

Likely Impacts of Rising Energy Prices on Irrigated Agriculture in Western Kansas

by Bill Golden, Terry Kastens, and Kevin Dhuyvetter

Introduction

Escalating fuel price and the associated negative impact on production agriculture have caused a great deal of concern among producers, policy makers, and other stakeholders. Cost of production has increased for all agricultural producers. Due to higher energy use, irrigated producers in western Kansas have been impacted more severely. Dhuyvetter et al. (2005) estimated that, due to an energy price increase relative to 2004 prices, the production cost per irrigated acre increased \$34.15 in 2005 and is expected to increase another \$12.97 in 2006.

With a rise in energy prices, the cost of crop production may increase for several reasons. First, as we have seen, there will be a direct increase in the price of fuel and of fertilizers and pesticides that are manufactured from fossil fuels. Seed costs might also increase due to the increased cost of producing and transporting seed. The cost of other production inputs requiring transportation likely will also increase. A long-run cost increase would be expected due to an increase in the cost of manufacturing, capital, and replacement items. Unfortunately, producers have limited ability, in the short-run, to pass these costs associated with higher fuel prices on to consumers.

The purpose of this research is to provide a normative economic analysis and qualitative discussion of the probable responses of irrigated producers in western Kansas to the increasing energy costs. Additionally, the impact of rising energy prices and producer responses to the Conservation Reserve Enhancement Program will be discussed.

Producers engaged in the production of irrigated crops face a variety of management decisions. These decisions include whether to irrigate or stop irrigating, which irrigation technology to adopt, which crop to produce, and how much water to use in the production process. These questions generally are thought to be approached and solved within a profit maximization framework. In essence, a producer will make the choice that maximizes profit. Normally, these decisions are simultaneously determined, whereby all combinations and their respective profits are compared and a single production plan chosen. An analysis and discussion based on simultaneously determined solutions can be very complex and frequently confusing. As such, this review will focus on the likely impacts that escalating energy costs will have on each decision individually, assuming all other factors are held constant.

Fuel Prices in Perspective

Agricultural producers currently are facing the highest nominal prices they have ever seen. However, we need to recognize that even though fuel prices were over 40% higher in 2005 than in 2004, the proportional increase in the cost of machinery operations will be considerably less because fuel only makes up a small percent of total machinery costs (Dhuyvetter and Kastens, 2005). Additionally, while nominal fuel prices are at record levels, in real (adjusted for inflation) terms, today's price is far lower than those seen in the late 1970s and early 1980s as illustrated in Figure 1 and adjusted to 2004 dollars.

In the face of the 1999 – 2000 increase in fuel price, the United States Department of Agriculture Economic Research Service (USDA-ERS) suggested that producers of energy-intensive crops such as corn would see substantial increases in production costs as

output prices remain relatively unchanged. Since producers cannot pass these costs on to consumers they are forced to absorb these increases, at least in the short run. Thus, even with reduced profits agricultural output was not expected to decline in the short-run (ERS, 2000).

More recently, the USDA forecasted net farm income to be relatively stable from 2006 to 2015, after declining from historically high levels in 2004 and 2005 (these historic highs occurred even with higher than normal fuel prices). Overall, farm cash receipts increase through the projections due to growing domestic use and export demand as well as increases in agricultural commodity prices. Rising production expenses and lower government payments, however, offset gains in cash receipts and other sources of farm income. Stable net farm income assists in asset accumulation and debt management. The debt-to-asset ratio fell moderately in the projections, continuing a generally declining trend since the mid-1980s (USDA, 2006).

The USDA further suggested that the increases in oil prices from late 2002 through 2005 resulted from strong crude oil demand, largely reflecting world economic recovery and rapid manufacturing growth in China and India. Oil prices, in real terms, are projected to fall from 2007 to 2010 as new crude supplies help offset the rise in demand from Asia. In subsequent years, crude oil prices are projected to rise, but only slightly faster than the general inflation rate. Factors expected to constrain long run oil price increases include: new oil discoveries; new technologies for finding, extracting, and refining oil; the ability to switch to non-petroleum fuels; and the ability to increase energy efficiency by substituting non-energy inputs for energy (USDA, 2006).

Fuel Prices and the Decision to Irrigate

In 1982, the High Plains Study Council released the *Summary of Results of the Ogallala Aquifer Regional Study, with Recommendations to the Secretary of Commerce and Congress*. The results of the High Plains Study projected substantial reductions in water use in the state of Kansas (Kansas Water Office, 1982) due to higher energy prices and reduced water availability. As illustrated in Figure 1, this period represented a time of exceptionally high fuel prices. The late 1970s and early 1980s also represented a period of rapid conversion from dryland production to irrigated production. In all likelihood this conversion was due to the relatively high profitability of irrigated production relative to dryland production.

Chanyalew, Featherstone, and Buller (1989) suggest that, as pumping costs increase, either from increased fuel price or increased pumping lift, the number of irrigated acres would decline. Buller and Williams (1990) suggested that if natural gas prices continued to rise relative to commodity prices, irrigated agriculture would become less important in western Kansas. This combination would first generate a shift away from corn to crops that require less water, and eventually a shift away from irrigated agriculture.

Peterson and Bernardo (2003) provided a concise evaluation of water-related literature generated over the previous 20 years. They found that the projections from the 1982 High Plains Study model grossly overestimated the conversion of irrigated land to dryland production. Much of the discrepancy could be attributed to assumptions built into the model concerning yields, prices, and technology. Two of the most critical factors were the over-estimation of energy prices and their impact on profitability.

