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The Western Economics Forum

A peer-reviewed publication from the Western Agricultural Economics Association

Purpose

One of the consequences of regional associations nationalizing their journals is that professional agricultural economists in each region have lost one of their best forums for exchanging ideas unique to their area of the country. The purpose of this publication is to provide a forum for western issues.

Audience

The target audience is professional agricultural economists with a Masters degree, Ph.D. or equivalent understanding of the field that are working on agricultural and resource economic, business or policy issues in the West.

Subject

This publication is specifically targeted at informing professionals in the West about issues, methods, data, or other content addressing the following objectives:

- Summarize knowledge about issues of interest to western professionals
- To convey ideas and analysis techniques to non-academic, professional economists working on agricultural or resource issues
- To demonstrate methods and applications that can be adapted across fields in economics
- To facilitate open debate on western issues

Structure and Distribution

The *Western Economics Forum* is a peer reviewed publication. It usually contains three to five articles per issue, with approximately 2,500 words each (maximum 3,000), and as much diversity as possible across the following areas:

- Farm/ranch management and production
- Marketing and agribusiness
- Natural resources and the environment
- Institutions and policy
- Regional and community development

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Retirement and Salinity Effects on Irrigation Technology Choices

Eric C. Schuck, W. Marshall Frasier, Robert Ebel , Eric Houk and Gareth Green[1]

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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Lastly, a significant portion of this article was written while Dr. Schuck was recalled to active duty for the US Navy in Kuwait. It is dedicated to the men and women of Maritime Expeditionary Security Squadron 9 and Port Security Unit 308.

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:

$$\pi_j = \pi_j (p,w,\theta,\omega) \quad (1)$$

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:

$$E[\pi_j (\bullet)] > E[\pi_k(\bullet)] \quad (2)$$

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.

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[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	**

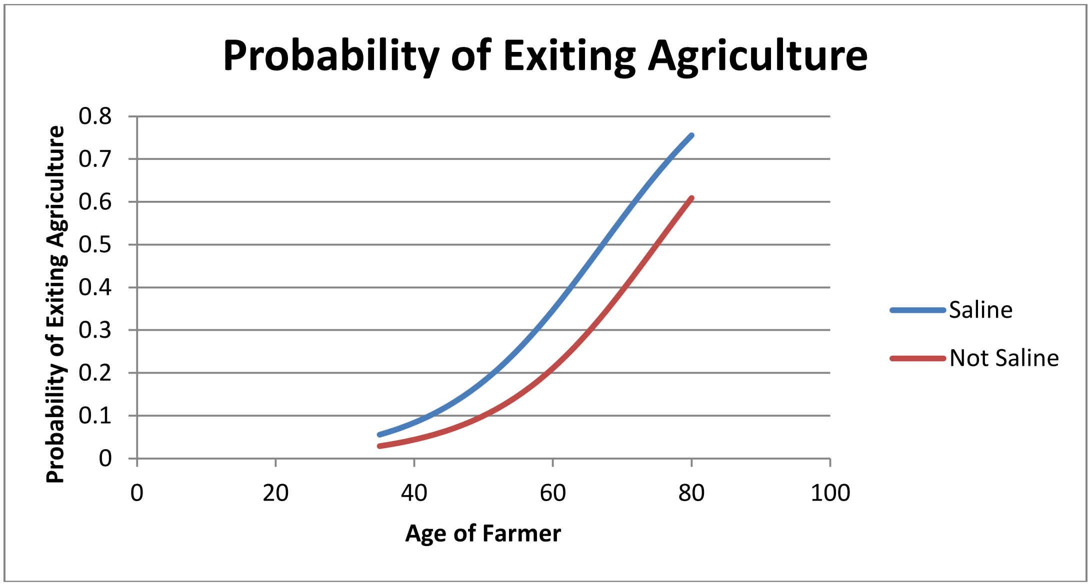
Goodness of Fit Measures:

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

Significance Level:

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

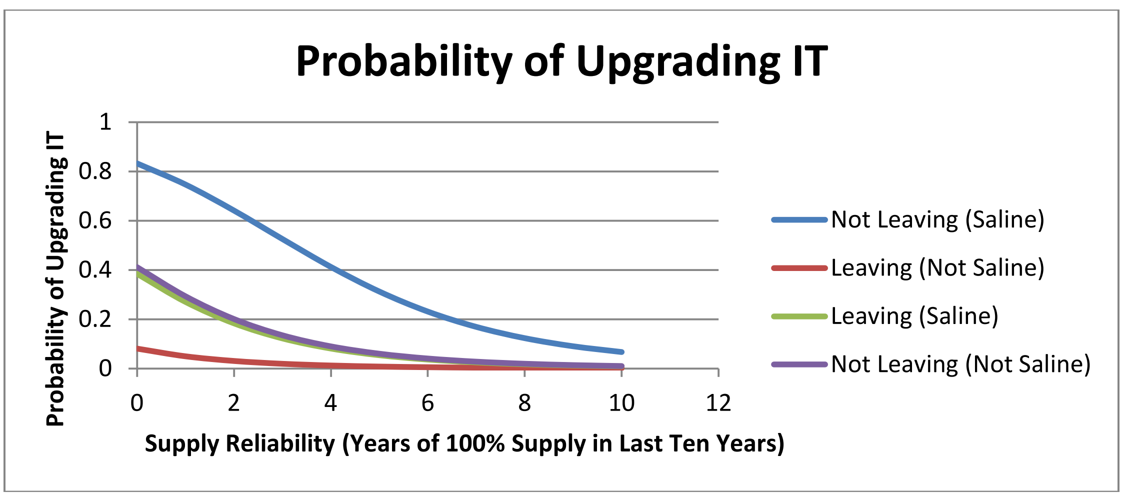
Figure 1: Probability of Exiting Agriculture as a Function of Age and Salinity



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.

References

Ben-Akiva, M. and S. Lerman. 1985. Discrete Choice Analysis: Theory and Application to Travel Demand. Cambridge, MA: MIT Press.

Carey, J. M., and D. Zilberman. 2002. "A Model of Investment under Uncertainty: Modern rrigation Technology and Emerging Markets in Water". *American Journal of Agricultural Economics* 84:171-83.

Caswell, M., and D. Zilberman. 1985. "The Choices of Irrigation Technologies in California". *American Journal of Agricultural Economics* 67:223-34.

Caswell, M., and D. Zilberman.. 1986. “The Effects of Well Depth and Land Quality on the Choice of Irrigation Technology”. *American Journal of Agricultural Economics* 68:798 811.

Colorado Department of Public Health and Environment. 1998. *Water Quality Limited Segments Still Requiring TMDL’s – Colorado’s 303d List and Related Water Quality Management Tasks*. Colorado Department of Public Health and Environment, Denver, CO.

Dinar, A. and D. Yaron. 1990. “Influence of Quality and Scarcity of Inputs on the Adoption of Modern Irrigation Technologies.” *Western Journal of Agricultural Economics* 15:224-33.

Dinar, A. and D. Zilberman. 1991. “Effects of Input Quality and Environmental Conditions on Selection of Irrigation Technologies.” in A. Dinar and D. Zilberman, eds., *The Economics and Management of Water and Drainage in Agriculture*, New York: Kluwer.

Frasier, W. M., Waskom, R. M., Hoag, D. L., and Bauder, T. A. 1999. “Irrigation management in Colorado: Survey data and findings”. Tech. Report TR99-5, Colorado State Univ. Agricultural Experiment Station, Fort Collins, Colo.

Green, G. and D. Sunding. 1997. “Land Allocation, Soil Quality, and the Demand for Irrigation Technology.” *Journal of Agricultural and Resource Economics*. 22(2):367-75.

Green, G., D. Sunding, D. Zilberman, and D. Parker. 1996. “Explaining Irrigation Technology Choices: A Microparameter Approach”. *American Journal of Agricultural Economics* 78:1064-72.

Greene, William H. *Econometric Analysis, 6th. Ed.* Upper Saddle River, NJ: Pearson-Prentice Hall, 2008.

Houk, Eric, W. Marshall Frasier and Eric Schuck. *The Agricultural Impacts of Irrigation Induced Waterlogging and Soil Salinity in the Arkansas Basin.* Agricultural Water Management. Volume 85, (2006), pp. 175-183.

Houk, Eric, W. Marshall Frasier, and Eric Schuck. Evaluating the Adoption of Higher EfficiencyIrrigation Systems in the Presence of Salinization and Waterlogging. Global Business and Economics Review. Vol. 7, No. 4 (2005), pp.343-352.

Lichtenberg, E. 1989. Land Quality, Irrigation Development, and Cropping Patterns in the Northern High Plains. *American Journal of Agricultural Economics*, 71:187-94.

Negri, D., and D. Brooks. 1990. “Determinants of Irrigation Technology Choice”. *Western Journal of Agricultural Economics*. 15:213-23.

Nieswiadomy, M. 1988. “Input Substitution in Irrigated Agriculture in the High Plains of Texas, 1970-80”. *Western Journal of Agricultural Economics* 13:63-70.

Ogg, C. W. and N. R. Gollehon.. 1989. "Western Irrigation Response to Pumping Costs: A Water Demand Analysis Using Climatic Regions." *Water Resources Research*. 25:767 73.

Perrin, Richard. 1972. "Asset Replacement Principles". American Journal Of Agricultural Economics. 54(1):60-67.

Perrin, Richard and Don Winkelman. 1976. "Impediments to Technical Progress on Smasll versus Large Farms". American Journal of Agricultural Economics. 58(5):888-894.

Salant, P. and D. Dillman. 1994. *How to Conduct Your Own Survey.* New York: John Wiley and Sons.

Schaible, G. D., and M. P. Aillery. 2003. "Irrigation Technology Transitions in the Mid-Plains States." *International Journal of Water Resources Development*. 19(1):67-88.

Schaible, G. D., C. S. Kim, and N. K. Whittlesey. 1991. "Water Conservation Potential from Irrigation Technology Transitions in the Pacific Northwest." *Western Journal of Agricultural Economics*, 16(2):194-206.

Schuck, E. C. and G. P. Green. 2001. "Field Attributes, Water Pricing, and Irrigation Technology Adoption*". Journal of Soil and Water Conservation*, 56 (4): 293- 298.

Eric C. Schuck, W. Marshall Frasier, Robert S. Webb, Lindsey J. Ellingson and Wendy J. Umberger. *Adoption of More Technically Efficient Irrigation Systems as a Drought Response.* International Journal of Water Resource Development. Volume 21, no. 4 (2005), pp. 651-662.

Shrestha, R., and C. Gopalakrishnan. 1993. Adoption and Diffusion of Drip Irrigation Technology: An Econometric Analysis. *Economic Development and Cultural Change*, 41:407-18.

United States Department of Agriculture. 2007. 2007 Census of Agriculture. National Agricultural Statistics Service United States Department of Agriculture. Washington, DC. Available online at http://quickstats.nass.usda.gov/

United States Department of Agriculture. 2002. 2002 Census of Agriculture. National Agricultural Statistics Service United States Department of Agriculture. Washington, DC. Available online at http://quickstats.nass.usda.gov/

Wichelns, D. 1991. "Increasing Block-Rate Prices for Irrigation Water Motivate Drain Water Reduction." in A. Dinar and D. Zilberman, eds., *The Economics and Management of Water and Drainage in Agriculture*, New York: Kluwer.

ANALYSIS OF ACRE's DRYLAND--IRRIGATED PROVISION

J. Clay Francis and Carl Zulauf[1,2]

Introduction

The Food, Conservation, and Energy Act of 2008 (2008 Farm Bill) provides farm commodity program participants with the choice of a traditional suite of fixed direct payment, marketing loan, and price counter-cyclical programs or a new Average Crop Revenue Election (ACRE) program suite. The ACRE suite consists of (1) 80 percent of the traditional program's direct payments, (2) marketing loans at 70 percent of the traditional program's loan rate, (3) and a new state revenue program. In a departure from the traditional farm programs, the ACRE state revenue program explicitly contains a differentiation by production practice. Specifically, separate ACRE state revenue benchmarks are established for dryland and irrigated acres if total acres planted to a crop in a state are at least 25% dryland and 25% irrigated.

