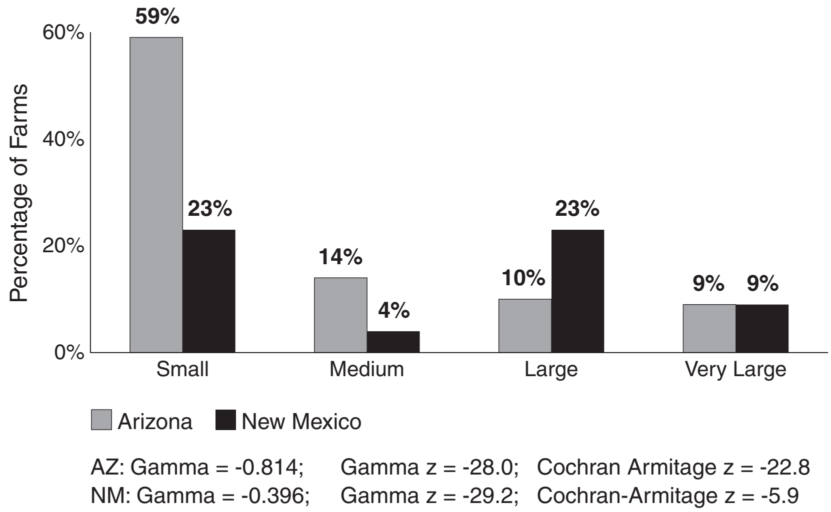

Figure 1. Percentage of farms not investigating irrigation improvements by farm sales class

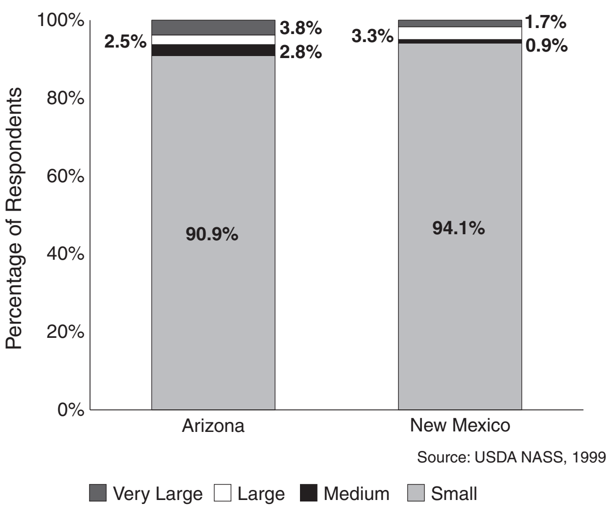

Figure 2. Farm size class shares of total responses 'have not investigated improvements' in irrigation improvements

Small farms account for over 90% of farms not investigating improvements in each state.

We carried out hypothesis tests, removing irrigators not investigating improvements. Table IV shows farms experiencing adoption barriers as a share of farms investigating improvements. The positive associations were weakened or reversed on some cases. However, in most cases there is still a positive and significant association between farm sales class and adoption barriers. This is a puzzle. Even excluding farms not investigating improvements, larger farms still reported facing more barriers to adopting irrigation system improvements. One explanation might be that larger farms might have more advanced systems in place already so that further investment may be less attractive (we are indebted to a reviewer for this observation).

Another possibility (also suggested by a reviewer) is that low water costs may reduce incentives for conservation investments. Regional water rights and pricing systems may indeed create barriers to investments in water conservation. Water rights in Arizona and New Mexico, as in much of the western United States, follow the 'prior appropriation' doctrine (Fleming and Hall, 2000; Pearce, 2006). Users establish rights over water through putting it to 'beneficial use', primarily agriculture and mining during western settlement. Those using surface water first established rights to that volume of water over all subsequent claimants. In times of water shortage, junior water rights holders forego all their water use before senior water rights holders are required to reduce use. If an irrigator reduces water consumption, however, this can be interpreted as a reduction in 'beneficial use' and the irrigator may lose rights over unused water.

