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ECONOMIC VIABILITY OF GRAIN SORGHUM AND CORN AS A FUNCTION OF IRRIGATION CAPACITY

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INTRODUCTION

Grain sorghum is often hailed as a crop with high water use efficiency and low input costs. For example, NRCS irrigation guide (NRCS, 2010) suggests that at Goodwell, OK, optimum production of corn requires 20 inches of irrigation water, while grain sorghum only requires 15.5 inches. This suggests that as water availability in the Panhandle region declines, grain sorghum may become a more viable crop for irrigation. In addition it is very well adapted to the southern plains and has a feed value that is comparable to corn (Chen et al. 1994). In fact, the energy content is approximately 90-95% of that for corn and the crude protein is 20-30% higher than corn. The 10-year average price for grain sorghum received by producers in the U.S. is $4.17/bu as compared to $4.39/bu for corn. Despite the higher water use efficiency of grain sorghum, its production in the southern high plains under irrigation is still dwarfed by irrigated corn production. Specifically, in the three Oklahoma Panhandle counties of Beaver, Texas and Cimarron there has been an average of 107,935 acres of irrigated corn in the past 10 years as compared to only 37,561 acres of grain sorghum. This suggests a potential for the expansion of irrigated grain sorghum in the future as water availability declines.

This disparity between corn and grain sorghum irrigated acres along with declining irrigation capacity in the region prompted our effort to conduct an economic analysis to determine the short-term and long-term profitability of corn and grain sorghum at irrigation capacities ranging from 6.4 to 0.8 gpm/acre. This analysis was conducted using simulated crop yields and irrigation estimates produced by the EPIC crop model. The model was calibrated using variety performance data collected from the OSU corn and sorghum variety performance trials conducted in the Oklahoma panhandle. It was also validated with data collected at the Oklahoma Panhandle Research and Extension Center.

CROP YIELD AS A FUNCTION OF IRRIGATION CAPACITY:

The yield and irrigation water applied presented in tables 1 and 2 are the result of model simulations in which irrigation was applied at 1.4 inches/application event at a frequency constrained by irrigation capacity and/or a soil moisture depletion. Specifically, the data presented shows the outcome of irrigation triggered when the soil moisture is depleted to 50, 70, or 90% of the plant available water capacity.

Table 1: Results from EPIC Simulation of Irrigated Sorghum Yields and Irrigation rates and irrigation use efficiency using Center Pivot System when irrigation was triggered when soil moisture is depleted to 50, 70 or 90% of plant available water capacity.

Irrigation Capacity	Yield (bu/acre)			Irrigation Applied (inches/acre)			Irrigation Use Efficiency (bu/inch)		
	Soil Moisture Trigger			Soil Moisture Trigger			Soil Moisture Trigger		
GPM/acre	50%	70%	90%	50%	70%	90%	50%	70%	90%
6.4	129	149	163	9.2	12.6	15.6	14	12	10
5.6	129	145	156	9.1	11.8	14.1	14	12	11
4.8	129	140	148	9	10.7	12.6	14	13	12
4.0	126	134	141	8.8	9.8	11.3	14	14	12
3.2	122	129	134	8.3	9.4	10.4	15	14	13
2.4	109	112	117	7.1	7.6	8.3	15	15	14
1.6	90	91	92	3.2	3.4	4.1	28	27	22
0.8	88	88	89	2.4	2.5	2.8	37	35	32

Table 2: Results from EPIC Simulation of Irrigated Corn Yields, Irrigation rates and irrigation use efficiency using Center Pivot System when irrigation was triggered when soil moisture is depleted to 50, 70 or 90% of plant available water capacity.

Irrigation Capacity	Yield (bu/acre)			Irrigation Applied (inches/acre)			Irrigation Use Efficiency (bu/inch)		
	Soil Moisture Trigger			Soil Moisture Trigger			Soil Moisture Trigger		
GPM/acre	50%	70%	90%	50%	70%	90%	50%	70%	90%
6.4	167	194	213	16.2	21.5	22.5	10	9	9
5.6	165	186	199	16.1	20.4	23.1	10	9	9
4.8	163	177	187	15.9	19	21.6	10	9	9
4.0	158	168	175	15.3	17.4	19.5	10	10	9
3.2	152	158	164	14.4	15.9	17.6	11	10	9
2.4	137	139	143	11.8	12.8	13.9	12	11	10
1.6	119	120	122	9.1	9.7	10.3	13	12	12
0.8	98	98	99	5.7	5.9	6.1	17	17	16