This article presents an analysis of the impact of the dryland-irrigated provision upon the cost and flow of payments by the ACRE state revenue program. Specifically, a historic, counter-factual analysis is conducted using data for the 1969-2008 crop years. Crops included in the analysis are barley, corn, upland cotton, peanuts, oats, rice, grain sorghum, soybeans, and wheat. One of the simulated ACRE programs contained the dryland-irrigated provision in the 2008 Farm Bill. The other simulated ACRE program had a single state revenue benchmark, and thus made no distinction between dryland and irrigated acres. No other difference existed between the simulated ACRE programs.

The ACRE provisions in the 2008 Farm Bill that are germane to this analysis are discussed in the next section. Discussions of the analytical procedures and results follow. The paper ends with a summary and conclusion section.

Overview of ACRE State Revenue Program

The 2008 Farm Bill gives farmers and landowners a choice between the traditional farm program suite and an ACRE farm program suite (U.S. Department of Agriculture (USDA), Farm Service Agency (FSA)). Twenty two crops are eligible for election into ACRE, including barley, corn, upland cotton, peanuts, oats, rice, grain sorghum, soybeans, and wheat. The unit of election is a farm as recorded at FSA. As long as an FSA farm is not in ACRE, election of ACRE remains open. Once ACRE is elected, the FSA farm is enrolled through the 2012 crop.

An ACRE state revenue payment occurs if a state's actual revenue per planted acre is less than the state's revenue benchmark, where, for state k, crop s, and crop year t:

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(1) ACRE state revenue benchmark per planted acre = (90% ● Olympic average yield (excludes low and high yield) per planted acre for the 5 most recent prior crop $years_{kst}$ ● average U.S. cash price for the 2 most recent prior crop $years_{st}$).
(2) ACRE actual state revenue per planted acre = (yield per planted $acre_{kst}$ ● Max[U.S. cash $price_{st}$; 70% of U.S. marketing loan $rate_{st}$)
(3) ACRE revenue payment per planted acre = MIN[ACRE state revenue benchmark per planted $acre_{kst}$ – ACRE actual state revenue per planted $acre_{kst}$; 25% ● ACRE state revenue benchmark per planted $acre_{kst}$]

Coverage level of the ACRE state revenue program is 90 percent (equation 1), and the ACRE state revenue payment is capped at 25 percent of the state revenue benchmark (equation 3).

The ACRE state revenue benchmark cannot increase more than 10 percent from the prior year's level (called a cap) nor decrease more than 10 percent from the prior year's level (called a cup). The 10 percent cap and cup, along with the use of historical moving averages, means that the ACRE state revenue benchmark may adjust more slowly than changes in market revenue. However, no floor exists on the revenue benchmark.

Planted acres equal the conventional definition for most eligible crops, but, for barley, corn, oats, grain sorghum, and wheat; FSA defined planted acres as harvested acres plus acres reported as failed acres to FSA. Failed acres are acres intended for harvest but not harvested. ACRE revenue payments can be received on only 83.3% of planted acres.

Due to a lack of data at the individual farm level, this analysis does not include the individual farm provisions of the ACRE program. These provisions include (1) an FSA farm eligibility condition in which an FSA farm's actual revenue for a crop must be less than the farm's benchmark revenue for the crop, (2) customization of the state revenue payment to the FSA farm by the ratio of farm yield to state yield, (3) a restriction that an FSA farm cannot receive ACRE revenue payments on more acres than the FSA farm's total base acres, and (4) a limit on the amount of ACRE revenue payments a farm entity can receive. For additional discussion of the individual farm provisions as well as other provisions of the ACRE program, see Zulauf, Dicks, and Vitale, Zulauf and Orden, and Zulauf, Schnitkey, and Langemeier.

Data and Analytical Methods

A historical counter-factual analysis was conducted. Specifically, the ACRE state revenue program was assumed to have existed over the 1974 through 2008 crop years with all planted acres enrolled in the ACRE program.

State level production and planted acre data as well as U.S. crop year average price data were obtained from USDA, National Agricultural Statistics Service (NASS). Because of the need to construct the five-year Olympic moving average of yield, data collection started with the 1969 crop year. Information was not available for all states for all of the 1969-2008 crop years, especially by dryland and irrigated production practice. Footnote c of Table 1 contains a list of the states and years for which separate information was available by dryland and irrigated production practice.

Data on failed acres were obtained by personal communication with USDA, FSA. This data began with the 1995 crop. For earlier years, failed acres for a state and crop were estimated by using the average share of planted acres that were failed acres from 1995 through 2008. We also estimated a regression equation in which failed acres for a state were estimated as a function of the difference between a state's planted and harvested acres. Most of the regression equations were statistically insignificant and explanatory power was generally low even when the equation was statistically significant.

Given the available data, 550 crop-state-year combinations would have qualified for separate dryland and irrigated ACRE revenue benchmarks if the ACRE state revenue program had existed over the 1974-2008 crop years (Table 1). For each of these 550 crop-state-year observations, 25% of the acres planted to the crop in the state for the year were in dryland production and 25% were in irrigated production.

The number of observations in which an ACRE state revenue payment occurred ranged from four for the peanut irrigated ACRE revenue benchmark to 40 for the upland cotton dryland ACRE revenue benchmark (Table 1). The relatively small number of observed payments by crop raises questions about the statistical power of the analysis at the individual crop level. Hence, the discussion of results in the next section is in terms of all crops combined.

Not including the farm related provisions noted in the previous section means that estimated ACRE state revenue payments are high. However, the focus of this article is on the comparative performance of the ACRE program with and without the dryland-irrigated provision. It is not clear that including the farm level provisions would alter the comparative relationships, but the possibility does exist.

Table 1. Number of Observations, Years and U.S. States That Qualified for Separate Dryland and Irrigated ACRE State Revenue Benchmarks, 1974-2008[a, b, c]

		Observations when ACRE State Revenue Payment Occurred		
Crop	Total Observations	Single Benchmark	Dryland Benchmark	Irrigated Benchmark
Barley	118	21	26	16
Corn	94	21	31	11
Cotton (upland)	106	32	40	28
Oats	68	32	30	34
Peanuts	8	6	8	4
Sorghum	26	7	5	9
Soybeans	41	10	15	11
Wheat	89	23	27	22
All Crops	550	152	182	135

NOTES:

a. Separate state benchmarks exist if at least 25% of a state's planted acres for a given crop in a given year are dryland and at least 25% are irrigated. No state qualified for separate benchmarks for rice.

b. An observation is a state-crop-year combination. For example, an observation is barley in 1990 for Colorado.

c. Availability of data by dryland and irrigated acres varies by crop and state. Barley: California (1975-2008); Colorado, Idaho, Montana, Oregon, and Wyoming (1969-2008). Corn: Colorado

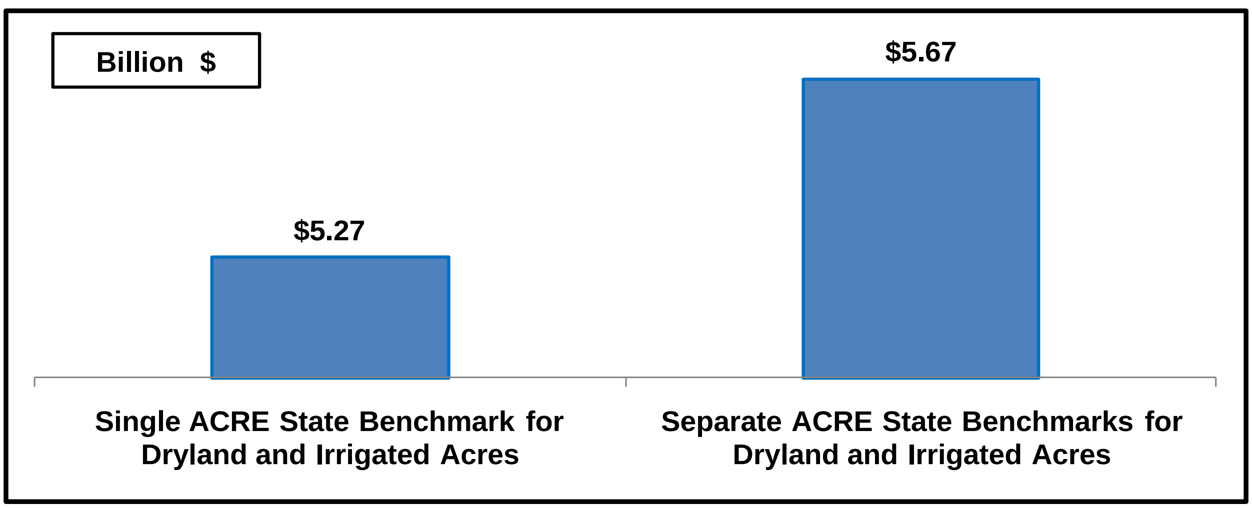
(1975-2008), Kansas (1974-2008), Nebraska (1991-2008), Oklahoma (1985-2008), and Texas (1981-2008). Cotton: Arkansas, Louisiana, Oklahoma, and Texas (1972-2008); Mississippi (1969-2008). Oats: Colorado (1986-2008), Montana (1982-2008), Oregon (1972-2008), and Wyoming (1969-2008). Peanuts: Oklahoma (1993-2003) and Texas (1993-2008). Sorghum: Colorado (1986-2008), New Mexico (1974-2008), and Texas (1971-2008). Soybeans: Arkansas (1991-2008), Nebraska (1974-2008), and Texas (1984-2008). Wheat: California (1974-2008); Idaho, New Mexico, and Utah (1972-2008).

SOURCE: original estimates using data from USDA, NASS and USDA, FSA

Results

Over all observations for which separate ACRE state benchmarks would have existed for dryland and irrigated acres had ACRE existed over the 1974-2008 crop years, ACRE state revenue payments were 7.6% larger with separate dryland and irrigated revenue benchmarks than with a single benchmark (Figure 1).

Figure 1. Comparison of Estimated Total Payments from an ACRE Program with a Single State Revenue Benchmark and an ACRE Program with Separate State Revenue Benchmarks for Dryland and Irrigated Acres, Years and States That Qualified for Separate Dryland and Irrigated ACRE Revenue Benchmarks, Selected U.S. Crops, 1974-2008

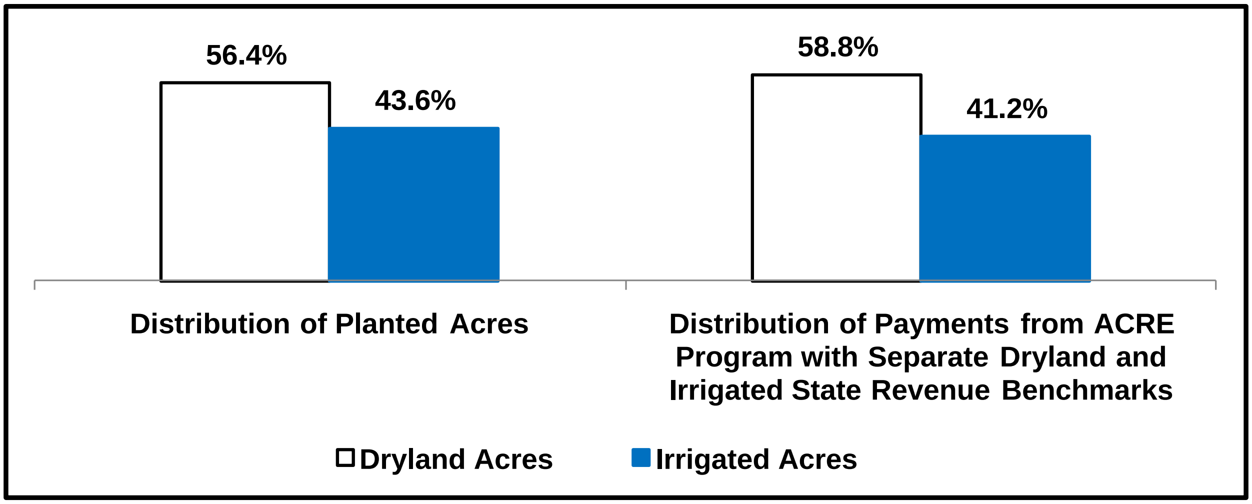


NOTE: see table 1 for information on the number of observations
SOURCE: original estimates using data from USDA, NASS and USDA, FSA

For the crops, years, and states in which separate ACRE benchmarks would have existed between 1974 and 2008, a greater share of acres were dryland (56.4%) than irrigated (43.6%) (Figure 2). For the single benchmark program, these shares would be the distribution of ACRE state revenue payments between dryland and irrigated acres. In comparison, the use of separate state revenue benchmarks shifted the share of ACRE state revenue payments to dryland acres, but only by 2.4 percentage points (Figure 2).

