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Block level estimates of cotton crop production for Sae in Amreli district

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Abstract
The study aimed to estimate the number of farmers growing cotton and cotton production for Amreli district. Employing a multi-stage sampling approach, we targeted a total of 100 farmers. Two talukas were selected from each district, followed by four villages from each taluka. At last, farmers from each village were chosen using Simple Random Sampling Without Replacement (SRSWOR) to ensure representativeness. Data collection involved direct interaction with each farmer through questionnaires, gathering information on landholding, fertilizer use, cropping patterns, and cotton yield specifically for the 2023 season. The district level data on crop production and related auxiliary variables were exploited through multiple linear regression model to estimate of crop production at block level. A scaled estimator of block level estimate also proposed. The percentage of cotton growing farmers ranged from 72% to 88%. BARE estimate of cotton production was found 19329.10 tonnes/ha over estimates the actual production. BARE estimates cotton yield of Rajula (55.57%) had lower standard errors. The correlation analysis showed a significant and positive association with factors such as total area under cotton cultivation, fertilizer consumption and rainfall. MLR revealed a positive and significant relationship between rainfall and cotton production. An empirical study for cotton production suggested that among scaled estimator, $\widetilde{Y}_q$ was more stable.

Keywords: Crop cutting experiments, BARE, SRSWOR, MLR, SAE

Introduction

Sample surveys is the only tool to gather information on various variables, where ultimate units of observation were selected randomly. The stratified multi stage complicated sampling design can help with this. It has been noted that various sampling strategies can deliver data at a higher degree of aggregation at the national, state, or district level. Recently, the government has changed its planning priorities from the macro to the micro levels, emphasizing the need for trustworthy data at the lower levels of aggregation, such as tehsil, block, and village panchayat, to ensure the most effective and efficient use of scarce resources. The problem of the development of reliable estimation at a lower level has been attempted by several researchers. These techniques are known as small area estimation. (Sharma, 2013)

The concept of a small area is not new. It has been derived from large scale surveys where survey statisticians are interested in estimating the characteristics of sub populations, known as domain, as well as population parameters like mean or total. The fact that domain studies use information from large scale surveys instead of planning surveys particularly because they demand so many resources to estimate domain characteristics makes them unique. Sometimes the typical direct sampling approach may not adequately reflect such domains in the sample when the domain sizes are very tiny, and as a result, estimations of these domain parameters may not be accurate. Such types of small domains are also called small areas. According to Brackstone (1987), “Any small domain may be regarded as a small area for which direct design based estimates cannot be reliably produced from the current sample survey program”.

The estimates of crop productivity/production are often provided at the district level. Aside from those that are available at the block and district levels, there are other factors relating to agricultural productivity.
These factors include the crop's understory, whether it is irrigated or not, how much fertilizer is used, and how much rain falls, *etc.* So, an initial attempt was undertaken to create an appropriate multiple regression model between crop production and associated factors (also known as predictor or independent variables) at the district level. Then, using the data from the fitted regression model at the district level, procedures have been devised to scale down the district level crop production estimates at the block level. (Sharma, 2013). In agriculture, it is common practice that crop estimation surveys are designed to provide reliable estimates at the aggregated administrative levels like states or districts.
Now there is a growing for reliable estimates for smaller area like community development blocks or *gram panchayt* or even for individuals villages. This need has arisen due to plan agricultural development for increasing production rapidly considering the resources and need of individual farmers and their environments. Since community development blocks have become the unit of planning, reliable data needed for formulating scientific plans and assessing their progress must be available.
The planners should also have an opportunity to examine the achievements as a result of various plan efforts made in the area. The key indicator of the achievements of such plan efforts is agricultural production. (Sharma, 2013)
Cotton, the king of apparel fibre, has played a key role in the development of human civilization. Even today, it occupies an outstanding position in the textile industry despite pressure of manmade fibres and blended fabrics. Gujarat is one of the leading cotton producing state in the country.
Gujarat contributes substantially to the national cotton area (24%) and productions (37%). Gujarat ranks first in cotton production occupying nearly 24% cropped area of Gujarat, cotton contributes nearly 1/3 to the State Gross Agricultural Product. In the last 10 years, greater than 500 Bt Cotton hybrids notified for commercial cultivation in central zone. Bt cotton area has grown by greater than 85% in last ten years unseating food crops. (Anon., 2023).

