

# ECONOMIC ANALYSIS OF EFFICIENT IRRIGATION FOR MAXIMIZING CORN YIELD

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## INTRODUCTION

This publication provides an economic analysis that quantified the partial net returns of irrigation frequency in a corn research trial at Milan, Tennessee. Additionally, this analysis examined the likelihood of profitable outcomes for the three irrigation treatments compared to rainfed plots. Agronomic data was collected from a field experiment that was conducted in large, replicated plots at the Milan Research and Education Center (REC), under a center pivot irrigation system equipped with variable rate irrigation (VRI) technology. Irrigation events were triggered by stage of production and soil moisture sensors. Results of this analysis can be utilized to guide Tennessee corn producers' irrigation frequency and timing decisions, as well as assist in evaluating the potential return on investment for irrigation systems.

## BASICS OF THE AGRONOMIC STUDY

Corn requires different amounts of water at different growth stages, particularly during reproductive stages (R1-R5). Timing, intensity and duration of rainfall events throughout the growing season will influence the decision to irrigate. To optimize yield, corn requires rainfall or irrigation at critical times during the season. Understanding the physiological responses of corn plants to a gradient of soil moisture can help determine at what soil moisture level yield is affected. This information can be used to avoid damage from water stress, as well as allow producers to apply an adequate amount of water without overwatering corn. Inappropriate irrigation scheduling can result in both excessive or inadequate water application, which can add unnecessary costs and significantly reduce the potential for corn profitability.

In 2020 and 2021, a field experiment was conducted in large, replicated plots at the Milan REC, under a center pivot irrigation system equipped with VRI technology. The corn hybrids DKC64-35 and P1464VYHR, both full-season (i.e., 114 relative maturity) were selected for this study in 2020 and 2021, respectively. Due to limitation in commercial seed availability, a comparable Pioneer hybrid was chosen for the second year of the study. The plots were arranged in randomized complete block design consisting of four levels of irrigation treatments, with four replications for each treatment, a total of 16 plots. The research plots were large (i.e., 112 × 118 ft) to allow a transitional area between irrigation treatments and accommodate a commercial combine for harvest. The irrigation timings were adjusted based on three critical growth stages:

- Mid- to late-vegetative stage (week 6-7 after emergence)
- At pollination (week 8-10 after emergence)
- At grain fill late in the season (week 11-17 after emergence)

The irrigation treatments consisted of:

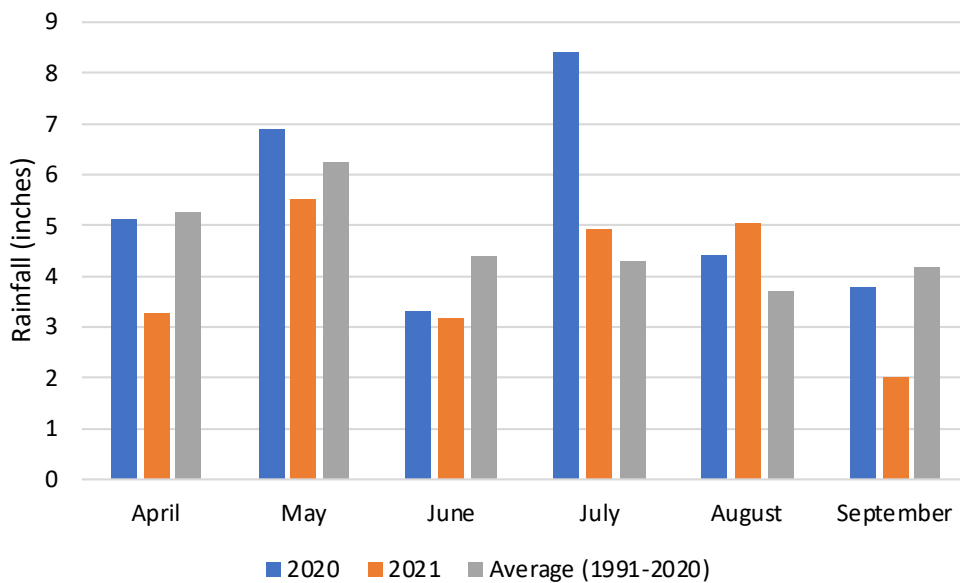
**RF** [rainfed (no irrigation)], (2) **i-1**, (3) **i-2** and (4) **i-3** (**Table 1**).

