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Yield Gaps in Sugarcane Cultivation under Irrigated *Vis-à-vis* Rain-fed conditions in Andhra Pradesh- An Econometric Estimation

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ABSTRACT

An econometric estimation of efficiency and yield gap in irrigated *Vis-a-vis* rainfed sugarcane cultivation in Visakhapatnam district of Andhra Pradesh was carried-out during 2021-22. The data on various aspects of costs and returns involved in crop along with constraints collected from farmers based on multistage sampling. Budgeting techniques, Cost Concepts, Benefit Cost Ratio (BCR), Bisliah model of Yield gap Analysis and Response-Priority Index were employed for achieving objectives. The results revealed, for plant crop, the BCR (on Operational Costs) was higher in rainfed (0.86) than irrigated (0.83). There was a 48.80 % yield gap between irrigated and rainfed, in which input usage (26.95%) had higher effect than cultural practices (21.85%). The most important constraint in Sugarcane cultivation is shortage of labour during crucial operations. Hence, irrigated sugarcane method is a more remunerative, yields can be sustainable if constraints are addressed and proper package of practices are followed.

Keywords: *Sugarcane, Yield gap analysis, Response-Priority Index, Srikakulam, Vizianagaram, Visakhapatnam, Andhra Pradesh*

As per the latest statistics of Food and Agriculture Organisation (FAO), in the world, during 2021, sugarcane is cultivated in 26.35 million hectares (m Ha) with production of 1,864.66 million tones (mt) . Among the countries, Brazil stands first place in area (9.98 m Ha) and production (715.66 mt) (FAO STAT, 2022). The area under sugarcane in India has steadily increased from 2.21 million hectares in 1931 to 3.28 million hectares in 1987-88 and to 5.16 million hectares in 2020-21. Total sugarcane production in the country during 2020-21 was estimated at 405.40 million tones (https://eands.dacnet.nic.in)

During 2020-21, among the states, Uttar Pradesh (UP) ranked first in terms of area (2.18 mHa) and production (178.34 mt), followed by Maharashtra, Karnataka, Tamil Nadu, Gujarat, Haryana, Bihar and Andhra Pradesh. Andhra Pradesh ranked 10th in both area (0.55 Lha) and production (41.40 Lt). In Andhra Pradesh, 17% of total sugarcane cropped area is being located in Visakhapatnam district, followed by Chittoor and West Godavari (https://sugarcane.dac.gov.in).

Among six agroclimatic zones of Andhra Pradesh, during 2019-20, North Coastal Zone (NCZ) comprises of 52.44% (45,052 Ha) of the area and 43.45% (67.14 Lt) of production The yields of sugarcane in North Coastal Zone is stagnant since last two decades (hovering between 70 to 75 tonnes per hectare). This was mainly because of the more area under rainfed condition (Nearly 40%) where average yield is 45 to 50 t/ha. To know the causes of yield stagnation along with constraints the present study was taken up with following objectives.

1) To work out costs and returns in cultivation of sugarcane under irrigated and rainfed conditions
2) To assess the most important factors effecting the production in sugarcane under irrigated and rainfed conditions
3) To estimate the sources of yield gaps between irrigated and rainfed method of cultivation in Sugarcane
4) To identify the most important constraints in sugarcane cultivation

MATERIALS AND METHODS

The study was conducted during 2021-2022. Multistage sampling technique was adopted in selecting the sampling units at various levels. Highest area under cultivation was taken as criteria in selection

of Zone, District, Mandal and Villages. Among six agroclimatic zones, North Coastal Zone (NCZ) was selected, among the three districts *Viz*., Srikakulam, Vizianagaram and Visakhapatnam of NCZ Visakhapatnam was selected. Same criteria was used for one mandal and three villages selection. For irrigated and rainfed sugarcane, 20 and Ten growers each were selected respectively. Thus, sample design was one zone, one district, three mandals, six villages and 180 farmers (120 and 60 for irrigated and rainfed cultivation) respectively.

