Analysis of Irrigated Corn Production Adoption Decisions in Alabama

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Introduction

Corn prices and production are increasing due to expanding ethanol markets and related supports for corn production. Persistence of this trend will likely lead to adoption of more intensive production practices and expansion of corn acreage to marginal areas. Alabama, unlike many traditionally agricultural states, has relatively abundant water supply that permits sustainable irrigated crop production but may also strain the natural resources. It is therefore important to know how private (producer) decisions on adoption of irrigated practices are likely to be affected by market conditions (prices, costs) and producer characteristics (risk attitudes, production scale and mix).

To show the viability of irrigation for corn, simulated corn yield data for irrigated and rainfed corn production in Northern Alabama is compared to analogous historical yields data. The use of simulated data is necessitated by the absence of reliable irrigated yield data from the area with predominantly rainfed crop production. The simulated yield series, combined with enterprise budget data on variable costs for both practices, irrigation investment costs, and other economic data, are used to generate stochastic profits from corn production. Based on these profit data, profitability of irrigated and rainfed corn production is compared for different assumed producer risk attitudes, corn prices, and interest/internal discount rates. Viability/Profitability comparison is done on the basis of certainty equivalent profits calculated by calibrating a CARA utility function parameters for different risk premium values.

Comparison of the simulated and historic yield series provides some evidence of their similarities. The results of profit analysis show that the certainty equivalent profit premium from irrigated production increases with risk aversion and with output prices. Raising corn prices magnifies rainfed yield volatility more than that of irrigated yield, making irrigated production more desirable. According to the numerical simulation results, investment in irrigation does not pay off at the price of $3.25/bu at all reasonable risk premiums and discount rates but becomes preferable for relatively low risk aversion levels when the price reaches $3.75/bu. Adoption of irrigated production is quite profitable at the current high prices of about $4.75/bu, even when the yield data are transformed to proxy for farm supports, which reduces yield variability and makes the cheaper rainfed production more attractive.

The rest of the paper is structured as follows. In Section 2, data used in the analysis is described. In Section 3, comparison of historical and simulated yield series is presented. In Section 4, the methodology and results of irrigation adoption decision analysis are discussed. Section 5 concludes.

2. Data Description

A set of simulated corn yield series has been provided by the Southeast Climate Consortium courtesy of Dr. McNider, UAH. Corn yields were simulated for Madison county, Alabama, using the Decision Support System for Agrotechnology Transfer (DSSAT) and weather data collected by Belle Mina weather station. Long-term historical weather data (1951-2005) were obtained from the National Weather Service (NWS) Cooperative Observer Program (COOP) network and compiled by the Center for Oceanic-Atmospheric Prediction Studies (COAPS), through the South-Eastern Climate Consortium (SECC). The weather variables include daily maximum and minimum temperatures and precipitation. A solar radiation generator, WGENR, with adjustment factors obtained for the southeastern USA, was used to generate daily solar radiation data. Regardless of their complexity and accommodation of biological and physical processes, crop simulation models are deterministic. Therefore, whatever randomness in simulated yields is observed for same plots and management practices comes from random weather realizations. In this way, the simulated data is analogous to a controlled experiment. At the same time, it would be hard to translate weather variability, expressed in so many ways, into yield variability through the model mechanics. For instance, cumulative measures of precipitation and solar radiation may not be correlated with yields if the weather patterns are different, as evidenced by a comparison of the effect on plant growth of a week with four rainy days each followed by a sunny one with a week in which it rains four days in a row (the first one is likely to be more favorable for growth). Thus, we do not try to deliberately draw parallels between climate indexes and our findings. Instead, we independently estimate the distributions of the simulated yields without forming any a priori expectations based on climate research.

The soil profile data for Madison county were obtained from the soil characterization database of the USDA National Resource Conservation Service. The yields were simulated separately for irrigated and non-irrigated practices. The simulated annual data covers the period from 1951 to 2003 and assumes modern “best” management practices.

Variable production cost data are compiled from enterprise budgets. Irrigation equipment costs are calculated using agricultural engineering data for a representative 140 acre farm. The variable costs items include seed, fertilizers and chemicals, labor, machinery, irrigation operating expenses calculated including investment costs, land rent (assumed $70/acre), and interest on operating capital. The irrigation investment costs for the farm include investment in pumping equipment, piping, and a pond, and amount to $175,000. The useful life of the investment component ranges from 10 (pump) to 56 years (pond).

