Retirement and Salinity Effects on Irrigation Technology Choices

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Introduction

Saline water supplies are a significant challenge for agricultural production throughout the western United States, particularly in those states served by the Colorado River and the Arkansas River. Indeed, water supplies in the Arkansas River basin of southeastern Colorado are so severely saline as to profoundly limit the types of crops that can be grown in the region and represents a significant reduction in the potential productivity of this multi-state basin (Colorado Department of Public Health, 1998; Houk, Frasier, and Schuck, 2005; Houk, Frasier, and Schuck, 2006). Additionally, downstream water quality in the region is markedly worse than upstream water quality as increasingly saline irrigation runoff returns to either the river system or to adjoining aquifers.

Adoption of less water-intensive irrigation systems is one method for dealing with this regional water quality problem. Less water intensive irrigation systems allow crop consumption rates to be maintained while simultaneously reducing water applications and diversions,. Less irrigation diversion leads toy reduced runoff levels and lower volumes of mineral salts introduced into the water supply system. More critically, the effects of saline water supplies tend to encourage adoption of more technically efficient irrigation systems (Dinar and Yaron, 1990; Dinar and Zilberman, 1991). Adoption of more technically efficient irrigation systems in the presence of saline soils and limited water supplies is a profit-improving decision (Wichelns, 1991).

Unfortunately, approximately 80% of all irrigators in the Arkansas River Basin still use some form of gravity irrigation system (Frasier, 1999). As part of an on-going effort to identify why irrigation diffusion is so low in the region, researchers at Colorado State University conducted a survey of irrigation practices in the region during the winter of 2005/2006. Covering over 700 irrigators (all active irrigators in the Colorado Agricultural Statistics Service database for Bent, Prowers, Otero Crowley and Pueblo counties), respondents identified both what type of

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irrigation system they employed and how salinity affected their decision-making. In the 30% of surveys returned in usable forms, a majority of irrigators indicated that salinity was a problem but less than 30% indicated a willingness to change irrigation systems. Two main reasons were given for the general unwillingness to adopt more technically efficient irrigation systems. The first was simply the cost of investing in new irrigation systems relative to the perceived improvements in yield or expanded crop selections. The second was somewhat more unexpected: impending retirement. Nearly 35% of all respondents indicated an intention either to exit or, more typically, retire from agriculture within the next five years, and that their unwillingness to invest stemmed from their expected departure from farming.

And these results exist within a demographic environment that is not positive for future investment: a consistently aged farming population. According to the 2007 USDA Census of Agriculture, the average age of a farmer in the United States was 54.9 at the time the CSU survey was conducted, while the average age of farmers in Colorado and Kansas (the area most affected by salinity problems in the Arkansas River basin) were 54.8 and 55.7, respectively. The corresponding figures from the 2002 Census of Agriculture for the United States, for Colorado and for Kansas were 55.3, 54.5 and 56. Given the relative ages of US farmers, the potential for retirement to affect investment decisions will be a consistent issue and the role of retirement in on-farm investment decisions will become quite critical. Building on the previously mentioned survey results, this research examines how the potential for retirement in the near term affects the decision to invest in durable, water-conserving technology. It extends existing irrigation technology adoption choice models to reflect that the decision to adopt a water-conserving technology is not only a function of the lifespan of the irrigation system, but also of the expected lifespan of the operator. This paper evaluates both the extent and magnitude the intention to retire has on investment in less water-intensive irrigation systems, and discusses the potential implications for regional water quality of reduced investment rates associated with retirement.

