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Analysis of yield gap and factor affecting yield gap of Sugarcane in Ahmednagar district of Maharashtra

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Abstract
The yield gap and factors influencing the yield gap in sugarcane cultivation with varied planting types were estimated in the current study. The source data gathered from 120 sugarcane farmers in Maharashtra Ahmednagar district. Five farmers from each of the four sugarcane planting types i.e adsali, pre-seasonal, Suru, and ratoon were chosen from three villages each in the tehsils of Karjat and Shrigonda. The yield observed at research station and demonstration plots are significantly higher than the actual yield. The sugarcane with ratoon planting type (18.26%) had the largest production gap (yield gap-II), followed by preseasonal (11.03%), adsali (10.59%) and suru (10.24%) Sugarcane. The planting materials, manure, fertilizer, and irrigation were determined to be most significant variable, controlling yield gap, according to the path analysis, which examined the direct the direct and indirect effect of inputs gap on the yield gap.

Keywords: Sugarcane, yield gap, direct effect, indirect effect

Introduction
Sugarcane is a most important cash crop of Maharashtra. After textiles, sugarcane is the primary raw material used in the second largest agro based sector. Sugar industry is the second biggest agro-based sector and serve as a hub for socioeconomic growth. Without any obstacles, the sugar business in Maharashtra has expanded during the past 70 years.

In Maharashtra Ahmednagar, Solapur, Kolhapur, Pune, Satara are the major sugarcane producing districts. Approximately 93 co-operative and 97 private sugar plants are producing ethanol, bio-compost, and a variety of other chemicals in Maharashtra this year. Sugarcane and the sugar industry are the foundation of Maharashtra economic growth. Due to its ability to create jobs and revenue, the sugarcane crop is essential to development. It is also notable for requiring quick investment, requiring a lot of labour yielding higher returns than other crops, and making a major economic contribution to both the state and nation.

On the list of Indian states that produce most sugarcane, Maharashtra comes in second. In year 2021-2022, Maharashtra ranked third in sugarcane productivity (88.00 tons/ha), Second in area (14.88 Lakh/ha) and production (132.03 million tons).

The state sugarcane production and area increased steadily from the base year due to a number of factors, including rising sugar and jiggery prices, the adaption of new cultivation technologies, the establishment of numerous sugar manufacturing facilities in the private and co-operative sectors, the increased availability of production inputs, and the state governments progressive policy measures. However, a variety of biotic and abiotic pressures are applied when growing sugarcane, which causes low sugar recovery and production volatility. In order to achieve the maximum productivity, it is necessary to find out the yield gap of sugarcane and factors influencing the yield gap.

Materials and Methods
Primary data gathered from the Ahmednagar district in the years 2021-2022. Total 120 sugarcane growers from the Ahmednagar district Karjat and Shrigonda tehsils were chosen for the study. Each tehsil had three villages chosen. Using a random sample technique, five farmers of each planting type adsali, preseasonal, suru, and ratoon sugarcane were chosen form each village in both tehsils. Thus 20 farmers were selected from each village. For the current study total 120 sugarcane growers were selected, 30 farmers from each type of sugarcane cultivation.

The information on research station yield and yields of field level demonstration plot were collected from the central research station Padegaon (M.S).

The information was collected for the crop that was harvested in 2021-2022.

Yield Gap Analysis

Yield Gap I

It is the difference between potential yield and potential farm yield

i.e. (Yp-Yd)

Yp = Potential yield (Yield realized at research station)
Yd = Potential farm yield (Yield realized on demonstration plot)

Yield Gap II

It is the difference between potential farm yield and actual yield.

i.e. (Yd-Ya)

Yd = Potential farm yield (Yield realized on demonstration plot)
Ya = Actual yield (Yield realized on sample farm)

Yield Gap III

It is a difference between potential yield and actual yield

i.e (Yp-Ya)

Yp = Potential yield (Yield realized at research station)
Ya = Actual yield (Yield realized on sample farm)

Indices of yield gap

1. Index of Yield Gap, IYG = $\frac{Yp-Ya}{Yp} \times 100$
2. Index of Realized Potential Yield, IRPY = $\frac{Ya}{Yp} \times 100$
3. Index of Realized Potential Farm Yield, IRPFY = $\frac{Ya}{Yd} \times 100$

Factors responsible for yield gap

The factor contributing towards yield gap studied using path analysis.