From an economic perspective, energy prices may become so high that producers are forced to curtail farming operations or shift to dryland production. Figure 2 illustrates the relationship between marginal cost, marginal revenue, and the point at which production may cease. So long as a producer operates where marginal cost equals marginal revenue (MR3) and both are above average total costs, then the producer will generate positive net incomes.¹ If costs are such that the producer operates where marginal cost, average total cost, and marginal revenues (MR2) are equal, then the producer will generate zero net income. In the event that energy prices escalate to the point where marginal cost, marginal revenue (MR3), and average variable costs are equal, then the producer will generate negative net income, but will cover average fixed costs. In the short run, production will continue as long as the revenues generated from production contribute to the payment of fixed overhead (at or below MR3). In the long run, when all costs are considered variable, production must occur where net income is positive (at or above MR2). Therefore, the current relationship between marginal revenue, marginal cost, and average total cost for irrigated producers in western Kansas must be determined.

Figure 3 illustrates the relationship between net farm income and fuel prices for the Kansas agricultural sector. Albright (2002) suggested that irrigated producers in western Kansas typically have higher net farm income than comparable nonirrigated producers. Dhuyvetter et al. (2005) suggested that, while the rise in energy prices has reduced profits, those profits are still positive. The most recent calculations from the Property Valuation Division of the Kansas Department of Revenue indicate that, while

¹ Marginal revenue is the revenue generated from the last unit of output. For example, the marginal revenue for a bushel of corn would be the market price of a bushel of corn. Marginal cost is the cost incurred from producing the last unit of output.

the eight-year average landlord net income (LNI) for irrigated producers in western Kansas is declining, it remains at a profitable level. Taken together, the preceding information suggests that the marginal revenue from irrigated production is currently greater than the average total cost of that production. This would indicate that average revenue from irrigated production, even with higher energy costs, is above both the point of zero net income and the shutdown point illustrated in Figure 3.

The Crop Water Allocator (CWA) is a computer program designed to aid irrigated producers in their management decisions.² CWA uses relationships between crop yields, rainfall, water application, crop prices, and production expenses to generate measures of net returns to management, land, and irrigation equipment. This computer-aid was designed specifically for western Kansas. Figure 4 illustrates the impact that increasing fuel price has on profitability. On average, each dollar increase in the price of natural gas decreases net returns by approximately five dollars per acre. The levels of profit generated by CWA further suggest that current levels of profitability are above the shutdown level depicted in Figure 2.

The evidence suggests that, in the short-run, the current level of fuel prices will not significantly reduce the number of irrigated acres in western Kansas. On average, producer profitability appears to be above the shutdown level. This should not be construed as indicating all producers will continue to irrigate. Albright (2002) provided data to suggest that there is significant variation (approximately \$130 per acre) in the profitability of irrigated producers using the same technology. Irrigated producers that have historically low profitability may face banker- or self-imposed credit constraints that

² Available at www.oznet.ksu.edu/mil.

limit their ability to produce irrigated crops in the immediate future. Higher energy costs also could result in marginally profitable land being taken out of farming.

In the long-run, current average profits combined with a projected slowing of fuel price increases would suggest that profitability will stay above the shutdown level. Some reduction in irrigated acreage may occur as the low profit producers face difficulty in replacing irrigation equipment as it wears out. However, it should be pointed out that past forecasts of reductions in total irrigated acreage resulting from the inability of irrigators to replace worn-out systems did not occur as projected by some economists (Peterson and Bernardo, 2003).

Fuel Prices and the Crop Choice Decision

The High Plains Study Council (1982), Buller (1988), Chanyalew, Featherstone, and Buller (1989), and Buller and Williams (1990) suggested that as the marginal cost of water increases producers will respond by shifting to crops with lower water requirements. Wu, Bernardo, and Mapp (1996) developed an econometric model to explain crop mix variation. Acreage elasticities suggested that crop mix response to crop price was inelastic, meaning that crop mix is relatively unresponsive to crop price. Additionally, saturated thickness had little impact on crop choice within a localized area. Across counties it was observed that areas with larger saturated thickness tended to allocate more acreage to corn. These long run elasticities suggest that producers react less to these variables than might be indicated by a linear programming model based on the assumption of short-term profit maximization. Peterson and Bernardo (2003) suggested that during the past two decades most economic models did not predict the increase in acres of high water use crops.

From an economic perspective, a producer will allocate water to its most profitable use. In essence, a producer will choose the crop that generates the most revenue, given his farm's water availability. This would suggest a crop selection that has the largest value marginal product of water, assuming water availability is sufficient to meet the crop's requirements. Table 1 provides information on the yield response to water, the value marginal product of water, and the marginal cost of water for a typical producer in western Kansas. The implication of these data is that corn production, even at today's high fuel price, generates the most income for an acre-inch of water applied. While not reported in this research, Kansas State University crop budgets also suggest that irrigated corn is more profitable than other crops.³ Additionally, simulation modeling with CWA, as reported in Figure 5, supports these findings.

Crop acreage trends, illustrated in Figure 6, further suggest that corn is the crop of choice in western Kansas. However, when comparing Figure 1 and Figure 6, it is apparent that the increase in fuel prices starting in 2000 may have been accompanied by a shift in irrigated acres from corn to grain sorghum. Additional research is required to determine: if this was a localized response or distributed uniformly across western Kansas; if the shift was a result of a relative output price difference between corn and grain sorghum; or if the shift was the result of declining water well capacity.

The crop response data (Table 1) represent the crop yield increase resulting from the first water applied. Economists, engineers, and producers are aware that the yield response to irrigation water is curvilinear and diminishes as additional water is applied. This implies that the last portion of water applied to corn might yield greater profits if it were allocated to another crop. With this in mind, a purely profit maximizing producer

³ Alfalfa has not been included in this discussion due to the lack of crop response data.

might allocate acreage under an irrigation system to multiple crops.⁴ Simulation modeling with CWA suggests that, as pumping capacities are limited or as the price of fuel increases, profits will be enhanced by growing multiple crops under a single irrigation system.