Background

Why and how irrigators choose an irrigation system is well-established in the economics literature, and typically reduces to a function of water price and quality (see Caswell and Zilberman, 1985; Lichtenberg, 1989; Negri and Brooks, 1990; Dinar and Yaron, 1990; Dinar and Zilberman, 1991; Shrestha and Gopalakrishnan, 1993; Green et al., 1996; Green and Sunding, 1997; Schuck and Green, 2001; Schuck et al., 2005). By reducing the amount of water which is applied but not effectively transmitted to a crop's root zone for consumption, more technically efficient irrigation systems (such as low-pressure sprinkler or drip systems) can increase water consumption while simultaneously reducing water applications. This allows irrigators to meet the consumptive requirements of their crops while using less water overall, an action that both reduces water application costs and frequently corresponds to moderate yield improvements (Dinar and Zilberman, 1991).

Additionally, by reducing the runoff of unconsumed water, improved irrigation systems can also reduce salinization that increases other production costs and reduces crop yield (Wichelns, 1991). Taken together, the cost reducing and yield improving effects of improved irrigation technology can improve on-farm profits and should promote adoption. However, while these general improvements should promote adoption, not all farms may be able to adopt more technically efficient systems. Specifically, not all farms are physically compatible with all irrigation systems, and farm specific variations in land attributes, cropping patterns, and water costs may make it difficult if not impossible for all farms to upgrade their irrigation systems due to characteristics or attributes unique to each farm (Green et al., 1996; Green and Sunding, 1997; Schuck and Green, 2001).

Irrigation Technology Adoption Model

The bio-physical limits of plants mean crop water demands tend to be fundamentally inelastic (Nieswiadomy, 1988; Ogg and Gollehon, 1989). Water-stressing can be a potentially effective option for dealing with agricultural water management problems. , The fundamental inelasticity of water demand means large scale changes in water use typically must occur at the extensive margin through scale and technology choices rather than the intensive margin through application rates. Changing irrigation systems, then becomes changing the entire production system of a farm.

Unfortunately, irrigation systems represent a significant investment for most farms. Replacement of major capital assets typically occurs when the expected returns of the capital (including any salvage costs) is sufficiently greater than the decision not to replace. (Perrin, 1972).The ability to adopt new capital must always be physically compatible with the enterprise (Perrin and Winkelman, 1976). The standard approach to analyzing the irrigation adoption decision was first put forward by Caswell and Zilberman (1986) and essentially reduces the adoption decision to a multinomial choice across systems of varying profitability. This decision is typically conditioned on higher water costs (either in terms of direct monetary costs or non-monetary costs related to scarcity and quality) but the hurdle rates for adoption tend to be very pronounced (Carey and Zilberman, 2002). As a result, adoption of a more technically efficient irrigation system is often stimulated by major external events such as a drought (Schuck et al, 2005). However, shocks can also arise due to choices made by the irrigator, such as the simultaneous decision to retire.

This model extends the basic irrigation technology adoption problem first put forward by Caswell and Zilberman (1986) to include an endogenous and simultaneous production shock, specifically the decision to retire from farming. The discussion begins by identifying the profits received by the irrigator. Assume that irrigators profit maximize and are constrained to quasi-concave production technologies. , where the following definitions apply:

- π_j : the profits to an irrigator under the *j-th* irrigation system
- *p:* a vector of output prices
- *w:* a vector of input prices
- θ: a vector of farm specific attributes
- ω: a vector of irrigator specific characteristics

Together, these give the farm-level profit function:

$$\pi_j = \pi_j\ (p,w,\theta,\omega) \tag{1}$$

The profit-maximizing irrigator will choose the *j-th* irrigation system over the competing *k-th* irrigation system if expected profits of the *j-th* system are greater than the expected profits under the *k-th* system, or:

$$E[\pi_j\ (\bullet)] > E[\pi_k(\bullet)] \tag{2}$$

This implicitly assumes that the investment time horizon for each irrigation system is comparable to the other, so relative differences in the lifespan of each system do not dominate the adoption decision. However, if irrigators shorten their time horizon due to an expected retirement such that the management horizon is less than the full lifespan of an irrigation system, the adoption decision will hinge upon the expected stream of profits over the abbreviated time. Consequently, when retirement is an option, modeling the decision to adopt must integrate the endogenous decision to retire as well. Retiring operators may not invest in long-run capital improvements or may simply not invest at all.