$r_{y1} = P_{y1} + r_{12} P_{y2} + r_{13} P_{y3} + r_{14} P_{y4} + r_{15} P_{y5}$ ..... (1)

$r_{y2} = r_{21} P_{y1} + P_{y2} + r_{23} P_{y3} + r_{24} P_{y4} + r_{25} P_{y5}$ ..... (2)

$r_{y3} = r_{31} P_{y1} + r_{32} P_{y2} + P_{y3} + r_{34} P_{y4} + r_{35} P_{y5}$ ..... (3)

$r_{y4} = r_{41} P_{y1} + r_{42} P_{y2} + r_{43} P_{y3} + P_{y4} + r_{45} P_{y5}$ ..... (4)

$r_{y5} = r_{51} P_{y1} + r_{52} P_{y2} + r_{53} P_{y3} + r_{54} P_{y4} + P_{y5}$ ..... (5)

The generalized formula may be written as

$r_{yi} = r_{1i} P_{y1} + r_{2i} P_{y2} + r_{3i} P_{y3} + \ldots\ldots\ldots + r_{ni} P_{yn}$ ..... (6)

Where
I = (1to 5) is the correlated cause and y is the effect

$$P_{yi} = bi \frac{\partial i}{\partial y} \quad \ldots\ldots\ldots\ldots (7)$$

The direct effect are given by the path coefficient (P_{yi}). The indirect effect is given by

$$\sum_{\substack{i=1 \\ i=j}}^{n} rij \; P_{yj} \quad \ldots\ldots\ldots\ldots (8)$$

The unexplained variance (residual effect) not accounted for the included variables can be obtained by

$$P_{yj} = (1-R^2)^{1/2} \quad \ldots\ldots\ldots\ldots (9)$$

Where,

$$R^{2} = \sum_{i=1}^{n} P_{yj}^{2} + \sum \sum_{\substack{i=1 \\ i=j}} P_{yi} P_{yj} rij. \ldots\ldots\ldots\ldots (10)$$

Results and Discussion

Yield Gaps in Sugarcane Cultivation

The yield Gap - I is a difference between Potential yield (Y_p) i.e. yield realized at research station and potential farm yield (Y_d) i.e. yield realized demonstration plot. The yield gap - II is a difference between potential farm yield (Y_d) and Actual yield (Y_a) i.e. yield realized farmer field. The yield Gap - III is a difference between potential yield and actual yield.

Table 1: Yield gap in Sugarcane Cultivation (tonne/ha)

Sr. No	Particulars	Planting Type			
		Adsali	Preseasonal	Suru	Ratoon
1	Potential yield	200	164	150	125
2	Potential Farm yield	170	145	127	115
3	Actual yield	152	129	114	94
4	yield Gap – I	30	19	23	10
5	yield Gap –II	18	16	13	21
6	yield Gap – III	48	35	36	31
7	Percent Yield gap – I	15.00	11.59	15.33	8.00
8	Percent Yield gap – II	10.59	11.03	10.24	18.26
9	Percent Yield gap – III	24.00	21.34	24.00	24.80

Adsali Sugarcane

The average yield performance of sugarcane in various field conditions is show in Table 1. The table shows that the production of adsali sugarcane varies significantly between sample farmer fields, demonstration plots and research station. In cultivation of adsali sugarcane the yield obtained on the demonstration plots (170 tons/ha) and research station (200 tons/ha) was significantly higher than the yield on the sample farm (152 tons/ha). The yield gap-I was 30 tonnes (15.00%), the yield gap-II was 18 tonnes (10.59%) and yield gap-III was 48 tonnes (24%).

Pre-seasonal Sugarcane

The research stations preseasonal sugarcane potential yield was 164 tons/ha, other than the demonstration plots potential farm yield was 145 tons/ha. The instance farms actual yield was 129 tons/ha. In preseasonal sugarcane yield gap-I was 19 tonnes (11.59%) and yield gap-II was 16 tonnes (11.03%). The total yield gap-III of 35 tons (21.34% was noted.