Analytical tools:

Apart from budgeting techniques and cost concepts following were employed;

1) Benefit Cost Ratio (BCR): It is calculated as Gross returns accrued divide by total cost incurred on i^{th} enterprise by j^{th} farmers as given below:

$$BCR_{ij} = \frac{\sum GR_{ij}}{\sum TC_{ij}}$$

2) Decomposition of sources of yield gaps:

The following Cobb-Douglas type of production function was fitted to identify the most important factors effecting the production in both Irrigated and Rain fed method of cultivation;

$$\mathbf{Y = a_o H^{a1} M^{a2} N^{a3} P^{a4} S^{a5} e^{u}}$$

Where,

Y= Out put of main produce (quintals) per hectare

$\mathbf{a_o}$ = Intercept

H = Human labour (man-days) per hectare

M = Manure (quintals) per hectare

N = Nitrogen (kg) per hectare

P = Phosphorous (kg) per hectare

K = Potassium (kg) per hectare

S = Seed rate (kg) per hectare

$\mathbf{e^u}$ = Error term

$\mathbf{a_1}$ to $\mathbf{a_5}$ are the elasticities of production

Then, to examine the structural break in production relations in irrigated and Rainfed sugarcane the above equation was estimated by the Ordinary Least Square (OLS) technique as follows;

$$\mathbf{Log\ Y_1 = Log\ a_o + a_1\ Log\ H_1 + a_2\ Log\ M_1 + a_3\ Log\ N_1 + a_4\ Log\ P_1 + a_5\ Log\ S_1 + a_6\ LogI_1 + U_1} \quad \text{——————} \quad \mathbf{(1)}$$

$$\mathbf{Log\ Y_2 = Log\ b_o + b_1\ Log\ H_2 + b_2\ Log\ M_2 + b_3\ Log\ N_2 + b_4\ Log\ P_2 + b_5\ Log\ S_2 + b_6\ Log\ I_2 + U_2} \quad \text{——————} \quad \mathbf{(2)}$$

Where, Y_1 and Y_2 are yield levels on rainfed and irrigated method plots respectively. The inputs have the symbols as stated above along with associated coefficients. The combination of different resources to yield gap was estimated with the Bisaliah (1977) model of Decomposition. The following functional forms specified as Eq (1) and (2) above mentioned were used.

$$\mathbf{Log\ (Y_2/Y_1) = [\ Log\ (b_o/a_o)\ ] + [\ (b_1\text{-}a_1)\ Log\ H_1 + (b_2 - a_2)\ Log\ M_1 + (b_3 - a_3)\ Log\ N_1 + (b_4\text{-}a_4)\ Log\ P_1 + (b_5 - a_5)\ Log\ S_1 + (b_6 - a_6)\ Log\ I_1\ ] + [\ b_1\ Log\ (H_2/H_1) + b_2\ Log\ (M_2/M_1) + b_3\ Log\ (N_2/N_1) + b_4\ Log\ (P2/P_1) + b_5\ Log\ (S_2/S_1) + b_6\ Log\ (I_2/I_1)\ ] + [\ U_2\text{-}U_1\ ]}$$

This equation involves decomposing the yield gap. The summation of 1st and 2nd bold bracketed term on the right hand side of equation represents the yield gap, attributable to the difference in the cultural practices. The 3rd term represents the yield gap attributable to the difference in the input use (input gaps) between irrigated method and rainfed method. The last term takes care of the random disturbance.