Madison county agriculture can be considered representative of Northern Alabama.

Table 1 contains some 2002 census data used in the analysis. The most notable fact is that only about 3.6% (3%) of the total harvested cropland (total cropland) are irrigated.

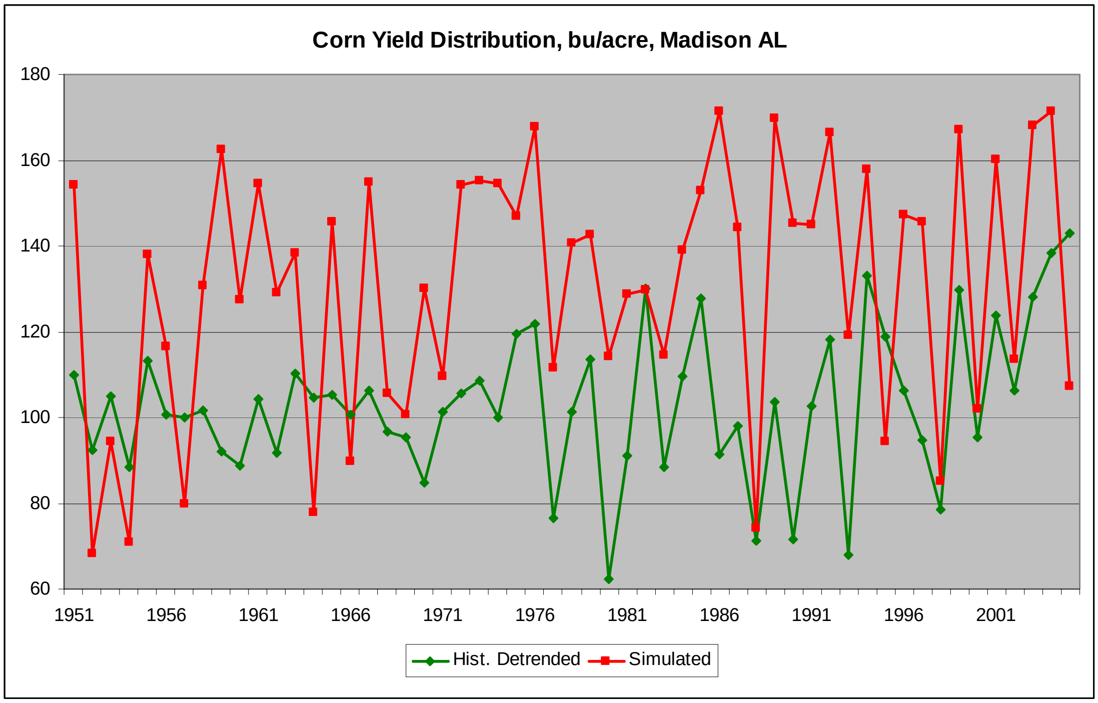
Table 1. Madison county, AL, 2002 Census of Agriculture

Average size of farm (acres)	178
Median size of farm (acres)	65
Total cropland (acres)	140,962
Total cropland - Harvested cropland (farms)	644
Total cropland - Harvested cropland (acres)	110,423
Irrigated land (farms)	58
Irrigated land (acres)	3,981
Government payments (farms)	285
Government payments ($1,000)	2,989
Government payments per acre of harvested cropland	27.06864
Irrigated percentage of total cropland	2.82%

3. Comparison between Simulated and Historical Yield Series

To ascertain the validity of the simulated yield data, we also use historical Madison county average yield series from the NASS database. Comparing the simulated and historical yields shows mixed results but confirms that the two series have important similarities. Figure 1 plots over the 1951-2005 period. Historical yield series is detrended using linear procedure and brought to the 2005 yield level. At this point, no corrective procedures were applied to past errors (i.e., scaling or ARIMA models). Visual inspection suggests that the series become more similar, and correlation is more pronounced since 1971, which is considered the starting point of reliable historical series. Data from before that comes from different distributions due to technological shifts and farm consolidation (Ker and Cobble, 2003; Vedeov and Barnett, 2004).