This system can take away economic incentives for water conservation by irrigators. For example, suppose an irrigator invested in new equipment or technology so that crops could be adequately irrigated with less water. Benefits to such investment may depend on what the irrigator could do with the 'saved' water. In many cases, irrigators are precluded from either selling water to other parties or applying the saved water to additional hectares. Instead, ownership of the water may revert to the state or the irrigation district (Fleming and Hall, 2000; Ward *et al*., 2007). In one survey of New Mexico irrigators, Ward *et al*. (2007) found that the main reason irrigators did not conserve water was lack of ability to sell the conserved water.

In the western United States, the US Bureau of Reclamation provides much of the surface water irrigation districts use and does so at subsidized rates. Low water costs reduce benefits of investing in water conservation. Moreover, many irrigation districts charge individual irrigators on a per

Table IV. Barriers to adopting irrigation improvements

Farm size	Risk of reduced yield or quality	Physical field or crop conditions	Installation costs greater than benefits	Lack of financial ability	Lack of landlord cost sharing	Uncertainty about future water availability	Will not be farming in the future	Other reasons
Arizona								
Small	8	11	28	22	--	3	--	8
Medium	10	8	37	57	4	7	22	32
Large	15	17	50	52	13	19	0	12
Very large	15	14	28	26	23	12	7	22
Gamma	0.25	0.14	0.06	0.14	0.63	0.42	0.38	0.31
Gamma z	8.51	4.72	2.20	4.84	17.66	14.54	13.28	10.80
Cochran–Armitage z	4.11	2.45	1.46	2.88	10.54	6.57	3.78	5.53
New Mexico								
Small	6	12	19	27	3	15	21	6
Medium	5	6	8	20	5	18	--	5
Large	26	16	28	34	16	17	4	7
Small	19	14	37	23	16	13	7	6
Very large	0.46	− 0.04	0.14	−0.06	0.61	0.01	−0.64	−0.01
Gamma	33.72	− 3.00	9.95	−4.76	45.22	1.16	−42.82	−0.68
Gamma z	9.75	− 0.39	5.44	−0.93	11.84	0.23	−8.34	−0.04
Cochran–Armitage z	6	12	19	27	3	15	21	6

Significance level = 5% for $|z| = 1.96$; = 1% for $|z| = 2.576$; = 0.1% for $|z| = 3.291$.

hectare basis for a fixed amount of water rather than charging for water directly (Michelsen *et al*., 1999). An irrigator may be charged US\$75 ha^{-1} of land irrigated and be entitled to 2.5 Ml ha^{-1} of water. The irrigator pays US\$75 ha^{-1} even if less than 2.5 Ml is used. Thus, water-conserving investments do not reduce water costs.

Figure 3 shows water purchase costs for Arizona and New Mexico irrigators by farm size. In New Mexico, the very large farms have lower water costs than smaller farms. Very large New Mexico farms are also more likely to cite that the costs of conservation investments outweigh their benefits (Table IV). This is consistent with the hypothesis that lower water costs discourage investment. Results for Arizona are less clear, however. While small farms have lower water costs than their larger counterparts (Figure 3), they are also less likely to cite the costs of conservation as outweighing benefits as a constraint on investment (Table IV). Multiple, complex factors correlated with farm size appear to be at work here, suggesting limits to using cross-tab data.

Economic constraints (installation costs outweighing benefits and lack of financing) are the dominant constraints. Lack of landlord financing appears to be more of a constraint for larger than smaller farms. In addition, 22% of Arizona medium farms and 21% of New Mexico small farms responded that they did not expect to be farming long enough to make investments pay off. This figure was 7% in each state for the very large farm class. This may be more significant considering that these larger farms account for a relatively larger of total water use.

