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Resource use efficiency and constraints in *Adsali sugarcane* production in Kolhapur district of Maharashtra

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Abstract

Adsali sugarcane is the longest-duration and most input-intensive of the sugarcane planting systems grown in western Maharashtra, making the efficient use of costly inputs central to its profitability. The present study examines the resource use efficiency and the major production constraints of *Adsali sugarcane* cultivation in Kolhapur district of Maharashtra, based on primary data collected from 90 farmers classified into small, medium and large-size groups for the reference year 2024-25. A Cobb-Douglas production function fitted with human labour, machinery, sugarcane setts, manure, nitrogen, phosphorus, potassium and irrigation as explanatory variables explained 76 to 88 per cent of the variation in sugarcane yield across the size groups, with nitrogen, phosphorus and irrigation emerging as the most consistently significant determinants of output across every farm-size category. Returns to scale exceeded unity in every size group (1.07 to 1.13), indicating increasing returns to scale and scope for expanding output through coordinated scaling-up of input use, particularly on large farms. The ratio of marginal value product to marginal factor cost (MVP/MFC) showed irrigation, nitrogen, phosphorus and potassium to be considerably under-utilised across all farm sizes, with irrigation returning the highest ratios (up to 31.00), while sugarcane setts on small farms and potassium on large farms returned negative ratios, indicating over-application and scope for cost saving. Garrett's ranking technique identified high labour cost (score 63.33), high fertilizer cost (63.23) and climate-related problems (62.02) as the foremost constraints faced by *Adsali sugarcane* farmers, followed by high irrigation cost, delayed payment by sugar factories, pest and disease incidence and high machinery hiring charges, suggesting that cost pressure and risk, rather than lack of technical awareness, chiefly limit input-use efficiency. The study recommends soil-test-based balanced fertilization, expansion of subsidised micro-irrigation, custom hiring services for labour- and machinery-intensive operations, and stronger enforcement of payment timelines by sugar factories to narrow the gap between economically optimal and currently practised input use and thereby improve farmer welfare.

Keywords: Resource use efficiency, Cobb-Douglas production function, Marginal value product, Garrett ranking, Constraints

1. Introduction

Sugarcane is one of the most important commercial crops in India, contributing significantly to farmers' income, employment generation and raw material supply for the sugar, jaggery and ethanol industries. India is among the world's largest sugarcane producers, with Maharashtra emerging as a leading producing state due to its favourable agro-climatic conditions, fertile soils and strong cooperative sugar sector. Within Maharashtra, Kolhapur district holds a prominent position in sugarcane cultivation, supported by productive soils, assured irrigation and several sugar factories, making the crop integral to the livelihood and socio-economic development of rural households in the district.

Adsali sugarcane, planted between mid-July and mid-August and harvested after about 18 months, is the longest-duration and generally the most productive of the planting systems followed in western Maharashtra, but it is also the most input-intensive, requiring heavy investment in labour, irrigation, manures, fertilizers and plant protection. Efficient allocation of these inputs relative to their marginal returns is essential for maximising farm profitability, particularly in a high-value, capital-intensive crop such as *Adsali* sugarcane. At the same time, farmers' ability to realise this efficiency is often constrained by production and marketing bottlenecks such as the cost and availability of labour, fertilizers and irrigation, climatic uncertainty and delays in payment by sugar factories. An assessment of both resource use efficiency and the constraints that limit optimal input use is, therefore, necessary to identify concrete measures for improving the productivity and profitability of *Adsali* sugarcane cultivation. The present study was undertaken with the specific objectives of (i) examining the resource use efficiency in *Adsali* sugarcane cultivation, and (ii) identifying the constraints faced by *Adsali* sugarcane farmers in Kolhapur district of Maharashtra and suggesting suitable measures to overcome them.