Figure 1. Historical vs. Simulated Rainfed Yield Series, 1951-2005



The yield variables are summarized in Table 2. The means of the variables appear to be different but the variances are not far apart, especially considering that historical county averages are expected to be more stable than individual (simulated) yields. It is not uncommon in economic research using simulated yield data to scale the yields to the historical mean when variance is more important.

Table 2. Simulated and Historical County Average Yields, Madison, AL

Variable	**Mean**	**Std. Dev.**	**Min**	**Max**
Rainfed	130.16	29.27	60.20	168.30
Irrigated	204.88	10.57	171.08	219.59
Irrigated 4%	133.15	28.13	65.78	169.50
Hist. County Av.	105.10	20.96	62.25	143

Table 3 shows correlation coefficients between the two series

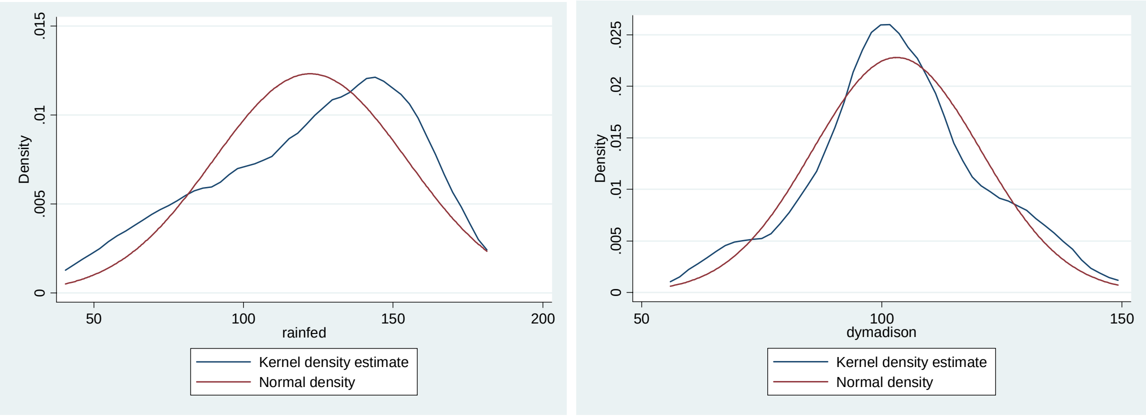
Table 3. Correlation coefficients for the 1971-2005 series

	Simulated yields			
	Rainfed	Irrigated	4% Irrigated	4% Irrigated, **1992-2005**
Historical yields	0.4711	0.2	0.4735	0.51

Most likely due to technological and institutional factors, the two series become more correlated closer to the present time. Both historical and simulated yield and economic returns series for Madison county do not show any evidence of autocorrelation (confirmed by correlograms) suggesting that weather carryover effects are not present in the simulated data. The unit root hypothesis is also rejected in both series.

Figure 2 shows kernel density plots of the simulated rainfed and historical county average yield distributions with corresponding normal distribution overlays.

Figure 2.



Simulated Rainfed Yield

Historical County Average Yield

Historical and simulated data distributions differ significantly in terms of their higher moments. Table 4 shows the differences between the simulated and historical yield distributions. The test statistics are from skewness and kurtosis tests for normality. The simulated yield is much more left skewed which corresponds to analogous findings of historical yield series analysis (Goodwin and Ker, 1998).

Table 4. Skewness and Kurtosis tests

Yields	Pr(Skewness)	Pr(Kurtosis)	adj chi2(2)	Prob>chi2
Rainfed	0.09	0.125	5.11	0.0777
Irrigated	0.004	0.018	11.47	0.0032
Irrigated 4%	0.094	0.135	4.96	0.0836
Historical	0.991	0.703	0.15	0.9296

While we can reject the hypotheses that the simulated yields are normally distributed, normality of dymadison can not be rejected at the 92% level. Shapiro-Wilk normality tests confirm this:

Table 5.

Yields	W	V	z	Prob>z
Rainfed	0.93806	3.141	2.455	0.00705
Irrigated	0.94353	2.864	2.256	0.01202
Irrigated 4%	0.9395	3.068	2.404	0.0081
Historical	0.98268	0.878	-0.279	0.6098

Further exercises show that the simulated yields are not lognormally distributed either.