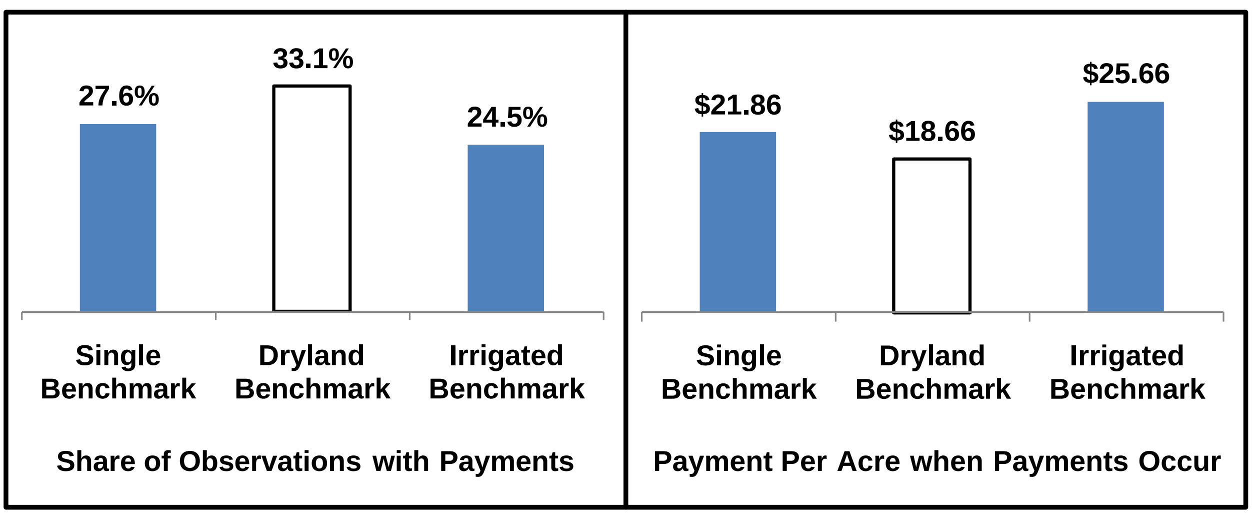
Establishing separate benchmarks is expected to result in more frequent payments for dryland than irrigated acres. The reason is that yields, hence revenue, are more variable on dryland acres. This expectation was confirmed. ACRE revenue payments occurred 8.6 percentage points more often for dryland acres than for irrigated acres (Figure 3).

Figure 2. Distribution of Planted Acres and Estimated ACRE State Revenue Payments by Dryland and Irrigated Acres, Years and States That Qualified for Separate Dryland and Irrigated ACRE Revenue Benchmarks, Selected U.S. Crops, 1974-2008



NOTE: see table 1 for information on the number of observations
SOURCE: original estimates using data from USDA, NASS and USDA, FSA

Figure 3. Share of Observations with Estimated ACRE State Revenue Payments and Average State Payment per Acre When Payment Occurs by Type of ACRE State Benchmark, Years and States That Qualified for Separate Dryland and Irrigated ACRE Revenue Benchmarks, Selected U.S. Crops, 1974-2008

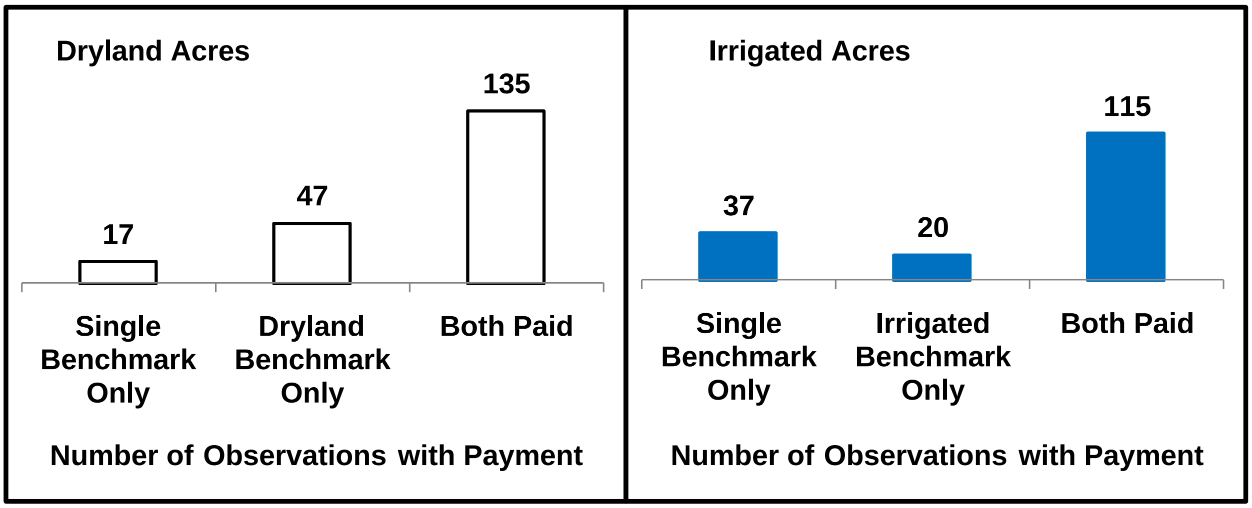


NOTE: see table 1 for information on the number of observations
SOURCE: original estimates using data from USDA, NASS and USDA, FSA

On the other hand, because irrigated yields are higher, per acre payments are expected to be higher for irrigated acres when payments occur. This expectation also was confirmed. Payment per acre was 38% higher for irrigated acres when payments occurred (Figure 3).

For a sizeable majority of observations, the ACRE program made state payments whether single or separate state benchmarks existed (Figure 4). However, there were observations in which state payments occurred when a single state benchmark existed but not when separate dryland-irrigated state benchmarks existed, and vice versa.

Figure 4. Number of Observations When an Estimated ACRE State Revenue Payment Occurred by Type of ACRE State Benchmark and by Whether Land is Dryland or Irrigated, Years and States That Qualified for Separate Dryland and Irrigated ACRE Revenue Benchmarks, Selected U.S. Crops, 1974-2008



NOTE: see table 1 for information on the number of observations
SOURCE: original estimates using data from USDA, NASS and USDA, FSA

The results of this study need to be confirmed by other studies. It would be useful to examine different observation periods, use alternative methodologies, and add ACRE's farm revenue loss eligibility condition to the analysis. In regard to the need to examine different observation periods, as a sensitivity test we divided our observation period in half, specifically subperiods of 1974-1990 and 1991-2008. We also examined the last 10 years, 1999-2008. The numerical values presented in Figures 1-4 vary by subperiod, especially the total ACRE payments presented in Figure 1. However; the story of comparative performance presented by Figures 1-4 was similar in each subperiod. Thus, while not a definitive test, the subperiod sensitivity test provides additional support for the results generated by this analysis.

Summary and Conclusion

Results of this historical, counterfactual analysis indicate that the creation of separate benchmarks for dryland and irrigated acres by the new Average Crop Revenue Election (ACRE) program is expected to increase the cost of the ACRE program by approximately 8% for those states and crops for which separate benchmarks can be created. It also slightly shifts payments to dryland acres. However, establishing separate revenue benchmarks for dryland and irrigated acres in a state will more accurately reflect the occurrence of gross revenue shortfall for irrigated and dryland acres than does a single benchmark that applies to all acres. Hence, it is not surprising that the size and timing of ACRE revenue payments change when separate benchmarks are created. In particular, compared with a single benchmark ACRE program, the separate benchmark ACRE program resulted in smaller, more frequent payments for dryland acres and larger, less frequent payments for irrigated acres. Moreover, there were observations in which the separate benchmark program resulted in payments while the single benchmark program resulted in no payment, and vice versa. In short, creating separate ACRE state revenue benchmarks for dryland and irrigated acres improves the risk management assistance provided by the ACRE state revenue program by better matching ACRE state revenue payments with the occurrence of revenue shortfalls on dryland and irrigated acres.

References

U.S. Department of Agriculture (USDA), Farm Service Agency (FSA). "Direct and Counter-Cyclical Program/ACRE." Internet site: http://www.fsa.usda.gov/FSA/webapp?area=home&subject=dccp&topic=landing (Accessed July 2010).

U.S. Department of Agriculture (USDA), National Agricultural Statistics Service (NASS). *Data and Statistics: Quick Stats.* Internet site: http://www.nass.usda.gov/Data_and_Statistics/Quick_Stats/index.asp (Accessed July 2010)

Zulauf, Carl R., Michael R. Dicks, and Jeffrey D. Vitale. "ACRE (Average Crop Revenue Election) Farm Program: Provisions, Policy Background, and Farm Decision Analysis." *Choices*. Volume 23, Issue 3 (3rd Quarter 2008): 29-35. http://www.choicesmagazine.org/magazine/issue.php?issue=5

Zulauf, Carl and David Orden. "The Revenue Program Option in the 2008 U.S. Farm Bill: Evaluating Performance Characteristics of the ACRE Program." *Agricultural and Resource Economics Review*. Volume 39, Issue 3, October 2010, pages 517-533.

Zulauf, Carl, Gary Schnitkey, and Michael Langemeir. "Average Crop Revenue Election, Crop Insurance, and Supplemental Revenue Assistance: Interactions and Overlap for Illinois and Kansas Farm Program Crops." *Journal of Agricultural and Applied Economics,* 42, 3(August 2010): 501-515.

Will Washington Provide Its Own Crop Feedstocks for Biofuels?

Suzette P. Galinato, Douglas L. Young, Craig S. Frear and Jonathan K. Yoder[1]

Introduction

Interest in biofuels has remained high due to concerns about the nation's reliance on potentially unstable fossil energy sources. American states and communities have also welcomed the potential for economic growth from biofuel plants. In response to these concerns, Washington and other states have enacted laws and regulations designed to promote biofuel development (U.S. Dept. of Energy, 2009).

Corn and sugar beets are among the potential ethanol feedstocks in Washington; however, Washington accounted for only 0.15% of the nation's grain corn (NASS, 2008). Consequently, large Pacific Northwest ethanol producers, such as Pacific Ethanol's plants at Boardman, Oregon and Burley, Idaho imported corn from the Midwest. Sugar beets are an unlikely in-state source of ethanol due to current competition from other irrigated crops, high production costs, and transportation disadvantages (Yoder et al., 2009). Only 1,600 acres of sugar beets have been produced recently in Washington. Sugar beets grown in other states are converted to sugar instead of ethanol.

Oilseeds are a favored biodiesel crop feedstock, but they are minor crops in Washington. Washington averaged 17,577 acres per year for all oilseeds (including canola/rapeseed, mustard, flaxseed, and safflower) over 1997, 2002, and 2007. Canola acreage averaged 10,448 acres per year for these three census years (NASS, 1997, 2002, 2007). The relatively high 2002 oilseed acreage represented only 0.25% of Washington's cropland. Washington produces virtually no soybeans, the nation's largest biodiesel feedstock.

