Integrating Cotton and Beef Production in the Texas Southern High Plains: A Simulation Approach

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Abstract

The continued decline in water availability in the Texas High Plains from depletion of the Ogallala aquifer and recently implemented water pumping restrictions will impact irrigated producers in the region. Research has shown that an integrated crop/livestock system requires less irrigation compared to a cotton monoculture system and may be more profitable. This study uses a simulation approach to evaluate the profitability of a cotton monoculture cropping system and an integrated cotton/forage/livestock system in the Texas Southern High Plains. Results show that the cotton monoculture system is the most profitable, although the integrated system uses less water.

Key Words: simulation, integrated livestock, economic viability

JEL Classifications: Q14, Q15

Introduction

Sustainability of irrigated agriculture in the Southern High Plains (SHP) of Texas is vulnerable due to dependency on water withdrawals from the Ogallala aquifer. It has been estimated that from predevelopment to 2009, water in storage in the Ogallala aquifer in Texas has declined by 144.5 million ac-ft.; about 28% of water in storage prior to development (McGuire, 2011; Dugan, McGrath and Zelt, 1994). In some areas of the southern Ogallala region, saturated thickness has declined by more than 50% from predevelopment levels (McGuire, 2011; Colaizzi et al., 2008). As a result of the decline in saturated thickness, well yields have decreased, necessitating drilling of additional irrigation wells, producers have adopted of more efficient irrigation systems, and there has been a reduction of irrigated land in areas where depletion of the aquifer has reached critical levels.

In response to state mandated Desired Future Conditions (DFC) for the Ogallala aquifer, the High Plains Underground Water Conservation District adopted a groundwater management plan to have 50% of the current saturated thickness of the aquifer remaining in 50 years. To meet this management plan the district implemented annual pumping limits to be phased in over a five year period (Ground Water Management Area #2, 2010).

Irrigated cotton, corn, grain sorghum, wheat and livestock are the predominant production systems within the SHP (USDA-NASS, 2012). The SHP is responsible for about 30% of U.S. cotton production, with about 70% from irrigated acres (USDA-NASS and TDA, 2009). The region’s feedlot industry produces about 25% of U.S. fed cattle annually (USDA-NASS and TDA, 2009). The agricultural sector contributes approximately 28% to the region’s economy through production and processing of agricultural commodities (Minnesota IMPLAN Group, 2009).

The effects of the 2011 drought had a devastating impact on regional producers, with this impact continuing in 2012 and possibly into 2013. In Texas alone, the drought was estimated to have accrued financial losses at over seven billion dollars (Fannin, 2012). State-wide producer reaction to the drought resulted in a reduction of planted cotton acres of 2.4 million for the 2012 growing season (USDA-ERS, 2012). Farmers in the SHP traditionally plant corn and cotton monoculture systems, but changes in crop mix and management strategies may become necessary to remain sustainable due to declining irrigation availability from aquifer depletion and water use restrictions.

Objective

The purpose of this study is to analyze the profitability of an integrated cotton/forage/livestock production system compared to a traditional cotton monoculture production system in the SHP of Texas. This study also seeks to determine which production system is more sustainable given reduced irrigation availability due to declining saturated thickness of the Ogallala aquifer and recently implemented pumping restrictions by water conservation districts.

Data and Methods

A ten-year study comparing productivity, water and energy use, and economic returns for an irrigated cotton monoculture system and an irrigated integrated cotton/forage/livestock system was conducted in Lubbock County, TX from 1999 to 2008. A complete randomized block design was used to replicate each system three times. Each replication of the cotton monoculture system was planted on 0.62 acres. Each replication of the integrated cotton/livestock system was planted on 9.88 acres, for a complete system area of 31.50 acres. Both systems were irrigated using sub-surface drip (SDI). In the integrated system, 53.5% (5.19 acres) was dedicated to WW-B. Dahl old world bluestem, and the remaining 46.5% was equally divided into 2.30 acre paddocks that included rye, cotton, and wheat rotations (Figure 1). The livestock component of the integrated system consisted of Angus and Angus x Hereford steers that sequenced grazed winter dormant bluestem, rye, and wheat. Methods and results for this study have been reported by Allen et al. (2012), Zilverberg et al. (2012), and Johnson et al. (accepted).