Golden (2005) suggests that asset specificity, producer crop preferences, landlord preferences, agronomic factors, crop rotational considerations, government programs, risk preferences, planning horizons, and management time are implicit constraints that may limit a producer's ability to operate as a profit maximizer in the short run and grow multiple crops under a single irrigation system. As reported by Golden and Peterson (2006) and depicted in Figure 7, multi-crop management schemes are limited in acceptance and do not appear to be impacted by energy prices.

The evidence suggests that, in the short-run, the current level of fuel prices will not significantly affect crop choice. Dhuyvetter et al. (2005) suggest that these price trends do not appear sufficient to alter a producer's acreage decision independent of other factors. This should not be construed as indicating all producers will maintain their current cropping schemes. Planting decisions ultimately will depend on relative price expectations, risk preferences, input availability, and costs at planting time. Also, as previously discussed, there is significant variation in the profitability of any irrigated crop between producers using the same technology. Irrigated producers who have historically low profitability may face banker- or self-imposed credit constraints that require they produce a crop with a lower cost structure. Additionally, we should be aware that some benefits to growing crops may not be fully reflected in a single year's net returns, such as agronomic benefits of crop rotations. Many factors influence a farmer's decision of what

⁴ A producer might also do this to spread the timing of water use across the irrigation season.

to plant from year to year. Short-term profit maximization is seldom the only criterion considered.

In the long-run, crop choice will be a function of the relative profitability among crops, which will depend on the available water, relative yield response to water, marginal values, and marginal costs. It should be pointed out that past forecasts of long-run crop mix change due to declining water availability and rising fuel costs did not occur as projected by some economists (Peterson and Bernardo, 2003)

Fuel Prices and the Water Allocation Decision

Once the producer has made the choice of what crop to produce he is faced with the choice of how much irrigation water to use in the production process. Production theory implies that a profit maximizing producer will use water to the point where the value marginal product of water, which is the additional revenue generated by the use of one more unit of water, is equal to the marginal cost of the additional unit of water. As a result, the demand curve for irrigation water is downward sloping, indicating that, as the price of water (which is positively correlated with fuel price) increases, the amount of irrigation water used in crop production decreases.

Extensive economic research has focused on the demand for irrigation water. Allen and Gisser (1984); Nieswiadomy (1985); Kim, Hanchar, and Moore (1987); Ogg and Gollehon (1989); Moore and Negri (1992); Moore, Gollehon, and Carey (1994); Schaible (1997); Peterson and Ding (2005); and Golden (2005) have all estimated the demand for irrigation water. The research consensus is that the price elasticity of demand is highly inelastic, meaning that the quantity demanded is relatively unresponsive to

price. The implication is that, once the crop choice is made, producers apply water based on a fixed land water ratio.

For illustrative purposes, the demand curve for irrigation water in corn production for western Kansas, as calculated by Golden (2005), is reported in Figure 8. This demand curve suggests that, in the current fuel price range, demand is very inelastic and unresponsive to price change. However, in the current range of fuel prices, irrigated producers would maximize profits by reducing water use. Past research suggests they will not reduce water use. Several researchers have indicated that fixed well water yields and the large fixed investment in irrigation equipment contribute to water consumption being especially unresponsive to price signals. Golden (2005) suggested that it is simply a response to risk aversion. Table 1 shows that the cost of pumping an additional inch of water is approximately \$4.28, while Kansas State University crop budgets suggest that the annual cost of an irrigated acre of corn in Southwest Kansas is in excess of \$700.⁵ These figures suggest that the downside risk of diminishing crop yield due to inadequate irrigation may be substantially higher than the cost associated with pumping an additional inch of water.

The evidence suggests that, in the short-run and given an existing technology and crop choice, the current level of fuel prices probably will not significantly impact the quantity of water consumed. Golden and Peterson (2006) reported that, for all crops and technological combinations, rain-adjusted water use per acre in western Kansas had a downward trend and was thus declining over time. These trends may be the result of producers ‘learning by doing’ and the recent trends in fuel price. In the long-run, escalating fuel prices will in all likelihood increase the downward slope of these trends.

⁵ Available at <http://www.oznet.ksu.edu/library/agec2/mf585.pdf>.

Fuel Prices and Technology Adoption

There is significant research focusing on irrigation technology adoption (Ellis, Lacewell, and Reneau (1985); Earls and Bernardo (1992); Dhuyvetter, Lamm, and Rogers (1994); Wu, Mapp, and Bernardo (1994); Williams et al. (1996); Delano and Williams (1997); DeLano, Williams, and O'Brien (1997); O'Brien et al. (1998); Green and Sunding (1997); Lamm and Trooien (2000); O'Brien et al. (2000); Peterson and Ding (2005); Golden (2005); and Golden and Peterson (2006)). These studies have analyzed technology adoption from various perspectives. Research suggests that irrigation technology is adopted as a result of an immediate crisis that threatens survival, the opportunity for better production, and the opportunity to reduce risks. Adoption rates are a function of producer age, education, management capacity, farm size and land quality, availability of financing and financial condition, cost of technology, accessibility of information, water source and availability, relative crop prices, availability of irrigation inputs, government programs, environmental regulation, farming tradition, and risk preferences.

Adopting more efficient irrigation technologies and farming practices will be a likely response to the increasing price of fuel and marginal cost of water. Conversion to more efficient irrigation technology is a common response from Kansas irrigated producers as illustrated in Figure 9. The adoption of irrigation technology has reduced the cost of production and enhanced producer profitability. However, it may also have contributed to producers shifting to water intensive crops such as corn and expanding acreage. As such, more efficient irrigation technology may not have led to reduced water consumption (Golden and Peterson (2006)).

In all likelihood the current trends of converting from flood irrigation technology to center pivot technology and/or adding low-pressure drop technology to existing center pivots will continue. Lamm and Trooien (2000) suggest that there will be significant fuel and water savings realized by converting to subsurface drip irrigation technology. Schlegel, Stone, and Dumler (2005) report significant water savings and, by inference, fuel savings, with the adoption of limited irrigation technology.

