AN EVALUATION OF PRODUCTION, COSTS, AND SUSTAINABILITY ON CROP PRODUCTION IN THE SOUTHERN HIGH PLAINS

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Abstract

The viability of the agricultural industry in the Texas High Plains depends on irrigation from the Ogallala aquifer to maintain yields and provide economic stability. With the risk of dwindling water supplies, producers and stakeholders have begun taking measures in order to develop new irrigation management practices to maintain economic performance and better manage the available water resources. The Texas Alliance for Water Conservation has been working closely with producers to gather information on inputs and production methods at the field level. Extensive data from 2005 to 2016 has been recorded and analyzed in order to capture the effects of irrigation and tillage system impacts for sites in Floyd and Hale Counties on the Southern High Plains of Texas (SHP). The objective of this project was to estimate production functions for cotton lint production relative to the level of irrigation across various delivery systems, and to evaluate the production cost impacts that these systems pose on producers in the SHP. The results show that SDI systems are expected to have higher cotton lint yields compared to center pivot systems. In the cost analysis, producers are faced with a series of tradeoffs. The evaluation of irrigation showed that SDI had the highest cost per acre and per unit of production, but had a higher gross margin due to increased lint yields. The analysis of tillage systems showed a variation in production cost on a per acre basis, but on a per unit of production basis only the no-till tillage system showed a lower cost while having the lowest lint yield.

Introduction

The history of the Texas High Plain's economy has been strongly dependent on production agriculture and integrated livestock systems across the region. After the introduction of innovative irrigation systems farmers were able to compensate row crops with additional water that natural rainfall could not provide to the area. The adaption led to a thriving economy that grew highly dependent on ground water supplied from the underlying Ogallala aquifer. Today, the region is faced with dwindling water supplies and the risk of irrigation not being available for future generations. Since irrigation for agriculture accounts for 95% of the water consumed from the aquifer, the depletion rate is greater than the recharge rate, which consistently lowers the saturated thickness of the aquifer over time (Texas Water Development Board). Producers are continuing to learn how to adapt to drought and volatile weather patterns, which have a massive impact on the livelihood of producers in West Texas. With the introduction of new irrigation technologies and seeds, producers can produce higher yields with the same amount of resources. In 2004, the Texas Alliance for Water Conservation (TAWC) project was created to collect data from sites in Floyd and Hale Counties in the SHP. Field level data related to production inputs, tillage practices and irrigation practices. The project includes commodities that range from cotton production, grain, hay, grazing, silage, and integrated livestock operations. The focus of the project is to promote water efficiency in operations while maintaining economic growth.

The purpose of this study is to analyze the effects of different irrigation and tillage systems under a production and cost analysis. By evaluating irrigation methods on a production platform, this will allow a comparison of performances of different systems and help identify efficiencies in systems. The cost analysis will allow tradeoffs to be identified within different types of tillage and irrigation systems. Based on information gathered from producers, this analysis can show how systems impact per acre and per unit production cost.

Materials and Methods

The Texas Alliance for Water Conservation (TAWC) includes partners from the Texas Water Development Board, Texas Tech University, Texas AgriLife Extension, the High Plains Underground Water Conservation District #1, producers from the Southern High Plains of Texas, and the United States Department of Agriculture. The TAWC works with producers to collect extensive data on each site that include: production outcomes, fertilizers, herbicides, insecticides, tillage systems, harvest aids, processing fees, irrigation methods, which is broken down into several income and cost evaluations. A record is kept for each producer for each site and field within that site by production year. The project includes approximately 29 producers across nine counties from an 11-year period, 2005-2016. The primary focus of this study is cotton production that includes 206 observations representing approximately 17,000 acres. The cotton production analysis evaluates different irrigation systems including subsurface drip (SDI), center pivot systems (LEPA, LESA, MESA), and dryland production sites. The data was separated by each system and a regression analysis was conducted for each system. Figure 1 explains the relationship between the effects of irrigation systems and total water on output in a production function model. The model explains the choices a producer faces between two irrigation systems such as SDI and LESA. Between the systems, they may witness a shift in the production curve that would allow the producer to apply the same amount of irrigation water to increase yield. Initially the two systems are the same through the dryland production where at a point the producer begins to irrigate. The SDI systems shows to be more efficient and more effective since SDI has advantages over the LESA system through improved crop yield and water efficiency. A producer can choose between the options of irrigating at (Irr1) to increase yields to (Y3) of the SDI system or reduce the amount of irrigation applied (Irr2) and produce the same yield (Y2) under a LESA system. Where (Y1) represents dryland yield production. For this study an observation (0,0) was added to each regression analysis in order to represent at zero total water zero production will be expected. Each regression is based on an initial 13 inches of rainfall. The x-axis explains total water use, which can be any combination of rainfall and irrigation. The y-axis represents lint production per acre.