The integrated cotton/forage/livestock system used 25% less irrigation compared to the cotton monoculture system (Allen et al., 2012). An economic analysis comparing the gross margin for each of the production systems showed that over the first four years (1999-2002) the integrated system was more profitable; however, the cotton monoculture system was more profitable during the last six years (2003-2008) (Johnson et al., accepted). This difference in profitability was primarily due to the introduction of higher yielding Fibermax cotton varieties which significantly increased cotton yields in both the cotton monoculture and integrated system.

For the purposes of this study, two simulation models were developed using Simetar© (Richardson, Schumann, and Feldman, 2008) to compare profitability over ten years for the cotton monoculture and integrated livestock production systems. Revenue, cash expenses, and gross margin were fit with 18 different distributions for each of the production systems. The random values were then simulated using 100 iterations. A test scalar was used to determine which distribution had the best fit for the historical data. All data was fit with an empirical distribution using percent deviations from the mean. Comparisons between the two systems were made based on the simulated results. Data to develop the simulation models was taken from production budgets complied for the two systems (Johnson et al., accepted).

Results

This study estimates the financial viability of each production system using simulated net returns. Figures 2, 5, and 8 show the probability distribution functions (PDFs) of revenue, cash expenses and gross margin, respectively, for the cotton monoculture and integrated livestock systems. Figures 3, 6, and 9 are the cumulative distribution functions (CDFs) for revenue, cash expenses, and gross income for each system, respectively. The CDFs show the probabilities of different outcomes and are used validate the model by comparing the historical observations to simulated values for each system. Figures 4, 7, and 10 are stoplight charts that show probabilities for revenue, cash expenses, and income, respectively.

Revenue

Simulated revenue for the cotton monoculture system varies from $500 to $1,050 per acre, with average return of $767 per acre. The simulated revenue for the integrated system varies from $676 to $1,554 per system acre, with average revenue of $1,090. The PDFs for each system shown in Figure 2 indicate that the average expected revenue for the integrated livestock system is greater than the maximum revenue that can be achieved under the cotton monoculture system. There is greater variability in the revenue received in the integrated system compared to the monoculture system with ranges of $878 and $550, respectively. The CDFs in Figure 3 show that the simulated values closely match the historical values. The stoplight chart shown in Figure 4 gives the probabilities of revenue being less than $700 and greater than $1,000. The cotton monoculture system has a 13% chance of receiving revenue greater than $1,000 compared to a 58% chance for the integrated system. The probability of the cotton monoculture system of receiving less than $700 is 41% compared to a 7% chance for the integrated system.

Cash Expenses

Simulated cash expenses for the cotton monoculture system vary from $495 to $896 per acre with an average of $657 per acre. Simulated cash expenses for the integrated system vary from $638 to $1,576 with an average of $986 per acre. The PDFs for cash expenses are shown in

Figure 5. The expenses in the integrated system have a range of $938, compared to $401 in the monoculture system, and have the potential to be $680 more than monoculture system. The CDFs for cash expenses in each system are shown in Figure 6 indicate that the simulated values closely follow the historical data. The stoplight chart shown in Figure 7 indicates that there is a 47% and 7% chance of expenses being less than $650 in the monoculture and integrated system, respectively. The probability of expenses greater than $850 is 13% in the monoculture system and 76% in the integrated system.

Gross Margin

The PDF's of gross margin for each system in Figure 8 show that the simulated gross margin for the cotton monoculture system varies from $-60 to $340 per acre with an average of $108 per acre. Simulated gross margin for the integrated system varies from $-110 to $260 per acre with an average of $104 per system acre. The integrated livestock system has the potential for more losses in net revenue than the monoculture system. The cotton monoculture system also has the potential to make more positive net returns than the integrated system. The CDFs in Figure 9 show that the simulated values closely match the historical data. Figure 10 shows the probability of each system receiving negative gross margins and gross margins greater than $150 per acre. The cotton monoculture system has a 14% chance of receiving negative gross margins and a 37% chance of exceeding $150 per acre. The integrated system has a 29% chance of receiving a negative gross margin and a 45% chance of exceeding $150 per system acre.