The decision to retire is best viewed in a simple random utility framework (Ben-Akiva and Lerman, 1985). Assuming that the indirect utility function with retirement is $V_R\ (r,M;\omega)$ and the indirect utility function without retirement is $V_{NR}\ (r,M;\omega)$ where r is a vector of consumption goods prices, M is income (either pre- or post-retirement, respectively), and ω is as previously defined, then the decision to retire will occur if:

$$E[V_R\ (r,M;\omega)] > E[V_{NR}\ (r,M;\omega)] \qquad (3)$$

assuming that irrigators maximize their expected utility.

Given the underlying assumption of utility maximization, the retirement decision suggested in (3) can be transformed into an empirically estimable discrete choice model (Ben-Akiva and Lerman, 1985). Unfortunately, modeling equation (3) in this manner implies that the irrigation technology adoption decisions in (2) may be jointly determined with and conditioned upon the outcome of (3). Fortunately, a discrete choice model can also handle this if the irrigation technology choice model is assumed to be jointly distributed with the retirement decision (Greene, 2008).

Empirical Analysis

The irrigators' technology adoption decision suggested by equations 2) and 3) can be modeled with the outcome of the model describing the irrigators' retirement decision from equation 3) included as an explanatory variable. This captures the endogeneity stemming from the retirement decision and allows differentiation between the irrigation technology adoption decision with and without the potential for irrigators' retirement. However, this requires the simultaneous estimate of the retirement decision, which implies a two-equation system with jointly determined and jointly distributed error terms. Fortunately, this can be accomplished (under certain conditions on the variance/covariance matrix) using two individual limited dependent variable models equations (Greene, 2008).

Given this potential endogeneity problem, two separate equations are estimated here. The first examines whether or not irrigators are planning on upgrading an existing irrigation system (regardless of type) within the next five years, while the second examines if the irrigators plan to retire during that same time frame.[2] Both choices are simple binary choices with the first conditioned upon the characteristics of the farm such as acreage, crop selection, water supply, water quality, and other relevant physical data unique to the farm. The second focuses primarily on characteristics unique to the irrigator, such as education, off-farm employment, age, gender, debt loads, and similar demographic items that are specific to the irrigator and not unique to the farm in a physical sense.

Adoption and diffusion of less water intensive irrigation systems (such as low pressure sprinklers or drip) are quite low in Arkansas River Basin (Frasier et al., 1999). Over 80% of all

[2] Representing this as a binomial choice is not as limiting as it may seem since the dominant form of irrigation in the region is gravity while most irrigators contemplating a change would move to low-pressure sprinklers (see Table 1 for a summary of the observed technology choices). Obviously, in a region with a greater diffusion of technology choices, this would not be possible.

irrigators in the region use some type of gravity irrigation system and run-off rates from irrigation can range as high as 60-70% of water applications. In an effort to identify why adoption rates for more technically efficient irrigation systems are so low in the basin, researchers at Colorado State University surveyed irrigators in the region to identify potential barriers to adoption.

This survey, commencing via mail in December 2005 and concluding in April 2006, contacted all 723 active records for irrigated farms in the Arkansas River Basin (consisting of Bent, Prowers, Otero, Crowley, and Pueblo counties) in the Colorado Agricultural Statistics Service database. Survey respondents were asked to identify their current cropping patterns, irrigation systems, and water supplies, and their perception of the effects of salinity on their farm and its production. Additionally, survey respondents were asked to identify any potential changes they might make in either their irrigation systems or cropping patterns in the next five years in response to the salinity problem in the basin.