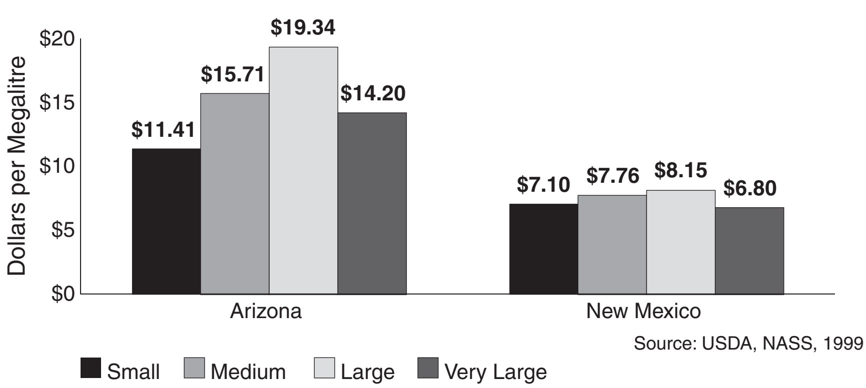

Figure 3. Purchased water cost by farm sales class (\$ Ml^{-1})

Participation in water conservation cost-share programs

Federal, state, and local agriculture conservation programs provide cost-share payments to farmers to encourage adoption of capital and technology to improve irrigation efficiency. Both large- and small-scale irrigators are eligible for program payments. The 1998 FRIS collected data on farm-level participation in cost-share programs, asking farmers whether in the previous 5 years they received irrigation-related cost-share payments for irrigation improvements from one or more of the following sources:

- USDA conservation cost-share programs (including the Environmental Quality Incentive Program (EQIP) and other earlier USDA cost-share programs);
- Non-USDA federal cost-share programs (including those from the Environmental Protection Agency (EPA), the Bureau of Reclamation, or other programs);
- State programs and local water management or supply district programs;
- Other cost-share programs;
- Any federal program;
- Any program of any source.

Among very large farms, 30% of New Mexico farms and 34% of Arizona farms participated in some form of cost-share program (Table V, last column). Participation rates for small farms were lower, 8% in both states. There is a significant positive association between cost-share program participation and farm size. In Arizona, the positive association is greater than in New Mexico, except for state and local programs. Here, there is a weak negative association $\gamma = -0.06$, while the trend coefficient is insignificant using the Cochran–Armitage test. The positive association is relatively strong for USDA program participation in Arizona, $\gamma = 0.82$. Only 1% of Arizona small farms reported having USDA contracts, while this number was 6% for New Mexico. In New Mexico, there was a significant, but weaker association between farm size and USDA program participation.

Table VI provides information about the targeting of EQIP (USDA) and state/local cost-share programs. In Arizona, EQIP (USDA) payments are targeted more toward larger farms, and fewer than 10% of small farms reported receiving USDA payments (Table VI). In contrast, 73.7% of New Mexico small farms received USDA cost-share payments. States have latitude in administration of EQIP programs and Arizona appears to have targeted larger irrigators. The very large farm class accounts for 65% of farms receiving EQIP payments and 77% of irrigation water applied. In contrast, the small farm class in New Mexico accounts for 73.7% of irrigators receiving EQIP payments, but less than 26% of irrigation water applied. Although participation rates increase with farm size in New Mexico, small farms account for a large share of total farms, over 88%. So they account for a large share of total contracts.

In both states, small farms account for the great majority of farms receiving state/local cost-share payments (Table VI). State/local programs target small farms, although these programs reach a small share of irrigators. In Arizona, only 7% of small irrigators received state/local payments. In New Mexico, this figure was 4%. However, small farms accounted for nearly 70% of farms receiving this assistance, even though they account for 4.4% of water use. In New Mexico, small farms accounted for 81% of farms receiving state/local cost-share payments, but less than 26% of water use.