Materials and Methods

In the present study districts were considered as broad area and villages were considered as small area. The sampling unit (Individuals farmers) were selected as multistage sampling method. Purposively selected districts were considered as first stage unit. Whereas, talukas within district, villages within taluka and farmers within villages were selected randomly as second, third and last stage unit, respectively.

Broad Area Ratio Estimator With No Auxiliary Data

The broad area ratio estimates of cotton growing crop or the smaller area is defined as

$$(Y) = \frac{n}{N} \times X \qquad (1)$$

Where, Y = Broad area ratio estimate of each small area.
X = Direct estimate of cotton crop growing regions in broad area.
N = Total number of cottons growing farmers in the broad area.
n = Total number of cottons growing farmers in the small area

SRSWOR By Using Mean Per Unit Method

SRSWOR by using the mean per unit method is the point estimate of the population mean, which is defined as the mean per unit method and is obtained by using the following formula.

$$\bar{Y} = \frac{1}{n}\sum_{i=1}^{n} y_i \qquad (2)$$

Where, y_i is the yield of i^{th} cotton growing farmer in the given year.

Variance of the sample mean $\bar{y}$

$$\hat{Y} = N\,\bar{y} \qquad (3)$$

$$V(\bar{y}) = \frac{N-n}{N}\,\frac{S_y^2}{n} \qquad (4)$$

Where S_y^2 is the sampling variance given by

$$S_y^2 = \frac{1}{N-1}\sum_{i=1}^{n}(y_i - \bar{y})^2$$

Furthermore, an unbiased estimator of $V(\bar{y})$, when the population variance is not known is,

$$\widehat{V(\bar{y})} = \frac{N-n}{N}\,\frac{s_y^2}{n} \qquad (5)$$

Where, s_y^2 is the estimator of S_y^2,

$$s_y^2 = \frac{1}{n-1}\sum_{i=1}^{n}(y_i - \bar{y})^2$$

Confidence limits on mean

If the sample size is sufficiently large so that the distribution of $\bar{Y}$ can be approximated by a normal distribution, with confidence coefficient 100 (1 – α/2) may be taken as,

$$\hat{\bar{Y}} \pm t_{\left(1-\frac{\alpha}{2}\right)} S.E\left(\hat{\bar{Y}}\right) \qquad (6)$$

For large sample size (n) $t_{\left(1-\frac{\alpha}{2}\right)}$ is the value of the standard normal variate corresponding to the value 100 (1 – α/2) of the normal probability integral. For smaller sample sizes, the confidence interval may be constructed using a t-variate for (n-1) degrees of freedom, where in $t_{\left(1-\frac{\alpha}{2}\right)}$ is the 100 (1 – α/2) th percentile point in the t-table for (n-1) degrees of freedom.

Multiple Linear Regression At District Level

In India, estimates for crop production/yield at district level were made available through CCEs. The district level estimates were then aggregated at state and national level. There was lack of estimates of below this level, *e.g.*, Block level which was an important level for policy planning for rural area therefore describe scale down approach using multiple linear regression at to obtain the block level estimates from district level crop production estimates. Availability of auxiliary variables that were related to cotton crop production/yield at both district and block level.

$$Y_i = f(X_{ij}|\beta) + \varepsilon_i \quad (7)$$

Where Y_i = crop production in i^{th} year (i = 1, 2, …, n)
X_{ij} = value of j^{th} auxiliary variables in the i^{th} year (i = 1, 2, …, n)
β = unknown parameters
ε_i = error term which follows iid ~ N (0, σ^2)