Following Salant and Dillman (1994), a single reminder letter was mailed to survey recipients one week following the initial mailout and the overall response rate to the survey was approximately 30% with 222 surveys returned. Survey respondents identified current cropping patterns, irrigation systems, and water supplies, as well as their perception of the effects of salinity on their farm and its production. The basic survey data is summarized below in Table 1. Two items related to water supply reliability are included in the table and worth specific noting. The first is a measure of overall supply stability, specifically how many years out of the last 10 years irrigators received a full allocation of water from their regional suppliers. The average was nearly 6, and most respondents indicated that despite a very severe drought in the region in 2002 their supplies were relatively stable. 2005 was also a relatively dry year, yet the respondents received nearly 60% of their allotments.

Irrigated operations accounted for over 90% of the entire sample.[3] Among these irrigated operations, there was also relatively little variation in water source, with well over 50% (and in some counties, over 80%) of water supplies coming from mutual-share ditch companies. Similarly, crop selection also showed little variation, with the two dominant crops in the region (corn and alfalfa) accounting for slightly over 20% of all acreage and 65% of all acreage, respectively.

[3] Only 78% of the respondents indicated that they considered themselves ‘irrigated’ farms, however, over 90% reported receiving some level of irrigation water in the 2005 growing year. Several of those who did not answer affirmatively to the question about irrigation offered answers such as “supposed to be” and may have been offering protest responses.

Table 1: Summary of Response for 2005 Irrigation System Survey

	Summary Statistics		
			Mean
Adopting New IT		%	22.22%
Leaving Farming		%	34.03%
Demographics			
	Age		59.5305
	Education		
	High School		26.60%
	Some College		31.38%
	Technical/Vocational		9.57%
	Bachelors		21.28%
	Grad/Prof.		11.17%
Financial			
	Annual Gross Sales		
	< $50,000		57.96%
	$50,000-99,000		23.37%
	$100,000-249,000		9.78%
	$250,000-499,000		4.35%
	$500,000-999,000		1.63%
	> $1,000,000		3.80%
	Debt/Asset Ratio		
	< .25		42.04%
	.25-.5		22.93%
	.5-.75		7.64%
	.75-1		0.64%
	>1		0.64%
	No Debt		0.64%
	Don't Know		9.55%
	Won't Tell		15.92%
Farm	Salinity Problem	%	66.67%
	Size	Acres	180.714
	Primary Crop in '05	Acres	1020.39
	Gravity	%	68.95%
	Supply in '05	%	59.79%
	Ten Year Average	Years/10	5.39232

Additionally, survey respondents were asked to identify any potential changes they might make in either their irrigation systems or cropping patterns in the next five years in response to the salinity problem in the basin. Over 60% of the respondents indicated that salinity severely affected their crop growth, with over half of the respondents indicating that they perceived a 25% yield loss due to salinity. Most indicated that they were not planning any major changes in production methods due to salinity either in terms of cropping patterns or irrigation technology choice, with less than 40% indicating any sort of planned change. Of potential changes, improvements in irrigation technology were the most common with over 20% of the respondents indicating the intention to change systems. Lastly, the survey contained four sections that asked questions about the farm's basic operations, perceived salinity problems, responses to salinity problems, and socio-economic characteristics. Most critically for this analysis, the section on responses to saline water supply included a question on whether or not the irrigator intended to upgrade from an existing irrigation system over the next 5 years, and two additional questions related to the retirement issue. The first question targeted those respondents who indicated that they did not intend to upgrade their irrigation systems specifically because they intended to leave farming in the next five years, while the second was included in the socio-economic section and simply asked if the respondent intended to retire in the next five years. The previously mentioned endogeneity issue arises from the part of the survey specifically identifying if the irrigators were retiring in lieu of adopting a less water intensive irrigation system.

Two important demographic variables are also considered. First, proportion of income derived from agriculture is expected to be important in terms of the decision to retire and may factor into the decision to invest. On average, respondents indicated that approximately 40% held off-farm employment while on-farm income accounted for less than 45% of all income. Much of the residual income appeared to come from spouses and various forms of government transfer payments. Finally, education often plays an important role in technology adoption decisions. The level of education was represented as an integer value as follows: high school = 1; some college = 2; vocational/technical degree = 3; bachelor's degree = 4; and graduate/professional degree = 5.

