Breakeven Evaluation of Irrigation System in Tennessee

Katryn Pasaribu[1], Lixia He[1], Christopher N. Boyer[1], Dayton M. Lambert[1], Burton C. English[1], Christopher D. Clark[1], Brain Lieb[2], Brian Waldron[3]

1. Department of Agricultural & Resource Economics, University of Tennessee, Knoxville
2. Department of Biosystems Engineering & Soil Science, University of Tennessee, Knoxville
3. Department of Civil Engineering-Water Resources, University of Memphis

Selected Paper prepared for presentation at the Southern Agricultural Economics Association's 2016 Annual Meeting, San Antonio, Texas, February 6-9, 2016

Breakeven Evaluation of Irrigation System in Tennessee

Abstract

Conflict over water use in the southeastern US is increasingly common as communities and industries fund themselves without adequate water supplies. However, agricultural water use in the southeastern states has received relatively little attention despite rapid growth in the use of irrigation by the region's farmers. This study determines the breakeven prices for dryland and irrigated crops produced in the Tennessee River Basin and Hiwassee-Mississippi watersheds. The analysis focuses on five major crops produced in the region: corn, soybean, cotton, wheat and sorghum. Tillage practices considered are conventional, reduced, and no-till. Irrigation technologies include furrows, center pivot, and big-gun/traveler systems. Water sources include surface and wells. Center pivot systems are currently the dominant irrigation practice in the region. We hypothesize that gravity-based systems are more profitable under certain conditions. Well installation costs largely determine the profitability of irrigation practices in the study area. Key differences will be driven by the relative price of commodities, the production portfolio of producers, and energy, labor, and installation costs. Repair expenses for irrigation systems are insensitive to different well depths, but sensitive to the type of irrigation system implemented. These findings will be useful for producers augmenting their operations with irrigation systems.

Keywords: Irrigation; Corn, Cotton, Soybean; Breakeven Price; Simulation

Introduction

Globally, irrigated acres are anticipated to expand in the future to meet the increasing demand for food and energy production (Rosegrant, Ringler, and Zhu, 2009; Schaible and Aillery, 2012). Much of this expansion in irrigated acres is expected to occur in sub-humid and humid regions that generally receive enough annual rainfall to grow crops without irrigation (Mullen, Yu, and G. Hoogenboom, 2009; Rosegrant, Ringler, and Zhu, 2009; Schaible and Aillery, 2012). In the United States (U.S.), irrigation acreage in sub-humid regions such as the southeast has expanded over the last several years (Banerjee and Obembe, 2013; Dalton et al. 2004; Salazar et al., 2012; Schaible and Aillery, 2012; Vories et al., 2009). From 1997 to 2012, the number of irrigated acres in the Southeastern U.S. (AL, AR, FL, GA, KY, LA, MS, NC, SC, TN) increased by over 21% (1,899,124 acres) while decreasing by 5% (2,366,065 acres) in the rest of the U.S. (U.S. Department of Agriculture National Agricultural Statistics Service [USDA NASS], 2014), with some of the largest absolute increases in irrigated crop production occurring in Georgia, Alabama, and Mississippi (Schaible and Aillery 2012), and the largest percentage increases occurring in Tennessee and South Carolina.

The Mid-South and Southeastern U.S. have a sub-humid climate and seasonal rainfall that generally receives enough seasonal rainfall sufficient for crop production. However, drought episodes can occur during the growing season, reducing yield (Vories and Evett, 2010). The purpose of irrigation is to supplement rainfed crop production during periodic short-term droughts. Timely irrigation in the southeast can provide many agronomic benefits such as increasing yields (Bruns, Meredith, and Abbas, 2003; Smith and Riley, 1992), decreasing crop disease (Smith and Riley, 1992; Vories et al., 2009), and stabilizing yields (Apland, McCarl, and

Miller, 1980; Dalton, Porter, and Winslow, 2004; Evans and Sadler, 2008; Salazar et al., 2012; Vories et al., 2009).

Economic research on irrigation in sub-humid and humid regions of the U.S. has primarily focused on the benefits from managing production risk through higher and more stable yields. Early research by Boggess et al. (1983) and Boggess and Amerling (1983) found that irrigation maximized crop net returns and reduced production risk under Florida growing conditions. However, Boggess et al. (1983) found that if crop prices decreased below a certain threshold, the cost of irrigation was greater than the benefits from irrigation. Crop prices, therefore, needed to remain above this threshold for irrigation to be economically feasible. Boggess, Anaman, and Hanson (1985) surveyed farmers in the southeastern U.S. Their research concluded that irrigation was the most common risk management response to rainfall variability. Dalton, Porter, and Winslow (2004) compared irrigation with crop insurance to manage potato production risk in the northeastern United States. They found that crop insurance was risk inefficient and supplemental irrigation was risk efficient depending on the scale (i.e., field size) of the system, with a larger scale providing more risk-management benefits.