The set of auxiliary variables may include area under the crop, farm harvest price, fertilizer consumption, rainfall *etc*. Let the fitted model, using least square (l.s.) technique, be denoted as,

$$\hat{Y}_i = f(X_{ij}|\beta) \quad (8)$$

Where, β = least square estimate of

$\hat{Y}_i$ = estimated value of Yi for corresponding values of X_{ij}
Decompose the sum of squares due to regression *i.e.*, SS_R ($\beta_1, \beta_2 \ldots \beta_p \mid \beta_0$) to define a weight that determines the relative contribution of each auxiliary variables included in the model follow:

$$W_j = \frac{\text{SS due to } j_{th} \text{ predictor}}{SS_R(\beta_1, \beta_2 \ldots \beta_p \mid \beta_0)} \quad (11)$$

Using these weights, an estimator of crop production (Y_q) for q^{th} block, (q = 1,2 ... Q) is constructed as

$$\widehat{Y_q} = \left(\sum_{j=1}^{P} W_j X_j\right) \hat{\hat{Y}} \quad (12)$$

Where, $\hat{\hat{Y}} = \frac{\hat{Y}}{A}$; $\hat{Y}$ is obtained through the fitted model (8).

A is the area under the crop in a given year
X_j is the value of j^{th} predictor at village level in a given year
weight Wj depends on the set of data on Y and X_{ij} used to fit model (7). To find out a stable value of Wj one can use iteration technique by fitting model (7) first with n years data and then with (n + 1), (n + 2) ... years data till we get a stable value of Wj. Consequently, the estimate $\widehat{Y_q}$ also be stable one. The estimator $\widehat{Y_q}$ was an unbiased estimator of Y_q if $\left(\sum_{j=1}^{P} W_j X_j\right)$ was constant quantity for given block and expected value of $\hat{\hat{Y}}$ is $\bar{Y}$ under assumption of the model (7).

The variance of Y_q is obtained as

$$V(\widehat{Y_q}) = \left(\sum_{j=1}^{P} W_j X_j\right)^2 \quad (13)$$

$$V(\hat{\hat{Y}}) = \left(\sum_{j=1}^{P} W_j X_j\right)^2 \frac{1}{A^2} V(\hat{Y}) \quad (14)$$

The variance of $\hat{Y}$ is easily available by fitting the model (7), which is equal to σ^2, the estimated error variance.
The estimator Y_q can also be referred to as synthetic estimator because Y_q also borrows the strength from $\hat{\hat{Y}}$ which is an estimate at the district level; whereas the coefficient of $\bar{Y}$ in () is the weighted value of the predictors at the block level.

Scalling Of Village Estimates To District Total Production

It is obvious that in general $\sum_{q=1}^{Q} \widehat{Y_q} \neq Y$ reported at district level through crop cutting experiments in a given year. Thus, a new estimator of Y_q is proposed as,

$$\widetilde{Y_q} = a_q \widehat{Y_q} \quad (15)$$

The question arises that how to choose a_q. The two alternatives choice of a_q are suggested below:
Choice I: The simplest choice of a_q is to take a_q = a, *i.e.*, the constant for each taluka. It can easily be shown that,

$$a = \frac{Y}{\sum_{q=1}^{Q} \widehat{Y_q}} \quad (16)$$

Thus, a new estimator of Y_q is given by,

$$\widetilde{Y_q}^{1} = \widehat{Y_q}\left[\frac{Y}{\sum_{q=1}^{Q} \widehat{Y_q}}\right] \quad (17)$$

$$a_q = 1 + \frac{\left(Y - \sum_{q=1}^{Q} \widehat{Y_q}\right)}{Q \; x \; \widehat{Y_q}}$$

Choice II: Another choice of a_q could be to minimize the sum of squared differences between $\widetilde{Y_q}$ and $\widehat{Y_q}$. To do so, by minimizing the sum of squared differences between $\widetilde{Y_q}$ and $\widehat{Y_q}$ subject to the condition.
Using a lagrange multiplier λ, to impose the desired constraint, by minimizing the function,

$$\varphi = \sum_{q=1}^{Q}\left(a_q \widehat{Y_q} - \widehat{Y_q}\right)^2 + 2\lambda\left[Y - \sum_{q=1}^{Q} a_q \widehat{Y_q}\right] \quad (18)$$