Profitability of each system is defined by gross margin (revenue less cash expenses). Based on gross margin, the cotton monoculture system was the most profitable. Second degree stochastic dominance was used to rank each system based on gross margin. The cotton monoculture system was the most preferred. A ranking procedure based on a negative exponential utility function was also performed in Simetar© using Stochastic Efficiency with Respect to A Function (SERF). The cotton monoculture system was also ranked as the most preferred.

An analysis of profitability per acre inch of irrigation applied (Table 1) indicates that in the first four years (1999-2002), the integrated system was more profitable per inch of water. Starting in 2003, the return per acre inch of irrigation in the cotton monoculture system rose dramatically from $0.38 to $21.03. This increase can be attributed to technological advancements in cotton crop genetics. In 2005, 2006, and 2008, the return per inch of irrigation in each system was comparable. The ten year average of gross margin per acre inch for the monoculture and integrated system are $8.90 and $12.40, respectively.

Discussion and Conclusions

The continued decline in water availability in the Texas High Plains from depletion of the Ogallala aquifer and recently implemented pumping restrictions will impact irrigated producers in this region. This study used a simulation approach to compare the profitability potential of two different production systems. This research has shown that an integrated livestock system generates more revenue than a cotton monoculture system, but also has higher expenses. The CDFs for gross margin show that the integrated livestock system is comparable to the monoculture system; however, ranking the systems using second degree stochastic dominance and stochastic efficiency shows the cotton monoculture system is the most preferred. Results from this study are consistent with Johnson et al. (accepted) and indicate that overall, cotton monoculture systems are more profitable in the Texas Southern High Plains than integrated cotton/forage/livestock systems. However, the integrated livestock systems still remain a viable option in the future as irrigation concerns become more prevalent.

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Appendix

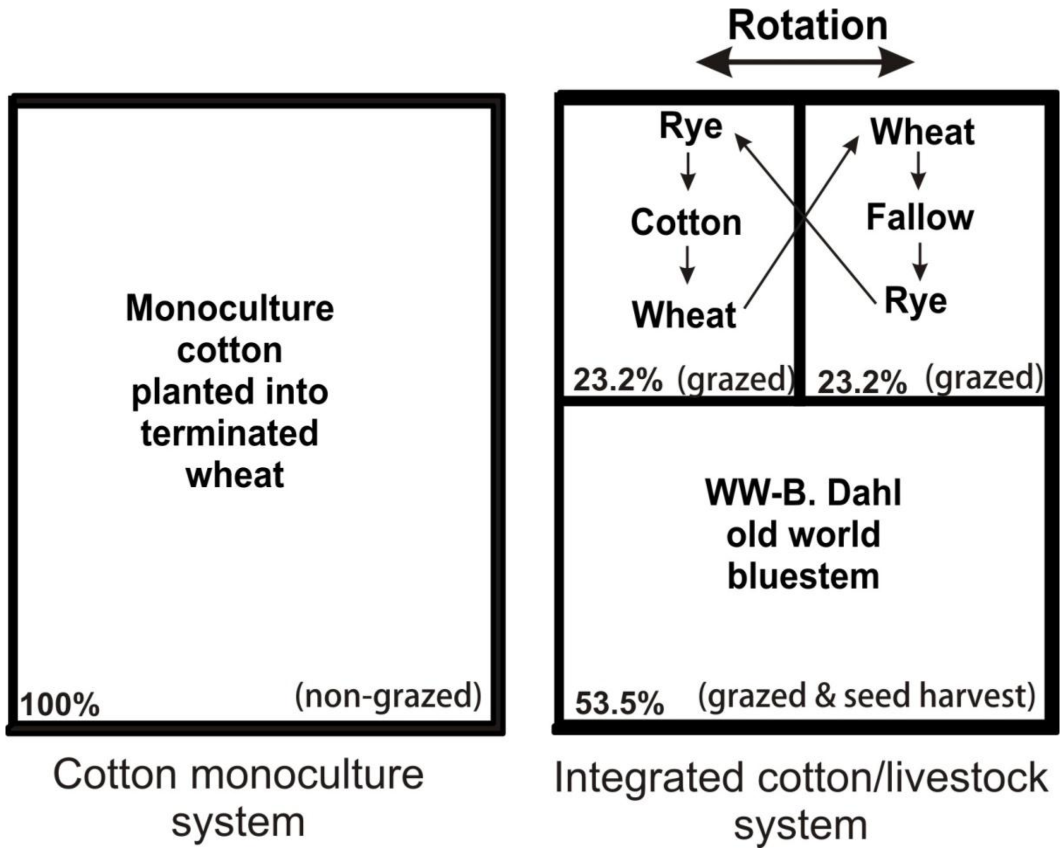

Figure 1. Diagrammatic representation of a cotton monoculture system (0.62 ac) and an integrated cotton-forage-beef stocker cattle system (9.88 ac). Adapted from Allen et al. (2005).