Klocke (2004) suggests that computer-aid technologies, such as the CWA and the Kansas Water Budget Model, have the ability to reduce water consumption and enhance producer profitability. Producers might also adopt more energy efficient pumping units. CWA suggests that conversion from natural gas to electricity can reduce pumping costs. The Associated Press reports that many western Kansas farmers who can switch from natural gas to electricity to power irrigation pumps are doing so.⁶ Producers will also consider new production technologies that are not exclusive to irrigation. Harman et al. (1985) indicate that returns to land, management, and risk are substantially higher using no-till technology. Kastens and Dhuyvetter (2006) suggest that precision technologies have the potential of reducing both fuel and fertilizer cost in irrigated production.⁷

Fuel Price and Land Rent

Several economic theories have been used to explain the monetary level of land rent. The 'contribution-based equitable rent' concept suggests that landowners and tenants should acquire approximately the same rate of return on their investment (Dhuyvetter and Kastens, 2001). Based on this principle, as input prices increase, then the tenant's rate of return decreases. To maintain equitable contributions the land rent

⁶Available at <http://www.kansas.com/mld/kansas/news/state/13257576.htm>.

⁷Available at [http://www.agmanager.info/dhuyvetter/presentations/KSUPACConf\(Jan2006\).pdf](http://www.agmanager.info/dhuyvetter/presentations/KSUPACConf(Jan2006).pdf).

would need to decline. The theory that land rent represents the ‘residual return to land’, suggests that land rent represents the net profits generated from a farming operation after all variable and fixed expenses have been paid, and the renter has received a fair wage (Johnson et al., 2000). Applying this theory also suggests that, as input prices increase, the landowner should expect a reduced residual return and thus a lower rent.

A likely impact of escalating fuel prices is a reduction in the land rent of irrigated cropland in western Kansas. Assuming producers do not make major production changes, Dhuyvetter et al. (2005) suggest that land rents would need to decrease by \$47.13 for irrigated acres from 2004 to 2006 in order to fully offset the impact of higher energy costs alone. In the short-run, a producer’s ability to renegotiate rental rates is limited, and as a result near-term profits will suffer⁸. Dhuyvetter and Kastens (2005) suggest that, in the long run, higher production costs will lead to either higher prices for commodities or a lowering of land costs.

The Impact of Fuel Price on CREP

The CREP is a voluntary and incentive based program that allows owners of irrigated land in western Kansas to retire their irrigated acreage and receive program payments for that acreage. Current provisions suggest that the Farm Service Agency (FSA) will set rental payments based on historic land rent values for irrigated cropland in the target area. Golden (2005) reviewed past voluntary, land-retirement schemes. He suggests that market participants have an expectation of receiving, at a minimum, the fair market value of their asset and implies that older and/or retired landowners will be the most likely to participate.

⁸ Where possible tenants will renegotiate land rent to reflect current fuel prices in the short-run.

A landowner will choose to participate in the CREP, all other factors held constant, if the net present value of the expected future income stream derived from the CREP program is greater than the expected net present value of the future income stream derived from crop production or land rent. Given that 1) irrigated cropland rent may decrease, 2) the most likely participants will be concerned with rental income as opposed to production income, and 3) FSA sets rental rates on historic values, then the CREP expected payments may be greater than expected land rent. Thus, we would expect the demand for CREP contracts to increase.

Conclusion

Since 2004, escalating fuel prices have increased costs in excess of \$110 million dollars for irrigated production in western Kansas.⁹ While a portion of this impact has been mitigated by higher crop prices and yields, it has most certainly decreased profits and has had a negative economic impact on irrigated producers and rural communities. Producers are unable to pass these costs on to consumers, and are economically constrained from changing irrigated acreage, crop choice, or water usage patterns in the short-run. As a result, producers are economically forced to continue with current management schemes and accept lower profits. In general, irrigated acreage, crop choice, and water usage patterns will change for only producers on marginal land or those with credit constraints. In this environment, CREP may represent an expected positive net present value alternative that would enhance participation.

In the long-run, if energy costs remain high, producers will make management decisions to lower this cost (e.g., negotiate lower rents, adopt technology and farming

⁹ Costs based on Dhuyvetter and Kastens (2005), and irrigated acreage in Crop Reporting Districts 10, 20 and 30.

systems that reduce fuel consumption). Irrigated acreage trends, crop choice trends, and water use trends will remain in place unless market forces act in such a manner to alter the current relationships between marginal revenues, marginal costs, and average total costs.