Average rainfall at Milan, TN, by month is shown in **Figure 1**. Irrigation treatments (i-1, i-2, i-3) varied from more frequent applications to less frequent applications (i-1 = 10; i-2 = 9; and i-3 = 5). For 2020, irrigation treatments are summarized in Table 1 and were as follows: RF — rainfed; i-1 — three applications in June, four applications in July and three applications

in August; i-2 — three applications in June, three applications in July and three applications in August; and i-3 — two applications in June, two applications in July and one application in August. Application amount was 0.55 inches for each application. Total amount of irrigation water applied for each treatment was: RF = 0; i-1 = 5.50; i-2 = 4.95; and i-3 = 2.75. For 2021, irrigation treatments were as follows: RF — rainfed; i-1 — two applications in June, one application in July and two applications in August; i-2 — two applications in June, one application in July and one application in August; and i-3 — two applications in June, zero applications in July and one application in August. Application amount was between 0.4 and 0.55 inches. Total amount of water applied for each treatment was: RF = 0; i-1 = 2.45; i-2 = 1.85; and i-3 = 1.2. Irrigation was initiated by soil sensors at a depth of 8 and 26 inches. Irrigation was scheduled using a formula that considers sensors depth, reading value and percentage (%) of crop rooting zone (Roach and Gholson, 2016). The sensor recording at 8 inches represents the top 50 percent of the rooting zone for the corn plant; therefore, the sensor value is multiplied by (0.5) to determine the actual soil water viability for that zone. The process was repeated for the sensor at 26 inches (i.e., 50 percent of rooting zone) then the overall available water was calculated. Irrigation was withheld if soil matric potential was greater than -70 (kPa). A detailed video discussion of the physiological and agronomic study and how irrigation events were triggered is available [here](#).

**Table 1. Irrigation occurrences and amounts by treatment and year.**

Treatment	Year	June		July		August		
		# of apps	Inches per app	# of apps	Inches per app	# of apps	Inches per app	Total irrigation water applied (inches)
RF	2020	-	-	-	-	-	-	0
RF	2021	-	-	-	-	-	-	0
i-1	2020	3	0.55	4	0.55	3	0.55	5.50
i-1	2021	2	0.55, 0.40	1	0.5	2	0.5	2.45
i-2	2020	3	0.55	3	0.55	3	0.55	4.90
i-2	2021	2	0.55, 0.40	1	0.5	1	0.4	1.85
i-3	2020	2	0.55	2	0.55	1	0.55	2.75
i-3	2021	2	0.4	0	0	1	0.4	1.20



**Figure 1. Monthly rainfall 2020, 2021 and average (1991-2020)**

For 2020 and 2021, planting dates were April 28 and April 15, and harvest dates were October 1 and September 29, respectively. Average yield by treatment ranged from 193.6 bu/acre to 248.4 bu/acre (Table 2).

**Table 2. Minimum, maximum and average observed corn yield by treatment (bu/acre)**

	2020			2021		
	Min	Max	Average	Min	Max	Average
RF	169.5	218.0	193.6	238.7	241.5	240.3
i-1	211.1	227.7	219.6	239.0	248.0	243.8
i-2	210.0	228.0	218.9	242.0	250.0	246.2
i-3	211.6	234.7	219.5	244.7	255.0	248.4

RF = rainfed; i-1 = irrigation treatment 1; i-2 = irrigation treatment 2; i-3 = irrigation treatment 3.

## ECONOMIC ANALYSIS

The physiological and agronomic study was extended to include an economic analysis that quantified the cost of irrigation frequency in corn production in Tennessee and the likelihood of profitable outcomes. Yield advantage over rainfed corn, variable irrigation costs and marketing year price determined the likelihood of profitably irrigating corn in Tennessee. A Gray, Richardson, Klose and Schumann (GRKS) distribution was generated using the agronomic data input into Simulation for Applied Risk Management (SIMETAR®). The distribution is used to simulate subjective probability distributions based on minimal data (minimum, midpoint and maximum). Using estimated variable irrigation cost per event (average of \$8.53/acre), quantity or water applied by treatment, average yield by treatment and marketing year average prices in Tennessee from 2006 to 2020, the likelihood of obtaining a net return per acre of less than zero dollars, zero dollars to \$100/acre and greater than \$100/acre, compared to rainfed, was generated by simulating 1,000 iterations. Fixed irrigation costs were not included in the analysis. So, the partial net returns advantage over rainfed production would need to cover the annualized fixed costs for the irrigation system.