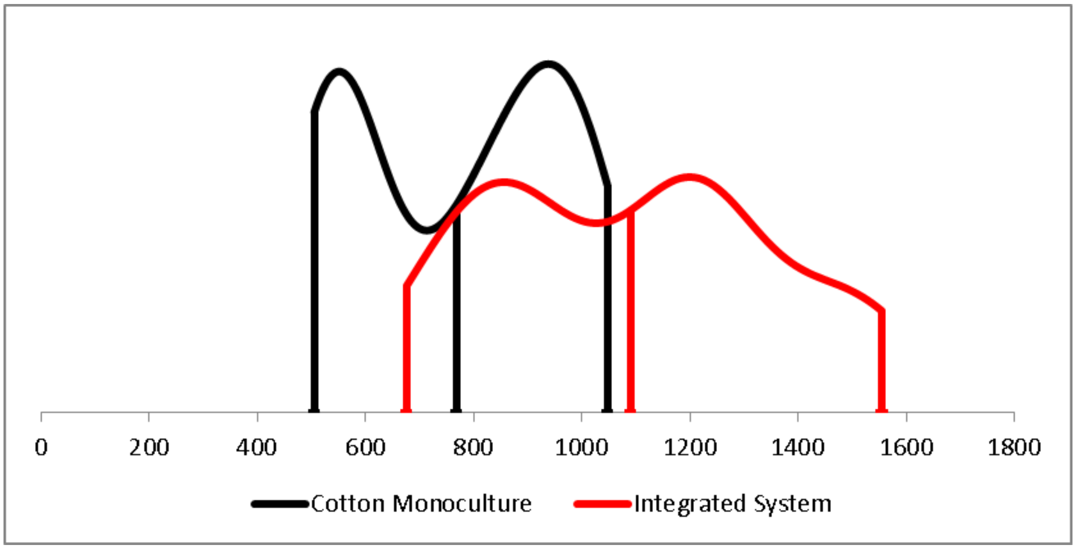

Figure 2. Probability distribution functions (PDFs) for revenue under the cotton monoculture and integrated systems.

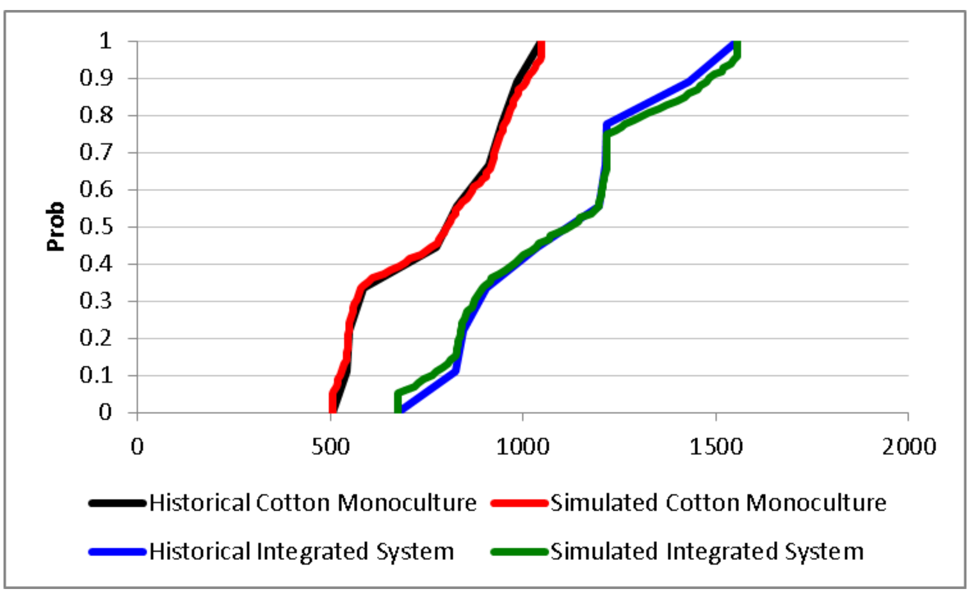

Figure 3. Cumulative distribution functions (CDFs) for revenue under the cotton monoculture and integrated systems.