Differentiating φ with reference to a_q and equating it to zero and solving for a_q, following equation was obtained,

$$a_q = 1 + \frac{\widehat{Y_q}\left(Y - \sum_{q=1}^{Q} \widehat{Y_q}\right)}{\sum_{q=1}^{Q} \widehat{Y_q}^{2}} \quad (19)$$

Thus, another new estimator of Y_q is given by,

$$\widetilde{Y_q}^{2} = \widehat{Y_q} + \frac{\left[Y - \sum_{q=1}^{Q} \widehat{Y_q}\right]}{Q} \quad (20)$$

Note that the scalled estimator $\widetilde{Y_q}^{2}$ are obtained by adjusting the original estimator Y_q by adding a factor which is ratio of the difference between the actual crop production at district level, Y and the sum of the original villages estimates, $\sum_{q=1}^{Q} Y_q$, to number of villages in district.

Efficiency Of Small Area Estimation Against Larger Area Estimation

In order to find out the relative performance of the estimators, the variance of these estimators is derived.
The variance of Y_q is already given in (4). However, an alternative expression for V (Y_q) is given by,

$$V(Y_q) = \left[\frac{\delta_q^2}{A^2}\right] V(\widehat{Y_q}) \quad (21)$$

Where $\delta_q = \sum_{q=1}^{q} W_j X_j$

The MSE of $\widetilde{Y_q}^1$ and $\widetilde{Y_q}^2$ are obtained as

$$MSE(\widehat{Y_q}) = \frac{(Y - \sum_{q=1}^{q} \widehat{Y}_q)^2\, Y_q^2}{\left(\sum_{q=1}^{q} \widehat{Y}_q\right)^2} + \frac{Y^2}{\left(\sum_{q=1}^{q} \widehat{Y}_q\right)^2} V(\widehat{Y_q}) \quad (22)$$

$$MSE\left(\widetilde{Y_q}^1\right) = \frac{Q-2}{Q} V(\widehat{Y_q}) + \frac{1}{Q^2} \sum_{q=1}^{Q} V(\widehat{Y_q}) \quad (23)$$

$$MSE\left(\widetilde{Y_q}^2\right) = \left[1 + \frac{Y - \sum_{q=1}^{Q} \widehat{Y_q}}{\sum_{q=1}^{Q} \widehat{Y_q}^2} \widehat{Y_q}\right]^2 \left[\frac{\delta_q^2}{A^2}\right] Var(\widehat{Y}) \quad (24)$$

In order to study the relative efficiency of the estimators, the MSE of these three estimators are compared.

The percent of standard error (% SE) of the estimates was calculated as

$$\% SE = \sqrt{\frac{\text{Variance/MSE of estimates}}{\text{Estimates of } Y_q}} \text{ X } 100 \quad (25)$$

The overall average error in $\widetilde{Y_q}^i$ as compared to $\hat{Y}_q$ was calculated as

$$E_i = \sqrt{\frac{\sum_{q=1}^{Q} \left(Y_q - \widetilde{Y_q}^i\right)^2}{Q}} \; (i = 1, 2) \quad (26)$$

Results

BARE Estimates For Total Numbers Of Farmers, Cotton Crop Production And Cotton Crop Yield.

Small area estimation techniques which include Broad area ratio estimation to know the percentage of farmers involved in cotton growing activity, total production of cotton crop, yield of cotton crop. BARE estimates for total numbers of cotton growing farmers were 80.45, 77.16 and 79.33 percent for Rajula, Babara and overall Amreli district. BARE estimates of total production of cotton for Amreli district were found to be 19329.10 tonnes. It was found that the expected production was over-estimated as compared to actual production for Amreli district in the year 2023. Minimum standard error of small area estimates of cotton yield for Amreli district found in Rajula (55.57) village. Based on this it concluded that the estimates of cotton yield for various villages within district were found to be have lesser standard error which make them more efficient.