3) Response-Priority Index (RPI):

Through extensive review on constraints in sugarcane production, six important constraints were prioritized. But, in the quantification of constraints expressed by the farmer, there was a problem whether to give more emphasis for number of responses to a particular priority or highest number of responses to a constraint in first priority. To resolve this Response Priority Index (Rao, 2011) was utilized as given below;

$$(RPI)_i = \frac{\sum_{j=1}^{k} f_{ij} X_{[(k+1)-j]}}{\sum_{i=1}^{l}\sum_{j=1}^{k} f_{ij}} \quad \text{——} \quad 0 \leq \text{RPI} \geq 6$$

Where,

$\mathbf{f_{ij}}$ = Number of responses for the $\mathbf{j^{th}}$ priority of $\mathbf{i^{th}}$ constraint (**i**=1, 2,…l; **j**= 1,2,3 …..k)

$\sum_{j=1}^{k} f_{ij}$ = Total number of responses for the i^{th} constraint

k = Number of priorities ***i.e.,* 6**

$\mathbf{X}_{[(k+1)-j]}$ = Scores for j^{th} priority

$\sum_{i=1}^{l}\sum_{j=1}^{k} f_{ij}$ = Total number of responses to all constraints

RPI_I = Response Priority Index for i^{th} constraint

Where,

larger the RPI higher the importance of the particular constraint.

RESULTS AND DISCUSSION

Comparative Costs and returns in cultivation of Irrigated and Rain fed Sugarcane

A perusal of table 1 reveals that the total cost of cultivation per hectare under irrigated conditions; in plant crop was 3,20,524 with working cost 2,24.625 (70.1% of total cost), in ratoon crop was 2,19,545 with working cost 1,64,469 (74.9 % of total cost). Under rainfed condition; in plant crop, cost of cultivation was 2,09,113 with working cost 1,57,250 (75.2 % of total cost), in ratoon crop, cost of cultivation was 1,37,926 with working cost 97,813 (70.9 % of total cost). In terms of percentages working cost is higher in rainfed sugarcane. Out of working cost, under irrigated conditions, 72% (1,61,730) was incurred on labour charges and 28% (62,895) was spent on materials in plant crop, where as, in rainfed condition 68% (1,06,930) was incurred on labour charges and 32% (50,320) was spent on materials. This shows the labour-intensive nature of sugarcane under irrigated conditions. Among the working costs, in irrigated plant crop, harvesting and transport charges was highest 87,000 (38.7%), followed by seed material and planting 32,938 (14.7%), TT Propping 26,438 (11.8%) *etc*. Similar kind of trend was noticed in all other methods. The higher costs were incurred on labour related activities than material related. That shows the labour intensive nature of sugarcane cultivation.

Rao (2012) reported that during 2008-09, operational cost of cultivation (per ha) of sugarcane in Visakhapatnam district was 90,939. In present study operational cost of cultivation (per ha) of sugarcane in Visakhapatnam district was 2,49,334. Thus, there was increase of 1,58,395 per hectare ***ie.,*** 157 per cent in 13 years. The major contributor for this increase was labour wages. Between these 13 years, labour wages (on an average) increased from 120/- to 375 /- per human-days ***ie.,*** more than 3 times.

Comparative resource use pattern in cultivation of irrigated and rainfed Sugarcane:

The per hectare productivity (Tonnes/Ha) under irrigated and rainfed condition was 7.3 and 4.9 (Table 2). Thus, there was 48.80 % higher yield in under irrigated than rainfed condition. Except potassium, all the resources use was higher in irrigated condition than rainfed condition. This was reflected in the cost of cultivation of sugarcane. Usage of potassium is higher in rainfed condition because potassium gives the crop resistance to drought condition.

Production function estimates in cultivation of irrigated and rainfed Sugarcane:

The Cobb-Douglas type of production function was fitted to the observations for the estimation of elasticities of important variables contributing to the yield of sugarcane crop in both irrigated and rainfed conditions (Table 3). The analysis of variance in respect of the production function showed significant variance indicating the overall significance of estimated production function. The value of coefficient of multiple determinations (R^2) in irrigated condition was 0.84, which suggest that the six resources included in the production function had jointly explained 84% of total variation. R^2 was 0.72, in rainfed method, which suggests that the six resources had jointly explained as high as 72% of total variation. That shows the variables taken into consideration were crucial factors in irrigated than in rainfed conditions. This is because irrigated sugarcane is being cultivated under controlled conditions than rainfed, which is vulnerable to natural vagaries.