To help with uncertainty in prices over time, three pricing scenarios were estimated: 1) a random price draw based on historical US Department of Agriculture (USDA) reported corn prices in Tennessee from 2000 to 2020 (minimum price was \$1.96/bu; maximum price was \$7.28/bu; and average was \$4.35/bu; standard deviation for the price series was \$1.40/bu); 2) a low price (\$2.93/bu; 2006); and 3) a high price (\$7.28/bu; 2012). The probability of a favorable outcome was greater under the high price than low price scenarios (Figure 2). Based on the random price draw, the probability of obtaining an unfavorable (less than \$0/acre return over rainfed) result was 21 percent for i-1, 18 percent for i-2 and 14 percent for i-3, and the probability of obtaining a favorable (greater than \$100/acre) result was 44 percent for i-1, 47 percent for i-2 and 53 percent for i-3. Overall, Figure 2 shows i-3 (53 percent — random price draw; 26 percent — low price; and 69 percent — high price) had the greatest probability of a favorable outcome followed by i-2 (47 percent — random price draw; 19 percent — low price; and 66 percent — high price). High corn prices increased the magnitude of the returns, as shown in the cumulative distribution function (CDF) (Figure 3). The CDF shows the accumulated likelihood (y-axis) of partial net returns (x-axis) exceeding the rainfed control. For example, irrigation treatment i-3 with high prices (i-3H; blue line in Figure 3) had a 50 percent probability of being below \$179.71/acre compared to rainfed. Similarly, irrigation treatment i-1 with low prices (i-1L; green line in Figure 3) had a 50 percent probability of being below \$39/acre compared to rainfed.



**Figure 2. Probability of having partial net returns, compared to rainfed production, of less than \$0, \$0 to \$100/acre or greater than \$100/acre compared to rainfed for irrigation treatment by price.**

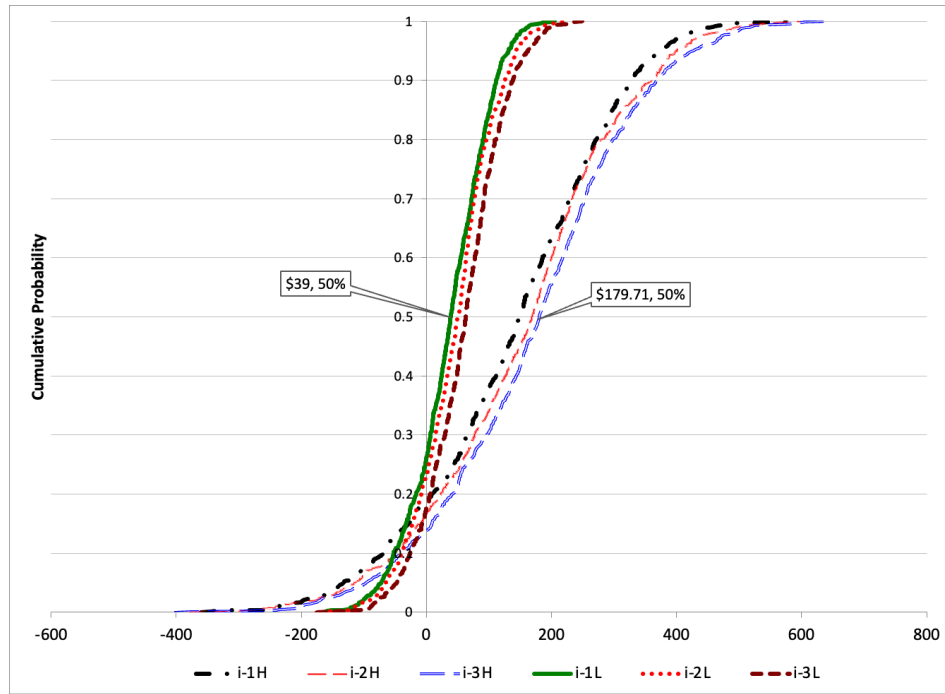


Figure 3. Cumulative distribution function of partial net returns for high (H) and low (L) corn price for three irrigation treatments (i-1, i-2 and i-3).