However, limited research exists on the profitability of irrigation of various crops and cropping practices in humid regions such as the southeast United States. DeJonge, Kaleita, and Thorp (2007) assessed the potential for irrigating corn in Iowa and calculated a breakeven corn price of $4.60/bushel for irrigation on a 125-acre field. They concluded that irrigation was not profitable given the expected corn price of $2/bushel used in the analysis. Boyer et al. (2014) determined the breakeven price of corn where investment in center-pivot irrigation would be profitable in Tennessee. They considered the effects of field size, energy price, and energy source on the breakeven price of corn. Field size and energy cost were found to be two important factors producers should take into consideration when selecting an irrigation system. The breakeven price of corn ranged between $6.97/bushel to $7.94/bushel for a 60-acre field, $4.64/bushel to $ 5.09/bushel for a 125-acre field, and $4.02/bushel to $4.37/bushel for a 200-acre field. Boyer et al. (2015) developed a simulation model to determine the probability of a positive net present value for center-pivot irrigation in Tennessee corn production while considering different farm sizes and energy sources. Results from this study suggest that corn yield was increased and stabilized with irrigation. They found farms with fields less than 200 acres were unlikely to generate positive net present values. However, with the increase in corn price since 2006, the probability of having a positive net present value was over 0.87 for all fields greater than 125 acres. Previous literature provides useful insights into the profitability of irrigating corn in the southeast, but research needs to be expanded to other crops, cropping systems, and irrigation system common to the southeast.

In the southeastern U.S., water availability has not historically received the attention that it has in the arid Southwest. However, the stress on Southeastern water resources is increasing due to expansion in irrigated acres, urbanization, population growth (Seager et al. 2009), and economic development (McNulty et al. 2008). Estimating breakeven prices of irrigated crop commodities in the southeast U.S. has implications for water supplies, water planning, and for future agricultural water management in Tennessee and the southeastern United States. The results could be also used to model policy mechanisms that incent producers to adopt more efficient irrigation systems or inform institutions that regulate access and quantity withdraw.

This study determines the breakeven prices for both irrigated and non-irrigated corn, soybeans, and cotton produced in the western Tennessee River Basin under conventional tillage and no-till (when planting occurs without tillage). Irrigation technologies include furrow and center pivot systems. Center pivot systems are currently the dominant irrigation practice in the region, although furrow technology is applicable in limited areas. We also considered underground water only for this study.

Data

Crop Budgets

For corn, cotton, and soybean, enterprise budgets were developed for six production systems for each crop. The production systems included: non-irrigated and no-till, non-irrigated and conventional tillage, irrigated and no-till using center pivot irrigation system, irrigated and conventional tillage using center pivot, Irrigated and no-till using furrow, and irrigated and conventional tillage using furrow. A total of 18 crop budgets were developed for this study.

The production expenses for crops budgets were primarily followed the 2015 University of Tennessee Extension Row Crop Budgets (UT) (2015). Tables 1 through 3 show the production costs not associated with irrigation for corn, cotton, and soybeans. The variable costs include seed, fertilizer, chemicals, labor, fuel, machine repairs and maintenance, land rent, crop insurance, scout, and operating loan interest. Fixed cost of non-irrigated crops includes capital recovery of machinery. These crop budgets contained the vast majority of the data needed to develop the 18-budgets in this analysis; however, some cost data for irrigated conventional till corn, non-irrigated and irrigated conventional till soybean, irrigated no-till cotton, and irrigated conventional till cotton had to be generated from various source. Since production costs can change across non-irrigated/irrigated and no-till/conventional till production systems, we used ratios of the expenses across the production systems to generate costs. For example, to generate fertilizer expense ($ /acre) of corn budgets for irrigated conventional till, we found the ratio of fertilizer expense for non-irrigated no-till corn production divide by fertilizer expense for irrigated no-till corn production and then set that ratio equal to the fertilizer expense of non-irrigated conventional till corn production divide by fertilizer expense for irrigated, conventional till corn production, which was missing. We solved the ration for the missing expense. The same ratios were used to find the seed and chemical expense for no-till and conventional till crops. We validated our generated data by comparing our numbers to the 2015 Crop Comparison Tool by Cooperative Extension and Outreach, Agricultural and Applied Economics College, University of Georgia (UGA-CAES, 2015). This crop comparison tool compares crops budgets between two tillage farming systems (strip till and conventional till) with and without irrigation system installed. Our generated costs were very similar to the costs in the 2015 Crop Comparison Tool.