References

- Albright, M. "Characteristics of Profitable Farms: An Analysis of Kansas Farm Management Association Enterprise Data." 2002. February 2006.
<http://www.agmanager.info/crops/prodecon/production/Albright%20R&P%202002.PDF>
- Allen, R.C. and M. Gisser. "Competition Versus Optimal Control in Groundwater Pumping When Demand is Nonlinear." *Water Resource Research*. 1984, 20(7): 752-756.
- Buller, O.H. and J.R. Williams. 1990. "Effects of Energy and Commodity Prices on Irrigation in the High Plains." Report of Progress No. 611 Kansas Agricultural Experiment Station, Kansas State University, Manhattan, KS.
- Chanyalew, D., A.M. Featherstone, and O.H. Buller. "Groundwater Allocation in Irrigated Crop Production." *Journal of Production Agriculture*. 1989, 2: 37-41.
- DeLano, D.R. and J.R. Williams. "Cost-Return Projections for Corn, Grain Sorghum, and Wheat Under Alternative Irrigation Systems." Staff Paper 97-3, Department of Agricultural Economics, Kansas State University, April 1997.
- DeLano, D.R., J.R. Williams, and D.M. O'Brien. "An Economic Analyses of Modifications for Flood and Center-Pivot Irrigation Systems." Staff Paper 97-6, Department of Agricultural Economics, Kansas State University, July 1997.
- Dhuyvetter, K.C., F.R. Lamm, and D.H. Rogers. "Subsurface Drip Irrigation for Field Corn: An Economic Analyses." Irrigation Management Series, Kansas State University Research and Extension Service, Publication L-909, Manhattan, Kansas, 1994.
- Dhuyvetter, K., S. Funk, T. Kastens, and M. Langemeier. "An Assessment of the State of the Agricultural Economy due to Increased Energy Prices." December 2005.
<http://www.agmanager.info/farmmgmt/income/papers/EnergyPriceUpdate.pdf>
- Dhuyvetter, K., and T. Kastens. "Impact or Rising Diesel Prices on Machinery and Whole-Farm Costs: An Update." September 2005.
<http://www.agmanager.info/farmmgmt/machinery/ImpactDieselPrices090705.pdf>
- Dhuyvetter, K., and T. Kastens. "Determining Equitable Crop Share or Cash Rental Arrangements Using the KSU-Lease Spreadsheet." September 2005.
<http://www.agecon.ksu.edu/kdhuyvetter/pdf%20files/Land%20and%20lease/KSU-Lease.PDF>
- Earls, R.C. and D.J. Bernardo. "An Economic Analyses of Irrigation Alternatives in the Central High Plains." Journal Article No. J-6154 of the Oklahoma Agricultural Experiment Station. *Journal of the American Society of Farm and Rural Appraisers*. 1992, 56: 18-26.

- Economic Research Service. "Gush in Oil Prices to Exert Modest Impact on U.S. Economy." *Agriculture Outlook*. May 2000.
- Ellis, J.R., R.D. Lacewell, and D.R. Reneau. "Estimated Economic Impacts From Adoption of Water-Related Agricultural Technology." *Western Journal of Agricultural Economics*. 1985, 10: 307-321.
- Golden, B. 2005. "The Value of Water Rights in the Rattlesnake Creek Sub-Basin: A Spatial-Hedonic Analysis." PhD Dissertation; Kansas State University, Department of Agricultural Economics.
- Golden, B. and Peterson J. 2006. "Evaluation of Water Conservation from More Efficient Irrigation Systems." Unpublished Report prepared for the Kansas Water Office.
- Green, G. P., and D. L. Sunding. "Land Allocation, Soil Quality, and the Demand for Irrigation Technology." *Journal of Agricultural and Resource Economics*. 1997. 22(2):367-375
- Harman, W, L., D. C. Hardin, A. F. Wiese, P. W. Unger, and J. T. Musick. "No-Till Technology: Impacts on Farm Income, Energy Use and Groundwater Depletion in the Plains." *Western Journal of Agricultural Economics*. 1985. 10(1): 134-146
- Harris, T.R. and H.P. Mapp. "A Stochastic Dominance Comparison of Water Conserving Irrigation Strategies." *American Journal of Agricultural Economics*. 1986, 68: 298-305.
- High Plains Study Council. 1982. "Summary of Results of the Ogallala Aquifer Regional Study, with Recommendations to the Secretary of Commerce and Congress." Washington, DC: Economic Development Administration.
- Hornbaker, R.H., and H.P. Mapp. "A Dynamic Analysis of Water Savings from Advanced Irrigation Technologies." *Western Journal of Agricultural Economics*. 1988, 13: 307-315.
- Johnson, B. B., R. A. Selley, H. Doug Jose, and J. D. Cole. 2000. "Cash Leasing of Cropland in Nebraska." February, 2006.
<http://www.ianrpubs.unl.edu/epublic/live/g1387/build/g1387.pdf>
- Kansas Water Office. 1982a. "Ogallala Aquifer Study in Kansas: Summary." Topeka, KS: Kansas Water Office.
- Klocke, N.L., G. A. Clark, S. Briggeman, L.R. Stone, and T.J. Dumler. 2004. Crop Water Allocator for Limited Irrigation. In Proc. High Plains Groundwater Conference. Lubbock, TX. Dec. 7-9, 2004. 196-206. February 2006.
<http://water.usgs.gov/wrri/04grants/Progress%20Completion%20Reports/2003KS31B.pdf>

Kim, C.S., J.J. Hanchar, and M.R. Moore. "A New Dynamic Model of Groundwater Mining." 1987. Resources and Technology Division, Economic Research Service, US Department of Agriculture, Technical Bulletin Number 1734.

Lamm, F.R. and T.P. Trooien. "SDI for Corn Production: A Ten Year Summary of Research." 2000. Kansas State University Research and Extension. March 10, 2004. <http://www.oznet.ksu.edu/sdi/Reports/2000/SDICornProd10.htm>

Mapp, H. P. "Irrigated Agriculture on the High Plains: An Uncertain Future." *Western Journal of Agricultural Economics*,. 1988. 13(2): 339-347

Moore, M.R. and D.H. Negri "A Multi-Crop Production Model of Irrigated Agriculture, Applied to Water Allocation Policy of the Bureau of Reclamation." *Journal of Agricultural and Resource Economics*. 1992, 17(1):29-43.

Moore, M.R., N.R. Gollehon, and M.B. Carey. "Multi-Crop Production Decisions in Western agriculture: The Role of Water Price." *American Journal of Agricultural Economics*. 1994a. 76: 859-874.

Nieswiadomy, M. "The Demand for Irrigation Water in the High Plains of Texas, 1957-80." *American Journal of Agricultural Economics*. 1985. 67(3): 619-626.

O'Brien, D.M., D.H. Rogers, F.R. Lamb, and G.A. Clark. "An Economic Comparison of Subsurface Drip and Center Pivot Sprinkler Irrigation Systems." *Applied Engineering in Agriculture*. 1998, 14: 391-398.

O'Brien, D.M., F.R. Lamb, L.R. Stone, and D.H. Rogers. "The Economics of Converting from Surface to Sprinkler Irrigation for Various Pumping Capacities." Irrigation Management Services, Kansas State University Research and Extension Services, Publication MF-2471, Manhattan, Kansas, November 2000.