### IRRIGATION PROFITABILITY DECISION AID

Irrigation costs vary based on the type of irrigation system, energy source, location, field size and well depth. As such, it is important for producers to estimate the costs specific to their operation. A decision aid was developed to allow users to estimate breakeven prices or yields, plus variability in outcomes for different combinations of price, fixed cost, variable cost, quantity of water applied and projected yield advantages over rainfed production. Additional irrigation break-even analysis was completed by Boyer et al., 2014, Boyer et al., 2015 and Pasaribu et al., 2021). Default estimates for fixed costs (establishment) and variable (operating) costs were provided for a center pivot irrigation system. Fixed costs (purchase price, site preparation, construction, interest, insurance and salvage value) were annualized based on the projected useful life for the irrigation system and estimated at \$99.83/acre (\$11,979 per year for 120 acres). Operating costs were estimated by irrigation event and quantity of water applied and included labor, energy, repair and maintenance, and other operating costs. Operating costs were estimated at \$8.53 per acre inch applied. Costs have risen in 2021 and 2022, and there is uncertainty about future costs. The decision aid allows producers to specify costs, price, yield advantage and water applied to estimate projected profitability under multiple scenarios.

		Projected Profitability for Irrigating Corn																				
		Price (\$/bu)																				
		3.50	3.75	4.00	4.25	4.50	4.75	5.00	5.25	5.50	5.75	6.00	6.25	6.50	6.75	7.00	7.25	7.50	7.75	8.00	8.25	8.50
User can specify value		0	-125.43	-125.43	-125.43	-125.43	-125.43	-125.43	-125.43	-125.43	-125.43	-125.43	-125.43	-125.43	-125.43	-125.43	-125.43	-125.43	-125.43	-125.43	-125.43	-125.43
		2	-118.43	-117.93	-117.43	-116.93	-116.43	-115.93	-115.43	-114.93	-114.43	-113.93	-113.43	-112.93	-112.43	-111.93	-111.43	-110.93	-110.43	-109.93	-109.43	-108.93
		4	-104.43	-102.93	-101.43	-99.93	-98.43	-96.93	-95.43	-93.93	-92.43	-90.93	-89.43	-87.93	-86.43	-84.93	-83.43	-81.93	-80.43	-78.93	-77.43	-75.93
		6	-97.43	-95.43	-93.43	-91.43	-89.43	-87.43	-85.43	-83.43	-81.43	-79.43	-77.43	-75.43	-73.43	-71.43	-69.43	-67.43	-65.43	-63.43	-61.43	-59.43
Current Harvest Price (\$/bu)	\$6.00	8	-90.43	-87.93	-85.43	-82.93	-80.43	-77.93	-75.43	-72.93	-70.43	-67.93	-65.43	-62.93	-60.43	-57.93	-55.43	-52.93	-50.43	-47.93	-45.43	-42.93
Irrigation Fixed Cost (\$/acre)	\$99.83	10	-83.43	-80.43	-77.43	-74.43	-71.43	-68.43	-65.43	-62.43	-59.43	-56.43	-53.43	-50.43	-47.43	-44.43	-41.43	-38.43	-35.43	-32.43	-29.43	-26.43
Variable Cost (\$/inch)	\$8.53	12	-76.43	-72.93	-69.43	-65.93	-62.43	-58.93	-55.43	-51.93	-48.43	-44.93	-41.43	-37.93	-34.43	-30.93	-27.43	-23.93	-20.43	-16.93	-13.43	-9.93
Water Applied (Inches)	3	14	-69.43	-65.43	-61.43	-57.43	-53.43	-49.43	-45.43	-41.43	-37.43	-33.43	-29.43	-25.43	-21.43	-17.43	-13.43	-9.43	-5.43	-1.43	2.57	6.57
Projected Yield Advantage (bu)	25	16	-62.43	-57.93	-53.43	-48.93	-44.43	-39.93	-35.43	-30.93	-26.43	-21.93	-17.43	-12.93	-8.43	-3.93	0.57	5.07	9.57	14.07	18.57	23.07