Non-parametric tests for equality of distributions are not very useful as the historical yield data pool both irrigated and non-irrigated yields. As common procedures for testing equality of variances rely on distributional assumptions which might not hold for the yield data, non-parametric Kolmogorov-Smirnov test is used. The two sample test is based on the maximum absolute difference (D) between the CDFs for two continuous random variables. Unlike conventional statistical tests, this is a non-parametric test that does not require the variables to be normally distributed. The null hypothesis for the Kolmogorov-Smirnov test is that there is no difference in the CDFs between two groups. The largest observed difference between the two CDFs being examined was compared to the critical value of D at the 5 percent level of significance to determine if there is a statistically significant difference between the curves. Test results reported in Table 6 show that the simulated and historic distributions are different (at 3.3% level). However, Kolmogorov-Smirnov tests are not reliable for sample sizes smaller than 50, and the differences between the series' max and min values might additionally bias the results.

Table 6. Kolmogorov-Smirnov Test

Smaller Group	D	P-value
1	0.2182	0.073
2	-0.2727	0.017
Combined K-S	0.2727	0.033

Similarity between the simulated and historical yield series can be traced by their dependence on the El Nino Southern Oscillation (ENSO) phases. The 1951-2005 period covers 13 ElNino, 13 LaNina, and 29 Neutral years. Table 7 compares the average yields in different ENSO phases.

Table 7. Yield Averages by ENSO Phase

ENSO Phase	Simulated		Historical
	Rainfed	Irrigated	
El Nino	107.4	200.3	96.3
La Nina	126.9	209.8	107.2
Neutral	127.0	206.4	104.4
Average	122.3	205.7	103.1

Table 8 shows results of regressing the yields on ENSO dummies

Table 8.

		ENSO Phase	
	El Nino	La Nina	Const
Rainfed	19.59	19.61	107.35
	(1.57)	(1.84)	(12.14)
Irrigated	9.51	6.09	200.26
	(2.69)	(2.02)	(80.11)
Historical	11.31	8.65	97.13
	(1.99)	(1.76)	(23.51)

El Nino has a negative impact on average yields, and it is larger for rainfed but more significant for irrigated production (*so it is hard to say where it's more pronounced*). This is slightly surprising considering that climatologic research finds El Nina years only slightly drier in North Alabama. At the same time, the results for the historical county yields are consistent with the earlier findings of Nadolnyak, Paz, and Novak (2007) based on historical yield analysis.

4. Profitability of Irrigation

Having found certain similarities between the two datasets that lend credence to the simulated data, we proceed to examination of the profitability of irrigated production. Table 9 summarizes the simulated data on yields and profits.

Table 9. Summary of Simulated Yields and Returns

Variable		Mean	Std. Dev.	Min	Max
Yield, bu	Rainfed	122.3193	32.38774	53.547	168.2986
	irrigated	205.7218	9.464152	171.0781	221.348
Production Value, $	Rainfed	397.5378	105.2602	174.0278	546.9706
	irrigated	668.5958	30.75849	556.004	719.381
Profit, $	Rainfed	11.08291	105.26	-212.43	160.52
	irrigated	39.48	30.75863	-73.11	90.27

As expected, on average, irrigated corn production is more profitable and less volatile. However, the data shows that in certain years irrigation can be less profitable than the alternative of no irrigation, which of course is due to higher production costs on irrigated land (the irrigated yields are always higher).

The profits in the dataset represent net income from production. Profits from irrigated production include all the associated irrigation expenses. Table 10 summarizes the operating cost components.

Table 10. Operating Costs.

Operating Costs		Irrigated	Rainfed
	Unit	Total price/acre ($)	Total price/acre ($)
Seed	thousand	29.80	37.25
Fertilizer			
Nitrogen	lbs	96.25	137.50
Phosphate	lbs	21.00	21.00
Potash	lbs	17.40	17.40
Lime	ton	17.33	17.33
Herbicides	acre	17.64	17.64
Insecticides	acre	11.55	11.55
Drying	bushel	15.77	26.74
Hauling	bushel	36.40	61.71
Tractor/Machinery	acre	26.62	26.62
Labor	hrs	11.83	11.83
Irrigation Operating Expenses	dollar	0.00	72.87
Land Rent	dollar	70.00	70.00
Interest on Operating Capital	dollar	14.86	21.18
Total Cost Per Acre per year		**386.45**	**550.61**

The difference is due to two factors: different input applications and the irrigation operating expenses. The latter is calculated as a sum of the annual operating costs (fuel, maintenance, and labor) and investment costs. Investment in irrigation equipment can be considered a sunk cost as its major components include digging a pond ($50,000), installation of pipes, pumps, and electric systems ($100,000), and transportation (freight) expenses. In the table above, the investment depreciation is calculated using a 7 year term at 7% interest but the assumption may vary. For this exercise, the variable input costs are assumed fixed; accommodation of their volatility requires accounting for possible correlations between the costs of different input items.