Table V. Participation in water conservation cost share programs (values are percentage yes responses)

Particulars	USDA cost-share payments	Non-USDA federal programs	State/local programs	Other programs	Any federal program	From any program source
Arizona						
Small	1	1	7	1	1	8
Medium	6	0	0	4	6	11
Large	12	4	5	6	12	18
Very large	26	5	8	5	27	34
Gamma	0.82	0.68	−0.06	0.57	0.83	0.55
Gamma *z* value	28.26	23.51	−2.10	19.54	28.53	18.88
Cochran–Armitage *z*	18.47	6.94	−0.02	6.54	19.03	13.96
New Mexico						
Small	6	5	4	3	7	8
Medium	15	5	5	5	15	15
Large	14	6	6	3	16	16
Very large	22	5	9	3	24	30
Gamma	0.49	0.08	0.28	0.04	0.49	0.48
Gamma *z* value	36.17	6.16	20.58	3.25	36.09	35.15
Cochran-Armitage *z*	10.38	0.81	4.01	0.26	11.03	11.74

Table VI. Farms receiving cost-share payments from EQIP (or other USDA programs) and from state programs or local water management or supply districts (1994–98) for irrigation or drainage improvements

Farms receiving EQIP payments										
	Small		Medium		Large		Very large		All farm size classes	
State	Farms	%	Farms	%	Farms	%	Farms	%	Farms	%
Arizona	17	9.3	14	7.7	33	18	119	65	183	100
New Mexico	333	73.7	42	9.3	25	5.5	52	11.5	452	100
Farms receiving payments from state and local programs										
Arizona	120	69.8	0	0	15	8.7	37	21.5	172	100
New Mexico	206	81.4	15	5.9	11	4.3	21	8.3	253	100

Table VII. Source of irrigation information relied on to reduce irrigation costs or to conserve water, 2008 Farm and Ranch Irrigation Survey (percent of farms using each source*)

	Arizona		New Mexico	
Information source	Farms	Irrigated hectares	Farms	Irrigated hectares
Extension/university specialists	24	47	30	28
NRCS, local conservation district, other federal or state agencies	25	36	25	29
Neighboring farmers	38	29	36	25
Private irrigation specialists or consultants	15	30	6	37
Irrigation equipment dealers	10	16	6	36
Irrigation district or water supplier	27	16	6	9
Media reports	7	12	6	8
Electronic information services (internet links)	11	13	3	12

*Farms may rely on more than one information source.

These results have implications for program targeting. Schaible (2004) has argued that one could increase the efficiency of water conservation programs by targeting those farms that account for relatively more water use. It appears that—in the mid-1990s—the administration of EQIP in Arizona did just this. In New Mexico, a large number of small farms still accounted for a large share of EQIP contracts. In both states, state/local programs appeared to target irrigators accounting for a small share of overall irrigation water use.

Data from the 2008 FRIS

The USDA released data from the 2008 Farm and Ranch Irrigation Survey on November 30, 2009 (USDA, NASS, 2009). Although published tables do not report differences in irrigator behavior by farm sales class, we may still examine patterns regarding irrigator scale of operation and water management. As in 1998, no single information source was used by more than half of irrigators or by irrigators that accounted for more than half of the irrigated area (Table VII). Table VII lists information sources by the number of irrigators that use them and the number of hectares these producers irrigate. If the percent of farms is greater than the percent of irrigated hectares for an information source, this suggests that smaller farms rely more on that source. Here scale is measured in terms of irrigated hectares. Conversely, if the percent of farms is smaller than the percent of hectares, larger farms rely more on the information source. Larger farms in Arizona rely more on extension, government agencies, private specialists, and equipment dealers. Smaller farms rely more on neighboring farms or their irrigation district or other water suppliers. In New Mexico, both large and small farms rely similarly on extension, but otherwise patterns are similar to Arizona.

The dominant methods to decide irrigation timing are still observing the crop's condition, feel of the soil, and calendar scheduling. A significant share of producers still have water delivered in turn by irrigation districts. Adoption rates of scientific irrigation scheduling methods, such as soil or plant moisture sensing devices, computer simulations, or reports of crop evapotranspiration (ET), remain low (Figure 4). Fewer than 5% of growers use these methods. About 5% of irrigators rely on government or private scheduling services, however. It is possible that these intermediaries use scientific scheduling methods.