Table 1: BARE estimates of the total number of cotton growing farmers in Amreli district

Sr. No.	Taluka	Villages	Total numbers of farmers (N)	Total numbers of sampled farmers (n)	Actual number of cotton growing farmers	Percentage of cotton growing farmers	Estimated number of cotton growing farmers
1	Rajula	Khakhbai	507	25	19	76	385
2		Dungar	541	25	20	80	433
3		Mandardi	128	25	17	68	87
4		Rajula	548	25	22	88	482
		Total	1724	100	78		1387
BARE = 80.45%							
5	Babara	Trambola	214	25	18	72	154
6		Khambhala	382	25	19	76	290
7		Sukhpur	197	25	20	80	158
8		Ishvariya	96	25	22	88	84
		Total	889	100	79		686
BARE = 77.16%							
9	Overall	Total	2613	200	157		2073
BARE = 79.33%							

Table 2: BARE estimates of total production of cotton for Amreli district

Total production of Cotton Growing Farmers (Tonnes)	Villages	Observed Area under Cotton Crop/25 Farmers (ha)	Observed Average production of Cotton (Tonnes/ha)	Total area under Cotton (ha)	Expected total production of Cotton (Tonnes)	Present total production of Cotton (Tonnes)
3297.62	Khakhbai	115.04	3297.62/621.60 = 5.30	3647	5.30 X 3647 = 19329.10	9114.58
	Dungar	49.28				
	Mandardi	155.52				
	Rajula	80.48				
	Trambola	78.88				
	Khambhala	43.68				
	Sukhpur	31.84				
	Ishvariya	66.88				
	Total	621.60				

Table 3: BARE estimates with standard error of cotton yield under SRSWOR for different villages of Amreli district

Sample Size (n)	Villages	Estimate (kg/ha) (2023)	Standard Error	Interval estimate based on			
				Sample Variance		Population Variance	
				Lower limit	Upper limit	Lower limit	Upper limit
200	Khakhbai	3747.03	105.00	3530.32	3963.74	3541.23	3952.83
	Dungar	1476.96	104.05	1262.20	1691.72	1273.01	1680.91
	Mandardi	5714.82	106.59	5494.82	5934.83	5505.90	5923.75
	Rajula	1653.53	55.57	1538.83	1768.22	1544.61	1762.45
	Trambola	1776.18	105.89	1557.63	1994.73	1568.63	1983.73
	Khambhala	1104.84	105.89	886.29	1323.39	897.29	1312.39
	Sukhpur	770.48	103.89	556.05	984.90	566.85	974.11
	Ishvariya	1233.02	107.00	1012.18	1453.86	1023.29	1442.74
	Overall	99.24					

Correlation Between Cotton Production And Other Variables For Amreli District

The association of cotton production for Amreli district showed positive correlations with key variable like area coverage (r = 0.726), fertilizer consumption (r = 0.737), rainfall (r = 0.467) and farm harvest price (r = 0.607) found to be positive and significant. It suggests that an increase in cotton cultivation area, fertilizer usage, rainfall, and farm harvest price significantly and positively contribute towards higher cotton production. Conversely, relative humidity in the morning (r = - 0.181), relative humidity in the evening (r = - 0.052), maximum temperature (r = - 0.448), and minimum temperature (r = - 0.374) exhibits negative and non significant correlations.

Table 4: Correlation between production (Y) and different variables of Amreli district

Variables	Production
Total area under Cotton crop (X_1)	0.726**
Fertilizer Consumption (X_2)	0.737**
Rainfall (X_3)	0.467*
Relative Humidity Morning (X_4)	-0.181
Relative Humidity Evening (X_5)	-0.052
Temperature Maximum (X_6)	-0.448
Temperature Minimum (X_7)	-0.374
Farm Harvest Price (X_8)	0.607**

** 1% Significance level, * 5% Significance level

Multiple Regression Model At District Level

The multiple linear regression analysis was employed to know the functional relationship between cotton production (Y) and different variables like total area under the cotton crop (X_1), fertilizer consumption (X_2), rainfall (X_3), relative humidity in the morning (X_4), relative humidity in the evening (X_5), maximum temperature (X_6), minimum temperature (X_7), and farm harvest price (X_8) of Amreli district by using least square technique and the results were presented in Table 5 showed values of regression coefficients, their standard error and coefficients of determinants (R^2) for the districts included in the study.