Suru sugarcane

Table 1 shows that, there is a significant difference in suru sugarcane productivity between research station, demonstration plots and sample farmer's fields. The potential yield of sugarcane in suru was 150 tons/ha at research station and 127 tons/ha potential farm yield at demonstration plots. The actual yield of sample farm was 114 tonnes/ha. The yield gap-I for suru sugarcane was 23 tons/ha (15.33%) and yield gap-II was 13 tons/ha (10.24%). The total yield gap-III was observed at 36 tons/ha (24.00%).

Ratoon Sugarcane

Ratoon Sugarcane yield of 125 tons/ha, 115 tons/ha and 94 tons/ha were attained on the research station farms, demonstration plots and sample farms in that order. Table shows that, there was 10 tons/ha (8.00%) yield gap between potential yield and the potential farm yield. Yield gap-II was 21 tons/ha (18.26%) and total yield gap (yield gap-III) it was 31 tons/ha (24.80%).

Estimated indices of yield gap

The estimated indices of yield gap in Adsali, pre-seasonal, suru and ratoon sugarcane farm are given in Table 2

In Table 2 it is observed the estimated index of yield gap highest for ratoon sugarcane (24.80%) followed by adsali (24.00%), suru (24.00%) and preseasonal (21.34%) sugarcane farms, respectively. It is indicates that there existed a tremendous scope to improve the sugarcane production to study area.

Table 2: Indices of yield gaps on sample sugarcane farms.

Sr. No	Particulars	Planting Type			
		Adsali	Preseasonal	Suru	Ratoon
1	Index of yield gap	24	21.34	24	24.80
2	Index of Realized potential yield	76	78.66	76	75.20
3	Index of Realized potential Farm yield	89.41	88.97	89.76	81.74

For the various planting types adsali, preseasonal, suru, ratoon crop the realized potential yield index values were 76.00, 78.66, 76, and 75.20 percent respectively. Certain components such as new technology produced research station may not be feasible for producers to use because of variations in the environment, socioeconomic and other associated restriction that operate at the farm level.

The sample suru sugarcane grower realized highest yield to the extent of 89.76% of the potential farm yield. It was followed by adsali (89.41%), preseasonal (88.97%), and ratoon sugarcane farms (81.74%). Thus, all the recommended package of practice and production technology used on the demonstration plots if they are adopted as such on the sample farms by the sample sugarcane growers could raise the yield by 10.59% on the adsali sugarcane farms, 11.03 % on pre-seasonal farms, while 10.24% and 18.26% on suru and ratoon sugarcane farms respectively.

Factor contributing to the yield gap in sugarcane

The path coefficient analysis helps us to identify different independent characters which affect dependent variable directly as well as indirectly.

The direct and indirect effects measured both in terms of correlation coefficient and percentage of inputs use gaps are presented in Table 3

It is observed from Table 3 that yield gap was result of gap in quantity of inputs used and composite variable that include all other factor affecting yield gap. These may be due to the change in climatic condition, various cultural and crop managements practices.

The result from correlation coefficients between yield gap and input used gap revealed that, In adsali sugarcane planting the total effect of planting material (0.67) and manure (0.58) were found be maximum

In pre-seasonal Sugarcane irrigation was found to be the most important variable conditioning yield gap as indicated by its correlation coefficient (0.71) and direct and indirect effect 57.75 per cent and 42.25 per cent respectively. The inputs variable Viz. human labour, machine labour, plant protection shows negative total effect which brought down its direct effect.

In case suru sugarcane fertilizer and irrigation was found to be the most important variable conditioning yield gap as indicated by its correlation coefficient 0.73 and 0.84.

In ratoon sugarcane total effect of manure (0.26) and bullock labour (0.33) was found to be highest.

The positive correlation between the input use gaps and the yield gap indicated a direct association between the input use difference and yield gap. The finding of the study clearly demonstrated the possibility of reducing the yield gap by reducing the input use gaps. In addition to this, the farmers ability to use higher level of inputs need to considered and there is a need to educate farmers about the benefits of using the recommended level of inputs.