Table 1 measures the adequacy of Washington's current canola, grain corn, and hypothetical sugar beet production in relation to specified biofuel targets. Data show 2007-2008 acres for canola and corn, but 1970-1978 average acres for sugar beets. The state's 2007 canola acreage would meet only 0.09% of the state's diesel consumption if it were replaced entirely with biodiesel. Ethanol from Washington's grain corn could satisfy 1.99% of the state's gasoline consumption. However, local livestock feeders often outbid ethanol producers for local grain corn. Ethanol from sugar beets at the high 1970's acreage could provide 2.64% of the state's

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gasoline consumption. Again, sugar producers might outbid ethanol producers for sugar beets. Current Washington grain corn and historical sugar beet production could supply less than two 40-million-gallon-per-year (MGY) plants each if the entire production was diverted to this purpose. Only 0.02% of the feedstock requirements of a 40 MGY biodiesel plant could be met by current in-state canola production. Undoubtedly, a different set of relative prices would be necessary to encourage production of biofuel crops to meet the state's fuel needs.

Table 1. Adequacy of Washington Canola, Sugar Beet and Corn Production to Meet Specified Demands

Item	Canola	Sugar beets	Corn
Acres of crops planted in Washington	10,449	76,911	90,000
In-state production as % of WA diesel or gasoline consumption per year	0.09	2.64	1.99
Number of 40 MGY plants supplied by in-state production	0.02	1.78	1.34

Notes: Canola acres and trend yield are derived from the 2007 Ag. Census. Biofuel conversion ratios are from Mattson, Wilson and Duchsherer 2007; Salassi 2007; and Lyons 2008. Historic WA sugar beet acreage and updated trend yields are from NASS (2008). MGY is million gallons per year. Washington consumes about 1 and 2.7 billion gal/yr of diesel and gasoline, respectively.

The objective of this study is to assess the economic feasibility of producing biofuel crop feedstocks within Washington State assuming infrastructure and biofuel production capacity were developed. We project profitable acreages of Washington’s crop feedstocks for 2008 in the short run and for the midpoint of a 2009-2011 medium term period using subregion linear programming models. The analysis uses subregion data on production possibilities, costs, crop prices, policies and available technology. The 2008 projections, based on spring forecasted or contract prices, are compared to actual crop acreages for that year. The 2010 projections, based on moving average price projections available in 2008, are compared to 2010 planted acreage reports. Although all projections were made in mid-2008, reporting was delayed for over two years to assess their *ex post* accuracy. The delayed *ex post* validation is rare in the empirical literature.

Most studies regarding ethanol and biodiesel production have focused on agribusiness and rural development considerations rather than on the feasibility of in-state feedstock production (e.g., Franken and Parcell, 2003; Kenkel and Holcomb, 2006; Parcell and Westhoff, 2006; Lambert et al., 2008; Susanto, Rosson and Hudson, 2008). Some previous state-level studies have estimated the stand-alone profitability of crop feedstocks. Many utilized enterprise budgeting to calculate the revenues, costs, and profits associated with the production of a particular crop such as oilseeds in Oregon’s Willamette Valley (Jaeger and Siegel, 2008) and in Maine (Sexton, 2003). Stebbins (2008) uses this approach and found that farm-scale cultivation of oilseeds in Vermont was feasible. A major limitation of single-crop analyses is that they do not allow for product-product competition for land and other resources. Important exceptions are the studies by De La Torre Ugarte et al. (2003) and Walsh et al. (2007) that allowed for product-product competition in 305 independent regional linear programming models for the central and eastern U.S. These results were utilized in their national demand, regional supply, and aggregate income model. Walsh et al. (2007) projected relatively optimistic cellulosic and food crop feedstock supplies to meet year 2025 transportation fuels, food, feed and export demands with some increased crop prices. While such long term national projections are valuable, they are strongly dependent on embodied assumptions on biofuel conversion technologies and cellulosic feedstock supply functions over long time periods. Financial stress in the biofuel industry during

2008-2009 — including excess capacity, bankruptcies, and plant closures — challenges optimistic long run projections in the absence of technological breakthroughs, more generous subsidies, or markedly different relative prices (Young, 2009).

This study allows for product-product competition in response to changing economic incentives. The *ex post* robustness of crop feedstock projections is tested by comparing them with subsequent published acreage data.

Methodology

Standard profit-maximizing risk-adjusted linear programming (LP) models are used to project crop acreages, diesel and nitrogen use and breakeven prices for biofuel feedstock crops. LP is a common approach for examining the feasibility of alternative production possibilities in a partial equilibrium framework (e.g., Taylor, Adams and Miller, 1992; Jaeger, 2004; Keplinger and Hauck, 2006). We provide projections for five production regions in Washington (four dryland and one irrigated) and two time horizons (short and medium run). The models calculate profit maximizing crop choice and input use subject to prevailing technology, price expectations, quantity and quality of land and other resources, agro-climatic conditions, and policy constraints.

Some assumptions underlying the feedstock projection model merit highlighting. First, the subregional models includes activities for all major crops and land use activities, including fallow and Conservation Reserve Program (CRP), as appropriate. Total regional cropland acreage is constrained at 2007 levels, with the exception of moving land to or from CRP. Second, farmers in these regions have demonstrated that they can shift cropping patterns with relatively minor adjustments in their current machinery and labor supplies given opportunities for custom hiring; hence, these resources are not constraining. Third, the projections assume that crops grown in the dryland regions, including spring wheat, winter wheat, barley, grain legumes (peas, lentils, and garbanzos), and canola, are grown in agronomically sound rotations. Canola, which dominates oilseed production in eastern Washington, represents all oilseeds in the projections. Past canola technology successes, such as Roundup Ready© canola and greater research funding for canola, are likely to sustain its dominance. Fourth, the profitability of producing a given rotation or crop is measured by total returns over total cost. Reporting results as net returns over total costs conforms to results in typical Cooperative Extension budgets for the region. Also, given the common machinery complements for the candidate crops, analysis generally showed the same relative results for returns over variable costs and returns over total costs.

For most crops, growers in the irrigated regions do not need to adhere to specific crop rotations due to access to irrigation. For example, while potato frequency is limited by phytosanitary requirements, wheat, grain corn, sweet corn, alfalfa and other crops can serve as rotation crops with potatoes. However, some crop choices in the irrigated region are dictated by processing plant contracts, i.e., potatoes, sweet corn, asparagus. Farmers in areas with junior water rights are also limited in terms of water availability during dry years, which affects crop choice. To reflect this complexity, we model acreages over the large set of choices within 10-year historical crop-specific upper and lower acreage bounds.

Data

Four eastern Washington dryland farming subregions were classified according to their annual average precipitation: high, 17-22 inches/year; medium, 15-17 inches/year; low, 12-15 inches/year; and arid, 7-12 inches/year. A fifth region included Washington's irrigated farmland.

A sixth region comprising the 19 counties entirely or partially west of the Cascade Mountains was not modeled because its current and past production of crop biofuel feedstocks has been miniscule (NASS, 2008).

Enterprise budgets of various crops grown in Washington State subregions were used to specify production functions incorporated in the LP projections (Yoder et al*.,* 2010). Input prices are specified at early 2008 levels for the short-run and are adjusted for the medium-run.

For the short-run, we use the 2008 spring contract crop prices for autumn harvest in all regions. These were $7.28/bu for grain corn (which was a high contract price spike at time of analysis), $38/ton for sugar beets, and $21.10/cwt for canola (including 20% risk discount). Exceptions to the pricing assumptions occur for land retained in the CRP, or planted to a crop with which most growers have no experience. These land uses receive adjustments for risk. Economic theory specifies that risk averse farmers will discount profit or price expectations for crops or land uses they perceive as more risky than average, or equivalently add a bonus to expectations for crops or land uses they see as less risky than average (Anderson, Dillon and Hardaker, 1977; Kurkalova et al., 2006). Because new crops generally present farmers and scientists with a risky learning curve, expected canola price is discounted by 20% as a conservative estimate to account for added yield risk and risk aversion of crop producers.[2] In comparison, Kurkalova et al. (2006) estimated risk premiums for wheat and other crops for conservation versus conventional tillage which were 30% to 32% of expected returns. Because CRP rents are guaranteed by the U.S. Treasury and have zero risk (Williams et al., 2010), they receive a conservative 20% price bonus.

For the medium-run scenario (2009-2011), all assumptions and data sources remain the same as those outlined for the short run, except for crop prices and production costs. We use the average of 2006, 2007 and 2008 prices as a forward projection of crop prices. These were $5.18/bu for grain corn, $38.5/ton for sugar beets, and $12.45/cwt for canola. Canola and CRP retain the same percentage risk adjustments as in the short run. The retreat of crop prices to a 3-year moving average in the medium run after the exceptionally high 2008 prices reflects historical cyclical patterns. As an example, farm gate mid-November 2008 prices for soft white wheat in eastern Washington had dropped to $5/bu from the $15/bu spike in January 2008. We also assume that all production costs, except diesel and nitrogen, will increase 7% by the 2010 medium-run midpoint compared to 2008 levels, and diesel and nitrogen will increase by 20.3% and 19.4%, respectively. Given limitations of the short-run comparative statics nature of LP results, the analysis does not consider wider variations in crop and input prices.

Projected acres from LP results are compared with reported acres from USDA-NASS data published in 2008 and 2010, unless otherwise specified. Reported canola, orchards and vineyards and summer fallow are from 2007 Ag. Census as these are not annually reported in NASS. Sugar beets and canola, as minor crops in WA, are no longer annually reported by NASS. The reported sugar beet acreage is from 2008. Edible legumes in the following tables consist of dry grain legumes, dry edible Pinto beans, and green peas.

[2] Canola prefers cooler temperatures during flowering than those prevalent in eastern Washington. WSU agronomic experiments have documented low yields of canola due to stand establishment and other problems (Yoder et al., 2010). Relative little agronomic and genetic research has been done to adapt canola to local conditions. This contrasts with 100 years of focused research on wheat and potatoes in the Pacific Northwest. Consequently, local canola growers face many challenges.

CRP acreages were based on active and expiring CRP acres in Washington subregions between 2008 and 2010 (USDA-FSA, 2008 and 2010). Historic acreages of dryland and irrigated regions are from NASS (1997, 2002, 2007). Orchard, barley, and other historic acreages are from NASS (1997, 2002, 2007, 2008).

Results of Crop Feedstock Projections

Short-run Projection and Validation

Table 2 presents 2008 projections of profitable feedstock crop acreage, and fuel and fertilizer usage for each of the five modeled production regions. Note that the projected production of a biofuel feedstock does not mean that the crop will be processed into biofuels since the output will be distributed among competing uses. Breakeven prices required for feedstock crops to be produced in a region are also reported.[3]

Table 2. Projected Profitable Biofuel Feedstock Acres and Energy Use by Subregion, Short Run (2008), Washington State

Region	Canola	Grain corn	Sugar beets	Diesel use (1000 gal)	Dry N use (1000 lbs)	Liquid N use (1000 lbs)
	------------acres------------					
Dryland Zones						
High (17-22 in/yr)	0	0	0	4,074	47,267	0
Med (15-17 in/yr)	0	0	0	1,509	23,608	0
Low (12-15 in/yr)	0	0	0	2,276	18,143	0
Arid (7-12 in/yr)	0	0	0	2,754	44,422	0
Irrigated	0	105,000	0	8,221	82,155	81,454
WA Total	0	105,000	0	18,334	215,595	81,454

In dryland eastern Washington, as expected, no typically irrigated crop feedstocks (i.e., grain corn and sugar beets) were projected in 2008 (Table 2). Of greater importance, no canola production was projected in the short run for these zones. Small canola acreages at recent levels can be expected to continue to meet rotational needs, special contracts, or agro-climatic niches. On the whole, however, canola rotations did not compete with the dominant rotations of winter wheat-spring grain-spring legumes (or fallow) in the two higher precipitation regions or with winter wheat-fallow in the two lower precipitation regions. Indeed, the breakeven prices to make spring canola profitable in the high and medium precipitation regions were $33.68/cwt and $146.31/cwt, respectively. These compare to a risk discounted 2008 spring contract price of $21.10/cwt.