		18	-55.43	-50.43	-45.43	-40.43	-35.43	-30.43	-25.43	-20.43	-15.43	-10.43	-5.43	-0.43	4.57	9.57	14.57	19.57	24.57	29.57	34.57	39.57
		20	-48.43	-42.93	-37.43	-31.93	-26.43	-20.93	-15.43	-9.93	-4.43	1.07	6.57	12.07	17.57	23.07	28.57	34.07	39.57	45.07	50.57	56.07
		22	-41.43	-35.43	-29.43	-23.43	-17.43	-11.43	-5.43	0.57	6.57	12.57	18.57	24.57	30.57	36.57	42.57	48.57	54.57	60.57	66.57	72.57
		24	-34.43	-27.93	-21.43	-14.93	-8.43	-1.93	4.57	11.07	17.57	24.07	30.57	37.07	43.57	50.07	56.57	63.07	69.57	76.07	82.57	89.07
Break Even Yield Advantage for Current Market Price (bushels)	20.90	26	-27.43	-20.43	-13.43	-6.43	0.57	7.57	14.57	21.57	28.57	35.57	42.57	49.57	56.57	63.57	70.57	77.57	84.57	91.57	98.57	105.57
		28	-20.43	-12.93	-5.43	2.07	9.57	17.07	24.57	32.07	39.57	47.07	54.57	62.07	69.57	77.07	84.57	92.07	99.57	107.07	114.57	122.07
Break even Price for Estimated Yield Advantage (\$/bu)	\$5.02	30	-13.43	-5.43	2.57	10.57	18.57	26.57	34.57	42.57	50.57	58.57	66.57	74.57	82.57	90.57	98.57	106.57	114.57	122.57	130.57	
		32	-6.43	2.07	10.57	19.07	27.57	36.07	44.57	53.07	61.57	70.07	78.57	87.07	95.57	104.07	112.57	121.07	129.57	138.07	146.57	155.07
		34	0.57	9.57	18.57	27.57	36.57	45.57	54.57	63.57	72.57	81.57	90.57	99.57	108.57	117.57	126.57	135.57	144.57	153.57	162.57	171.57
		36	7.57	17.07	26.57	36.07	45.57	55.07	64.57	74.07	83.57	93.07	102.57	112.07	121.57	131.07	140.57	150.07	159.57	169.07	178.57	188.07
		38	14.57	24.57	34.57	44.57	54.57	64.57	74.57	84.57	94.57	104.57	114.57	124.57	134.57	144.57	154.57	164.57	174.57	184.57	194.57	204.57
		40	21.57	32.07	42.57	53.07	63.57	74.07	84.57	95.07	105.57	116.07	126.57	137.07	147.57	158.07	168.57	179.07	189.57	200.07	210.57	221.07
		42	28.57	39.57	50.57	61.57	72.57	83.57	94.57	105.57	116.57	127.57	138.57	149.57	160.57	171.57	182.57	193.57	204.57	215.57	226.57	237.57
		44	35.57	47.07	58.57	70.07	81.57	93.07	104.57	116.07	127.57	139.07	150.57	162.07	173.57	185.07	196.57	208.07	219.57	231.07	242.57	254.07
		46	42.57	54.57	66.57	78.57	90.57	102.57	114.57	126.57	138.57	150.57	162.57	174.57	186.57	198.57	210.57	222.57	234.57	246.57	258.57	270.57
		48	49.57	62.07	74.57	87.07	99.57	112.07	124.57	137.07	149.57	162.07	174.57	187.07	199.57	212.07	224.57	237.07	249.57	262.07	274.57	287.07
		50																				

Figure 3. Cumulative distribution function of partial net returns for high (H) and low (L) corn price for three irrigation treatments (i-1, i-2 and i-3).

## SUMMARY AND CONCLUSIONS

Irrigation costs vary based on the type of irrigation system, energy source, location, field size and access to water/well depth. Producers should evaluate the variable and fixed costs for their individual operation. The analysis above indicated that the i-3 treatment (less frequent applications) had the greatest likelihood of obtaining the highest net returns compared to rainfed production for the agronomic study completed at Milan, Tennessee. However, the likelihood of exceeding partial net returns above rainfed of greater than \$100/acre was strongly influenced by the price of corn.

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