Production Model

$$\textit{Yield}_{\textit{Irrigation System}} = \beta_0 + \beta_1 (\textit{Seasonal Rainfall}) + \beta_2 (\textit{Irrigation}) + \beta_3 (\textit{Irrigation}^2)$$

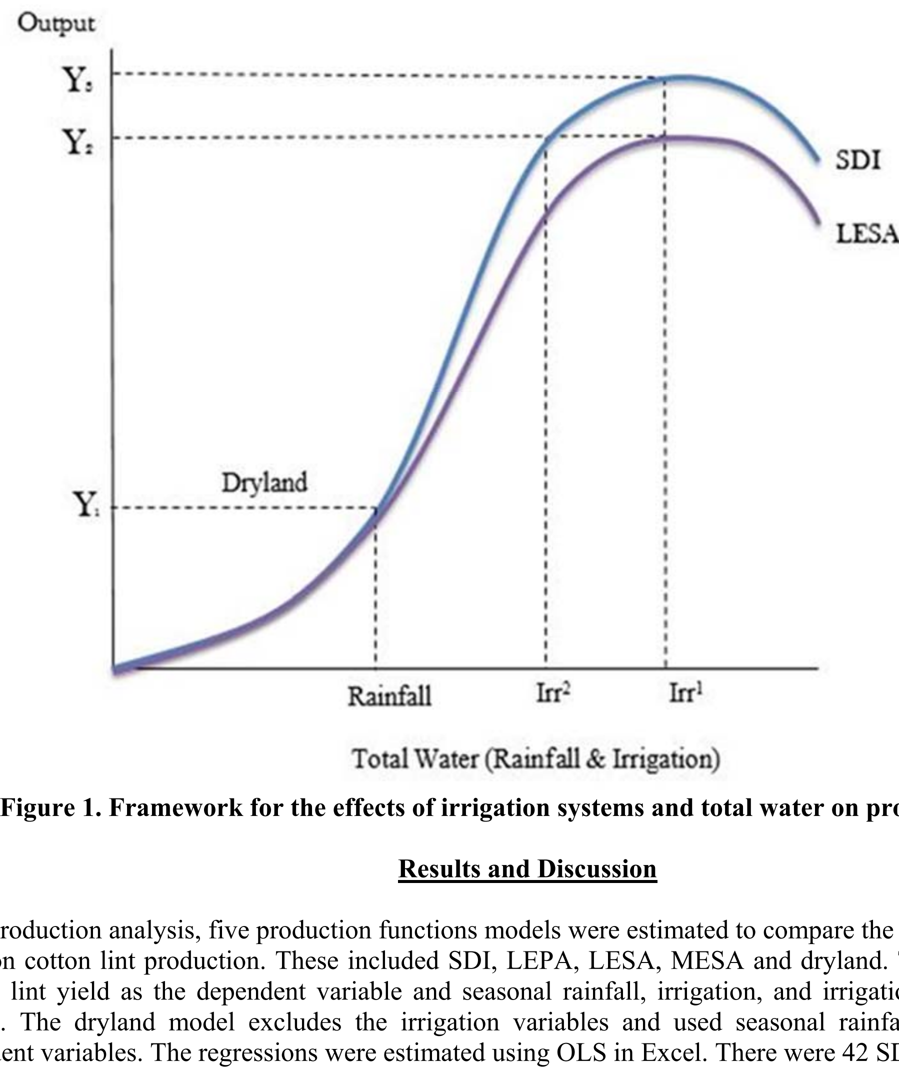

Figure 1. Framework for the effects of irrigation systems and total water on production output.