2. Methodology

The study was conducted in Hatkanangale and Shirol tehsils of Kolhapur district, purposively selected on the basis of area under *Adsali* sugarcane cultivation. A sample of 90 *Adsali* sugarcane farmers, comprising 30 each from small (below 0.40 ha), medium (0.41 to 0.80 ha) and large (0.81 ha and above) size groups, was selected through a multi-stage random sampling procedure from six villages for the reference year 2024-25. Data on the physical quantities of human labour, machinery, sugarcane setts, manure and NPK fertilizers and irrigation used, together with sugarcane yield, were collected through personal interviews using a structured schedule.

2.1 Statistical analysis of data

On the basis of 90 farmers data, different statistical tools were used for the further study.

A. Functional analysis

Regression analysis was used to predict the dependent variable from selected independent variables, with several functions tested for the best fit. The most suitable model was chosen based on the significance of partial regression coefficients, the highest coefficient of determination (R^2) and the lowest mean error sum of squares. Among the tested models, the Cobb–Douglas production function was found to fit best, as it provided maximum R^2 and minimum error. This function described the relationship between inputs and output and can be specified as follows.

$$Y = f\left(X_1 X_2, X_3 \ldots X_8\right)$$

Where Y is per hectare output of a particular crop with a given set of inputs X_1, X_2, X_3,...X_n per hectare. In simple words production function can be defined as Mathematical and technical relationship existing between the input and output. In functional analysis, it was essential to choose an appropriate form of production function taking into consideration the data to be analyzed.

The Cobb-Douglas type of production function was used to specify as follows.

$$Y = aX_1^{b_1}X_2^{b_2}X_3^{b_3}X_4^{b_4}X_5^{b_5}X_6^{b_6}X_7^{b_7}X_8^{b_8}\ldots X_n^{b_n}e^u$$

where,

Y = Yield in tonnes per hectare

a = Intercept

b_1, b_2, b_3, b_4, b_5, b_6, b_7, b_8 = Partial Regression coefficient of respective factor as follows.

X_1 = Human labour in days/ ha.

X_2 = Machinery in hours/ ha.

X_3 = Sugarcane setts in kg.

X_4 = Manure in qt./ ha.

X_5 = Nitrogen in kg./ ha.

X_6 = Phosphorus in kg./ ha.

X_7 = Potassium in kg./ ha.

X_8=Irrigation in hours.

e^u = Error term

Cobb-Douglas production function as given above was estimated for input-output data to study the combination of variables and resource productivity. Regression analysis was performed after removing the out layers (abnormal values) from data.

B. Resource use efficiency

Marginal value product of particular resources represents the "expected addition of one unit of that resource while other inputs are held constant." to the marginal factor cost.

$$\text{MVP} = \text{MPP} \times P_y$$

$$\textbf{MVP of } \mathbf{X_i} = \mathbf{b_i}\,\frac{\mathbf{GM(Y)}}{\mathbf{GM(X)}}\,\mathbf{P_y}$$

where,

b_i = Elasticity of production of i^{th} input

X_i= Geometric mean of i^{th} input

Y = Geometric mean of output

P_y = Per unit price of output

C. Constraints in production of Adsali sugarcane

Garret"s ranking technique was used to rank the constraints faced by the farmers in *Adsali* Sugarcane production. Rank was given by the farmers to the constraints faced by them and was changed into per cent position by using the following formula:

$$\text{Per cent position} = 100\left(R_{ij} - 0.50\right)/N_j$$

where,

R_{ij} = Rank given to the i^{th} constraints by the j^{th} farmer

N_j = Number of constraints ranked by j^{th} farmer

3. Results and discussion

3.1 Cobb-Douglas production function

Table 1. Results Estimated of Cobb-Douglas Production Function

Sr No.	Variables	Sugarcane Production			
		Small	**Medium**	**Large**	**Overall**
1	**Intercept**	1.0121	1.1232	0.9673	0.8981
		(0.2081)	(0.4726)	(0.2724)	(0.2620)
2	**Human Labour (X_1)**	0.1670	0.2186***	0.2449***	0.2148**
		(0.0979)	(0.0802)	(0.0705)	(0.0925)
3	**Machinery (X_2)**	0.0419	0.1044**	0.0586	0.0486
		(0.0643)	(0.0442)	(0.0450)	(0.0343)
4	**Sugarcane Setts (X_3)**	-0.0152	0.0336	0.1811**	0.0347
		(0.0326)	(0.0524)	(0.0767)	(0.0621)
5	**Manure (X_4)**	0.2102*	0.0281	0.0348	0.0281
		(0.0986)	(0.0595)	(0.0533)	(0.0444)

(continued on next page)

Sr No.	Variables	Sugarcane Production			
		Small	Medium	Large	Overall
6	**Nitrogen (X_5)**	0.2489***	0.1737**	0.2751***	0.1835***
		(0.0899)	(0.0805)	(0.0742)	(0.0603)
7	**Phosphorus (X_6)**	0.1541**	0.1333**	0.1437*	0.1765***
		(0.0652)	(0.0606)	(0.0686)	(0.0552)
8	**Potassium (X_7)**	0.1225**	0.2012**	-0.0251	0.1426**
		(0.0496)	(0.0974)	(0.0508)	(0.0620)
9	**Irrigation(X_8)**	0.1428***	0.1974***	0.2171***	0.1959**
		(0.0569)	(0.0431)	(0.0712)	(0.0895)
10	**R^2**	**0.76**	**0.88**	**0.81**	**0.79**
11	**Return to Scale**	**1.07**	**1.09**	**1.13**	**1.02**

(Figure in parenthesis indicates a standard error)
(*, **, * Significant at 1%, 5% and 10% level respectively)**

The fitted Cobb-Douglas function explained 76, 88, 81 and 79 per cent of the variation in cane yield on small, medium, large and overall farms, respectively, a satisfactory level of fit for a farm-level cross-sectional model. Nitrogen, phosphorus and irrigation were positive and statistically significant across every size category as well as in the overall equation, confirming that balanced nutrient management and assured water supply are the most consistently important determinants of *Adsali* cane yield irrespective of farm size. Human labour was significant from the medium category onward, machinery only on medium farms, sugarcane setts only on large farms and manure only on small farms, while potassium was positive and significant on small, medium and overall farms but turned negative and non-significant on large farms, suggesting possible over-application of potash on that segment. The estimated returns to scale exceeded unity in every size group, ranging from 1.07 on small farms to 1.13 on large farms, indicating the prevalence of increasing returns to scale and suggesting that a proportionate expansion of all inputs together would yield a more than proportionate increase in sugarcane output, particularly on large farms. The variation in R^2 across farm-size groups is also noteworthy: the medium-farm category recorded the highest R^2 (0.88), suggesting that medium farmers follow relatively more uniform and predictable input-use practices, whereas the comparatively greater heterogeneity in production behaviour among small and large farmers likely reflects differing access to credit, extension services and resource endowments across these groups. These findings are consistent with Jawanjal *et al.* (2014) [1] and Pokharel *et al.* (2019) [2], who also reported nitrogen, phosphorus and irrigation as key determinants of sugarcane yield.

3.2 Resource use efficiency

Table 2. Resource Use Efficiency (MVP/MFC Ratio) of Inputs Used in *Adsali* Sugarcane Cultivation

Input	Small	Medium	Large	Overall
Human labour (X_1)	0.91	1.27	1.59	1.26
Machinery (X_2)	0.89	1.94	0.97	0.91
Sugarcane setts (X_3)	-0.39	0.93	5.57	0.97
Manure (X_4)	4.71	0.66	0.88	0.67
Nitrogen (X_5)	12.53	8.95	15.22	9.59
Phosphorus (X_6)	6.97	6.24	7.23	8.35
Potassium (X_7)	7.04	11.92	-1.57	8.50
Irrigation (X_8)	18.76	27.67	31.00	27.02

