Irrigation Scheduling in Crop Production in Louisiana

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Introduction:

Irrigation strategies such as how much water to apply and when to apply it depends on crop specific criteria. Under- irrigation and over irrigation both have drawbacks. Under irrigation generally results in lower yields and returns whereas over irrigation results in environmental pollution, aquifer decline, increased pumping costs, and reduced profits. Optimal irrigation is an economically and environmentally desirable criteria. Many studies have evaluated irrigation scheduling in terms of irrigation technology efficiency and profitability under water supply constraints (Watkins et al., 2014; Sayin and Yilmaz, 2015; and Chebil et al., 2014). Intermediate and highly- efficient irrigation systems use less water compared to inefficient system such as flood irrigation (Peterson & Ding, 2005). Most of the studies concerning irrigation scheduling are field based experiments. Economic studies on water scheduling use dynamic programming (Rougé and Tilmant, 2016; and Singh, 2014). This study primarily evaluates the irrigation efficiency in Louisiana soybean production using an input oriented data envelope approach.

Objective:

- To estimate the technical and scale efficiency score of irrigation in Louisiana soybean production.

Survey and Data Description :

- We designed a field verification questionnaire consisting four sections: general irrigation system information, land and irrigation preparation information, irrigation system maintenance and repair cost, and irrigation scheduling.
- We sent out field verification questionnaire to selected soybean producers who were willing to provide detail information about their irrigation during the 2015 and 2016 crop years.
- We used information from 16 Louisiana soybean producers from seven parishes..

Table 1: Descriptive statistics of input and output variables

Variable	Description	Mean	Std. Dev.
YIELD	Soybean yield per acre in 2015 (bushels/acre)	60.31	7.28
ACRE	Total number of acres irrigated	82.13	45.06
RAIN	Total rainfall during crop period 2015 (inch)	5.31	3.11
N_IRRI	Number of irrigation made in crop period 2015	5.19	1.72
IW_AP	Amount of irrigation water (1000 gal./acre)	266.92	177.49
COS.L	Labor cost per acre in 2015 crop period	2.62	1.40
COS.E	Energy cost per acre for 2015 crop period	17.29	9.43
COS.RE	Total maintenance and repair cost	1310	984.30

- Average soybean yield was 60.3 bushels/acre, average amount of water applied was 266,924 gallons/acre, and average rainfall during crop period 2015 was 5.3 inch.
- Average labor cost, energy cost and total maintenance cost were $2.62/acre, $17.29/acre and $1,310 respectively.

Method:

Input oriented Banker, Chames, and Cooper (BCC) model can be used to estimate the technical efficiency. Mathematically:

$$Min_{\theta,\lambda}\ \theta$$
$$s.t.\ \sum_{k=1}^{k} \lambda_k\, y_{m,k} \geq y_{m,o}\,;\ \sum_{k=1}^{k} \lambda_k\, x_{n,k} \leq \theta..xx_{n,o}\,;\ \sum_{k=1}^{k} \lambda_k = 1;\, and\ \lambda_k \geq 0$$

Water use efficiency is estimated using input oriented DEA model which can be obtained by solving the extended BCC model. Mathematically, we can express it as:

$$Min_{\theta,\lambda}\ \theta^w$$
$$s.t. \sum_{k=1}^{k} \lambda_k\, x_{n-w,k} \leq\ x_{n-w,o}\, t. \sum_{k=1}^{k} \lambda_k\, y_{m,k} \geq\ y_{m,o}\,;$$
$$\sum_{k=1}^{k} \lambda_k\, x_{w,k} \leq\ \theta^w..x_{w,o}\,;\ \sum_{k=1}^{k} \lambda_k = 1;\, and\ \lambda_k \geq 0.$$

Here, θ is the technical efficiency, λ_k is a vector of elements determining efficiency, x_n, y_m are inputs and output and $\sum \lambda_k$=1 is convexity constraint.

The BCC model is based on variable returns to scale. We estimate technical and scale efficiency of Louisiana soybean production using single stage DEA model.

Results:

Table 2 displays the estimated technical efficiency under CRS and VRS, scale efficiency and return to scale status obtained from single stage input oriented DEA.

Table 2: Efficiency scores for examined firms

DMU	YIELD	ACRE	RAIN	IW_AP	COS.L	COS.E	COS.RE	CRS.TE	VRS.TE	SCALE	RTS
1001	50	116	10	579.31	3.19	8.62	1700	0.863	1.000	0.863	IRS
1002	51	90	2	40	1.667	33.33	1500	1.000	1.000	1.000	-
1003	55	14	3	23.143	2.857	21.43	300	1.000	1.000	1.000	-
1004	70	48	12	192	1.25	10.42	780	1.000	1.000	1.000	-
1005	71	120	7	300	3.333	17.50	1200	0.633	1.000	0.633	DRS
1006	54	70	7	510.17	4.429	14.29	2800	0.563	0.678	0.830	IRS
1007	60	48	4.7	446.87	1.25	21.88	500	0.647	0.702	0.922	IRS
1008	68	70	6.5	246.85	0.571	11.43	2360	1.000	1.000	1.000	-
1009	65	34	2	160.94	0.882	11.77	320	1.000	1.000	1.000	-
1010	59	160	4.5	475.31	3.125	9.38	1200	0.937	1.000	0.937	IRS
1011	53	80	4.5	331.2	5.75	12.00	700	0.700	0.861	0.813	IRS
1012	55	60	9.2	418	3.333	9.33	700	0.877	1.000	0.877	IRS
1013	63	135	5	101.33	3.407	14.82	3000	1.000	1.000	1.000	-
1014	66	120	3.5	175	3.333	15.42	700	0.853	0.863	0.989	DRS
1015	55	14	3	54	1.429	42.86	200	1.000	1.000	1.000	-
1016	70	135	1	216.53	2.074	22.22	3000	0.685	0.887	0.772	DRS
Avrg	60.312	82.125	5.31	266.92	2.62	17.29	1310	0.86	0.937	0.915	

Results and Discussion:

- Number of producers operating under IRS, DRS and CRS are six, three and seven respectively.
- The average score of technical efficiency under CRS is 86%, under VRS is 93.7% and scale efficiency is 91.5%.
- Producers operating under the IRS are inefficient and their performance can be improved by reducing the inputs by the ratio of 1-θ_i. For example, efficiency score 86.3% of DMU 1001 under CRS represents that one can obtain the same output by reducing the input by the ratio of 13.7%.
- Average efficiency score of 86% under CRS indicates that the performance of firms can be improved by reducing inputs by 14% in average depending on the firm specific TE scores.
- Holding inputs other than water applied constant, estimated average technical efficiency score under VRS is 54.1% which indicates that overall performance can be improved by reducing 45.9% inputs (tends to save water).

Conclusion:

We accessed detail information about crop irrigation from seven parishes of Louisiana soybean producers who were willing to participate in our irrigation verification survey. Survey participants recorded detailed information such as cost, output, irrigation system information, operation and application. We estimated the technical and scale efficiency of soybean production using an input oriented single-stage data envelop approach. Estimated results indicated that the average technical efficiency under variable returns to scale (VRS) was 93% and 86% under constant returns to scale (CRS). Average scale efficiency was estimated at 91%. Out of 16 DMUs, three firms were operating under DRS and six firms were operating under IRS. Additionally, we estimated the efficiency score by holding inputs other than water applied constant. In this case the estimated average technical efficiency under VRS was 54.1%. In future, this study will be extended by using stochastic frontier analysis with more sample size.