Results and Discussion

For the production analysis, five production functions models were estimated to compare the effects of irrigation and rainfall on cotton lint production. These included SDI, LEPA, LESA, MESA and dryland. The regression analysis specified lint yield as the dependent variable and seasonal rainfall, irrigation, and irrigation2 as the independent variables. The dryland model excludes the irrigation variables and used seasonal rainfall and rainfall2 as the independent variables. The regressions were estimated using OLS in Excel. There were 42 SDI, 46 LEPA, 49 LESA, 46 MESA, and 11 dryland observations used in the analysis.

Each system was compared on the average amount of irrigation (in/ac), average lint yield/acre, and the water use efficiency based on production in lbs/acre inch of water. Figures 2 to 6, give the estimated production functions based on yield responses to total water and the plotted data points of production outcomes of TAWC producers. Tables 1 to 5, provide the summary outputs for each regression. Due to extreme weather conditions in 2011, the data points from that year are highlighted in each graph.

Subsurface Drip (SDI) Production

Model 1

$$Yield_{SDI} = \beta_0 + \beta_1 (Seasonal\ Rainfall) + \beta_2 (Irrigation) + \beta_3 (Irrigation^2)$$

- $R^2 = 0.40$

Table 1. Parameter estimates for SDI irrigation system on cotton yield production.

Variable	Parameter Estimate	t-Stat	P-Value
Intercept	362.2951	1.4091	0.1669
Rainfall	22.6743	2.0796	0.0443
Irrigation	76.3878	3.0642	0.0040
Irrigation^2	-1.01622	-1.547	0.1299

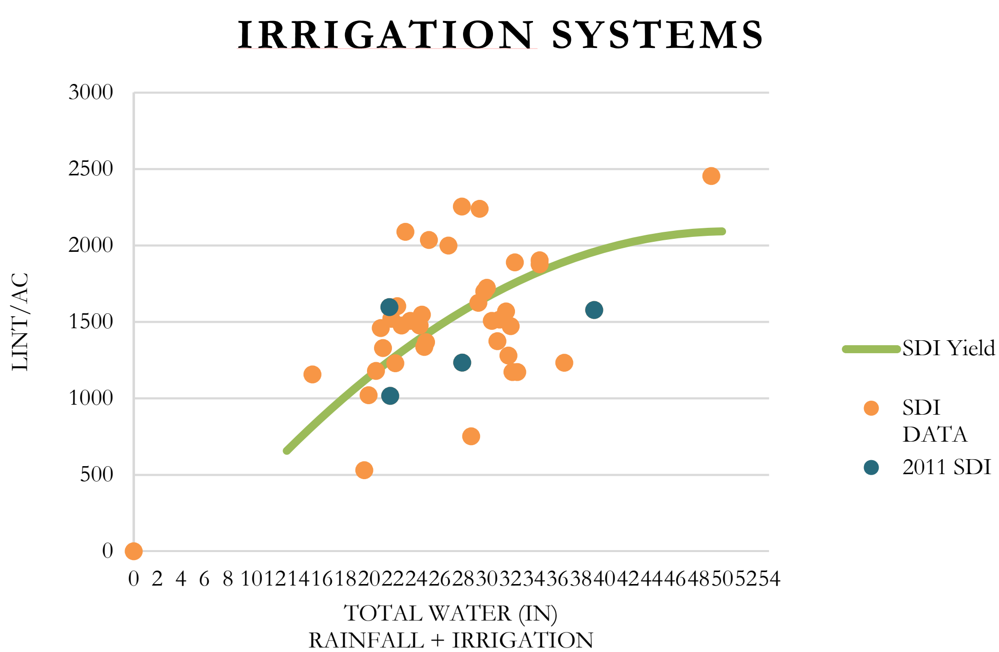

Figure 2. Effects of a SDI irrigation system on cotton production.

The rainfall, irrigation, and irrigation2 variables show to be significant in the model at the 90% confident level. The average irrigation applied was 14 inches with an average lint yield of 1,476 lbs/ac. The water use efficiency for the SDI systems was 105 lbs/ac inch.