(MVP/MFC = 1 indicates efficient use; > 1 indicates under-utilisation; < 1 indicates over-utilisation)

Irrigation emerged as the most severely under-utilised input across all farm-size categories, with MVP/MFC ratios ranging from 18.76 on small farms to 31.00 on large farms, implying that the marginal return from additional irrigation is many times its marginal cost. Nitrogen, phosphorus and potassium likewise recorded ratios well above unity in most categories, ranging roughly between 6 and 15, confirming that fertilizer application remains sub-optimal and that judicious additional doses would be economically rewarding. Human labour and machinery were close to the efficient benchmark on small farms but distinctly under-utilised on medium and large farms, while manure was heavily under-utilised on small farms (4.71) but close to efficient levels on medium and large farms. Two clear inefficiencies were noted: sugarcane setts returned a negative ratio (-0.39) on small farms, suggesting an excessive seed rate or poor seed quality, and potassium returned a negative ratio (-1.57) on large farms, indicating imbalanced or excessive application. This differentiated pattern of resource-use efficiency across farm-size groups underscores the need for scale-specific extension recommendations rather than uniform input-use advisories, particularly with regard to correcting the setts rate on small farms, moderating potassium application on large farms, and encouraging wider adoption of irrigation and balanced fertilization across all size groups. These results are in line with Jawanjal *et al.* (2014, 2022) [1] and Pandey *et al.* (2020) [3], who similarly reported under-utilisation of irrigation and major nutrients in sugarcane production.

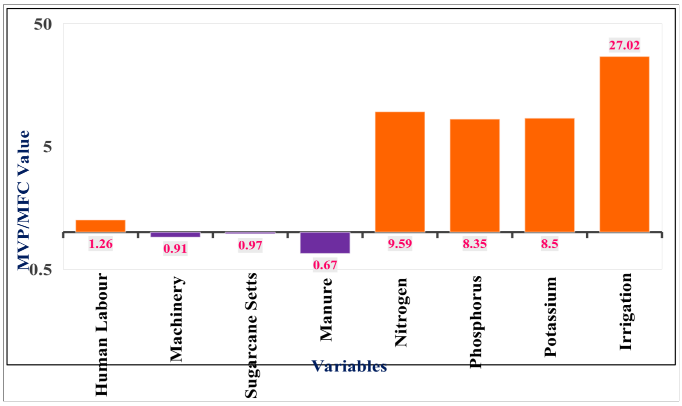

Figure 1. Resource Use Efficiency of Selected Input for *Adsali* Sugarcane on Overall Basis

3.3 Constraints faced by Adsali sugarcane farmers

Table 3. Constraints Faced by *Adsali* Sugarcane Farmers

Sr. No.	Constraints in Production of *Adsali* Sugarcane	Score	Rank
1	High labour cost	63.33	1
2	High fertilizer cost	63.23	2
3	Climate related problem (Drought, Unseasonal rain, Floods, Lodging of Sugarcane)	62.02	3
4	High irrigation cost	48.41	4
5	Delay in payment by sugar factories	42.81	5
6	Pest and Diseases incidence (White grub, Woolly aphid attacks)	36.28	6
7	High machinery hiring charges	30.80	7