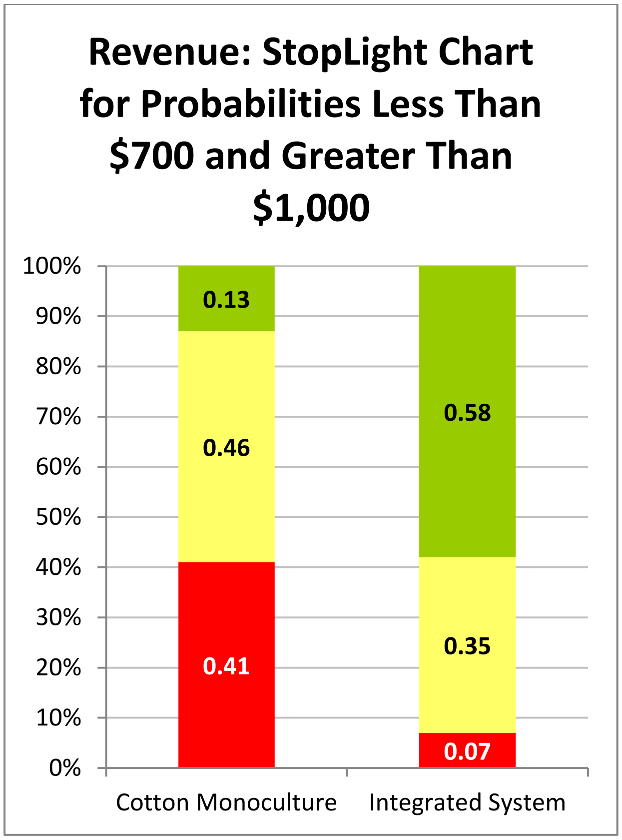

Figure 4. Stoplight/Probability chart for revenue under the cotton monoculture and integrated systems.

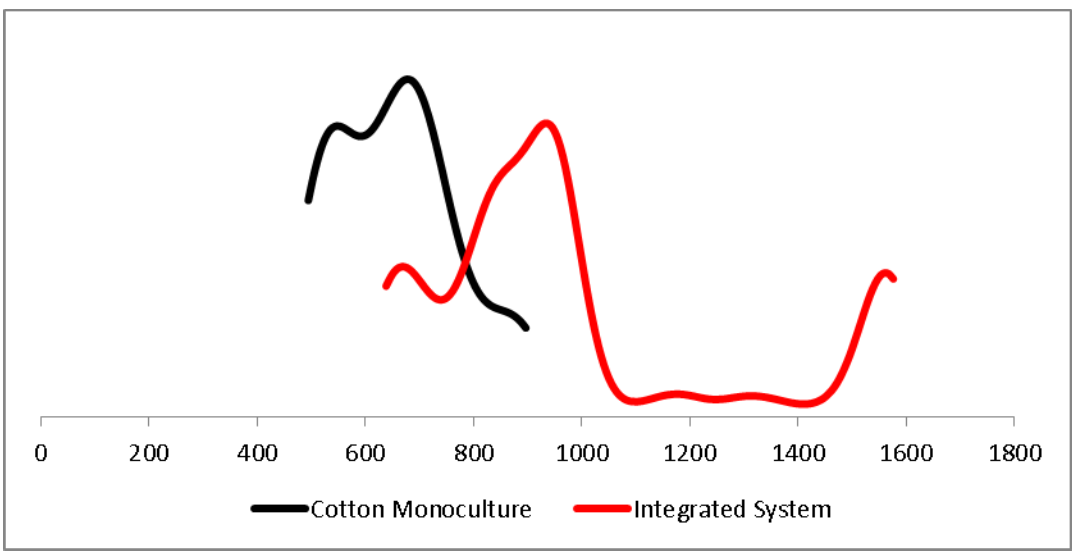

Figure 5. Probability distribution functions (PDFs) for cash expenses under the cotton monoculture and integrated systems.