Except, seed rate under rainfed condition all other variables found significant. Negatively significant was noticed in Phosphorous in rainfed condition and Potassium in irrigated condition. Coefficients of all variables are higher in irrigated than rainfed except Human Labour and Potassium. That shows the more

response of rainfed sugarcane for Potassium than other nutrients in comparison with irrigated conditions.

Sources of yield gap between Irrigated and Rain fed Sugarcane:

The decomposition analysis of yield gaps showed that the 48.80 % of potential farm yield of sugarcane left untapped by rainfed method (Table 4). Among the different sources of yield gap, input usage (26.95%) turns out to be major contributor than cultural practices (21.85%). This shows that irrigation is an important factor in the sugarcane cultivation. In input usage manure turns out to be very crucial factor. In the raw data also wherever manure was applied more than 15 tonnes/ ha, the yield was more than 90 tonnes/ha. The next important factors are potassium and labour. But, Nitrogen (-1.77) and Phosphorous (-2.45) contributed negatively to the usage which shows that there was usage of higher dose of these nutrients than requirement. Thus, increase in dose of Nitrogen and Phosphorous automatically results in input usage negative effect and results in decrease in yields. Through appropriate usage of inputs can reduce the yield gap between rainfed and irrigated method to the tune of 48.80 per cent.

Rao (2012) by using the Bislaih (1977) model of decomposition, estimated that yield gap between irrigated and rainfed method of sugarcane was 67.79 %, in which input usage (41.86%) had higher role than cultural practices (25.93%). Similar trend was noticed in the present study; but reduction in quantum of difference between irrigated and rainfed ***i.e.,*** 67.79% in 2008-09 to 48.80% in 2021-22, shows that much efforts done in research and extension front are reaching to farmers.

Identification of important constraint:

The farmers were asked to prioritize the major constraints they are facing in sugarcane cultivation. Then all these were sorted and sieved finally identified six major constraints on the base of repetitiveness. Out of 1,080 responses, 249, 185, 124, 227, 174 and 136 responses were for constraints 1 to 6 respectively. Thus, taking the total responses (if we are not asked the respondent to prioritise) in to consideration it is concluded that constraint one *Viz.,* remunerative price is the major constraint. Maximum responses in respective priorities were enumerated. Constructed the (RPI) Responses-Priority Index, by taking into the consideration of maximum responses and their respective priorities (Table 5). In RPI highest value was for third constraint *Viz.,* Labour shortage. So, most important constraint in sugarcane cultivation in North Coastal Zone is difficulty in getting labour during important operations. Other constraints in descending order are shortage of irrigation water, not getting remunerative prices, high cost of machines, difficulty in getting good quality seed material and occurrence of pests and diseases (Manjula *et al.* 2021) respectively.

1. Higher return on Investment was found in ratoon crop than plant crop
2. Most important factor under rainfed and irrigation conditions were human labour
3. There was 48.8 %of yield gap between irrigated and rainfed; in which, 26.95 % and 21.85% were contributed by in-put use and cultural practices respectively.

Policy Implication

1) There was a higher yield in plant crop than ratoon crop. But, BCR was higher for ratoon crop. That is why farmers are going for ratooning continuously and average yields are decreasing. Hence, to increase the yields farmers should be sensitized through various extension agencies and institutes to take-up fresh plantings after one or two ratoons. Otherwise seed material should be supplied at subsidized rate.
2) Input use (26.95%) is major contributor for yield gap than Cultural practices (21.85%) between irrigated and rainfed method, reveals that judicious use of inputs will increase the yields up to 44.82%. Hence, farmers should be trained on optimum input usage

The major constraint in sugarcane cultivation is Labour shortage. Hence, farm machinery implements should be supplied to farmers on custom hired basis.