Ogg, C.W. and N.R. Gollehon. "Western Irrigation Response to Pumping Cost: A Water Demand Analysis Using Climatic Regions." *Water Resource Research*. 1989, 25: 767-773.

Peterson, J. and D. Bernardo. 2003. "A Review of Economic Analyses of Water Policies and Irrigation Issues in the High Plains: 1980 - 2000." Research Report No. 36. Kansas Agricultural Experiment Station, Kansas State University, Manhattan, KS.

Peterson, J.M. and Y. Ding. "Economic Adjustments to Groundwater Depletion in the High Plains: Do Water-Saving Irrigation Systems Save Water?" Unpublished manuscript, 2005.

Schaible, G.D. "Water Conservation Policy Analysis: An Interregional, Multi-Output, Primal-Dual Optimization Approach." *American Journal of Agricultural Economics*. 1997, 79: 163-177.

Schlegel, A., L. Stone, and T. Dumler. “ Limited Irrigation of Four Summer Crops in Western Kansas.” Kansas State University, Agricultural Experiment Station and Cooperative Extension Service. Report of Progress 945. 2005.

USDA. “ USDA Agricultural Baseline Projections to 2015.” February 2006.
<http://www.ers.usda.gov/publications/oce061/oce20061.pdf>

Williams, J.R., R.V. Llewelyn, M.S. Reed, F.R. Lamb, and D.R. Delano. “Economic Analyses of Alternative Irrigation Systems for Continuous Corn and Grain Sorghum in Western Kansas.” Report of Progress No. 766, Agricultural Experiment Station, Kansas State University, July 1996.

Wu, J.J., H.P. Mapp and D.J. Bernardo. “A Dynamic Analyses of the Impact of Water Quality Policies on Irrigation Investment and Crop Choice Decisions.” *Journal of Agricultural and Applied Economics*. 1994, 26: 506-524.

Wu, J.J., D.J. Bernardo, and H.P. Mapp. “Integration Economic and Physical Models for Analyzing Water Quality Impacts of Agricultural Policies in the High Plains.” *Review of Agricultural Economics*. 1996, 18: 353-372.

Tables

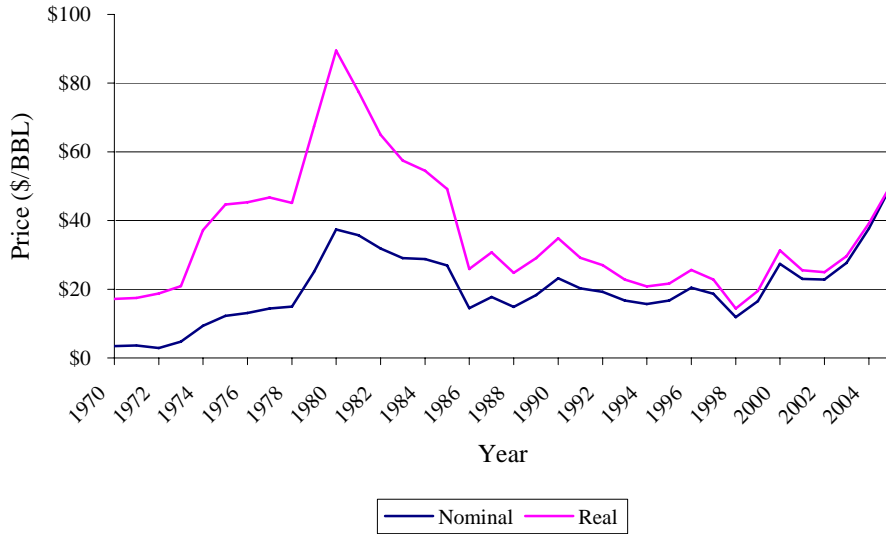
Table 1. Yield Response to Water, Marginal Value, and Marginal Cost in Western Kansas

| Crop | Yield Increase per Inch of Water | Crop Price | Value of the Marginal Product | Marginal Cost of Water |
|------------|----------------------------------|------------|-------------------------------|------------------------|
| Corn | 13.3 | \$2.51 | \$33.38 | \$4.28 |
| Soybeans | 4.5 | \$6.10 | \$27.45 | \$4.28 |
| Sorghum | 9.4 | \$2.19 | \$20.59 | \$4.28 |
| Sunflowers | 6 | \$2.92 | \$17.52 | \$4.28 |
| Wheat | 4.6 | \$3.37 | \$15.50 | \$4.28 |

Yield increase is based on a discussion with Loyd Stone and is measured in bushel per inch of net irrigation water. Crop prices are in dollars per bushel and were obtained from KSU extension at <http://www.oznet.ksu.edu/library/agec2/mf1013.pdf>. The marginal cost is in dollars per inch of net irrigation water and obtained from the Crop Water Calculator bases on a natural gas price of \$8.10 per million cubic feet, a static water level of 120 feet, and a pivot pressure requirement of 35 psi.