<<< INSERT TABLES 1-3 HERE >>>

Irrigation System Costs

Irrigation costs are a function of field size; therefore, we present the variable and fixed costs for irrigation by field size in Table 4. Field sizes of 60 acre, 125 acres, and 200 acres were selected to reflect the range of field sizes in Tennessee. The variable costs included irrigation supply (pipes and dykes), energy for running irrigation system, labor for irrigation operation, repair and maintenance for irrigation equipment, and operating interest for irrigation. Energy cost of irrigation is a function of several variables such as the amount of water applied, price of energy, pump depth, water pumping pressure head for each irrigation system, a conversation factor to find total dynamic head, and coefficient of pumping fuel requirement, which indicates the amount of energy per unit for lifting one foot height of one acre-foot of water (gallon/acre-feet/feet). We followed the energy cost equation and coefficient assumption presented by Rogers and Alam (2006) assuming diesel as the energy source in this analysis. To make these calculation, we applied the amount of water applied annual was 7.2 acre-inches for each crop (UT 2015). An average pump operating PSI was for a center-pivot system was 39 and the average PSI for the furrow system was 2 (U.S. Department of Agriculture (USDA), 2013). A well-depth of 300 feet and an average pumping depth of 60 feet were used, which is a typical well depth in Tennessee (USDA, 2013). The average pumping depth used was 60 feet was used, which is a typical well depth in Tennessee (USDA, 2013). The average diesel price was $2.82/gal (U.S. Energy Information Administration, 2015).

<<< INSERT TABLES 4 HERE >>>

For this study, irrigation supplies costs was $3.45/acre, following assumption in 2015 Arkansas Crop Enterprise Budgets by University of Arkansas, Cooperative Extension Services, Division of Agriculture (UA-CESDA, 2015). Repair and maintenance expense for the irrigation systems were calculated as a percentage of the initial cost of the equipment, as proposed in the American Agricultural Economic Association (AAEA) Commodity Costs and Returns Handbook (2000). We used 2% of the initial investment cost, which is within the range stated in the AAEA Handbook (2000). Labor expense included monitoring soil water status and other irrigation management activities that are typical for Tennessee. For center-pivot irrigation, we assumed $12/acre for center pivot system (Boyer et al., 2014; 2015). Furrow system labor expenses were not available. Since more labor is required with furrow irrigation, we assumed the cost of labor for furrow irrigation was $36/acre (Buchanan and Cross, 2002). The operating interest expense was 3% of total variable irrigation costs,

The fixed costs of irrigation included the initial investment for furrow and center pivot for different field sizes. Irrigation system initial investment includes well installation expense, power unit expense, and additional external components only for center pivot system, such as sprinkler and spans. Each field size exerts different power unit expense and external components expense. To find initial investment costs, we used data presented in Boyer et al. (2014; 2015), which presented actual bid price non-towable center-pivot systems in West Tennessee, and the 2015 Arkansas Crop Enterprise Budgets (UA-CESDA, 2015). Annual capital recovery expense per acre was calculated following formula from the Tennessee Irrigation Handbook (Buchanan and Cross, 2002). We assumed the different useful life for different components of the components. The useful life for the well was 25 years, the pump was 20 years, power unit was 15 years, sprinklers were 20 years, and spans were 20 years. We also assumed the producer financed the cost of the well and system over five years at a 6% interest rate (UT, 2015).

Yield

Corn, soybean, and cotton yield distributions were generated using Erosion/Productivity Impact Calculator (EPIC). Crop yields were simulated for Memphis, Adler, and Reelfoot soil types common to western Tennessee. Yields for each crop were simulated for a 100-year period under recommended fertilizer rates, irrigated/dryland, conventional tillage and no-till cultivation. Crop yields were detrended by regressing yields on a trend variable. Detrended yields were benchmarked to the yields used to calculate University of Tennessee 2015 crop budgets. The distribution of crop yield under irrigation or non-irrigation, no-till or conventional till were presented in Table 5.

<<< INSERT TABLES 5 HERE >>>

Monte Carlo Analysis

To conduct the breakeven analysis on each crop and production system combination, net returns were first calculated for each crop by production systems and field size. Equation (1) expresses the calculation of net returns at the deterministic case:

$$NR_{ijkf} = P_i Y_{ijk} - C_{ijkf} \quad (1)$$

where NR_{ijk} is the net returns (\$/acre) for crop i ($i = corn, soybean,$ and $cotton$) with irrigation system j ($j = non-irrigation, furrow,$ and $center\ pivot$) using tillage method k ($k = no-till, conventional\ tillage$) on field size f (f= 60, 125, and 200 acres); P_i is the crop commodity price; Y_{ijk} is the crop yield; and C_{ijkf} is the total cost of production (\$/acre) under different production system.