As expected, this analysis shows that grain yields for both crops are maximized when soil moisture is maintained at 90% of plant available water holding capacity with 6.4 GPM/acre irrigation capacity (i.e. when moisture was not a constraining factor). In this scenario the sorghum and corn crops received 15.6 and 22.5 inches of irrigation water respectively, which is comparable to the NRCS estimates for average crop requirement. In every scenario presented the irrigation use efficiency is higher for grain sorghum than corn, as is expected. These yields may be compared to average yields reported by NASS in Texas county between 2000-2008 (172 bu/acre for irrigated corn and 82 bu/acre for grain sorghum). Based on this comparison, average corn yields from NASS are on average 20% below expected yields with 6.4 gpm/acre irrigation capacity. In contrast, average grain sorghum yields from NASS are on average 50% of the simulated yields at 6.4 gpm/acre. The 10 year average corn and sorghum yields from performance trials conducted in Texas County of 200 bu/acre and 141 bu/acre, respectively, produced with an average of 21 and 8 inches of water (table

3), respectively, suggests that the model may underestimate the efficiency of grain sorghum while it provides outcomes that are consistent with trial data for corn. Furthermore, the variety performance data also demonstrate that on average the county corn yields are 14% below those achieved in the performance trial and the county grain sorghum yields are 41 % below what is achieved in the performance trial.

Table 3: Average corn and sorghum yields, and irrigation water applied to hybrid performance trials located in Texas County.

Year	------------Corn†---------		-----------Sorghum††--------	
	Average bu/ac	Irrigation inches	Average bu/ac	Irrigation inches
2005	196	17	149	10
2006	183	20	143	5
2007	178	20	92	4
2008	246	21	115	6
2009	226	21	148	9
2010	179	18	145	8
2011	85	21	166	10
2012	240	26	152	11
2013	236	26	145	10
2014	228	18	159	9
Average	200	21	141	8

†Corn average yields were measured at Joe Webb's farm.
††Sorghum average yields were measured at OPREC.

ECONOMIC ANALYSIS BASED ON MODEL SIMULATED YIELDS

Tables 4 and 5 contain the production budgets and estimated net revenue for corn and sorghum, respectively, when irrigated to maintain soil moisture at 90% of plant available water. This soil moisture threshold was selected because the lower yields resulting from lower soil moisture thresholds did not increase short term profit. However, utilization of drier thresholds did show promise in maximizing the long-term net present value of irrigation water.

As expected, corn generates greater profit when irrigation capacity is equal to or greater than 5.0 gpm/acre. Furthermore, it maximizes net revenue at all irrigation capacities because of the greater yield that can be achieved. However, this greater yield comes at a higher variable cost of production. This analysis suggests that although high yielding corn may be an economically superior option when ample water is available, the production of lower cost crops with greater water use efficiency characteristics should be considered in situations with limited irrigation water.

Limitations to irrigated grain sorghum production:

There are certainly practical limitations to the extensive production of irrigated grain sorghum in the Oklahoma panhandle. For example, grain sorghum does not currently contain the crop protection genetics that corn contains, making it more challenging to manage pests such as weeds and insects. As such, grain sorghum will need to be incorporated as a component of a crop rotation system to succeed. Work conducted at the Oklahoma Panhandle research and extension center has shown that both corn and grain sorghum production can be improved when they are produced in rotation. The sugarcane aphid also presents a new uncertainty as to its long-term impact on grain sorghum production costs. As such, producers should adjust the production budgets presented to include their costs associated with managing the new pest.

It is unlikely that grain sorghum will gain production acres in excess of the corn acres. However, this research adds to the body of evidence suggesting that both economic and agronomic benefits could be realized if at least a portion of the 107,935 acres of corn were planted to grain sorghum in situations where irrigation capacities are below 5 gpm/acre.

REFERENCES

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Table 4. Estimated Net Revenue over Variable Cost for Grain Sorghum Irrigated by Central Pivot when Irrigation Occurs at the 90% soil moisture trigger by Well Capacity for a 120 Acre Pivot