Low Energy Precise Application (LEPA) Production

Model 2

$$Yield_{LEPA} = \beta_0 + \beta_1 (Seasonal\ Rainfall) + \beta_2 (Irrigation) + \beta_3 (Irrigation^2)$$

- $R^2 = 0.45$

Table 2. Parameter estimates for LEPA irrigation system on cotton yield production.

Variable	Parameter Estimate	t-Stat	P-Value
Intercept	86.6417	0.3768	0.7081
Rainfall	39.1594	4.3437	0.0000868
Irrigation	72.1670	3.1519	0.0029
Irrigation^2	-0.9988	-1.6027	0.1164

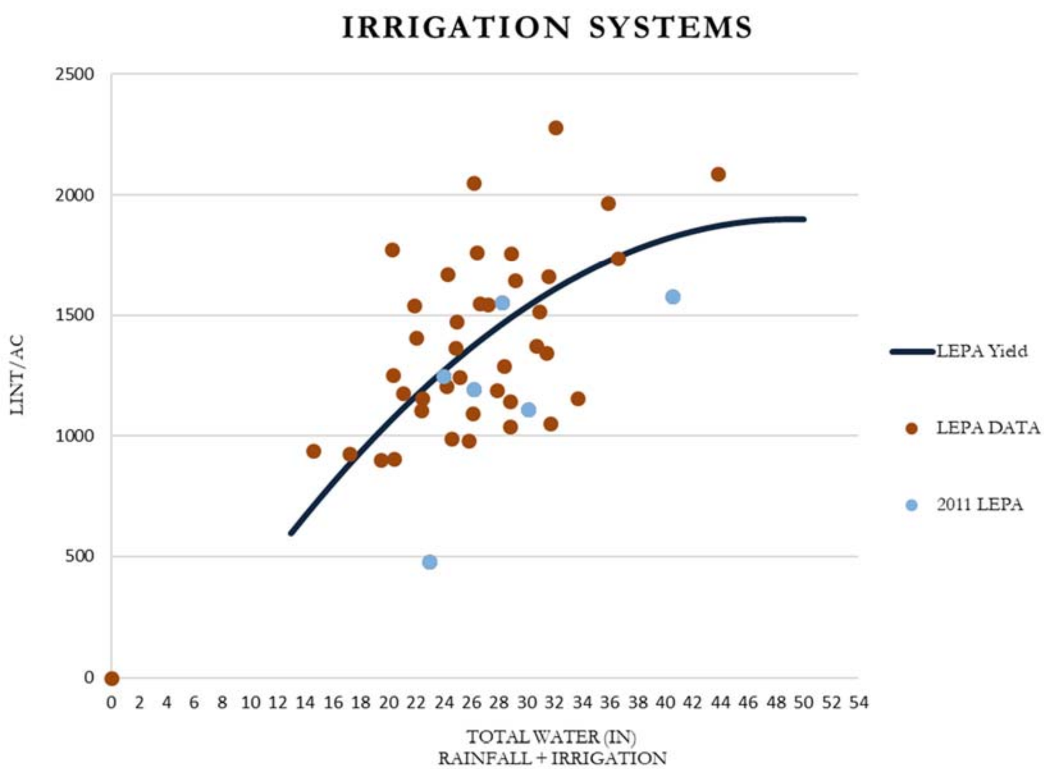

Figure 3. Effects of a LEPA irrigation system on cotton production.

The rainfall, irrigation, and irrigation2 variables show to be significant in the model at the 90% confident level. The average irrigation applied was 14 inches with an average lint yield of 1,335 lbs/ac. The water use efficiency for the LEPA systems was 94 lbs/ac in.