Regression equation for Amreli district

$Y = 89440.1 + 1.841\ X_1 + 0.006\ X_2 + 5.896^*\ X_3 - 439.091\ X_4 + 448.044\ X_5 - 2288.119^{**}\ X_6 + 71.106\ X_7 + 0.259\ X_8$

The results indicated that certain factors do not exhibit a significant relationship with cotton production. These included total area under the cotton crop (X_1), fertilizer consumption (X_2), relative humidity in the morning (X_4), relative humidity in the evening (X_5), minimum temperature (X_7) and farm harvest price (X_8).

Interpretation of results of regression analysis for Amreli district

The larger areas exhibit an anticipated count 1.841 units higher compared to smaller areas, with other variables held constant

If the fertilizer consumption (X_2) of the cotton crop increase by one year, the difference in the counts would be expected to be increase by 0.006 units, while holding the other variables in the model constant.

Each unit increase in rainfall (X_3) during the cotton crop's growth period is met with a substantial boost of 5.896 units in the expected counts, while other variables remain steady.

A rise in morning humidity (X_4) per unit growth period is associated with a decrease of -439.091 units in expected counts, holding other variables constant.

Conversely, an increase in evening humidity (X_5) per growth period sees a robust surge of 448.044 units in expected counts, all other factors remaining stable.

The temperature's maximum (X_6) rise per growth period introduce a considerable decrease of -2288.119 units in expected counts, with other variables unchanged

Conversely, an elevation in minimum temperature (X_7) per growth period corresponded to an increase of 71.106 units in expected counts, keeping other variables constant.

An upward shift in farm harvest price (X_8) throughout the growth period of the cotton crop was associated with a modest increase of 0.259 units in the expected counts. This relationship holds under the assumption that all other variables remain constant.

The details of standard errors, coefficient of determination (R^2) and regression coefficients were presented in table no. 4.14. Rainfall (X_3) was found to be a statistically significant and favourable factor that increases cotton yield. On the other hand, the effect of maximum temperature (X_7) was not only negative but also quite large. The high coefficient of determination (R^2) of 90.60% indicated that the variables included in the model had significant and sufficient explanatory power and can be used to interpret variations in district-level cotton production.

Table 5: Regression coefficients, their standard error and R^2 of MLR analysis for Amreli districts

Variables	Regression Coefficient	Standard Error	R^2 (%)
Total area under Cotton crop (X_1)	1.841	0.990	0.906
Fertilizer Consumption (X_2)	0.006	0.045	
Rainfall (X_3)	5.896*	2.626	
Relative Humidity Morning (X_4)	-439.091	238.706	
Relative Humidity Evening (X_5)	448.044	228.352	
Temperature Maximum (X_6)	-2288.11**	780.422	
Temperature Minimum (X_7)	71.106	332.667	
Farm Harvest Price (X_8)	0.259	0.611	

** 1% Significance level, * 5% Significance level

Contribution Of Individual Variable Towards Sum Of Square Due To Regression And Value Of The Weights (W_j) For Different Districts

Using the analysis of variance, the individual contribution of independent variables *viz.*, total area under the cotton crop (X_1), fertilizer consumption (X_2), rainfall (X_3), relative humidity in the morning (X_4), relative humidity in the evening (X_5), maximum temperature (X_6), minimum temperature (X_7) and farm harvest price (X_8) towards the regression sum of square and their weights (W_j) calculated based on regression sum of square were presented in table no. 6.

The result presented in table no. 6 revealed that the maximum weights were observed in X_2 (0.1415) followed by X_8 (0.1415), X_5 (0.1411), X_4 (0.1320), X_3 (0.1310), X_7 (0.1102), X_6 (0.1102) and X_1 (0.0916)

Table 6: Contribution of individual variable towards regression sum of square and their weights (Wj) for Amreli districts