Net profit per acre is calculated as the difference between the product of price and yield and the per acre costs of production. The volatility of profits is thus entirely due to the simulated yield volatility which, in turn, is due entirely to weather by construction. Table 11 summarizes the two variables for an assumed price of $3.25/bu and 7 year, 7% depreciation.

Table 11. Profits per acre.

	Mean	Std. Dev.	Min	Max
Profit, $/acre				
Rainfed	11.08291	105.26	-212.43	160.52
Irrigated	39.48	30.75863	-73.11	90.27

Not surprisingly, irrigated production is more profitable on average and much less volatile. The differences are magnified by the prices. However, as long as producers are risk averse, these numbers are not sufficient to properly describe the tradeoff between mean and variance in making production and therefore irrigation adoption decisions. Financial literature uses several measures of performance of risk-reducing innovations (mean-variance analysis) such as value at risk (VAR), mean root square loss (MRSL), and certainty equivalent revenues (CER) (Miranda and Glauber, 1997). In production analysis, comparison of certainty equivalent revenues is perhaps the best indicator of a practice’s profitability, as agricultural producers are usually viewed as risk averse and the level of aversion matters (Schnitkey, Sherrick, and Irwin, 2003). In order to determine the thresholds in risk aversion levels, prices, and interest rates that make *switching* to (investment in) irrigation individually rational for a representative producer,

we estimate certainty equivalent revenues for the stochastic per acre profits from the two production practices and compare their differences to the costs of irrigation investment.
For the utility function, constant absolute risk aversion (CARA), or negative exponential, specification of the form $U(R)=1\text{-}exp(\text{-}A{*}R)$ is used. The function is defined over non-negative values of income R and is concave over that range. $A=(0;\, inf]$ is the coefficient responsible for reflecting the level of risk aversion: greater values correspond to greater risk aversion. The assumption on value of A is crucial as the function is extremely sensitive to it. Assigning widely different values A has led to some confusion in interpretation of estimation results (Babcock, Choi, and Feinerman, 1993). In order to only reflect reasonable risk attitudes, assumptions are made about risk premium levels rather than the risk aversion coefficient.

Risk premium is a percentage (share) of the expected stochastic income an individual is hypothesized to be willing to give up in order to eliminate all risk. Most common values for it range from 30% to 5% (Vedenov and Barnett, 2004). Having assumed a risk premium of θ, the risk aversion coefficient (A) is obtained by numerically solving a fixed point problem via function iteration by equating expected utility of revenue to the utility expected revenue scaled by the risk premium:

$$E[U(R)] = \mathrm{E}[1\text{-}exp(\text{-}A{*}R)] = 1\text{-}exp(\text{-}A{*}\,\mathrm{E}[R]) = U((1\text{-}\,\theta)E[R])$$

Sensitivity analysis is conducted for risk premiums ranging from 40% to 5% (lower than 5% are virtually the same as risk aversion). The corresponding A's range from 0.016 to 0.0018. Prices ($/bushel) range from $3.25 to $4.25. Lower prices seem irrelevant in the face of surging demand for corn for ethanol. As Westcott notes in the 2007 USDA report, "*As the ethanol industry absorbs a larger share of the corn crop, higher prices for corn will intensify demand competition among domestic industries and foreign buyers of feed grains. USDA's 2007 long-*

term projections show average corn prices reaching $3.75 a bushel in the 2009/10 marketing year and then declining to $3.30 by 2016/17 as the ethanol expansion slows. Corn prices at these levels are record high and are unprecedented on a sustained basis, exceeding the previous high average over any 5-year period by more than 50 cents a bushel". In January '08, March corn futures prices hovered around $4.75 (CBOT data) but the upward trend depends heavily on the future of ethanol and government support of its production.