When the producer net returns are equal to zero; thus, their total cost of production (C_{ijkf}) equals their total revenue ($P_i Y_{ijk}$), the producer breakeven. We have data for yields and costs; therefore the breakeven price of a crop is found by setting the net returns equation equal to zero and solve for the breakeven price of the commodity for each budget. The breakeven price of the crop i with irrigation system j using tillage method k for field size f is:

$$P_{ijkf}^{BE} = \frac{C_{ijkf}}{Y_{ijk}}. \quad (2)$$

The determinist analysis only provides a point estimate, while stochastic analysis can how variability in some variables will affects the decision of different production systems (technology options). To conduct stochastic breakeven analysis, diesel price, pumping depth, and crop yields were assumed stochastic. Diesel price followed a uniform distribution, with the low bound of \$1.00/gal and a high bound of \$4.64/gal (US Energy Information Administration 1994-2015). Well depth was assumed to follow a triangular distribution with the minimum depth of 50 feet, mode of 60 feet, and a maximum depth of 250 feet (USDA, 2013). Corn, soybean, and cotton yield distributions were bootstrapped from the generated data in EPIC. Breakeven prices for each crop and production system were simulated over 10,000 iterations, assuming the following distributions for these variables.

Sensitivity Analysis

Sensitivity breakeven prices were further analyzed by re-running the Monte Carlo analysis assuming incremental changes in technology cost and efficiency. The installation costs for wells, per unit pump costs, power unit for furrows and center pivot systems, well pump costs, well installation costs, center pivot spans, and conversion factor for calculating total dynamic head (i.e., the total equivalent height that water to be pumped) were varied between ± 10% of their base values at each Monte Carlo iteration. Plant water use efficiency for each crop was varied between -5% and 0% of the respective base values. Center pivot and furrow delivery efficiency (measured as psi) was varied from -50% to 0% (1 to 2) in 1-unit increments for furrow and center pivot systems, from ± 10% (35 to 43).

Preliminary Results

Refer to Figure 1 to see the expected breakeven prices of corn, cotton, and soybean by production systems and field size. Figure 2 shows a sensitivity analysis of the breakeven prices of corn, cotton, and soybean when the cost and efficiency of irrigation systems was modified.

Reference

Apland, J., B.A. McCarl, and W.L. Miller. “Risk and the Demand for Supplemental Irrigation: A Case Study in the Corn Belt.” *American Journal of Agricultural Economics* 62(1980):142-45.

Banerjee, S., and B.A. Obembe. “Econometric Forecasting of Irrigation Water Demand Conserves a Valuable Natural Resource.” *Journal Agricultural and Applied Economics* 45(2013):557-68.

Boggess, W.G., and C.B. Amerling. “A Bioeconomic Simulation Analysis of Irrigation Investments.” *Southern Journal of Agricultural Economics* 15(1983):85-91.

Boggess, W.G., K.A. Anaman, and G.D. Hanson. “Importance, Causes and Management Responses to Farm Risks: Evidence from Florida and Alabama.” *Southern Journal of Agricultural Economics* 17(1985):105-16.

Boyer, C.N., J.A. Larson, R.K. Roberts, A.T. McClure, and D.D. Tyler. 2014. “Farm-Level Corn Irrigation in Tennessee: The Impact of Field Size and Energy Cost on Profitability.” *Agricultural Systems* 127:61-69.

Boyer, C.N., J.A. Larson, R.K. Roberts, A.T. McClure, D.D. Tyler, and A. Smith. 2015. “Effects of Recent Corn and Energy Prices on Irrigation Investment in a Humid Region.” *Journal of Agricultural and Applied Economics* 47(01):105-122.

Bruns, H.A., Meredith, W.R., and Abbas, H.K., 2003. Effects of furrow irrigation on corn in the humid sub-tropical Mississippi delta. Crop Manage. Available at: http://www.plantmanagementnetwork.org/cm/.

Buchanan, J.R. and Cross, T.L., 2002. Irrigation cost analysis handbook. *Agricultural Extension Service, The University of Tennessee.*

Boggess, W.G., G.D. Lynne, J.W. Jones, and D.P. Swaney. "Risk-Return Assessment of Irrigation Decisions in Humid Regions." *Southern Journal of Agricultural Economics* 15(1983):135-43.