Low Energy Sprinkler Application (LESA) Production

Model 3

$$Yield_{LESA} = \beta_0 + \beta_1 (Seasonal\ Rainfall) + \beta_2 (Irrigation) + \beta_3 (Irrigation^2)$$

- $R^2 = 0.35$

Table 3. Parameter estimates for LESA irrigation system on cotton yield production

Variable	Parameter Estimate	t-Stat	P-Value
Intercept	441.3735	2.2127	0.0320
Rainfall	20.2871	2.1734	0.0350
Irrigation	57.6617	2.0738	0.0438
Irrigation^2	-0.7278	-0.8547	0.3972

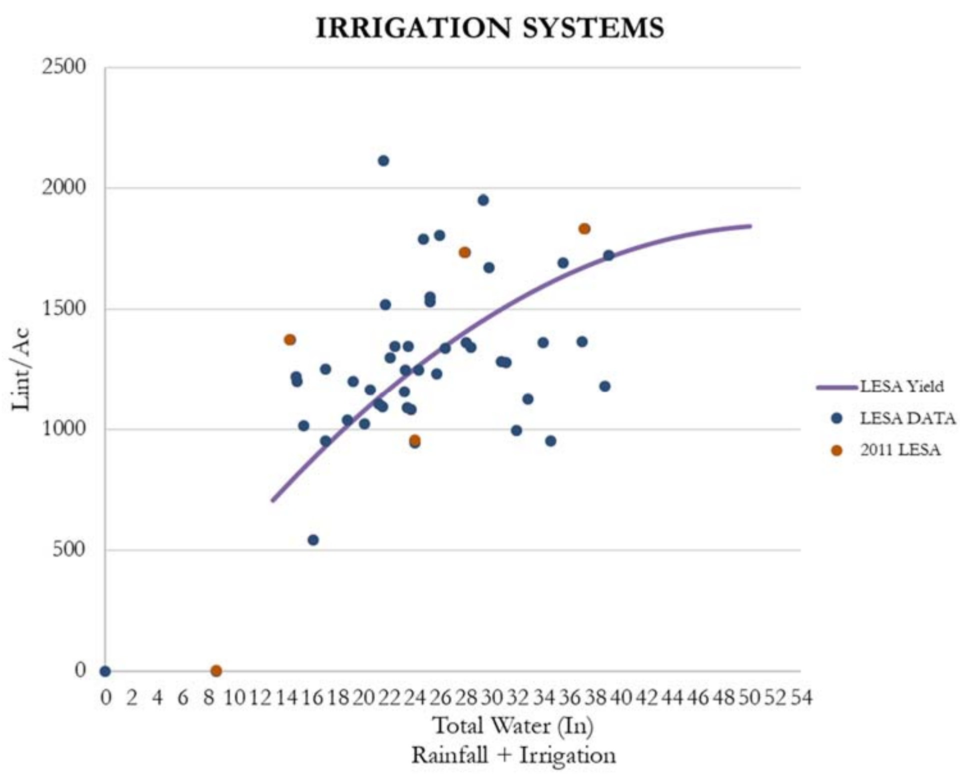

Figure 4. Effects of a LESA irrigation system on cotton production.

The rainfall and irrigation variables show to be significant in the model at the 90% confident level. The average irrigation applied was 12 inches with an average lint yield of 1,258 lbs/ac. The water use efficiency for the LESA systems was 104 lbs/ac in.

Mid-Elevation Spray Application (MESA) Production

Model 4

$$Yield_{MESA} = \beta_0 + \beta_1 (Seasonal\ Rainfall) + \beta_2 (Irrigation) + \beta_3 (Irrigation^2)$$

- $R^2 = 0.45$

Table 4. Parameter estimates for MESA irrigation system on cotton yield production.

Variable	Parameter Estimate	t-Stat	P-Value
Intercept	113.6278	0.6043	0.5488
Rainfall	35.9483	3.2492	0.0022
Irrigation	77.7530	2.6424	0.0115
Irrigation^2	-1.2200	-1.0924	0.2808