Results

Estimation of the joint decision to retire and/or to adopt new irrigation technology in response to salinity was executed in LIMDEP as two binomial logit equations with one regression describing the decision to update technology and the other representing the decision to retire, with the former a function of the latter. As a result, the two decisions can be modeled as single-equations with no loss in statistical efficiency because it implies the variance-covariance matrix between the two regressions is upper triangular, i.e., the decision to change technology depends upon the decision to retire, but not vice versa (Greene, 2008).

The coefficients, t-values, and relevant measures of goodness of fit for each decision are reported in Tables 2 and 3. Following a test down procedure, the two decisions were reduced to two distinctively different sets of explanatory variables. To start, the decision to retire was conditioned almost entirely upon demographic issues and financial issues, specifically: the age of the farmer (in years), whether or not the farmer had a college education (binary), the gross sales of the farm (in dollars), the size of the household (in people), whether or not the farm had off-farm income (binary), and whether or not the farm had a perceived salinity problem (binary). As indicated by the Likelihood Ratio Test, McFadden's R-Squared and percentage of correct predictions, the overall performed relatively well. More specifically, the slope coefficient for the age of the farmer was statistically significant at a 1% level and suggested a positive marginal effect on the probability of retiring. i.e., older farmers are more likely to retire. Of equal interest, the dummy variable for on-farm salinity issues also had a statistically significant coefficient, albeit at a more marginal 10% level. This also had a positive marginal effect, suggesting that salinity increases the likelihood of retirement.

Table 2: LOGIT Output for Exiting Agriculture

	Exiting Agriculture			
Variable	Unit	Coefficient	Std. Error	
Intercept		-6.60015	1.6992	
Farmer's Age	Age in Years	0.08804	0.021343	***
College Degree	(0/1)	-0.57695	0.402767	***
Gross Sales	Dollars	-1.5E-06	1.17E-06	
Household Size	# of People	0.217811	0.176692	
Off-Farm Income	(0/1)	-0.13927	0.419932	
Salinity Problem	(0/1)	0.685722	0.418712	*
Goodness of Fit	**Measures:**			
	Chi Squared		34.37687	***
	McFadden's R-Squared		0.16261	
	D. of F.		6	
	% of Correct Predictions		76.36%	
Significance Level:				
	*		10%	
	**		5%	
	***		1%	

Both of these relationships are demonstrated in Figure 1. As can be seen in the figure, the probability of retirement rises relative to age both with and without an on-farm salinity problem. However, the additional positive effect of an on-farm salinity problem is to lead the probability of exiting farming to rise over 50% at approximately 65 years of age while farmers without a salinity problem reach this threshold nearly eight years later. Consequently, it appears that one of the main effects of salinity is to accelerate the rate at which farmers exit the industry.
The consequences of this effect can be seen in the second model, the model to adopt upgraded irrigation technology. Unlike the decision to exit agriculture, the decision to upgrade irrigation technology was more a function of the physical characteristics of the farm. Specifically, the decision to upgrade irrigation technology was a function of the following: whether or not the farm had a perceived salinity problem (binary); the fraction of the farm’s water entitlements

delivered in 2005 (expressed as a percentage); the reliability of the farm's water entitlements (expressed as the number of years over the previous ten in which the farm received a full allotment of water); the square of water supply reliability to assess non-linearities in water supply; whether or not the farmer intended to exit farming over the next five years (binary, and the dependent variable for the previous model); and the number of planted irrigated acres in 2005. As with the previous model, the overall model performed well based on the Likelihood Ratio test, the McFadden's R-Squared, and the percentage of correct predictions; the Likelihood Ratio test indicates overall model significance at the 1% level. Additionally, the coefficients on all of these variables were statistically significant at least at a 10% level, with the supply, reliability, exiting farming, and acreage levels all significant at the 5% level.