Dalton, T.J., G.A. Porter, and N.G. Winslow. 2004. "Risk Management Strategies in Humid Production Regions: A Comparison of Supplemental Irrigation and Crop Insurance." *Agricultural and Resource Economic Review* 33(2004):220-32.

DeJonge, K.C., A.L. Kaleita, and K.R. Thorp. "Simulating the Effects of Spatially Variable Irrigation on Corn Yields, Costs, and Revenue in Iowa." *Agricultural Water Management* 92(2007):99-109.

Evans, R.G., and E.J. Sadler. 2008. "Methods and Technologies to Improve Efficiency of Water Use." *Water Resource Research* 44(2008): doi:10.1029/2007/WR006200.

Force, A.T., 2000. Commodity Cost and Returns Estimation Handbook. *A Report of the AAEA Task*.

McNulty, S. C., G. Sun, E. C. Cohen, and J. A. M. Myers, 2008. "Change in the Southern U.S. Water Demand and Supply over the Next Forty Years." In W. Ji, ed. *Wetland and Water Resource Modeling and Assessment: A Watershed Perspective*. Boca Raton, FL: CRC Press, pp. 43-57.

Mullen, J.D., Y. Yu, and G. Hoogenboom. "Estimating the Demand for Irrigation Water in a Humid Climate: A Case Study from the Southeastern United States." *Agricultural Water Management* 96(2009):1421-28.

Rosegrant, M.W., C. Ringler, C., and T. Zhu. "Water for Agriculture: Maintaining Food Security under Growing Scarcity." *Annual Review of Environment and Resources* 34(2009):205-22.

Salazar, M.R., J.E. Hook, G. Garcia, J.O. Paz, B. Chaves, and G. Hoogenboom. "Estimating Irrigation Water use for Maize in the Southeastern USA: A Modeling Approach." *Agricultural Water Management* 107(2012):104-11.

Schaible, G.D., and M.P. Aillery. "Water Conservation in Irrigated Agriculture: Trends and Challenges in face of Emerging Demand." United States Department of Agricultural Economic Research Service Bulletin 99, Washington, DC, 2012.

Seager, R., A. Tzanova, and J. Nakamura. 2009. "Drought in the Southeastern United States: Causes, Variability over the Last Millenium and the Potential for Future Hydroclimate Change." *Journal of Climate* 22:5021-5045.

Smith, M.S., and T.J. Riley. "Direct and Interactive Effects of Planting date, Irrigation, and Corn Earworm (Lepidoptera: Noctuidae) Damage on Aflatoxin Production in Preharvest Field Corn." *Journal of Economic Entomology* 85(1992):998–1006.

University of Arkansas, Cooperative Extension Services, Division of Agriculture (UA-CESDA). 2015. *2015 Crops Enterprise Budget for Farm Planning*. Available online at: http://www.uaex.edu/farm-ranch/economics-marketing/farm-planning/budgets/crop-budgets.aspx.

University of Georgia, Cooperative Extension and Outreach, Agricultural and Applied Economics College (UGA-CAES). 2015. *2015 Crop Comparison Tool*. Available online at: http://www.agecon.uga.edu/extension/budgets/cct/index.html.

U.S. Department of Agriculture, National Agricultural Statistics Service (USDA NASS). 2014. *Farm and Ranch Irrigation Survey*. Available online at: http://www.agcensus.usda.gov/Publications/2012/Online_Resources/Farm_and_Ranch_Irrigation_Survey/.

University of Tennessee. 2015, *Field Crops Budget 2015*, University of Tennessee. Available from: http://economics.ag.utk.edu/budgets.html.

Vories, E.D., and S.R. Evett. 2010. Irrigation research needs in the USA mid-south and southeast, humid and subhumid regions, Proceedings for the 5th National Decennial Irrigation Conference, ASABE # IRR10-8679, Phoenix, AZ, December 5-8.

Vories, E.D., P.L. Tacker, S.W. Lancaster, and R.E. Glover. "Subsurface Drip Irrigation of Corn in the United States Mid-South." *Agricultural Water Management* 96(2009):912-16.

Table 1. Enterprise Budgets ($/acre) for Non-irrigated and Irrigated Corn in 2015

	Non-Irrigated		Irrigated	
Input	No-till	Conventional Till	No-till	Conventional Till
Variable Costs				
Seed	93.90	93.90	106.42	106.42
Fertilizer	146.10	146.10	199.20	199.20
Lime	15.00	15.00	15.00	15.00
Chemical	83.93	71.85	83.93	71.85
Labor	5.68	8.55	5.68	8.55
Fuel	15.61	21.91	15.61	21.91
Repair	20.74	27.80	20.74	27.80
Scout	5.50	5.50	5.50	5.50
Rent	98.00	98.00	165.00	165.00
Crop Insurance	13.86	13.86	13.86	13.86
Operating Loan Interest	14.95	15.07	14.95	15.07
Fixed Cost				
Machinery Capital Recovery	56.10	57.77	56.10	57.77
Total Non-Irrigation Cost ($/acre)	569.37	575.31	701.99	707.93

Source: 2015 Row Crop Budgets, UT-Extension, Institute of Agriculture, University of Tennessee.