The Garrett ranking identified high labour cost (score 63.33) and high fertilizer cost (63.23) as the two foremost constraints perceived by *Adsali* sugarcane farmers, followed closely by climate-related problems such as drought, unseasonal rainfall, floods and lodging of the crop (62.02). The near-identical scores of these three constraints indicate that farmers do not perceive a single dominant barrier but rather a cluster of closely ranked cost- and climate-related pressures that jointly erode profitability, a pattern consistent with the production function and resource-efficiency results discussed above, where labour and the major fertilizer nutrients were shown to be significant yield determinants that nevertheless remain under-utilised, possibly because their high perceived cost discourages farmers from applying them at the economically optimal level. High irrigation cost was ranked fourth (48.41), a particularly noteworthy result given that irrigation returned the highest MVP/MFC ratios in the efficiency analysis; this juxtaposition suggests that farmers are aware of the profitability of additional irrigation but are constrained mainly by the cost of accessing water rather than by any doubt about its returns. Delay in payment by sugar factories (42.81) was ranked fifth, reflecting a working-capital constraint that can disrupt the timely purchase of labour, fertilizer and irrigation inputs for the subsequent cropping cycle. Pest and disease incidence, particularly white grub and woolly aphid attacks, was ranked sixth (36.28), and high machinery hiring charges was ranked last (30.80); although perceived as comparatively less severe than the cost- and climate-related factors, these represent recurring operational challenges that can undermine yield gains and constrain mechanisation, especially on small farms. Overall, the constraint ranking reveals a clear hierarchy in which the cost of critical inputs, namely labour, fertilizer and irrigation, together with climatic uncertainty, dominate farmer concerns, followed by institutional payment delays and, finally, biotic and mechanisation-related challenges. The results are in line with the findings of Chand *et al.* (2016) [4] and Lavanya *et al.* (2019) [5], who similarly reported cost of inputs and climatic uncertainty as leading constraints in sugarcane production.

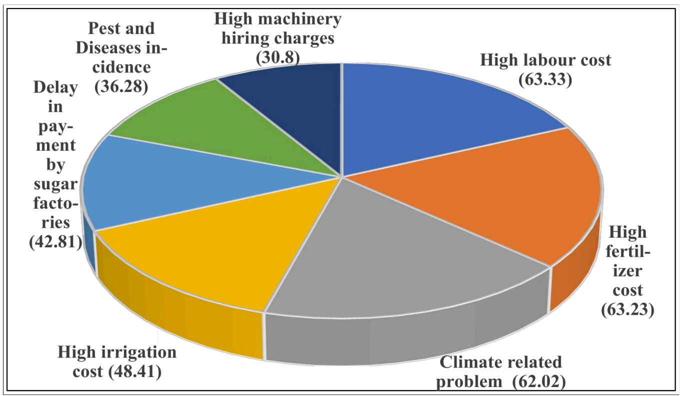

Figure 2. Constraints Faced by *Adsali* Sugarcane Farmers

4. Conclusions

1. The fitted Cobb-Douglas production function explained 76 to 88 per cent of the variation in sugarcane yield across farm-size groups, with nitrogen, phosphorus and irrigation emerging as the most consistently significant determinants of *Adsali* sugarcane yield on small, medium and large farms alike.
2. Returns to scale exceeded unity in every farm-size group, ranging from 1.07 on small farms to 1.13 on large farms, confirming increasing returns to scale and considerable scope for raising output through a coordinated, proportionate expansion of input use, particularly on large farms.
3. The MVP/MFC analysis showed irrigation, nitrogen, phosphorus and potassium to be considerably under-utilised across all farm sizes, with irrigation returning the highest ratios (up to 31.00 on large farms), whereas sugarcane setts on small farms (-0.39) and potassium on large farms (-1.57) were over-applied, pointing to specific, farm-size-linked inefficiencies rather than a uniform pattern of resource use.
4. Garrett's ranking of constraints identified high labour cost (score 63.33), high fertilizer cost (63.23) and climate-related problems (62.02) as the foremost constraints faced by *Adsali* sugarcane farmers, followed by high irrigation cost, delayed payment by sugar factories, pest and disease incidence and high machinery hiring charges, indicating that cost pressure and risk, rather than lack of technical awareness, are the principal barriers to efficient input use.

5. Suggestions

1. Custom hiring centres for labour and machinery should be set up at the village level to reduce the cost burden on farmers, and sugar factories should ensure timely payments for sugarcane supplied.

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