Well Capacity	GPM/acre	6.7	5.8	5	4.2	3.3	2.5	1.7	0.8
Yield	bu/ac	163	156	148	141	134	117	92	89
Nitrogen	lbs/ac	181.6	173.6	165.5	157.3	149.2	130.7	102.5	98.7
Phosphorous	lbs/ac	29.4	28.1	26.8	25.4	24.1	21.1	16.6	16.0
Irrigation†	acre-inch	15.6	14.1	12.6	11.3	10.4	8.3	4.1	2.8
Net Revenue ($4.16/bu)	$	677.4	647.7	617.3	586.8	556.5	487.6	382.6	368.2
Fertilizer-Nitrogen	$	99.9	95.5	91.0	86.5	82.0	71.9	56.4	54.3
Fertilizer-Phosphorous	$	15.3	14.6	13.9	13.2	12.5	11.0	8.6	8.3
Seed Cost	$	16.1	16.1	16.1	16.1	16.1	16.1	16.1	16.1
Herbicide Cost	$	52.4	52.4	52.4	52.4	52.4	52.4	52.4	52.4
Insecticide Cost	$	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Crop Consulting	$	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3
Drying	$	21.2	20.2	19.3	18.3	17.4	15.2	12.0	11.5
Miscelleneous	$	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
Custom Hire	$	132.5	129.4	126.2	122.9	119.7	112.5	101.3	99.8
Non Machinery Labor	$	18.0	18.0	18.0	18.0	18.0	18.0	18.0	18.0
Interest	$	15.7	15.1	14.4	13.8	13.1	11.7	9.5	9.2
Irrigation Cost	$	90.4	79.8	70.3	62.6	56.8	44.9	21.9	14.8
Sub Total	$	477.7	457.3	437.9	420.1	404.4	369.9	312.5	300.7
Crop Insurance	$	22.9	22.0	21.0	20.2	19.4	17.8	15.0	14.4
Total Variable Cost	$	500.6	479.3	458.9	440.3	423.8	387.7	327.5	315.1
Net Revenue-Var Cost	$	176.8	168.4	158.4	146.5	132.7	100.0	55.1	53.1

†irrigation is the depth of water applied with a center pivot irrigation system assuming that only 85% of water is delivered to root zone. Irrigation depth also reflects depth of water to be applied under intensive irrigation scheduling management.

Table 5. Estimated Net Revenue over Variable Cost for Corn Irrigated by Central Pivot when Irrigation Occurs at the 90% soil moisture trigger by Well Capacity for a 120 Acre Pivot

Well Capacity	GPM/acre	6.7	5.8	5	4.2	3.3	2.5	1.7	0.8
Yield	bu/ac	213	199	187	175	164	143	122	99
Nitrogen	lbs/ac	196.8	183.0	171.9	160.9	151.0	130.9	112.1	90.9
Phosphorous	lbs/ac	28.5	26.5	25.0	23.4	21.9	19.0	16.3	13.2
Irrigation	acre-inch	22.5	23.1	21.6	19.5	17.6	13.9	10.3	6.1
Net Revenue ($4.48/bu)	$	956.1	890.9	837.3	784.0	736.4	639.0	547.6	443.9
Fertilizer-Nitrogen	$	108.2	100.7	94.6	88.5	83.0	72.0	61.7	50.0
Fertilizer-Phosphorous	$	14.8	13.8	13.0	12.1	11.4	9.9	8.5	6.9
Seed Cost	$	112.6	112.6	112.6	112.6	112.6	112.6	112.6	112.6
Herbicide Cost	$	61.0	61.0	61.0	61.0	61.0	61.0	61.0	61.0
Insecticide Cost	$	16.0	15.7	15.5	15.2	15.0	14.6	14.1	13.6
Crop Consulting	$	6.5	6.5	6.5	6.5	6.5	6.5	6.5	6.5
Drying	$	27.7	25.9	24.3	22.7	21.4	18.5	15.9	12.9
Miscelleneous	$	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
Custom Hire	$	161.5	155.1	149.9	144.7	140.0	130.5	121.5	111.4
Non Machinery Labor	$	18.0	18.0	18.0	18.0	18.0	18.0	18.0	18.0
Interest	$	20.0	19.0	18.1	17.3	16.5	14.9	13.4	11.8
Irrigation Cost	$	130.0	130.5	120.4	107.4	96.1	75.3	55.5	32.7
Sub Total	$	686.5	668.8	643.9	616.0	591.6	543.8	498.8	447.4
Crop Insurance	$	33.0	32.1	30.9	29.6	28.4	26.1	23.9	21.5
Total Varible Cost	$	719.4	700.9	674.8	645.6	620.0	569.9	522.7	468.8
Net Revenue-Var Cost	$	236.6	190.0	162.5	138.4	116.4	69.1	24.9	-25.0

†irrigation is the depth of water applied with a center pivot irrigation system assuming that only 85% of water is delivered to root zone. Irrigation depth also reflects depth of water to be applied under intensive irrigation scheduling management.