No canola is projected in 2008 for the irrigated zone, but the oilseed was somewhat more

[3] The breakeven price is required to make the crop compete successfully with other candidate crops. It does not mean that the crop breaks even with its sole total costs of production.

competitive there. The breakeven price fell short of the risk discounted contract price by only $3.45/cwt ($24.55–$21.10). The low irrigated canola projections square with field reports. One canola grower reports that the number of 160-acre irrigation circles of canola in the Columbia Basin dropped from 25 in 2007 to only 7 in 2008 (J. Schibel, personal communication, 2008). The observed reluctance of farmers to grow canola, despite record prices, would seem to justify the risk discounts previously noted. More importantly, record high prices for traditional crops in this region (alfalfa, wheat, corn) discouraged production of alternative crops (Painter and Young, 2008). Similarly, no sugar beet acres were projected for the irrigated zone in 2008. The breakeven price of sugar beets was $43.32/ton, about $5 more than its projected price. On the other hand, growers were projected to continue producing high-value crops such as potatoes, sweet corn, high quality alfalfa hay, apples and wine grapes (Yoder et al., 2010).

Table 2 also shows a projected 105,000 acres of irrigated grain corn in 2008. This compares to 90,000 reported acres in 2008 (Table 3). The model over-projected grain corn acreage due to the short-lived high spring contract corn price used in the analysis. Our projection for wheat is 14% less than the 2008 reported acres (Table 3). This projection was affected by the unprecedented variability of soft white prices, ranging from $15.12/bu to $4.30/bu during the 2008 calendar year (Union Elevator, 2009). A unique historical acreage constraint for barley, where agronomic considerations often outweigh profit maximization, contributed to the 77% over-projection for this crop. In general, however, the match between projected and actual acreages for most crops in Table 2 is considered reasonable given the variability of 2008 crop prices.

Potential Feedstock Availability: Medium-run (2009-2011) Projections

Table 4 presents projections for the midpoint of the 2009-2011 medium run. Again, canola and sugar beets fail to compete profitably with other Washington crops. Due to the projected cyclical downturn in crop prices in the medium run, breakeven prices for canola and sugar beets exceed projected market prices by a greater margin than in the short run. Again, the price shortfall for canola is smallest in the irrigated region with a breakeven of $27/cwt compared to a risk adjusted expected price of $12.45/cwt. The sugar beet breakeven price of $47.14/ton exceeds the projected price of $38.5/ton. A deteriorating profit outlook reduces projected grain corn production from 105,000 acres in 2008 to only 55,000 acres in the medium run (Table 2 and Table 4). No sugar beets were projected for 2010, as in 2008.

Table 3. Projected and Reported Acres for Washington, short run

Results	Alfalfa hay	Asparagus	All barley	Edible legumes	Canola	Grain corn
	- - - acres - - -					
Projected, 2008	460,998	7,793	336,873	246,141	0	105,000
Reported	425,000	7,000	190,000	208,400	10,449	90,000
Difference	*8%*	*11%*	*77%*	*18%*	--	*17%*
	Hops	Mint	Onions, storage	Orchards & vineyards	Potatoes	Sugar beets
	- - - acres - - -					
Projected, 2008	29,850	27,925	17,704	310,403	134,207	0
Reported	30,595	29,900	20,000	360,250	155,000	1,600
Difference	*-2%*	*-7%*	*-11%*	*-14%*	*-13%*	--
	Sweet corn	Wheat	Summer fallow	CRP		
	- - - acres - - -					
Projected, 2008	68,575	1,951,383	1,139,246	1,538,165		
Reported	78,100	2,260,000	1,295,750	1,538,165		
Difference	*-12%*	*-14%*	*-12%*	*0%*		

Notes: Reported acres are from USDA-NASS, late 2008, except those for canola, orchards and vineyards and summer fallow. Projected orchard and vineyard acres were exogenously set at 2002 Ag. Census levels as 2007 Census results were not available at time of analysis. Reported and projected CRP acres from USDA-Farm Service Agency are identical as there were no CRP bid rounds in the state during 2008.

Table 4. Projected Profitable Biofuel Feedstock Acres and Energy Use by Subregion, Medium Run (2009-2011), Washington State

Region	Canola	Grain corn	Sugar beets	Diesel use (1000 gal)	Dry N use (1000 lbs)	Liquid Nitrogen use (1000 lbs)
	------------acres------------					
Dryland Zones						
High (17-22 in/yr)	0	0	0	4,074	40,821	0
Med (15-17 in/yr)	0	0	0	1,509	23,608	0
Low (12-15 in/yr)	0	0	0	964	15,551	0
Arid (7-12 in/yr)	0	0	0	2,754	44,427	0
Irrigated	0	55,000	0	7,824	74,655	73,954
WA Total	0	55,000	0	17,125	199,062	73,954

Table 5 examines the *ex post* accuracy of the medium term projections at the midpoint year of 2010. Not surprisingly, the deviations of projected from reported increase for 2010 versus 2008. Again our unique historical constraint on barley acreage, unwise in retrospect, causes a large projection error for this crop. Excluding barley for both years, the mean absolute % deviation is 17 for 2010 compared to 11 in 2008 (Tables 3 and 5). The growth in forecast errors over only two years suggests caution regarding longer forecasts.

Of most interest to this study is the accuracy of projections for biofuel feedstock crops. As previously discussed from Table 4, zero production of both canola and sugar beets was again projected for 2010. This projection is reinforced by the fact that NASS no longer reports annual acreage of these two crops in Washington due to low plantings. On the other hand, the model under-projected Washington's grain corn acreage in 2010 by 73%. The discrepancy between the actual and projected corn acreage in the medium run was due to shifting price relationships not captured in our model. With falling crop prices and increasing costs in the medium run model, the deteriorating profit outlook reduced the projected grain corn production from 105,000 acres in 2008 to only 55,000 acres in the medium run. As a small corn producer with volatile production history, percentage errors in Washington's corn acreage are magnified. Because Washington's grain corn is primarily directed to livestock feed, this discrepancy is unlikely to have a large impact on supplies of in-state ethanol feedstocks.

Table 5. Projected and Reported Acres for Washington, medium run

Results	Alfalfa hay	Asparagus	All barley	Edible legumes	Canola	Grain corn
	- - - acres - - -					
Projected, 2010	460,998	7,793	336,873	218,347	0	55,000
Reported	430,000	6,000	85,000	212,700	10,449	205,000
Difference	*7%*	*30%*	*296%*	*3%*	--	*-73%*
	Hops	**Mint**	**Onions, storage**	**Orchards & vineyards**	**Potatoes**	**Sugar beets**
	- - - acres - - -					
Projected, 2010	29,850	27,925	17,704	310,403	134,207	0
Reported	24,115	N/A	22,000	360,250	135,000	1,600
Difference	*24%*	--	*-20%*	*-14%*	*-1%*	--
	Sweet corn	**Wheat**	**Summer fallow**	**CRP**		
	- - - acres - - -					
Projected, 2010	68,575	1,951,474	1,139,336	1,538,165		
Reported	65,900	2,310,000	1,295,750	1,445,228		
Difference	*4%*	*-16%*	*-12%*	*6%*		

Conclusions

Crop feedstock projections in this analysis included consideration of product-product competition within agro-climatically distinct subregions of Washington State. Furthermore, projections of 2008 and 2010 crop acreages included a rare comparison against *ex post* reported acreages, with reasonable results for most crops.

The results of this study indicate the infeasibility of sustaining a large-scale biofuel industry in Washington based on locally produced oilseeds, sugar beets, and grain corn given short run and medium run expected prices and technology. Our conclusions regarding the infeasibility of agricultural crops as feedstock are supported in part by a study in the neighboring state of Oregon (Graf and Koehler, 2000). The projected breakeven prices for Washington farmers to profitably produce these crops exceed current and projected prices. Large ethanol and biodiesel processors in the state import nearly all of their virgin crop feedstocks.

This sobering assessment of one western state's projected shortfall in producing its own crop feedstocks for biofuels has important implications for state-level policymakers and agricultural research directors. In an earlier multi-faceted report to the Washington Legislature (Yoder et al., 2009), the crop feedstock projections received the most critical attention from reviewers. Some politicians, biofuel entrepreneurs, and even agricultural scientists possess strong optimistic beliefs about the state's potential for self sufficiency in crop feedstocks, despite long standing comparative agronomic and economic advantages by other high value crops.

References

Anderson, J.R., J.J. Dillon, and J.B. Hardaker. 1977. *Agricultural Decision Analysis*. Ames, IA: Iowa State University Press.

De La Torre Ugarte, D.G., M.E. Walsh, H. Shapouri and S.P. Slinsky. 2003. "The Economic Impacts of Bioenergy Crop Production on U.S. Agriculture." *Agricultural Economic Report No. 816*. Washington, DC: U.S. Department of Agriculture, Office of the Chief Economist, Office of Energy Policy and New Uses.

Franken, J.R.V. and J.L. Parcell. 2003. "Cash Ethanol Cross-Hedging Opportunities." *Journal of Agricultural and Resource Economics,* 35(3): 509-516.

Graf, A. and T. Koehler. 2000. "Oregon cellulose-ethanol study." Oregon Office of Energy, Salem, OR. Available at http://secureinfo.oregon.gov/ENERGY/RENEW/Biomass/docs/OCES/OCES.PDF?ga=t [Accessed July 2011.]

Jaeger, W.K. 2004. "Conflicts over Water in the Upper Klamath Basin and the Potential Role for Market Based Allocations." *Journal of Agricultural and Resource Economics,* 29(2): 167-184.

Jaeger, W.K. and R. Siegel. 2008. "Economics of Oilseed Crops and Their Biodiesel Potential in Oregon's Willamette Valley." *Special Report 1081*. Oregon State University, Corvallis, OR.

Kenkel, P. and R.B. Holcomb. 2006. "Challenges to Producer Ownership of Ethanol and Biodiesel Production Facilities." *Journal of Agricultural and Applied Economics,* 38(2): 369-375.

Keplinger, K.O. and L.M. Hauck. 2006. “The Economics of Manure Utilization: Model and Application.” *Journal of Agicultural and Resource Economics,* 31(2): 414-440.

Kurkalova, L. C. Kling, and J. Zhao. 2006. “Green Subsidies in Agriculture: Estimating the Adoption Costs of Conservation Tillage from Observed Behavior.” *Canadian Journal of Agricultural Economics,* 54(2): 247-267.

Lambert, D. M., M. Wilcox, A. English and L. Stewart. 2008. “Ethanol Plant Location Determinants and County Comparative Advantage.” *Journal of Agricultural and Applied Economics,* 40(1): 117-135.

Lyons, K. 2008. Biofuel Development in Washington. WSU Extension Energy Program, Washington State University, Pullman, WA. Online. Available at http://www.bioenergy.wa.gov/documents/biofuelactivities.pdf. [Accessed January 2011.]

Mattson, J.W., W.W. Wilson and C. Duchsherer. 2007. “Structure of the Canola and Biodiesel Industries.” *Agribusiness & Applied Economics Report No. 606*. Center of Excellence for Agbiotechnology: Oilseed Development - Department of Agribusiness & Applied Economics, North Dakota State University. Online. Available at http://ageconsearch.umn.edu/bitstream/7644/1/aer606.pdf. [Accessed January 2011.]

National Agricultural Statistics Service (NASS). 1997. *1997 Census of Agriculture Volume 1 National, State and County Data*. Washington, D.C.: U.S. Dept. of Agriculture.

National Agricultural Statistics Service (NASS). 2002. *2002 Census of Agriculture Volume 1, Chapter 2: Washington County Level Data*. Washington, D.C.: U.S. Dept. of Agriculture.