Table 3: LOGIT Output for Upgrading Irrigation Technology

	Upgrading IT			
Variable	Unit	Coefficient	Std. Error	
Intercept		-2.76107	1.52573	*
Salinity Problem	(0/1)	1.96066	1.1313	*
% of Supply in 2005	% of Supply Delivered in 2005	0.033812	0.015831	**
Supply Reliability	Years of Full Supply in Last Decade	-0.53281	0.238659	**
Supply Reliability^2	Years of Fully Supply^2	0.010908	0.006287	*
Exiting Farming	(0/1)	-2.07298	0.93701	**
Planted Acreage in 2005	Acres	0.001888	0.000929	**

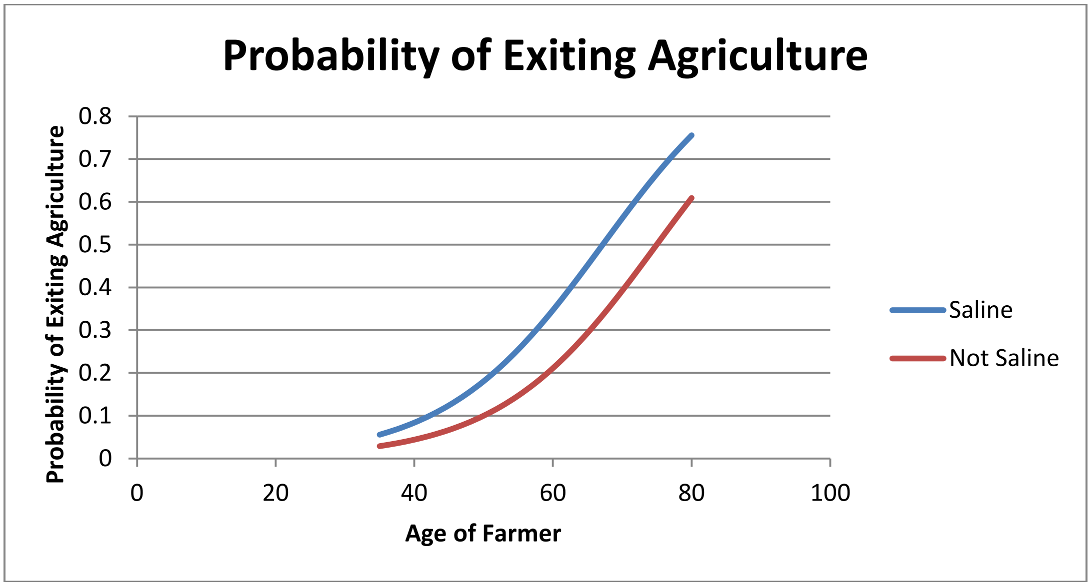
Goodness of Fit Measures:

Chi Squared		28.324	***
D. of F	.	6	
McFadden's R-Squared		0.31282	
% of Correct Predictions		83.95%	

Significance Level:

*	10%
**	5%
***	1%

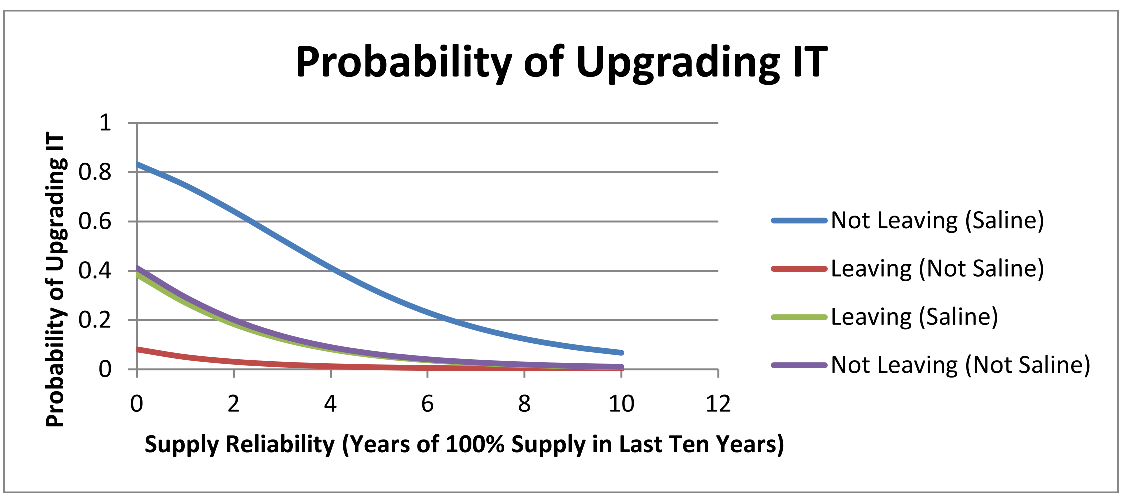
Figure 1: Probability of Exiting Agriculture as a Function of Age and Salinity