Irrigation costs also vary by the interest rate assumed. The depreciation is calculated as a payment for a loan (investment) based on the lifetime of investment components (ranging from 15 to 56 years, constant payments and a constant interest rate, except that the interest rate is interpreted as an internal discount rate. The investment cost component for different discount rates enter the profit per acre calculation and thus affect the outcome.

The simulated yields are scaled by a coefficient that equates the means of the historical and irrigation percentage weighted simulated series. '02 NASS census data for Madison county, AL, shows that about 2% of acreage was irrigated. Table 12 below shows the differences in certainty equivalent net revenues per acre from irrigated and rainfed corn production.

Column 4 reports the difference between certainty equivalents of the profits from irrigated and rainfed production. The difference represents gross returns to (investment in) irrigation. Comparing these data for different risk premiums to the investment costs for different interest rates defines the breakeven points beyond which irrigation becomes individually rational. This is important for an area with only 2% of harvested cropland being irrigated. The results show that the certainty equivalent profit "premium" for irrigation increases with risk aversion and with output prices. The monotonicity of these relationships has been confirmed by more extensive analysis.

Table 12. Certainty Equivalent Revenues for Irrigated and Rainfed Production, No Yield Supports

θ	**Rainfed, $/acre**	**Irrigated, $/acre**	**Irrigated - Rainfed**
Price=$3.25/bu			
40%	-69.32	30.42	**$99.74**
35%	-58.15	32.01	**$90.16**
30%	-46.97	33.37	**$80.34**
25%	-35.79	34.57	**$70.36**
20%	-24.62	35.64	**$60.26**
15%	-13.44	36.65	**$50.09**
10%	-1.76	37.64	**$39.40**
5%	9.99	38.63	**$28.63**
Price=$3.75/bu			
40%	-42.61	129.88	**$172.48**
35%	-29.32	132.13	**$161.45**
30%	-15.67	134.03	**$149.70**
25%	-1.64	135.68	**$137.32**
20%	12.75	137.16	**$124.42**
15%	27.43	138.53	**$111.10**
10%	43.00	139.88	**$96.88**
5%	58.76	141.20	**$82.45**
Price=$4.25/bu			
40%	-8.40	228.66	**$237.06**
35%	6.75	231.72	**$224.97**
30%	22.71	234.28	**$211.57**
25%	39.54	236.49	**$196.95**
20%	57.24	238.46	**$181.22**
15%	75.72	240.26	**$164.54**
10%	95.66	242.02	**$146.36**
5%	116.01	243.74	**$127.72**

Annual Irrigation Investment Cost:

Discount Rate	**Total**	**W/out pond**
3%	**$72.23**	59.99
5%	**$90.72**	71.62
7%	**$109.82**	84.25
10%	**$140.72**	104.83

Both results are intuitive: the more risk averse the producer, the more she will prefer the (always) less volatile profits from irrigated production, *ceteris paribus.* Raising corn prices magnifies rainfed yield volatility more than that of irrigated yield, making irrigated production more desirable. According to the numerical simulation results, and assuming constant output and input prices (more on those below), investment in irrigation does not pay off at the price of $3.25/bu at all reasonable risk premiums and discount rates. However, it makes sense to invest in irrigation at 15% premium level and 7% internal discount rate when the price reaches $3.75/bu. When the price reaches $4.25/bu, something not observed until recently, irrigation always pays off. These results perhaps help explain the observed lack of irrigation in Nothern Alabama.

As agricultural production is subject to a number of government supports, modified and raw yield series are used in the calculations. The modified yield series are truncated at the 80% percent of the mean to reflect a set of government supports (counter-cyclical, deficiency payments, and disaster assistance) and crop insurance that put a lower limit on yields. For the illustrative purposes of sensitivity analysis, the number is chosen arbitrarily due to the difficulty of correctly incorporating the actual supports. Table 13 shows results for the censored yield series.

Again, the results are quite intuitive. Introduction of hypothetical yield supports reduces profit variability and increases the certainty equivalent of profits from rainfed production. As a result, irrigation investment becomes worthwhile only at the high price of $4.25.