Table 2. Enterprise Budgets ($/acre) for Non-irrigated and Irrigated Cotton in 2015

	Non-Irrigated		Irrigated	
Input	No-till	Conventional Till	No-till	Conventional Till
Variable Costs				
Seed	32.26	32.26	32.26	32.26
Tech Fee	62.60	62.60	62.60	62.60
Fertilizer	105.07	105.07	110.37	110.37
Lime	15.00	15.00	15.00	15.00
Chemical	158.16	146.70	158.16	146.70
Labor	9.87	14.13	10.79	15.45
Fuel	25.78	35.10	27.80	37.85
Repair	17.64	28.20	19.79	31.64
Scout	9.50	9.50	9.50	9.50
Rent	98.00	98.00	165.00	165.00
Crop Insurance	9.76	9.76	9.76	9.76
Operating Loan Interest	16.31	16.69	16.31	16.69
Fixed Cost				
Machinery Capital Recovery	127.28	140.87	121.05	133.97
Total Non-Irrigation Cost ($/acre)	687.23	713.88	758.39	786.79

Source: 2015 Row Crop Budgets, UT-Extension, Institute of Agriculture, University of Tennessee.

Table 3. Enterprise Budgets ($/acre) for Non-irrigated and Irrigated Soybean in 2015

Input	Non-Irrigated		Irrigated	
	No-till	Conventional Till	No-till	Conventional Till
Variable Costs				
Seed	50.40	50.40	50.40	50.40
Fertilizer	39.00	39.00	39.00	39.00
Lime	15.00	15.00	15.00	15.00
Chemical	130.28	96.30	130.28	96.30
Labor	5.43	8.15	5.43	8.15
Fuel	14.08	19.66	14.08	19.66
Repair	17.54	24.00	17.54	24.00
Scout	5.50	5.50	5.50	5.50
Rent	98.00	98.00	165.00	165.00
Crop Insurance	9.66	9.66	9.66	9.66
Operating Loan Interest	11.55	10.97	11.55	10.97
Fixed Cost				
Machinery Capital Recovery	61.06	62.88	61.06	62.88
Total Non-Irrigation Cost ($/acre)	457.5	439.52	524.50	506.52

Source: 2015 Row Crop Budgets, UT-Extension, Institute of Agriculture, University of Tennessee.

Table 4. Total Irrigation Cost for Furrow and Center Pivot Irrigation System by Field Size

	Field Size		
Cost Items	60 acres	125 acres	200 acres
	Furrow System		
Variable Cost			
Energy Cost ($/acre)	23.43	23.43	23.43
Irrigation Supplies ($/acre)	3.45	3.45	3.45
Irrigation Repair ($/acre)	19.44	12.25	9.77
Irrigation Labor ($/acre)	36	36	36
Operating Loan Interest ($/acre)	2.46	2.25	2.18
Fixed Costs			
Well Installation ($)	45,000	45,000	45,000
Pump for well ($)	20,000	24,500	26,500
Power Unit ($)	8,000	12160	20,400
Total Fixed Cost ($)	73,000	81,660	91,900
Annualized Fixed Cost ($/acre)	77.10	41.91	29.99
Total Irrigation Cost ($/acre)	161.89	119.29	104.82
	Center Pivot System		
Variable Cost			
Energy Cost ($/acre)	39.39	39.39	39.39
Irrigation Supplies ($/acre)	3.45	3.45	3.45
Irrigation Repair ($/acre)	60.18	38.42	34.32
Irrigation Labor ($/acre)	12	12	12
Operating Loan Interest ($/acre)	3.45	2.79	2.67
Fixed Costs			
Well Installation ($/ft)	45,000	45,000	45,000
Pump for well ($)	20,000	24,500	26,500
Power Unit ($)	10,000	15,200	25,500
Sprinklers ($)	2,000	2,600	4,500
Spans ($)	48,000	65,000	99,000
Total Fixed Cost ($)	125,000	152,300	200,500
Annualized Cost ($/acre)	141.98	83.66	69.13
Total Irrigation Cost ($/acre)	260.45	179.72	160.97