NOTE: Evaluated at mean of continuous variables and mode of categorical variables.

In terms of the marginal effects, supply reliability is negatively correlated with upgrading irrigation technology, suggesting that irrigators with relatively more stable water supplies are the least likely to upgrade their systems. If a relatively less reliable water supply is perceived as a cost, this result is consistent with previous irrigation technology adoption models. What are of greater interest, however, are the effects of retirement and salinity. Retirement appears to reduce the likelihood of adopting an upgraded irrigation system, while salinity increases the probability of adoption. The critical issue, then, is which of these two effects prevails.

Figure 2: Probability of Upgrading IT as a Function of Salinity, Retirement Intentions, and Supply Reliability



NOTE: Evaluated at mean of continuous variables and modes of categorical variables.

The relative magnitude of the retirement effects compared to the salinity effects can be seen in Figure 2. As the figure indicates, irrigators who do not intend to retire are markedly more likely to adopt upgraded irrigation systems. Impending retirement virtually undoes the effects of salinity to the point that the probability of upgrading irrigation systems for individuals who neither have salinity problems nor intend to leave are virtually indistinguishable from individuals who are leaving and have salinity problems. This has significant implications for the potential to promote adoption of relatively more efficient irrigation systems as the US agricultural population continues to rise.

Conclusions

In regions affected by saline water soils, water supplies, and runoff, adoption of more technically efficient irrigation systems are frequently promoted as a means of reducing both the consequences and scope of salinity. However, in the course of surveying irrigators in the severely saline Arkansas River basin of Colorado, irrigators indicated that impending retirement was a major reason for not upgrading from gravity irrigation systems to relatively more efficient sprinklers. Through models of both the decision to retire and to adopt more technically efficient irrigation systems as a function of both on-farm salinity and the retirement decision, it appears that while saline water supplies do encourage adoption of more technically efficient irrigation systems, the corresponding effects of retirement on irrigation technology are negative and largely undo the effects of saline water supplies. Furthermore, saline water supplies also correspond to retiring from agriculture nearly 8 years earlier than in the absence of salinity. Given the rising average age of farmers in the United States, this implies that the age threshold where farmers are no longer willing to adopt improved irrigation will be achieved sooner and represents a significant barrier to reducing the effects of salinity in the Arkansas River Basin.

What remains to be seen, however, is whether or not the transition from one generation of farmers to the next has positive or negative effects on both adoption rates and salinity controls. The present model simply identifies both that salinity hastens retirement and that retirement is a barrier to adoption. But the long term implications for adoption of less water intensive irrigation systems is unclear. Specifically, if saline water supplies accelerate generational transfers through retirement and younger generations are more willing to adopt 'better' irrigation systems, rising retirement rates may actually improve water quality in the long run. However, within the context of the current results it is not possible to assess the specific intentions of the irrigators so while it can be said that the intention to retire exerts a significant and negative effect on irrigation technology adoption and that the effects of the decision to retire are largely countervailing to the positive adoption effects of saline water supplies, the cross-generational effects of this transfer require additional research.

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