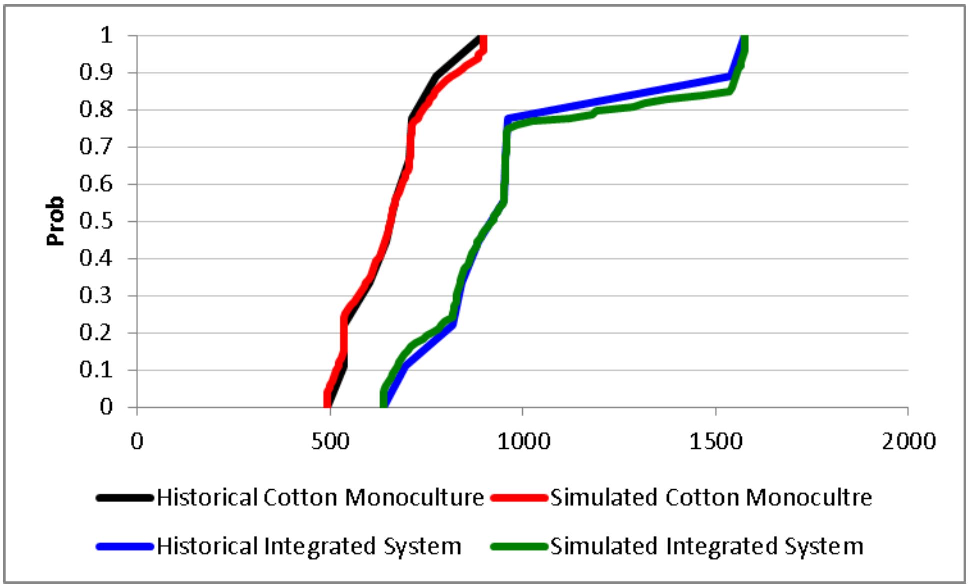

Figure 6. Cumulative distribution functions (CDFs) for cash expenses under the cotton monoculture and integrated systems.

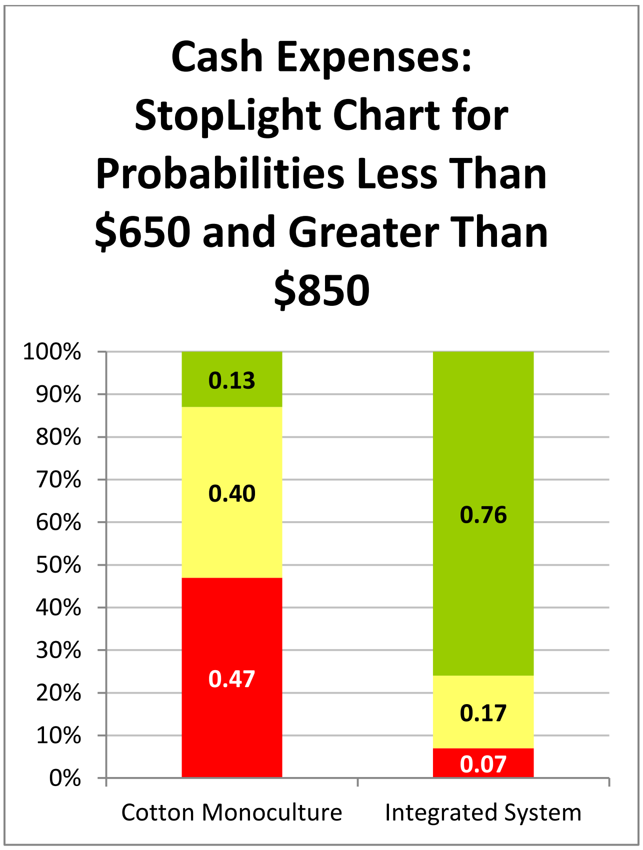

Figure 7. Stoplight/Probability chart for cash expenses under the cotton monoculture and integrated systems.