We now turn to barriers to making improvements to reduce energy use or conserve water. In Arizona, growers who did not report any barriers accounted for 48% of farms and 58% of water applied (Table VIII). In New Mexico, these figures were 22% of farms and 58% of irrigated hectares. Large farms (where scale is measured by water use) are less likely to report barriers. In contrast, making improvements was not a priority for 28% of Arizona farms accounting for 13% of applied water, or for 33% of New Mexico farmers accounting for 17% of applied water (Table VIII). These results are consistent with the analysis

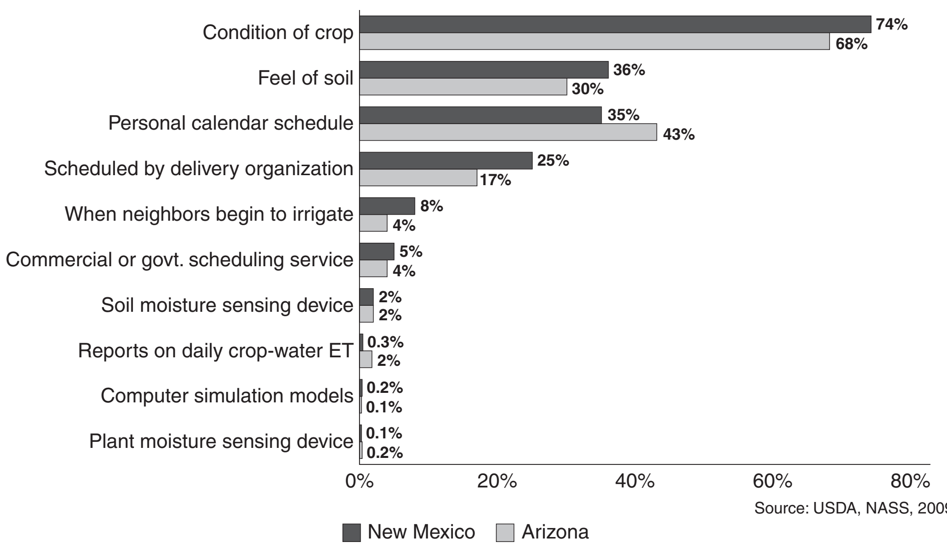

Figure 4. Methods used in deciding when to irrigate, 2008 Farm and Ranch Irrigation Survey

Table VIII. Barriers to making improvements to reduce energy use or conserve water, 2008 Farm and Ranch Irrigation Survey (percent of farms facing each barrier*)

Respondents	Arizona		New Mexico	
	Farms	m^3 applied	Farms	m^3 applied
Not reporting any barriers	48	58	22	58
Facing some barrier(s)	62	42	78	42
Improvements not a priority	28	13	33	17
Risk to crop yield or quality	10	4	4	7
Physical constraints	6	6	7	5
Cost reductions < installation costs	4	9	18	6
Lack of financing	28	12	28	10
Landlord will not share costs	2	13	1	3
Uncertainty about future water availability	12	5	20	9
Will not be farming long enough	12	4	9	3

*Farms may face more than one barrier.

of the 1998 data, suggesting smaller-scale operators are less likely to seek out irrigation improvements. For larger operations (in terms of water use), relatively important barriers are economic (expected cost savings from energy or water conservation are less than installation costs; lack of landlord cost sharing). For smaller operations, lack of financing and uncertainty about future water supplies are important barriers. A higher proportion of smaller-scale operations do not expect to continue farming long enough to make improvements worthwhile. These operators account for 4% (3%) of Arizona's (New Mexico's) irrigation water.

The 2008 FRIS data suggest changes in government funding of irrigation and drainage improvements (Figure 5). The share of irrigators receiving funding from sources other than USDA has declined since 1998. Second, there is less difference in targeting of irrigators under USDA programs across Arizona and New Mexico. In both states, growers accounting for more than 40% of state irrigated hectares received USDA payments. These were less than 20% of growers in each state. This suggests USDA programs in New Mexico, as in Arizona, are targeting irrigators that account for larger shares of irrigated area.