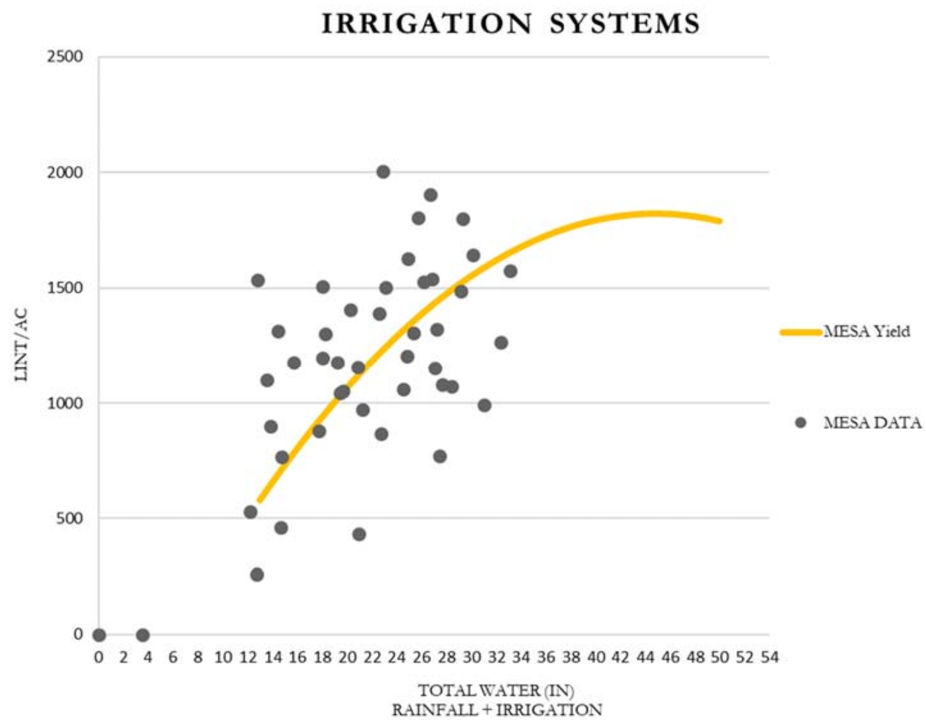

Figure 5. Effects of a MESA irrigation system on cotton production.

The rainfall and irrigation variables show to be significant in the model at the 90% confident level. The average irrigation applied was 10 inches with an average lint yield of 1,183 lbs/ac. The water use efficiency for the MESA systems was 117 lbs/ac in.

Dryland Production

Model 5

$$Yield_{Dryland} = \beta_0 + \beta_1 (Seasonal\ Rainfall) + \beta_2 (Seasonal\ Rainfall^2)$$

- $R^2 = 0.68$

Table 5. Parameter estimates for Dryland irrigation system on cotton yield production.

Variable	Parameter Estimate	t-Stat	P-Value
Intercept	-1826.2533	-2.6926	0.0273
Rainfall	282.2563	3.1849	0.0129
Rainfall^2	-7.5246	-2.7899	0.0235

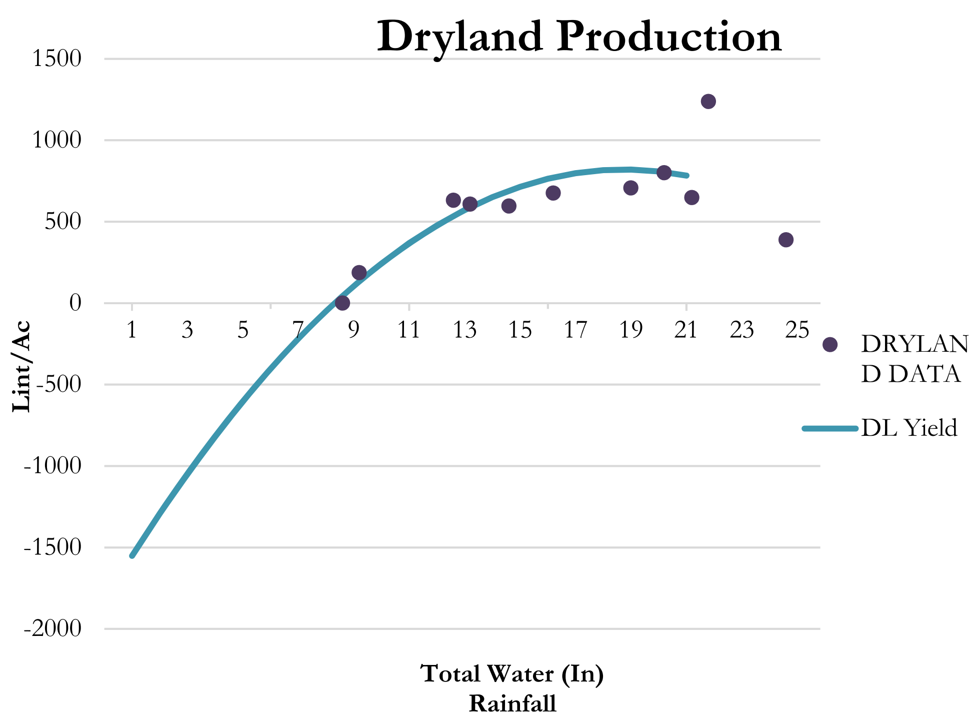

Figure 6. Effects of rainfall on dryland on cotton production.