National Agricultural Statistics Service (NASS). 2007. 2007 Census of Agriculture Volume 1, Chapter 2: Washington County Level Data. Washington, D.C.: U.S. Dept. of Agriculture.

National Agricultural Statistics Service (NASS). 2008. 1960-2008 Quick Stats: Agricultural Statistics Data Base. Washington D.C.: U.S. Dept. of Agriculture.

Painter, K.M. and D.L. Young. 2008. “A Rising Price Tide Has Raised All Commodities, but Winter Canola Still Nets Less than Soft White Winter Wheat in the Irrigated Columbia Basin.” Abstract in 2008 Dryland Field Day Abstracts: Highlights of Research Progress. CSS Technical Report 08-1, pp. 20-21. Washington State University, Pullman, WA.

Parcell, J.L. and P. Westhoff. 2006. “Economic Effects of Biofuel Production on States and Rural Communities.” *Journal of Agricultural and Applied Economics*, 38(2): 377-387.

Salassi, M.E. 2007. “The Economic Feasibility of Ethanol Production from Sugar Crops.” Louisiana Agriculture Magazine Winter. Online. Available at http://www.lsuagcenter.com/en/communications/publications/agmag/Archive/2007/Winter/The+Economic+Feasibility+of+Ethanol+Production+from+Sugar+Crops.htm. [Accessed January 2011.]

Sexton, P. 2003. “Potato Facts: Spring Canola, An Oilseed Crop for Potato Growers.” *Extension Bulletin No. 2438*. The University of Maine Cooperative Extension, Orono, ME. Online. Available at http://www.umext.maine.edu/onlinepubs/htmpubs/2438.htm. [Accessed January 2011.]

Stebbins, E.J. 2008. “The Market Potential of Farm-Scale Oilseed Crop Products in Vermont.” A study prepared for the Vermont Sustainable Jobs Fund and the Vermont Biofuels Association. Department of Community Development & Applied Economics, University of Vermont.

Susanto, D., C.P. Rosson and D. Hudson. 2008. “Impacts of Expanded Ethanol Production on Southern Agriculture.” *Journal of Agricultural and Applied Economics,* 40(2): 581-592.

Taylor, M.L., R.M. Adams and S.F. Miller. 1992. “Farm-level Response to Agricultural Effluent Control Strategies: The Case of the Willamette Valley.” *Journal of Agricultural and Applied Economics,* 17(1): 173-185.

Union Elevator. Farm Gate Prices; Union Elevator Graphs, 2009. Online. Available at: http://www.unionelevator.com/index.cfm?show=10&mid=38. [Accessed January 2011.]

U.S. Dept. of Agriculture, Farm Service Agency (USDA-FSA). 2008. *Conservation Programs*. Washington, D.C. Online. Available at: http://www.fsa.usda.gov/FSA/webapp?area=home&subject=copr&topic=crt. [Accessed January 2011.]

__________. 2010. *Conservation Programs*. Washington, D.C. Online. Available at: http://www.fsa.usda.gov/FSA/webapp?area=home&subject=copr&topic=crt. [Accessed January 2011.]

U.S. Dept. of Energy. 2009. “State and Federal Incentives and Laws.” Alternative Fuels and Advanced Vehicles Data Center. Online. Available at http://www.afdc.energy.gov/afdc/laws/. [Accessed January 2011.]

Walsh, M.E., D.G. De La Torre Ugarte, B.C. English, K. Jensen, C. Hellwinckel, R.J. Menard and R.G. Nelson. 2007. “Agricultural Impacts of Biofuels Production.” *Journal of Agicultural and Applied Economics,* 39(2): 365-372.

Williams, J.R., R.V. Llewelyn, D.L. Pendell, A. Schlegel, and T. Dumler. 2010. “A Risk Analysis of Converting CRP Acres to a Wheat-Sorghum-Fallow Rotation.” *Agronomy Journal*, 102(1): 612-622.

Yoder, J. K., D. Young, K. Painter, J. Chen, J. Davenport and S. Galinato. 2009. “Potential for a Sugar Beet Ethanol Industry in Washington State.” Report submitted to the Washington State Department of Agriculture. Online. Available at: http://agr.wa.gov/AboutWSDA/Docs/EthanolfromWASugarBeetsWSUStudyMarch2009.pdf. [Accessed January 2011.]

Yoder, J., C. R. Shumway, P. Wandschneider, D. Young, H. Chouinard, A. Espinola-Arredondo, S. Galinato, C. Frear, D. Holland, E. Jessup, J. LaFrance, K. Lyons, M. McCullough, K. Painter and L. Stodick. 2010. “Biofuel Economics and Policy for Washington State.” *Washington State University Agricultural Research Center Research Bulletin XB1047E.* College of Agricultural, Human, and Natural Resource Sciences, Washington State University, Pullman, Washington. Online. Available at: http://cru.cahe.wsu.edu/CEPublications/XB1047E/XB1047E.pdf. [Accessed January 2011.]

Young, D.L. 2009. “Biofuels: Political/Economic Boondoggle or Energy Salvation for Western States.” *Journal of Agricultural and Resource Economics,* 34(3): 383-39

Wheat Stubble
To Burn or Not to Burn: An Economic Analysis

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Introduction

Wheat producers' options for managing wheat stubble in central Kansas after harvest include using a no-till system that leaves the residue in place, tilling the ground to incorporate some or all residue into the soil, and/or burning the stubble. According to Shroyer, Hargrove and Al-Khatib (2006), wheat producers burn stubble fields before fall planting in order to remove residue for easier planting, while at the same time providing control of some disease organisms and weed species. Burning of wheat stubble also has some disadvantages. These include long-run reduction in soil organic matter, loss of nutrients, hardening of the seedbed and reduced water infiltration capacity. These disadvantages are issues that the farm manager must weigh in the decision to burn or not.

One disadvantage from society's point of view that is receiving increased attention is air quality concerns due to smoke from rangeland and cropland burning. There has been increasing scrutiny of open burning, including agricultural burning, in recent years in some states such as Washington, Oregon, and Idaho. This is also occurring in Midwestern states, notably Kansas. The Kansas Department of Health and Environment (KDHE) has developed the Smoke Management Initiative, a comprehensive plan to address the negative impacts of open burning in the state. While the KDHE recognizes the importance of fire as a range and crop management tool, the goal is for landowners to manage burning in a way that reduces the impact of smoke (KDHE, 2008). Oklahoma is in the process of developing a smoke management plan (Blocksome, 2011).

Cropland comprises 27.5% of the land area burned in Kansas while rangeland is 71.7% according to a study conducted by Sonoma Technology (2004). The cropland burned consists of 76.1% wheat acreage, 13.6% is in hay production and the remaining acreage spread among other crops. This report also indicated that Kansas burned 5,205,313 acres of private rangeland and crop residue while Iowa burned 2,247 acres, Missouri 290,978 acres, Nebraska 215,526 acres, Oklahoma 2,303,359 acres, and Texas 3,798,581 acres.

Heavy rangeland burning occurs primarily in eastern Kansas in the Flint Hills region, where as much as 80% of the total acreage of rangeland is burned in several counties. Crop residue burning in continuous wheat is primarily an issue in central Kansas (KDHE, 2008). Recent information regarding the amount of wheat stubble burning is not available. The EPA (1992) reported that 600,000 acres of agricultural crop residue were burned annually in Kansas, with the primary crop being wheat.

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The current smoke management plan is voluntary and focuses on counties that traditionally burn significant areas of rangeland or pasture. Burning of materials such as land-clearing debris, crop residues, construction debris, firefighter training burns, and yard waste is prohibited during the month of April in 16 Kansas counties in the Flint Hills region (KDHE, 2010). Pasture burning is allowed. However, landowners are encouraged to use a website to obtain information from an environmental model to avoid burning on days when the model shows smoke is likely to impact urban areas. KDHE will address crop residue burning and will work with the agricultural community to reduce the acreage of croplands burned each year and to develop alternatives to burning (KDHE, 2008).

The goal of this analysis is to examine distributions of net returns to land and management to determine which tillage system or burning of winter wheat stubble is preferred under various cost scenarios and levels of risk aversion. There currently is no restriction or penalty for burning crop residue other than the prohibition in the month of April. Wheat stubble would not typically be burned in April, as the wheat is still growing, but would generally be burned soon after wheat harvest in the summer. Crop residue burning may be more restricted in the future. The U.S. Environmental Protection Agency (EPA) will weigh the air quality concerns against the agronomic justifications in deciding whether to limit cropland burning in the future (Shroyer, Hargrove and Al-Khatib, 2006). Although there is potential for future restrictions on burning wheat stubble other than in the month of April, there are currently none. Therefore, we focus on the manager's production risk using net returns of burning or not burning wheat stubble. The following systems were examined in the analysis; burn continuous wheat - BWW, reduced-till continuous wheat - RTWW, and no-till continuous wheat - NTWW.

Data and Methods Overview

Net returns from enterprise budgets were developed for the three systems. Yield and input data for the budgets were collected from the Harvey County Experiment Station in south-central Kansas from 1997 to 2006. Yield characteristics are reported in Table 1. Net returns to land and management were calculated using yields and prices based on actual historical yields, historical monthly price series, and several input cost scenarios.

Table 1. Crop Yield and Price Summary Statistics for South-central Kansas from 1997 to 2006.

	Systems[1]		
Yields	BWW	RTWW	NTWW
Mean (bu./acre)	48.8	46.5	49.7
Std. Dev.	15.4	18.6	13.2
C.V.[2]	0.32	0.40	0.27
Min	29.7	14.3	29.3
Max	74.2	76.9	71.3
Prices	Wheat 2006-2010	Wheat 2001-2005	Glyphosate 2001-2010
Mean	$5.67	$3.30	$41.52
Std. Dev.	$1.60	$0.38	$8.62
C.V.[2]	0.28	0.11	0.21
Minimum	$3.53	$2.94	$25.65
Maximum	$10.60	$4.58	$50.06

[1]RT = Reduced-till, NT = No-till, B = Burn, WW = Continuous Wheat

[2]C.V. = Coefficient of Variation (Std. Dev./Mean)

Study Area

The Harvey County Experiment Field is located near Hesston, Kansas. Harvey County is in the Central Great Plains Winter Wheat and Range Land Resource Region. The area landscape is nearly level to gently sloping (USDA-NRCS, 2006). Annual precipitation for the experiment field area averages 35 inches per year (USDA – NASS, 2008).

Field Operations and Input Costs

Winter wheat was drilled in rows spaced at eight inches. For the reduced tillage system (RTWW), weeds were controlled using a combination of disk, chisel, roller harrow, field cultivator, sweep treader and mulch treader. Herbicides were applied, if needed, in October/November or in April. In the BWW system, the stubble was burned soon after harvest in a manner similar to that used by growers of continuous wheat in the region. Stubble was ignited on the downwind side of each plot, forcing the burn front to move upwind across the plot when wind and moisture conditions were conducive for producing high burn temperatures and thorough combustion of stubble and weed seeds on the soil surface. Remaining weeds were controlled with some of the same tillage operations used in the RTWW system during the summer and fall as needed. A single fall or spring application of herbicide was used in the BWW system, as needed for additional weed control. In the no-till system (NTWW), weed control was accomplished solely with herbicides, which were applied three or four times per year. Costs were calculated using the average annual frequency of the field operations used during the experiment.

All field operation costs, with the exception of burning costs, were 2011 projected custom rates for Kansas (Dhuyvetter, 2011). The cost of burning an acre of wheat stubble was initially set at $7.00/acre, near the midpoint of the range reported by Gee and Biermacher (2007) for rangeland burning of $3.98/acre for a large burn of 833 acres and $9.87/acre for a smaller burn of 172 acres.

Nitrogen and phosphorus sources and rates were the same in each system. Fertilizer costs are for 107 lbs of N from urea before planting in the fall and 72 lbs of di-ammonium phosphate (DAP) at planting.