Table 3: Direct and indirect effects of input use on yield gap in Sugarcane

Sr. No	Particulars	Planting Type			
		Adsali	Preseasonal	Suru	Ratoon
A					
1	Direct effect of human labour	-0.32 (-64.00)	-0.55 (229.17)	0.27 (50.00)	-0.14 (-63.64)
2	Indirect effect of human labour	0.82 (164.00)	0.31 (-129.17)	0.27 (50.00)	0.36 (163.64)
3	Total effect of human labour	0.50 (100)	-0.24 (100)	0.54 (100)	0.22 (100)
B					
1	Direct effect of bullock labour	0.35 (62.50)	0.17 (43.59)	0.08 (17.78)	0.68 (206.06)
2	Indirect effect of bullock labour	0.21 (37.50)	0.22 (56.41)	0.37 (82.22)	-0.35 (-106.06)
3	Total effect of bullock labour	0.56 (100)	0.39 (100)	0.45 (100)	0.33 (100)
C					
1	Direct effect of machine labour	-0.13 (-41.94)	-0.04 (33.33)	-0.12 (-150.00)	-0.08 (-266.67)
2	Indirect effect of machine labour	0.44 (141.94)	-0.08 (66.67)	0.20 (250.00)	0.11 (366.67)
3	Total effect of machine labour	0.31 (100)	-0.12 (100)	0.08 (100)	0.03 (100)
D					
1	Direct effect of manure	0.44 (75.86)	0.47 (68.12)	0.12 (20.00)	0.09 (34.62)
2	Indirect effect of manure	0.14 (24.14)	0.22 (31.88)	0.48 (80.00)	0.17 (65.38)
3	Total effect of manure	0.58 (100)	0.69 (100)	0.60 (100)	0.26 (100)
E					
1	Direct effect of planting material	0.23 (34.33)	-0.11 (-15.71)	-0.08 (22.86)	-
2	Indirect effect of planting material	0.44 (65.67)	0.81 (115.71)	-0.27 (77.14)	-
3	Total effect of planting material	0.67 (100)	0.70 (100)	-0.35 (100)	-
F					
1	Direct effect of fertilizer	0.36 (87.80)	0.10 (25.64)	0.38 (52.05)	0.86 (477.78)
2	Indirect effect of fertilizer	0.05 (12.20)	0.29 (74.36)	0.35 (47.95)	-0.68 (-377.78)
3	Total effect of fertilizer	0.41 (100)	0.39 (100)	0.73 (100)	0.18 (100)
G					
1	Direct effect of plant protection	-0.05 (-29.41)	0.08 (-44.44)	0.01 (-6.67)	-0.08 (36.36)
2	Indirect effect of plant protection	0.22 (129.41)	-0.26 (144.44)	-0.16 (106.67)	-0.14 (63.64)
3	Total effect of plant protection	0.17 (100)	-0.18 (100)	-0.15 (100)	-0.22 (100)
H					
1	Direct effect of irrigation	0.02 (8.33)	0.41 (57.75)	0.50 (59.52)	0.20 (285.71)
2	Indirect effect of irrigation	0.22 (91.67)	0.30 (42.25)	0.34 (40.48)	-0.13 (-185.71)
3	Total effect of irrigation	0.24 (100)	0.71 (100)	0.84 (100)	0.07 (100)
I					
1	Direct effect of area	-0.44 (80.00)	-0.28 (-254.55)	0.24 (-53.33)	-0.58 (148.72)
2	Indirect effect of area	-0.11 (20.00)	0.39 (354.55)	-0.69 (153.33)	0.19 (-48.72)
3	Total effect of area	-0.55 (100)	0.11 (100)	-0.45 (100)	-0.39 (100)

Summary and Conclusions

The yield gap analysis shows the highest yield gap was observed in the case of yield gap- III (potential yield – actual yield) 21.34 to 24.80 per cent. The yield gap- II (demonstration plot yield – actual yield) was 10.24 to 18.26 per cent, while yield gap- I (potential yield – demonstration plot yield) was observed to the 8.00 to 15.33 per cent.

The path analysis measured the direct and indirect effect of input gaps on yield gaps explained that the total effect of planting material (0.67) and manure (0.58) was found to be highest in adsali planting type sugarcane while irrigation (0.71) in presesonal sugarcane. In suru sugarcane fertilizer (0.73) and irrigation (0.84) was found to be the most important variable conditioning yield gap. In ratoon planting type total effect of manure (0.26) and bullock labour (0.33) found to be highest.

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