A note on price volatility is in order. Current simulation results reflect only yield volatility and ignore price volatility. Output prices, however, are another source of revenue uncertainty. Volatility of agricultural prices is sometimes measured as standard deviations of the logarithms of ratios of the current year's price to preceding year's price ($\mathrm{Std}[\log(P_t/P_{t-1})]$). For corn, it's about 16-17 (USDA ERS reports). As local adoption of irrigated production practices is not likely to affect prices, price volatility can be viewed as exogenous. Hedging against price risk using futures markets does not completely eliminate price volatility. An additional complication of accommodating arises from the fact that prices and yields are likely to be negatively correlated. Wang et al. (1998) report a price-yield correlation coefficient of -0.46 corn in Iowa; however, the magnitude of correlation depends on a particular area. Thus, introducing price volatility may lower the bar for economic efficiency of irrigation. No expectation is held about input costs.

Table 13. Certainty Equivalent Revenues for Irrigated and Rainfed Production, Yields Capped Below %80 of Original Mean

θ	**Rainfed, $/acre**	**Irrigated, $/acre**	**Irrigated - Rainfed**
Price=$3.25/bu			
40%	-12.61	30.42	**$43.02**
35%	-7.89	32.01	**$39.90**
30%	-3.16	33.37	**$36.53**
25%	1.62	34.57	**$32.94**
20%	6.50	35.64	**$29.14**
15%	11.55	36.65	**$25.10**
10%	17.07	37.64	**$20.58**
5%	22.97	38.63	**$15.66**
Price=$3.75/bu			
40%	39.96	129.88	**$89.92**
35%	45.58	132.13	**$86.55**
30%	51.35	134.03	**$82.68**
25%	57.29	135.68	**$78.39**
20%	63.48	137.16	**$73.68**
15%	69.99	138.53	**$68.54**
10%	77.20	139.88	**$62.68**
5%	85.00	141.20	**$56.20**
Price=$4.25/bu			
40%	91.85	228.66	**$136.82**
35%	98.30	231.72	**$133.42**
30%	105.05	234.28	**$129.23**
25%	112.16	236.49	**$124.33**
20%	119.70	238.46	**$118.76**
15%	127.76	240.26	**$112.50**
10%	136.84	242.02	**$105.18**
5%	146.78	243.74	**$96.95**

Annual Irrigation Investment Cost

Discount Rate	**Total**	**W/out pond**
3%	**$72.23**	59.99
5%	**$90.72**	71.62
7%	**$109.82**	84.25
10%	**$140.72**	104.83

Of course, considering the irrigation equipment lifetime of 20 years, price *expectations* should play a role in decision making, but so should the opportunity costs, attachment to the land, and other values. Another possible drawback of this analysis comes from the fact that the cost and yield data for irrigated production are calculated assuming irrigation regardless of the weather conditions, whereas in practice irrigation may be stopped under particularly favorable weather conditions (i.e., investment in irrigation is irreversible but its usage is not).

Conclusion

In this paper, corn yield simulation data for irrigated and rainfed corn production in Northern Alabama is compared to analogous historical yields data. The simulated yield series, combined with enterprise budget data on variable costs for both practices, irrigation investment costs, and other economic data, are used to generate stochastic profits from corn production. Based on these profit data, profitability of irrigated and rainfed corn production is compared for different assumed producer risk attitudes, corn prices, and interest (internal discount) rates. Comparison is done on the basis of certainty equivalent profits calculated by calibrating a CARA utility function parameters for different risk premium values.

Comparison of the simulated and historic yield series provides weak evidence of their similarities. The discrepancies are explained by county-level averaging, underreporting catastrophic yields, and other peculiarities of historical data. The results of profit analysis show that the certainty equivalent profit premium from irrigated production increases with risk aversion and with output prices. Raising corn prices magnifies rainfed yield volatility more than that of irrigated yield, making irrigated production more desirable. According to the numerical simulation results, investment in irrigation does not pay off at the price of $3.25/bu at all reasonable risk premiums and discount rates but becomes profitable at 15% premium level and 7% internal discount rate when the price reaches $3.75/bu. When the price reaches $4.25/bu, irrigation always pays off. Censoring the yield series at 0.8*(mean) to proxy for government supports and crop insurance reduces profit variability and increases the certainty equivalent of profits from rainfed production. As a result, irrigation investment becomes worthwhile only at the high price of $4.25.

These results may help explain the observed lack of irrigation in Nothern Alabama. They also can be useful in evaluating (the effects of) potential adoption of corn irrigation practices in areas with traditionally low irrigation levels due to the expanding ethanol markets.

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