Glyphosate is the predominant herbicide used in the no-tillage system. It comprises 60% of the total cost of all chemicals used in the NTWW system. The initial analysis used a price of $25.65 per gallon with 4.5 lbs of active ingredient per gallon, the average price reported by USDA (2010) for spring of 2010. Glyphosate prices have been quite variable over the last ten years, ranging from $25.65 to $50.06/gallon in the last 10 years for April prices (USDA, 2010). This variability was considered in further analysis of yield, output price, and glyphosate cost variability.

Simulated Net Returns

Simulation and Econometrics to Analyze Risk (SIMETAR©) developed by Richardson, Schumann and Feldman (2004) was used to simulate yield, output price and glyphosate cost distributions and calculate distributions of net returns to land and management with 2011 costs. Net return distributions were constructed using equation 1.

$$NR_{ik} = Y_{ik} \times EP_i - C_k - G_{ik} - HC_{ik} \tag{1}$$

where

NR_{ik}	=	net return to land & management ($/acre) for observation i for crop production system k,
i	=	observation, i = 1 to 1000,
k	=	crop production system k, k = 1-3,
Y_{ik}	=	simulated yield (bu/acre) for observation i for crop production system k,
EP_i	=	simulated price ($/bu) for observation i,
C_k	=	preharvest production costs ($/acre) in production system k, excluding glyphosate,
G_{ik}	=	simulated glyphosate cost ($/acre) for observation i in production system k, and
HC_{ik}	=	harvest cost ($/acre) for yield observation i in production system k.

Crop yields, wheat prices and glyphosate costs are stochastic, while all other costs are pre-determined. Observations from a simulated correlated multivariate empirical yield distribution derived from actual historical yields was multiplied by observations from a simulated empirical wheat price distribution derived from actual historical prices to calculate gross returns for each production system. Simulated empirical glyphosate costs, other current-year production costs, and harvest costs were then subtracted from gross returns to obtain the net return.

The yield, price and glyphosate cost distributions were generated in the following manner: a cumulative probability distribution function (CDF) using the 10 years of yield data with the probability ranging from 0.0 to 1.0 was formed by ordering the data and assigning a cumulative probability for each observation. Ten years of annual average glyphosate prices were used for the glyphosate cost distribution. The same process was repeated using monthly prices from January 2006 through December 2010. This 60-month empirical price data was used to capture the variability and the general increase in wheat prices after 2005. Irwin and Good (2011) contend that there has been a structural shift upward in prices beginning in 2007.

A monthly price series beginning in 2006 was used because monthly wheat prices in south-central Kansas for 2006 were higher in every corresponding month than for the years 2001 through 2005 with the exception of January 2004 and 2005. Further, in 8 of the 12 months of 2006, the monthly prices were $1.00/bu. or higher than those in 2005. The analysis was also performed using a 2001 to 2005 monthly wheat price distribution. A summary of the price distribution characteristics is reported in Table 1. Wheat prices were not allowed to fall below the 2011 commodity program loan rate. Commodity program payments were not considered because they do not impact the manager’s production method decision.

The following explains the SIMETAR procedure used to generate the yield distributions. The empirical distribution shape is specified by the historical data used because too few observations exist to estimate parameters for another distribution (e.g., normal distribution). A cumulative probability distribution function (CDF) using the 10 years of yield data with probability ranging from 0.0 to 1.0 is constructed by ordering the data and assigning a cumulative probability for each observation (data point). Each observation is assumed to have an equal probability of occurring, so the additional probability for each sequential observation is equivalent. A simulated distribution of 1000 observations is generated by drawing 1000 values from a uniform standard deviate ranging in value from 0.0 to 1.0, similar to using the rand() function in a spreadsheet. The corresponding price or yield assigned to the distribution is from the cumulative probability represented by the uniform standard deviate value. If the value is 0.615, the price drawn would correspond to the 0.615 or 61.5% level of the cumulative distribution. If the value from the uniform standard deviate falls between the cumulative probabilities assigned the original data values, the yield is found by interpolation (Pendell et al., 2007). The same procedure is used to generate the wheat price and glyphosate price distributions. A multivariate distribution has been shown to correlate random yields appropriately, based on their historical correlation (Richardson, Klose and Gray, 2000). The multivariate distribution is a closed-form distribution, which eliminates the possibility of simulated values exceeding values observed in history (Ribera, Hons and Richardson, 2004).

Correlation between yields was included in the simulated net returns. Yield correlations range from 0.74 to 0.94. T-tests and F-tests were used to test for significant differences between the simulated data and the actual data. The statistical tests indicate that there were no statistically significant differences between the mean and variances of the experimental yield data, historical prices and costs and the simulated yields, prices and costs.

Risk Analysis Methods

Stochastic efficiency with respect to a function (SERF) was used to determine the preferred strategy when risk is considered. SERF orders a set of risky alternatives in terms of certainty equivalents (CEs) and risk premiums (RPs) derived from the difference in CEs for a specified risk preference (Hardaker et al., 2004). The CE value is the amount of certain payoff an individual would require to be indifferent between that payoff and the payoff of the risky alternative. The difference between CE values at a specific risk aversion level is known as the risk premium and represents the minimum certain amount that would have to be paid to an individual in order for the individual to be willing to switch from the less risky alternative to the more risky alternative (Hardaker et al., 2004).

The calculation of the CE depends on the utility function specified. A negative exponential utility function used in the SERF analysis conforms to the hypothesis that managers prefer less risk to more given the same expected return. With a negative exponential utility function, an absolute risk aversion coefficient (RAC) defined by Pratt (1964) as, $r_a(w) = -u''(w)/u'(w)$ is used. This ratio of the derivatives of the decision-maker's utility function, u(w), was used to derive the CEs. This functional form assumes managers have constant absolute risk aversion. Under this assumption, managers view a risky strategy for a specific level of risk aversion the same without regard for their level of wealth. Babcock, Choi, and Feinerman (1993) note this functional form is often used to analyze farmers' decisions under risk. For additional justification for this functional form, refer to Schumann et al. (2004), who demonstrate the negative exponential function can be used as a reasonable approximation of risk averting behavior.

The simulated net return data outcomes from each crop production system were sorted into cumulative distribution functions (CDFs) which were used in the SERF analysis. Once the strategies were ranked using the CE results, a utility-weighted risk premium (RP) was calculated (Hardaker et al. 2004). This was accomplished by subtracting the CE of a less preferred strategy from the preferred strategy. The risk premiums and the resulting rankings are reported in the analysis in graphical form for a range of RACs from risk-neutral to extremely risk-averse. Decision-makers with RACs equal to zero are considered risk-neutral while managers with RACs greater than zero exhibit risk-averse behavior. Anderson and Dillon (1992) proposed a relative risk aversion coefficient (RRAC) definition of 0.0 as risk neutral and 4.0 as extremely risk averse. Thus, as suggested by Hardaker et al., 2004 the upper range of absolute RAC for use with a negative exponential utility function was calculated by dividing 4.0 by an appropriate level of wealth. In this case, the measure of wealth is the average per acre net worth of farms in south-central Kansas in 2009 of $507/acre (KFMA, 2010). Ribera, et al. (2004) and Pendell et al. (2007) provide other applications of the methodology.

Results

An initial static analysis was performed without simulation using 2011 costs, average yields and the average monthly price for the period 2006-2010. Net returns were highest for NTWW and were $8.35/acre larger than BWW (Table 2). Total costs were lower for NTWW and gross returns were higher. Under this initial analysis that used average yields and prices, lower glyphosate prices will further increase the NTWW system net return advantage over the BWW system. On the other hand, the glyphosate price would need to rise to $44.28 per gallon or higher for BWW to have equivalent or higher net returns than NTWW. According to USDA (2010), this has happened six times in the last 10 years, though recent prices have been significantly lower.

Table 2. Cost and Net Returns in $/acre.

	Systems[1]		
	BWW	RTWW	NTWW
Planting	$15.56	$15.56	$15.56
Seeds	$19.88	$19.88	$19.88
Fertilizer Application	$4.99	$4.99	$4.99
Fertilizer	$71.05	$71.05	$71.05
Fertilizer (applic.+ inputs)	$76.04	$76.04	$76.04
Burn	$7.00	$0.00	$0.00
Tillage	$34.80	$40.88	$0.00
Chemicals application	$1.28	$2.57	$16.67
Chemicals	$2.55	$5.93	$25.51
Chemicals (applic.+ inputs)	$3.83	$8.50	$42.18
Harvest[2]	$28.61	$28.10	$28.80
Interest	$6.50	$6.61	$6.39
Total cost	$192.21	$195.56	$188.84
Gross Returns	$276.76	$263.69	$281.74
Net Returns[3]	$84.55	$68.12	$92.90

[1] RT = Reduced-till, NT = No-till, B = Burn, WW = Continuous Wheat
[2] Based on 10-year average crop yield, 2006-2010 average wheat price and 2011 costs.
[3] Net Return to Land and Management

The simulated net returns analysis reported in Table 3 shows that NTWW had slightly higher net returns than BWW and a lower standard deviation and coefficient of variation. When the price series from 2001-2005 was used to calculate the average net returns, they were negative (Table 3). In that case, the BWW system was less negative than the other systems.

Table 3. Simulated Net Return Characteristics.

	2006-2010 Wheat Prices			2001-2005 Wheat Prices		
	Systems[1]			Systems[1]		
	BWW	RTWW	NTWW	BWW	RTWW	NTWW
Mean	$84.18	$69.37	$85.40	$-32.50	$-43.84	$-38.86
Std.Dev.	$116.85	$127.09	$108.66	$47.22	$54.87	$40.05
C.V. [2]	1.39	1.83	1.27	NA	NA	NA
Min	-$82.18	-$134.30	-$78.71	$-100.43	$-148.00	$-108.46
Max	$562.63	$585.57	$535.53	$121.41	$143.59	$123.54

[1] RT = Reduced-till, NT = No-till, B = Burn, WW = Continuous Wheat
[2] C.V. = Coefficient of Variation (Std. Dev./Mean)

In the future, some of the wheat straw left on the soil surface in a no-tillage system may have value as a biomass feedstock for alternative energy production. Nelson et al. (2010) estimated that wheat straw harvest would average 0.30 tons/acre in this region. This residue removal level is the largest harvest that would allow the rate of soil erosion from both rainfall and wind to be less than the NRCS-prescribed tolerable soil loss limit, T, and the level of soil organic matter to be unchanged or positive. Further, additional carbon sequestered in the soil with no-tillage may have value if carbon markets for agricultural offsets develop in the future.

Risk Analysis

The SERF analysis under the 2006-2010 monthly wheat price series indicates that NTWW was preferred to BWW at all levels of risk aversion. Although NTWW was preferred to BWW, the risk premiums were always less than $5.00 per acre up to an RAC of 0.0079 (Figure 1). Figure 2 reports the probability of net return for each of the three strategies being less than $0.00/acre, between $0.00 and $100/acre and more than $100/acre. The figure shows NTWW system had a higher probability of returns above $0.00 (78%) and $100/acre (38%) than the other strategies. The RTWW system had the greatest probability of having a net return below $0.00/acre (33%).

Figure 1. Risk premiums relative to burning wheat stubble 2006-2010 crop prices ($/acre).