Figures

Figure 1. Average Annual Crude Oil Price



Source: United States Department of Energy at www.economicmagic.com

Figure 2. Relationship Between Marginal Cost (MC) and Marginal Revenue (MR)

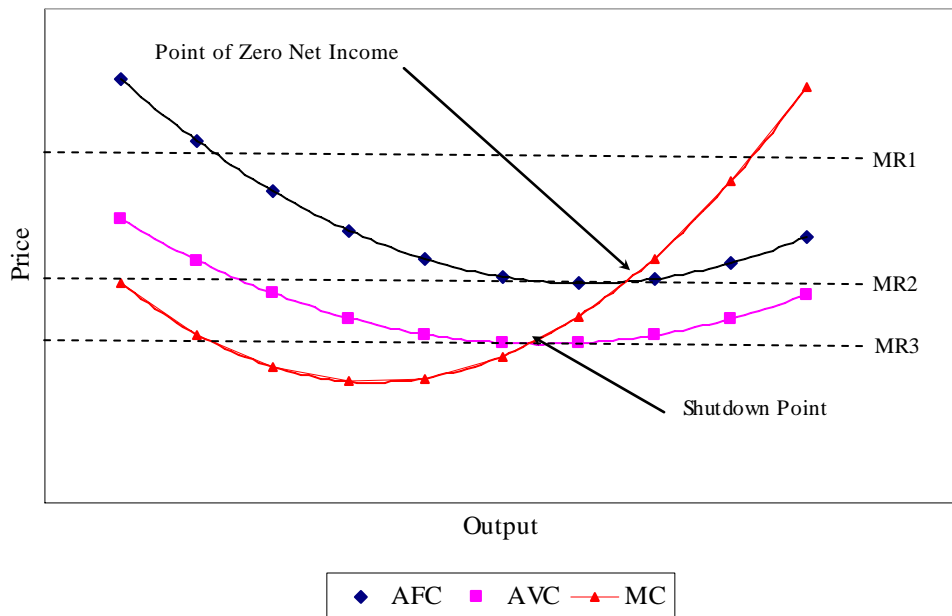
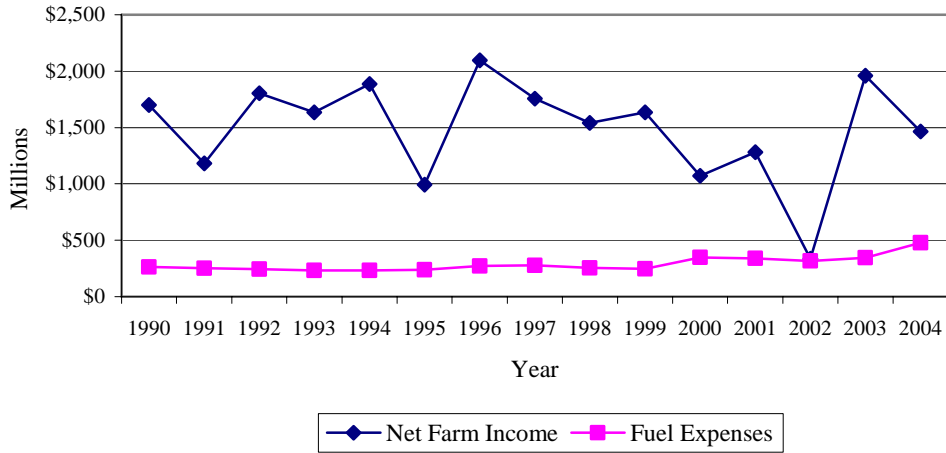
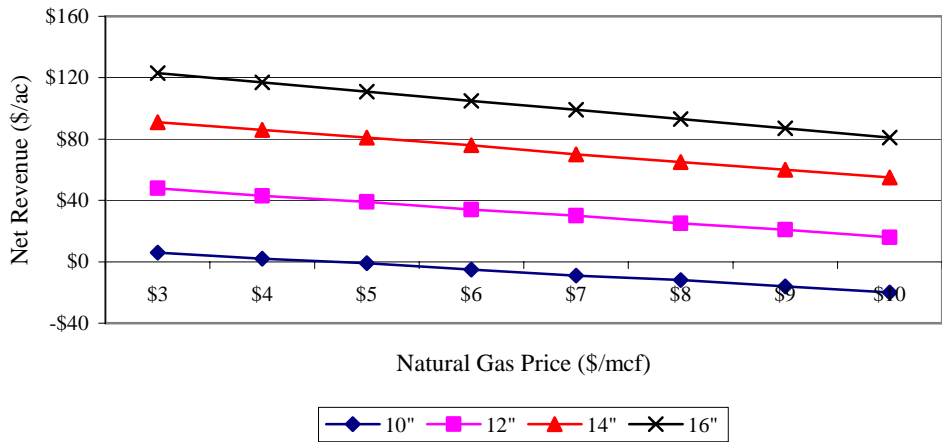


Figure 3. Kansas Agricultural sector Net Farm Income and Fuel Expense



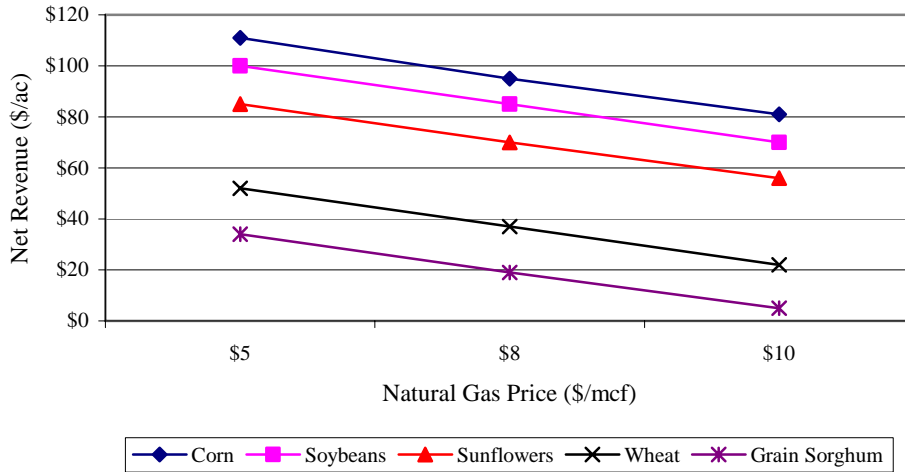
Source: USDA-ERS at <http://www.ers.usda.gov/Data/FarmIncome/Finfidmu.htm>.