CONCLUSIONS

This study employed a simple economic framework to examine irrigator demand for information to develop and test hypotheses concerning scale of farm operation and water management practices. The Goodman–Kruskal gamma coefficient and the Cochran–Armitage trend test were used to test several hypotheses about the relationship between farm size and water management. These approaches were effective at moving beyond mere descriptions of cross-tab data to formal hypothesis tests of irrigator behavior. Tests of Arizona and New Mexico data from USDA's Farm and Ranch Irrigation Survey supported the posited hypotheses. Larger operations (in terms of sales) were more likely to use irrigation management information from any given source. Reliance on lower-cost sources of general information was more common, while larger operations relied more on private, tailored sources of information. Smaller farms were less likely to investigate irrigation improvements or to use management-intensive methods for irrigation scheduling. Larger operations were

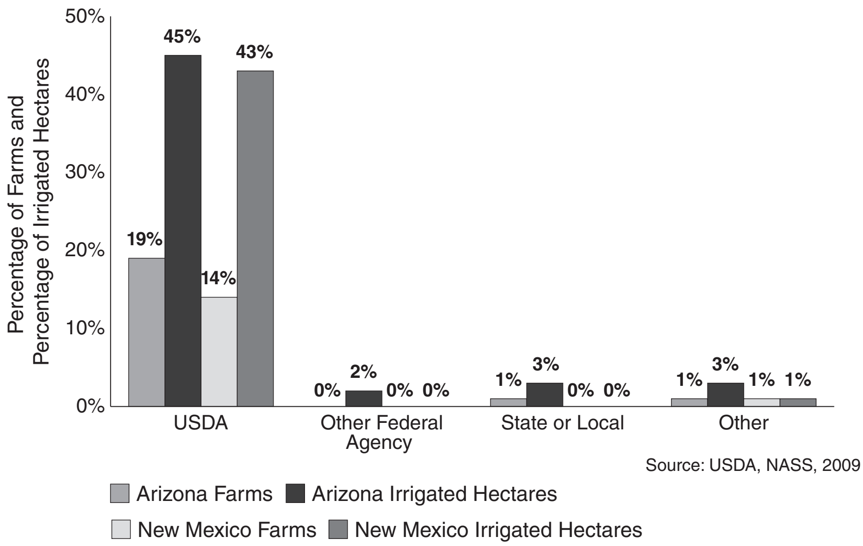

Figure 5. Irrigators receiving payments for irrigation and/or drainage improvements, 2008 Farm and Ranch Irrigation Survey

more likely to use data provided more directly (e.g. media and Internet reports) than smaller operators, who rely more on information provided by intermediaries. Adoption of scientific irrigation scheduling methods (such as soil moisture-testing devices) is low across all producer groups, but especially low for smaller-scale irrigators.

No single institutional source of irrigation information was relied upon by more than half of any farm size group. A significant share of irrigators did *not* rely on public sources of irrigation information (university/extension specialists or government specialists). The data also revealed the importance of irrigation districts. In many cases, districts decided timing of irrigation and were a source of irrigation information, particularly for smaller farms. This has important implications for outreach and technology transfer. Many irrigators are not directly seeking out public information providers, while irrigation districts play a central role in scheduling and information provision. Public agencies might fruitfully target irrigation district staff for their information services, acting as ‘wholesalers’ of information to the districts, which in turn interact with irrigators directly. Another implication of this research is that farms of different sizes have different information needs and incentives for investment in water conservation. Public programs may thus be more effective if they tailored program delivery to the particular needs of different farm size classes. Because of the nature of the survey data, this study has focused on the demand for water management information. A fruitful area of future research would be to assess the supply side—the efforts of various agencies to provide water management information and assistance.

Finally, Schaible (2004) has argued that one could increase the efficiency of cost-share programs by targeting farms that account for more water use. Results indicated a significant positive association between farm size and participation in federal cost-share programs to encourage adoption of improved irrigation practices.

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