Source: Boyer et al. (2014; 2015), The Tennessee Irrigation Handbook (Buchanan and Cross, 2002); AAEA Handbook (AAEA, 2000); 2015 Arkansas Crop Enterprise Budgets (2015); and 2015 Row Crop Budgets UT-Extension (2015)

Table 5. Summary Statistics of Corn, Soybean, and Cotton Yields for Tennessee

Crop	Irrigation	Tillage	Mean	Standard Deviation
Corn (bu/acre)	Non-Irrigated	No-Till	150	9.23
	Non-Irrigated	Conventional	150	10.75
	Irrigated	No-Till	225	14.52
	Irrigated	Conventional	225	15.70
Soybean (bu/acre)	Non-Irrigated	No-Till	45	2.90
	Non-Irrigated	Conventional	45	1.99
	Irrigated	No-Till	60	1.98
	Irrigated	Conventional	60	1.79
Cotton (lb/acre)	Non-Irrigated	No-Till	875	231.02
	Non-Irrigated	Conventional	875	239.94
	Irrigated	No-Till	1100	312.86
	Irrigated	Conventional	1100	326.42

Source: Crop yields were simulated using Erosion/Productivity Impact Calculator for West Tennessee soils, detrended, and benchmarked to yields used to calculate University of Tennessee 2015 crop budgets

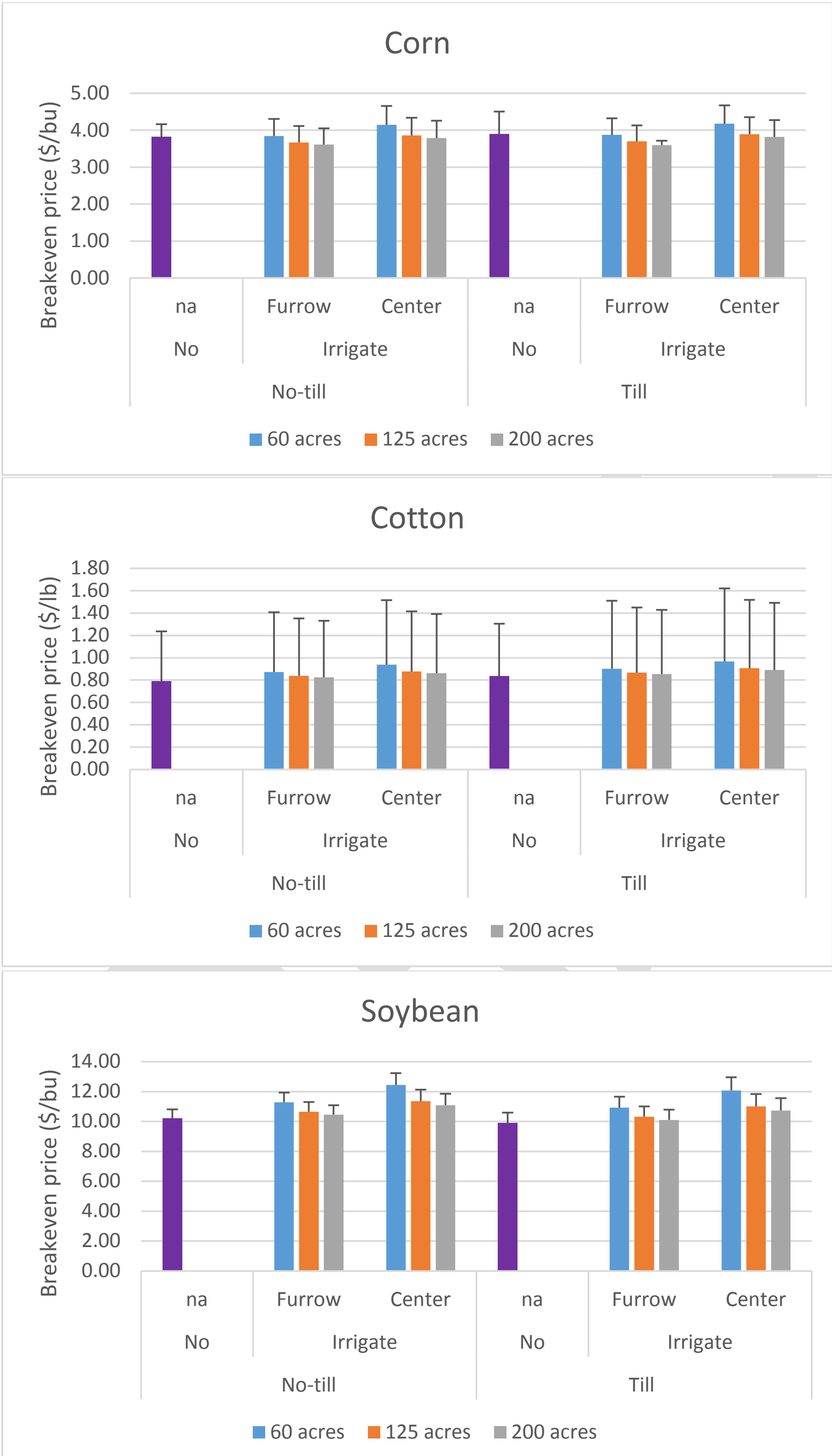

Figure 1. Breakeven Price of Corn, Cotton, and Soybean in Tennessee by Production System and Farm Size