Figure 4. Impacts of Energy Prices on Net Returns to Management, Land and Irrigation Equipment for Corn Production; Calculated at Various Water Application Amounts



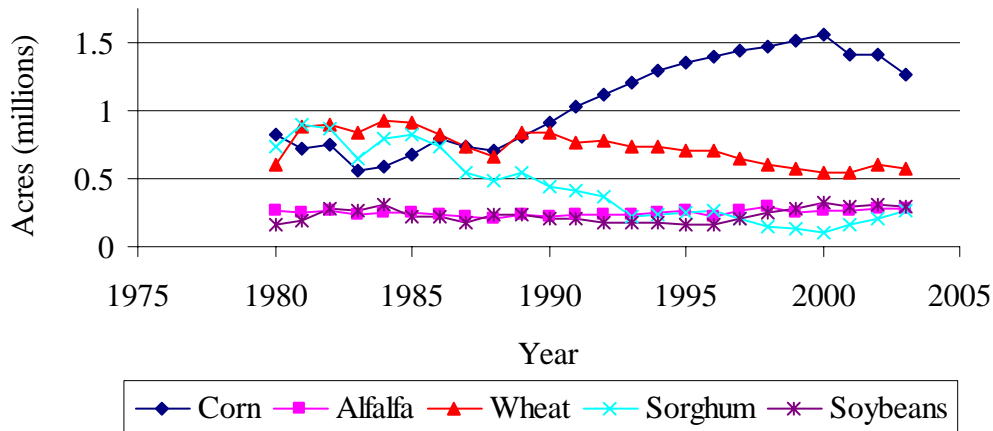
Based on CWA output at 11" of rainfall and a corn price of \$2.56 per bushel. All other variables were set to default values.

Figure 5. The Impact of Fuel Price on Crop Net Revenue.



Based on CWA output at 11" of rainfall and a corn price of \$2.56 per bushel. All other variables were set to default values.

Figure 6. Trends in the Irrigated Crop Mix in Western Kansas.



Source: Kansas Agricultural Statistic Service. Includes Crop Reporting Districts NW10, WC20, SW30, C50, and WC60.

Figure 7 Proportion of Producers Growing Multiple Crops on a Single PDIV

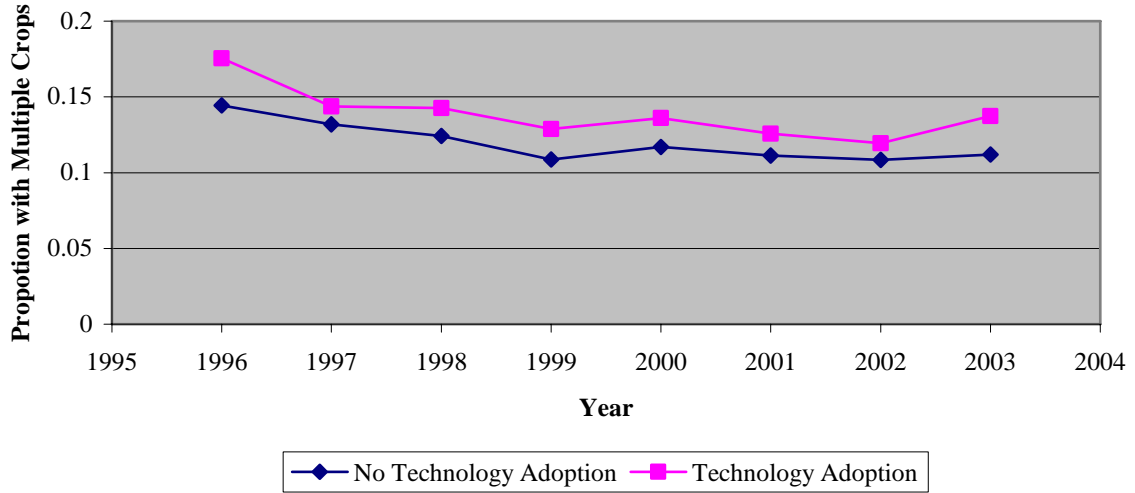
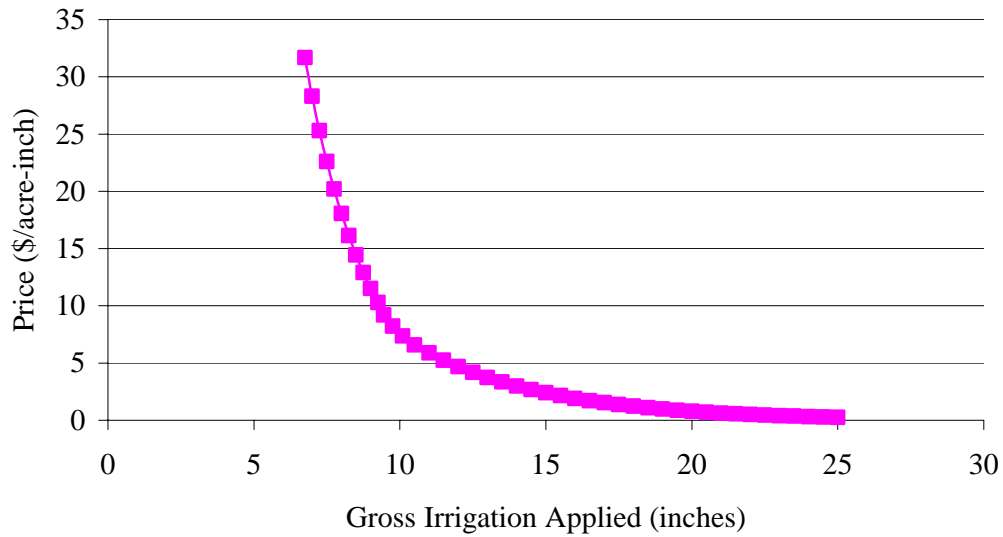


Figure 8 The Demand for Water for Center Pivot Irrigated Corn in GMD#3.



Assumes the price of corn is \$2.50 per bushel.

Figure 8 Irrigation Technology Adoption in Western Kansas.