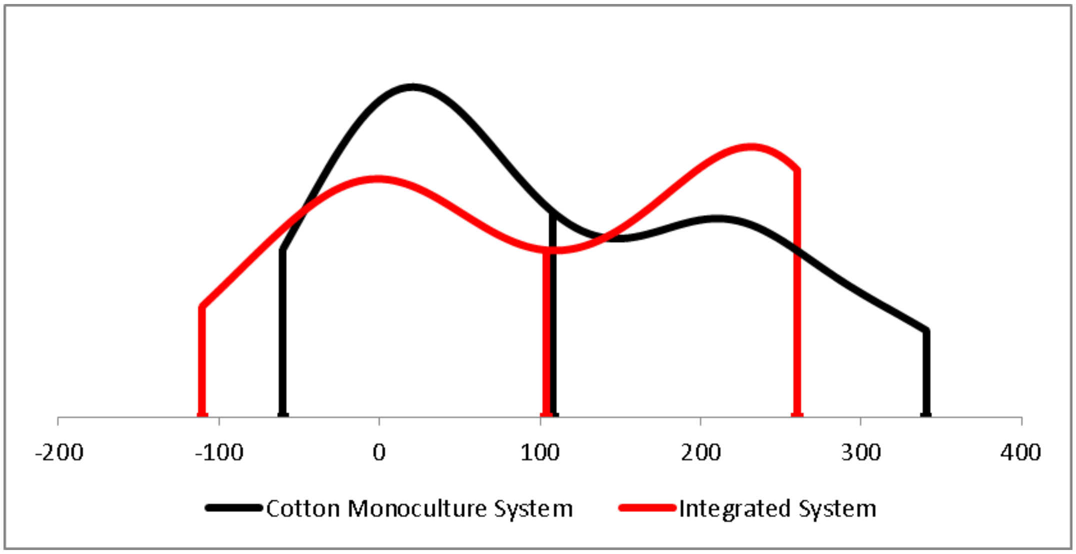

Figure 8. Probability distribution functions (PDFs) for gross margin under the cotton monoculture and integrated systems.

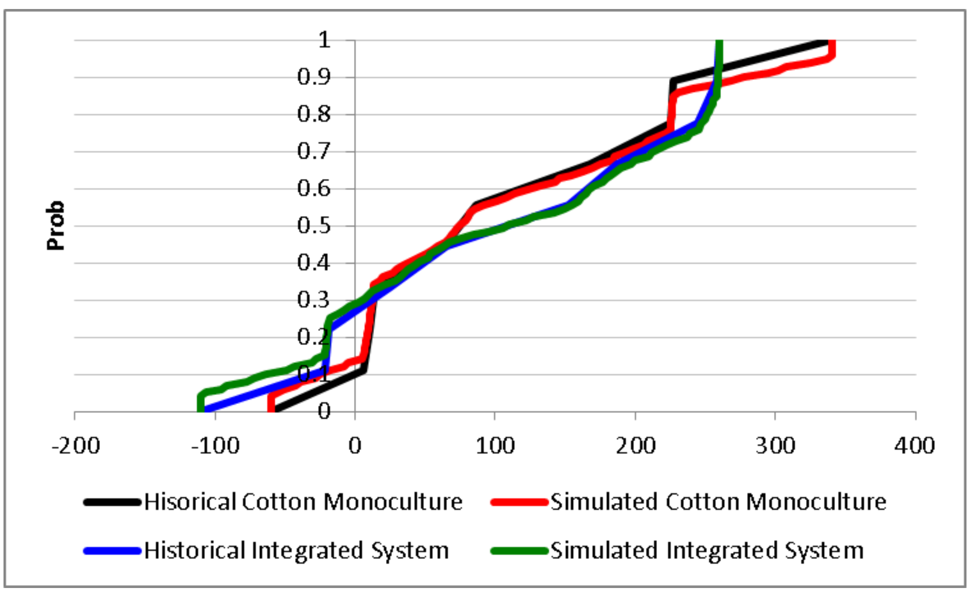

Figure 9. Cumulative distribution functions (CDFs) for gross margin under the cotton monoculture and integrated systems.

Figure 10. Stoplight/Probability chart for gross margin under the cotton monoculture and integrated systems.

Table 1. Gross Margin per Acre Inch of Water for the cotton monoculture and integrated systems.

Gross Margin Per Acre Inch of Water		
Year	**Cotton Monoculture**	**Integrated**
1999	0.69	12.20
2000	-2.79	-1.08
2001	0.77	4.69
2002	0.38	1.72
2003	21.03	19.85
2004	19.25	32.89
2005	4.71	-2.06
2006	3.80	-7.23
2007	13.87	32.71
2008	27.51	30.46
Average	8.92	12.41