The rainfall and rainfall2 variables show to be significant in the model at the 90% confident level. The dryland production function shows that at least 8 inches of water is needed to produce a crop without supplemental irrigation. Dryland production showed to have an average lint yield of 589 lbs/ac.

The production equations for the irrigation system analysis show that rainfall contributes 20-39 lbs of production per inch. The MESA and SDI irrigation systems showed to have the highest return in lbs of production per inch of water applied. Figure 7 shows the combination of all systems on one graph in order to see the differences between each irrigation system. There appears to be little difference between the center pivot systems, but the SDI system has higher production output across irrigation levels.

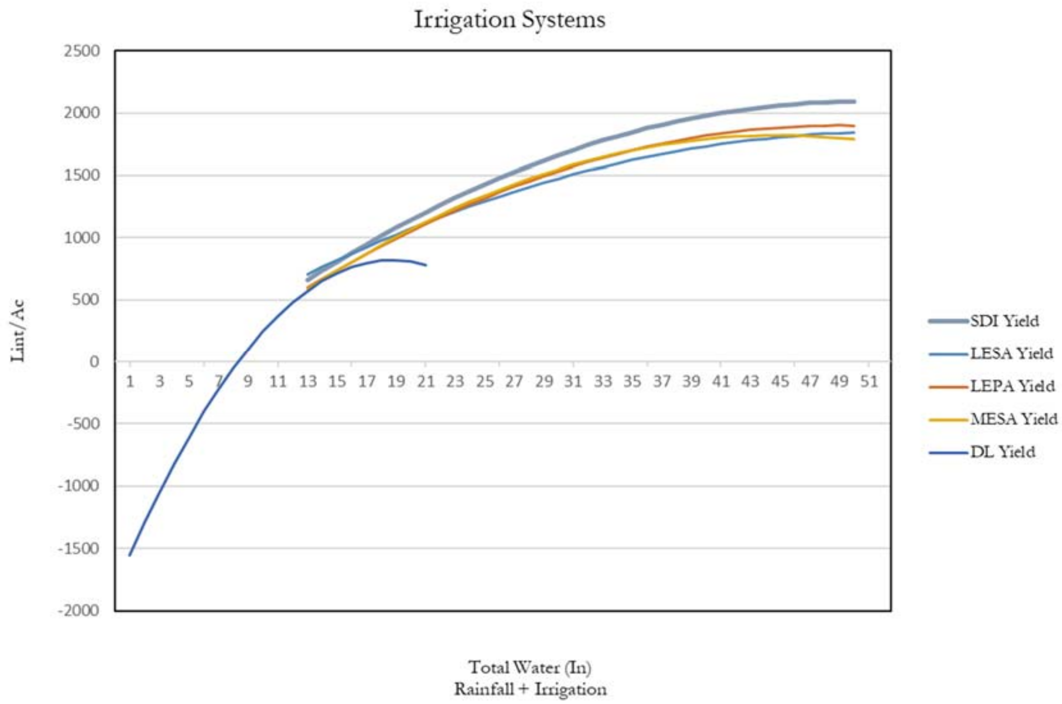

Figure 7. Analysis of production efficiency of all evaluated irrigation and dryland systems.