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Table 1: Comparative cost of cultivation (per Ha) of irrigated and rainfed Sugarcane in Visakhapatnam district of Andhra Pradesh - 2021-22

Particulars	Irrigated		Rain-fed	
	Plant	Ratoon	Plant	Ratoon
Land preparation / Stuble Shaving	10,125	5,625	10,125	3,750
Furrow preparation	5,500	0	5,000	0
Seed material/ / Gap filling	24,938	3,750	24,938	3,563
Cutting and Transplanting cost	8,000	0	5,438	0
Manures and fertilizers Application	25,750	30,000	19,125	18,750
Weeding & Plant protection	24,375	21,000	13,625	11,250
Irrigation	12,500	5,000	2,250	2,500
TT propping (3 times)	26,438	21,094	16,750	10,000
Harvesting & transportation	87,000	78,000	60,000	48,000
Working cost	2,24,625	1,64,469	157,250	97,813
Interest on working capital	24,709	9,423	9,009	5,604
Operational cost	249,334	1,73,891	166,259	1,03,416
Depreciation	5,813	4,388	2,138	1,813
Land cess	750	750	500	500
Rental value of Own land	57,000	35,625	35,625	28,500
Interest on fixed capital	7,628	4,892	4,592	3,698
Fixed costs	71,190	45,654	42,854	34,510
Total cost of cultivation	3,20,524	2,19,545	2,09,113	1,37,926
Gross Returns (@Rs 2850/ton)	2,06,625	1,85,250	1,42,500	1,21,125
BCR on OC	**0.83**	**1.13**	**0.86**	**1.17**
BCR on TC	**0.64**	**0.84**	**0.68**	**0.88**

Table 2: Comparative resource use (per Ha) between irrigated and rainfed Sugarcane in Visakhapatnam district of Andhra Pradesh 2021-22

S.N	Resource Particulars	Units	Irrigated		Rainfed	
			Plant	Ratoon	Plant	Ratoon
1	**Human Labour**	Mandays	472	287	245	148
2	**Manure**	Quintals	11	7.2	4.5	2.75
3	**Nitrogen**	Kilograms	169	245	148	210
4	**Phosphorus**	Kilograms	172	160	165	140
5	**Potassium**	Kilograms	55	68	80	52
6	**Seed Rate**	Kilograms	8,500	500	7,500	400
7	**Productivity**	Quintals/ hectare	730	675	525	490

Table 3: Cobb-Douglas production function estimate for Irrigated and Rain fed Sugarcane (plant crop)

S.N	Particulars	Method of Cultivation	
		Irrigated	Rainfed
1	Human Labour (X_1)	0.58 *	1.16 *
2	Seed Rate (X_2)	0.41 *	-0.19
3	Manure (X_3)	0.49 **	0.31 **
4	Nitrogen (X_4)	0.51 **	0.36 *
5	Phosphorus (X_5)	0.23 *	- 0.02 **
6	Potassium (X_6)	-0.16 *	0.32 **
7	Intercept	- 2.42 **	- 2.52 **
	R^2	**0.84**	**0.72**
	F Value	**210 ** **	**195 ** **

Note: 1) * and ** indicates significance at 5 and 1 per cent respectively
2) Figures in parenthesis are standard errors for the respective regression coefficients

Table 4: Decomposition of yield gap between Irrigated and Rain fed sugarcane (plant)

S.N	Sources of Difference	%
A.	Total	48.8
1	Cultural Practices	21.85
2	Input Usage	26.95
a.	Human Labour (X_1)	4.32
b.	Seed Rate (X_2)	10.59
c.	Manure (X_3)	13.27
d.	Nitrogen (X_4)	-1.77
e.	Phosphorus (X_5)	-2.45
f.	Potassium (X_6)	2.98

Table 5: Responses-Priority Index (RPI) for constraints in cultivation of Sugarcane

Constraint Number	Constraints Name	RPI	Ranks
1	Remunerative Cane price	**0.84**	II
2	High cost of machinery	**0.3**	V
3	Labour shortage	**0.93**	I
4	Irrigation Water	**0.72**	III
5	Seed Material Availability	**0.29**	VI
6	Occurrence of pests and diseases	**0.41**	IV

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