Sr. No	Variable	Contribution of Variable		W_j
1	Total area under Cotton crop (X_1)	$SS_R (B_1 \| B_0)$	2.764 X 10^8	0.0916
2	Temperature Maximum (X_6)	$SS_R (B_2 \| B_0, B_1)$	3.327 X 10^8	0.1102
3	Temperature Minimum (X_7)	$SS_R (B_3 \| B_0, B_1, B_2)$	3.327 X 10^8	0.1102
4	Rainfall (X_3)	$SS_R (B_4 \| B_0, B_1, B_2, B_3)$	3.965 X 10^8	0.1310
5	Relative Humidity Morning (X_4)	$SS_R (B_5 \| B_0, B_1, B_2, B_3, B_4)$	3.985 X 10^8	0.1320
6	Relative Humidity Evening (X_5)	$SS_R (B_6 \| B_0, B_1, B_2, B_3, B_4, B_5)$	4.259 X 10^8	0.1411
7	Farm Harvest Price (X_8)	$SS_R (B_7 \| B_0, B_1, B_2, B_3, B_4, B_5, B_6)$	4.269 X 10^8	0.1415
8	Fertilizer Consumption (X_2)	$SS_R (B_8 \| B_0, B_1, B_2, B_3, B_4, B_5, B_6, B_7)$	4.270 X 10^8	0.1415
	Total		30.166 X 10^8	1

Efficiency Of Small Area Estimation Against The Larger Area Estimation

By using Weights (W_j) and districts data on the variables *viz.*, X_1, X_2, X_3, X_4, X_5, X_6, X_7 and X_8, three different Synthetic estimators ($\tilde{Y}_q$, $\tilde{Y}_q^1$, $\tilde{Y}_q^2$) were determined. Based on these estimators the block (village) level estimates of cotton production, their percent standard error and percent relative efficiencies were calculated for different districts for the year 2023. The overall average error in percentage were also calculated for all the districts and the results were presented in table no. 8.Result presented in table no. 8 showed that the block (village) level synthetic estimates obtained from three different estimators were subject to maximum of almost 5% standard error. The percent standard error for block estimates varied between 2.64 to 2.79 percent in case $\tilde{Y}_q$ followed by 3.79 to 4.37 percent in case $\tilde{Y}_q^1$ and 4.37 to 4.93 percent in case of $\tilde{Y}_q^2$. It showed that the range of percent standard error for block estimate is smaller for $\tilde{Y}_q$ as compared to the other estimators. An overall average error was also found to be 772.96 in case of $\tilde{Y}_q$ was smaller as compared to other estimators. Therefore, it concluded that $\tilde{Y}_q$ was best scaled improved estimator for estimating the block level estimates as compared to other estimator.

Table 8: Synthetic estimates of cotton production of different villages of Amreli district in the year 2023

	Village	Actual Production	Estimated Production	Estimate of Cotton Production			% Standard error		
				$\tilde{Y}_q$	$\tilde{Y}_q^1$	$\tilde{Y}_q^2$	$\tilde{Y}_q$	$\tilde{Y}_q^1$	$\tilde{Y}_q^2$
1	Khakhbai	2847.74	3171.32	3747.03	3914.56	1739.76	2.69	3.96	4.54
2	Dungar	1181.57	1187.80	1476.96	1542.96	685.75	2.77	4.27	4.84
3	Mandardi	3886.08	2821.84	5714.82	5970.33	2653.42	2.64	3.79	4.37
4	Rajula	1455.10	1280.50	1653.53	1727.46	767.74	2.73	4.14	4.71
5	Trambola	1278.85	1069.06	1776.18	1855.59	824.68	2.73	4.12	4.70
6	Khambhala	839.68	1123.58	1104.84	1154.23	512.98	2.78	4.31	4.87
7	Sukhpur	616.38	1263.72	770.48	804.92	357.73	2.79	4.37	4.93
8	Ishvariya	1085.06	1538.78	1233.02	1288.14	572.49	2.74	4.18	4.75
Overall average error (E_i)							772.96	1104.57	1208.52

Conclusion

In the present study, the percentage of cotton growing farmers were 79.33%. BARE estimate of cotton production was found 19329.10 tonnes over estimates the actual production. BARE estimates cotton yield of Rajula (55.57%) had lower standard errors. The correlation analysis showed a significant and positive association with factors such as total area under cotton cultivation, fertilizer consumption and rainfall. MLR revealed a positive and significant relationship between rainfall and cotton production. An empirical study for cotton production suggested that among scaled estimator, $\tilde{Y}_q$ was more stable.

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