For the variable cost analysis, data was gathered from the TAWC enterprise budgets that included pre-harvest per acre input costs (seed, fertilizer, herbicide, insecticide, irrigation pumping costs, and tillage costs) and the harvest costs per acre (harvest aids and ginning costs). An economic comparison was used to evaluate the different variable costs of irrigation systems and tillage systems. Each analysis broke down the variable production cost per system based on cost per acre in $/ac, cost per unit of production in $/lb, gross margin per acre and the average yield in lbs/ac. The gross margin is calculated by subtracting the variable cost from gross income. If sites had multiple fields, the variable cost was weighted to the associated acres for that site to form a single observation. For this analysis, the 2011 data was excluded due to the extreme values caused by drought. In order to capture seed income two separate analyses were conducted for both tillage and irrigation systems. For the irrigation systems there were 37 SDI, 39 LEPA, 43 LESA, and 39 MESA observations. For tillage systems, there were 70 conventional tillage, 12 no-till, 9 strip till, and 33 minimum tillage observations.

Irrigation Systems

Table 6. Variable cost analysis of irrigation systems.

Irrigation System		SDI	LESA	LEPA	MESA
Variable Cost	$/ac	789	660	726	600
Variable Cost	$/lb	0.54	0.52	0.53	0.48
Avg. Yield	lbs/ac	1529	1296	1391	1265
Gross Margin	$/ac	447	369	439	336

Table 7. Variable cost analysis of irrigation systems with the consideration of seed income.

Irrigation System w/ Seed Income		SDI	LESA	LEPA	MESA
Variable Cost	**$/ac**	**569**	**474**	**526**	**418**
Variable Cost	**$/lb**	**0.40**	**0.38**	**0.38**	**0.34**
Avg. Yield	**lbs/ac**	**1529**	**1296**	**1391**	**1265**
Gross Margin	**$/ac**	**447**	**369**	**439**	**336**

Tillage Systems

Table 8. Variable cost analysis of tillage systems.

Tillage System		Conventional	No Till	Strip Till	Minimum Till
Variable Cost	**$/ac**	**741**	**571**	**751**	**708**
Variable Cost	**$/lb**	**0.54**	**0.48**	**0.56**	**0.55**
Avg. Yield	**lbs/ac**	**1419**	**1218**	**1355**	**1336**
Gross Margin	**$/ac**	**415**	**452**	**390**	**470**

Table 9. Variable cost analysis of tillage systems with the consideration of seed income.

Tillage System w/ Seed Income		Conventional	No Till	Strip Till	Minimum Till
Variable Cost	**$/ac**	**537**	**395**	**556**	**516**
Variable Cost	**$/lb**	**0.40**	**0.34**	**0.42**	**0.40**
Avg. Yield	**lbs/ac**	**1419**	**1218**	**1355**	**1336**
Gross Margin	**$/ac**	**415**	**452**	**390**	**470**

Tables 6 through 9, breakdown the variable cost for a cotton operation by irrigation and tillage management systems in the SHP. Two analyses were conducted for each system to account for the income from seed production in order to find a better value for a breakeven analysis. No fixed costs were included in the calculations. The irrigation systems showed that the lowest variable cost system was a MESA irrigation system; however, the MESA system had the lowest gross margin and lint yield. The highest variable cost system for irrigation systems was SDI, but it also had the highest gross margin and lint yield output. The SDI, LESA, and LEPA showed to have similar variable cost when compared on $/lb basis. The analysis of tillage systems showed that no till had the lowest variable cost and lint yield output. The gross margin for no till showed to be the second highest, but it is also important to take into consideration that there were limited observations for no till and strip till management systems.

Summary

The purpose of this study was to analyze producer economic and production outcomes based on the performance of separate management systems in the SHP. On a production basis, the SDI irrigation system showed a higher yield than the center pivot systems. The water efficiency of the MESA systems showed to be higher than the other systems. This could be caused by management or production methods that allowed those fields to be more productive. Evaluation of the variable cost based on systems showed that on a per acre and per pound analysis SDI had the highest cost, but it also had the highest gross margin. In order to be confident in the variable cost analysis more observations would be needed for no till and strip till management systems. Although it appears that tillage systems do not influence the yield production based on the cost per pound of production analysis. The dynamics of a grower's management decisions also have a major impact on the economic and environmental outcomes for crop production. Since the results show that farmers are faced with a series of tradeoffs, future research should determine the interactions between irrigation and tillage systems to evaluate the best combination of methods. In further analysis, in order to capture the exact water use efficiency the dryland yield should be incorporated in order to account for the increased production per unit of irrigation.

Acknowledgments

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