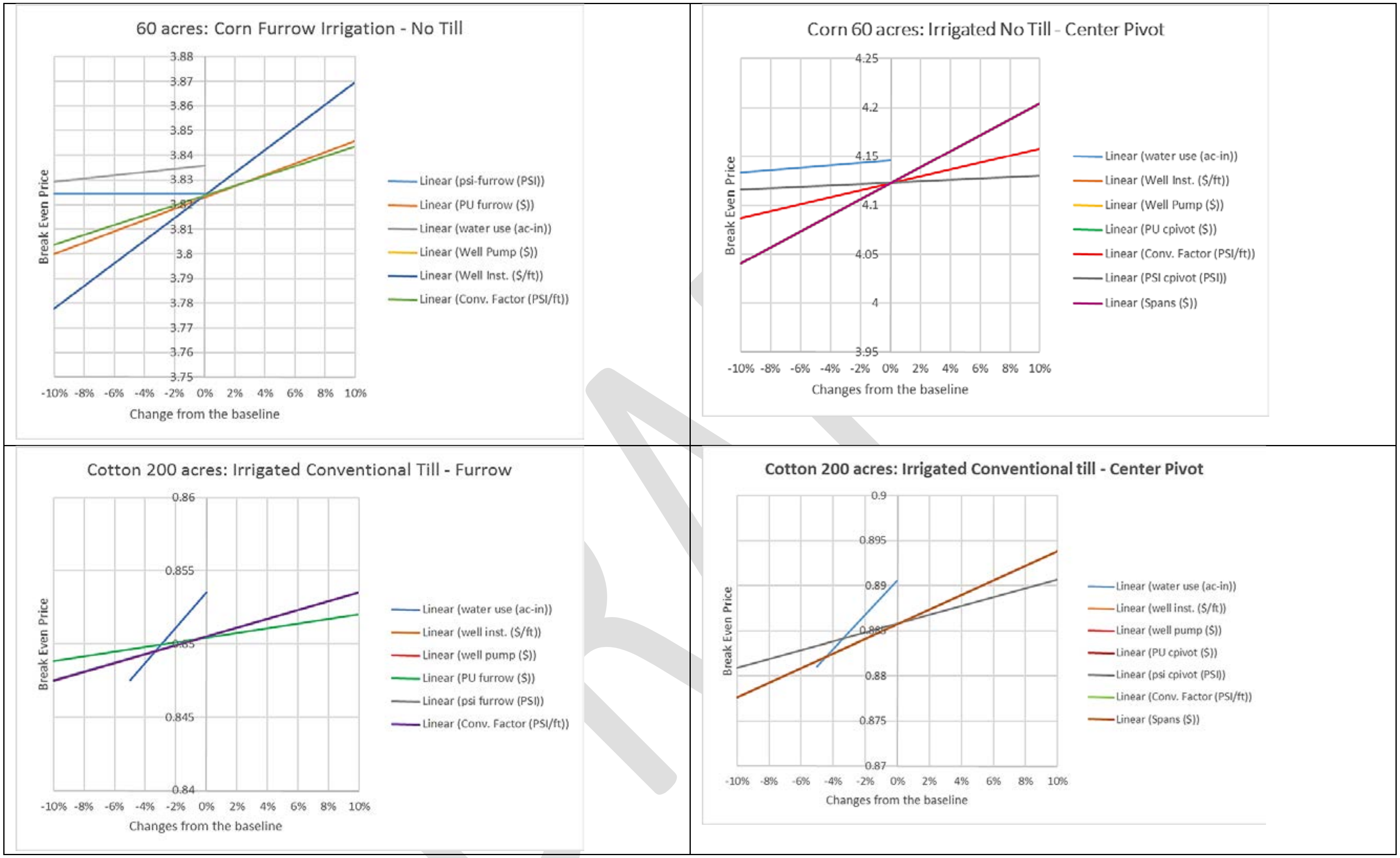

Figure 2. Sensitivity Analysis Breakeven Prices with a Change in the Irrigation System Efficiency and Costs