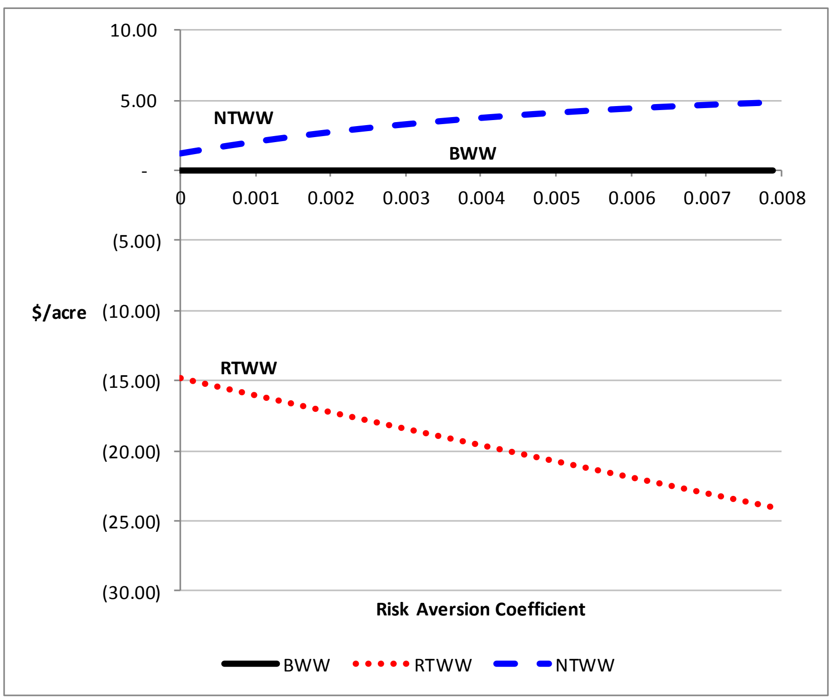
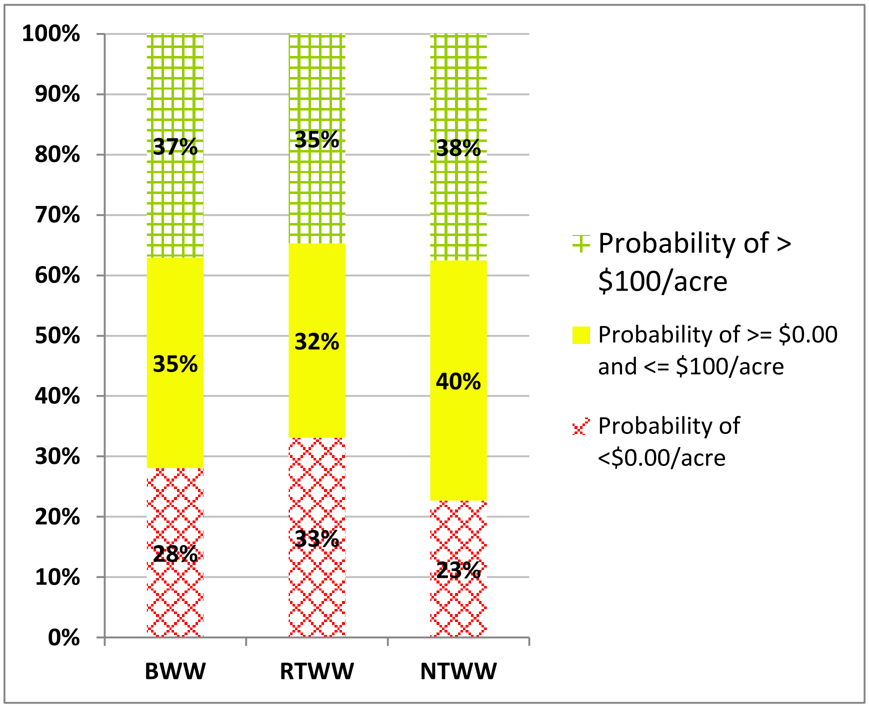


Figure 2. Probability of Net Returns with 2006-2010 Wheat Prices.

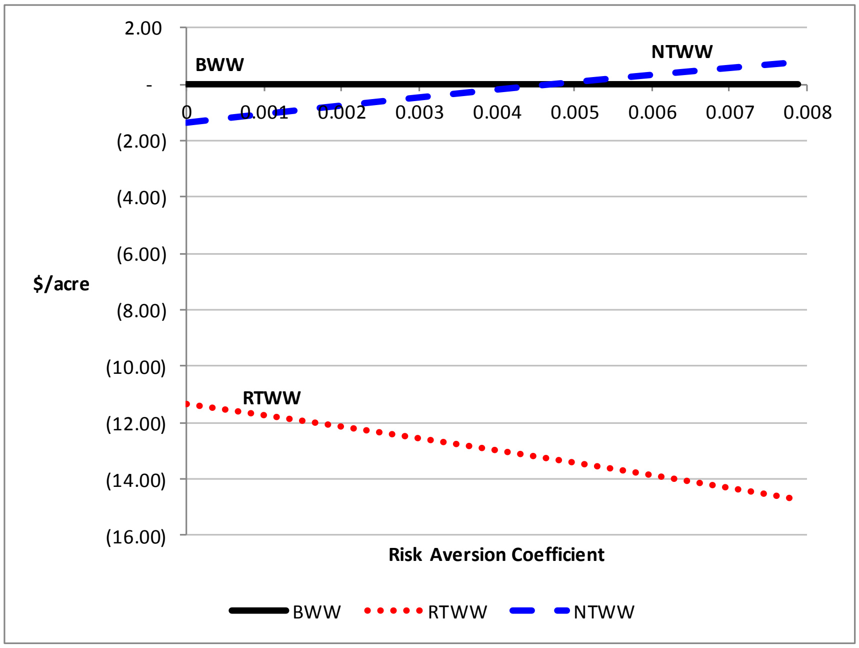


Under the 2001-2005 monthly price series, SERF analysis indicates the BWW strategy was preferred to the NTWW strategy up to an RAC of 0.0047 (Figure 3). According to Anderson and Dillon (1992), this RAC would correspond to moderate risk-averse behavior.[2]

SERF analysis with the 2006 through 2010 wheat price series was performed using the lowest and highest glyphosate price during the last 10 years of $25.65 and $50.06/gallon respectively. NTWW was preferred to BWW at all levels of risk aversion. Under the highest price of glyphosate, NTWW was preferred up to a RAC of 0.004. Under this scenario, the largest risk premium or the incentive needed to use NTWW instead of BWW was $3.16/acre. A price of $50.63/gallon was needed to make the NTWW system less preferred at all levels of risk aversion to BWW.

[2] Similar results were obtained with a power utility function for both wheat price series.

Figure 3. Risk premiums relative to burning wheat stubble 2001-2005 crop prices ($/acre).



Conclusions

The NTWW system generally has higher net returns and less risk than BWW. However, the differences are small, indicating that relatively small incentives to use NT rather than burning may be useful. The BWW and NTWW systems have greater net returns than RTWW. Therefore, in situations where weed problems develop in continuous no-till wheat, the system that burns wheat residue is a better alternative than reduced tillage. Although NTWW looks economically superior to the BWW system, factors including tradition, higher glyphosate costs, and lower commodity prices than currently exist may also contribute to wheat stubble being burned.

The results of this study suggest that minor policy changes that increase the transaction costs for burning crop residue may be all that are needed to reduce crop residue burning. The risk premium that would need to be paid to encourage NTWW instead of BWW is $3.16/acre at its largest under the 2006 through 2010 wheat price series and highest glyphosate price scenario. Possible additional polices include requiring an approved burning plan, charging for a burn permit, and notification of intent to burn, providing a subsidy to use no-tillage, or requiring the land manager to get approval for burning based upon predictions of smoke impact on air quality with an environmental smoke model, each of which would increase the relative cost of burning and make NTWW more economically viable.

References

Anderson J.R. and Dillon J.L. 1992. *Risk Analysis in Dryland Farming Systems*. FAO, Rome.

Babcock, B.A., E.K. Choi, and E. Feinerman. 1993. "Risk and Probability Premiums for CARA Utility Functions." *J. Agric. Res. Econ.* 18: 17-24.

Blocksome, C. 2011. Personal Communication via e-mail to author. July 20, 2011.

Dhuyvetter, K.C. 2011. *Historical Custom Rates in Kansas and Projections for 2011*. Kansas State University Department of Agricultural Economics. January. (Available at: http://www.agmanager.info/farmmgt/machinery/KCD_CustomRates(Jan2011).pdf)

Environmental Protection Agency (EPA). 1992. *"Prescribed Burning Background Document and Technical Information Document for Prescribed Burning Best Available Control Measures*." U.S. EPA Office of Air Quality Planning and Standards Document. EPA-450/2-92-003. September.

Gee, K. and J. Biermacher. 2007. *Prescribed Burning – What is the cost?* The Samuel Roberts Noble Foundation. July. (Available at: http://www.noble.org/ag/research/Articles/PrescribedBurning/index.html)

Hardaker, J.B., J.W. Richardson, G. Lien, and K.D. Schumann. 2004. "Stochastic Efficiency Analysis with Risk Aversion Bounds: A Simplified Approach." *Australian Journal of Agricultural and Resource Economics*. 48:253-70.

Irwin S. and D. Good. 2011. *A New Era in Crop Prices?* (Available at: http://www.farmdocdaily.illinois.edu/004190print.html)

Kansas Dept. of Health and Environment. 2008. *Appendix 12.1 Kansas Smoke Management Initiative*. (Available at: http://www.sharetheair.org/air/notices_kdhe.shtml)

Kansas Dept. of Health and Environment. 2010. *State of Kansas Flint Hills Smoke Management Plan*. (Available at: http://www.kdheks.gov/bar/air-monitor/flinthillsinfo/SMP_v10FINAL.pdf)

Kansas Farm Management Association. 2010. *South Central Profitlink Summary 2009*. Kansas State University Agricultural Experiment Station and Cooperative Extension Service. (Available at: http://www.agmanager.info/kfma/)

Nelson, R., M. Langemeier, J. Williams, C. Rice, S. Staggenborg, P. Pfromm, D. Rogers, D. Wang, and J. Nippert. 2010. *Kansas Biomass Resource Assessment: Assessment and Supply of Select Bio-based Resources*. Research report prepared for the Kansas Bioscience Authority, Olathe, KS. September.

Pendell, D.L., J.R. Williams, S.B. Boyles, C.W. Rice, and R.G. Nelson. 2007. "Soil Carbon Sequestration Strategies with Alternative Tillage and Nitrogen Sources under Risk." *Review of Agricultural Economics.* 29: 247-268.

Pratt, J.W. 1964. "Risk Aversion in the Small and in the Large." *Econometrica.* 32: 122-136.

Ribera, L.A., F.M. Hons, and J.W. Richardson. 2004. "An Economic Comparison between Conventional and No-tillage Farming Systems in Burleson County, Texas." *Agronomy Journal.* 96: 415-424.

Richardson, J.W., K. Schumann, and P. Feldman. 2004. *SIMETAR©. Simulation for Excel to Analyze Risk*. Agricultural and Food Policy Center, Dept. of Agric. Econ., Texas A&M University.

Richardson, J.W., S.L. Klose, and A.W. Gray. 2000. "An Applied Procedure for Estimating and Simulating Multivariate Empirical Probability Distributions in Farm Level Risk Assessment and Policy Analysis." *Journal of Agr. Appl. Econ*. 32: 299-315.

Schumann, K.D., J.W. Richardson, G. Lien, and J.B. Hardaker. 2004. "Stochastic Efficiency Analysis Using Multiple Utility Functions." Paper presented at the AAEA Annual Meeting, Denver, CO. August 1-4.

Shroyer, J., B. Hargrove, and K. Al-Khatib. 2006. *Agronomy e-Update No. 40*. July 12. (Available at: http://www.agronomy.kstate.edu/DesktopModules/ViewDocument.aspx?DocumentID=1538)

Sonoma Technology, Inc. 2004. *Research and Development of Planned Burning Emission Inventories for the Central States Regional Air Planning Association*. July 30.

U.S. Department of Agriculture. 2006. Natural Resources Conservation Service. *Major Land Resource Region Custom Report*. (Available at: http://www.cei.psu.edu/mlra/)

U.S. Department of Agriculture. 2008. National Agricultural Statistics Service. *Kansas County Farm Facts*. Washington DC. (Available at: http://www.nass.usda.gov/Statistics_by_State/Kansas/Publications/Annual_Statistical_Bulletin/County_Farm_Facts/2007/book07.pdf)

U.S. Department of Agriculture. 2010. *National Agricultural Statistics Service Annual Agriculture Price Summaries*. (Available at: http://usda.mannlib.cornell.edu/usda/nass/AgriPric//2010s/2010/AgriPric-04-30-2010.pdf)

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