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Economic analysis of yield gap in cotton

M. P. TAKOTE*, S. S. THAKARE AND S. G.TALE

Shri Shivaji Agriculture College, Amravati - 444 601

****E-mail : monaltakote@gmail.com***

ABSTRACT : In this study, an attempt has been made to study the economic analysis of yield gap in cotton. The primary data on input used and there upon costs were collected from three tehsils *viz.,* Amravati, Morshi and Achalpur, while the secondary data on area, production and productivity pertained to the periods 1986-1987 to 2015-2016 was collected from various Government publications. The study revealed that the production (i.e. 2.52%/annum) and productivity (*i.e.* 5.65%/annum) of cotton showed positive and significant growth. The yield gap analysis shows that at overall, yield Gap I (difference between potential yield and actual yield) worked out to be 519 kg/ha and yield Gap II (demonstration plot yield and actual yield) was 319 kg/ha. The highest total yield gap was recorded in large farmers (434 kg/ha) while lowest in small farmers (251 kg/ha). Magnitude and direction of yield gap shows that the yield gap is increased at increasing rate. The path analysis measured the direct and indirect effect of input gaps on yield gaps explained that the total effect of bullock labour (0.62) was found to be highest in small farmers while machine labour (0.59), plant protection (0.55) found to be highest in small group farmers. At overall level total effect of seed and fertilizer (0.48) and (0.55) respectively. The manure and plant protection effect is (0.40) and (0.54).

Key words: Coefficient of variation, compound growth rates, cotton, path analysis, yield gap

Cotton (*Gossypium* spp.) is a fibre crop, originally from the India, but now cultivated world wide. It has been described as the "King of Fibre" or "White Gold". India is the largest cotton producing and second largest cotton exporting country. In 2016-2017 the world production of cotton was 22.99 (MT). In India area was 105 (lakh ha.) with production of 351 (lakh bales of 170 kgs) and productivity 568 (kg/ha). India's share out of world production is 26 per cent according to The Cotton Corporation of India Ltd. In Maharashtra in 2016-2017, area, production and productivity of cotton was 38.06 (lakh ha.), 89 (lakh bales of 170 kgs) and 398 (kg/ha), respectively. In 2015-2016, Area, Production and Productivity of cotton in Amravati district was 2000 (00' ha), 4170 (00' tons) and 355 (kg/ha), respectively.

Cotton is the world's most widely cultivated fibre crop. It provides direct livelihood to 6 million farmers and about 40.50 million people are employed in cotton trade and its processing. It provides the basic raw material (cotton fibre) to cotton textile industry. There are three primary products derived from cotton production : lint, linters and cottonseed. Cotton lint used in clothing and shoe strings, Linters are used in plastic and paper products. Cottonseed is crushed into three separate products- oil, meal and hulls.

MATERIALS AND METHODS

Collection of data : The study was based on primary as well as secondary data on area, production and productivity of cotton collected from various Government publications for last 30 years. The entire study was split up into three sub-periods like P1 (1986-1987 to 1995-1996), P2 (1996-1997 to 2005-1906) and P3 (2006-2007 to 2015-2016).

Primary data : The primary data on inputs used and yield obtained from cotton were collected from selected farmers by survey method. The data on inputs used and yield obtained from demonstration plot were collected from research unit/station. In all 100 farmers were selected for the study. The data was pertain to the year 2016-2017. The selected farmers were stratified into three groups on the basis of size of holdings *viz.,* small farmers (i.e. 44) with the size of holding (0.01 to 2.00 ha), medium farmers (*i.e.* 33) with (2.01 to 4.00 ha) and large farmers (*i.e.* 23) (4.01 ha. and above).

Analytical tools : One of the objectives of the present study about the performance of cotton in Amravati district was examined by estimating.

i. Compound growth rate of area, production and productivity.

ii. Degree of instability in area, production and productivity.

i. Estimation of growth rates : The growth rates in area, production and productivity were studied by estimating compound growth rates at different periods.

The growth rate was estimated by using following exponential model.

$$Y = a.b^t$$

Where,

Y = Area/Production/Productivity

a = Intercept

b = Regression coefficient

t = Time variable

From the estimated function the compound growth is worked out by

CGR (r) = [Antilog (log b -1)] x 100

Where,

r = Compound Growth Rate

ii. Degree of instability : The degree of instability in area, production and productivity of cotton for different period was measured by using coefficient of variation and coefficient of instability.

Coefficient of variation (CV) = $\frac{\sigma}{\overline{X}} \times 100$

Where,

σ =Standard Deviation $\sqrt{\frac{\Sigma(X-\overline{X})^2}{n}}$

$\overline{X}$ = Arithmetic Means

Coefficient of instability was worked out by using Coppock's instability index.

$$V = \log \frac{\Sigma(\log \frac{X_1+1}{X_t} \ldots\ldots m)^2}{N}$$

$$CII = [\text{Antilog}(\sqrt{V \log}) - 1] \times 100$$

Where,

X_t = Area /Production / Productivity of cotton

N = Number of years

m = Arithmetic mean of the differences between the log

of X_t and X_t-1, X_t-2 etc.

V log = Arithmetic Variance of series.

Yield gap analysis

Yield Gap I : It is the difference between potential yield and actual yield

(i.e. Yp-Ya).

Yield Gap II : It is the difference between potential farm yield and actual yield. (i.e. Yd-Ya)

The magnitude and direction of yield gap will be studied by fitting quadratic function.

$$Y = a + bT + cT^2$$

Where,

Y = Yield Gap

T = Time

So, about existing of acceleration or deceleration with a specified time period is based on the sign and statistical significance of the estimation of c in the quadratic trend function.

Factors responsible for yield gap : The factor contributing towards yield gap was studied using path analysis.

Path coefficient analysis technique was carried out to estimate direct and indirect contribution of input gap (x) is to yield gap (Y).

A path coefficient is the ratio of the standard deviation of the effect or it is a standardized partial regression coefficient (Deway and Lu, 1959). In the present investigation, the effect of difference actual utilization of key inputs and human labour (md), bullock labour (pd), seed (kgs), plant nutrients (Rs.) and plant protection (Rs) between the farmers and field demonstration plot independent variable (Xi) were used. The path coefficients across different categories of farm will be studied by solving the following simultaneous equations.

$r_{y1} = P_y1 + r_{12} Py_2 + r_{13}Py_3 + r_{14}Py_4 + r_{15}Py_5$ .....(1)

$r_{y2} = r_{21}P_{y1} + Py_2 + r_{23} Py_3 + r_{24} Py_4 + r_{25} Py_2$ .....(2)

$r_{y3} = r_{31}P_{y1} + r_{32} Py_2 + Py_3 + r_{34} Py_4 + r_{35} Py_5$ .....(3)

$r_{y4} = r_{41}P_{y1} + r_{42} Py_2 + r_{43} Py_3 + Py_4 + r_{45} Py_5$ ..... (4)

$r_{y5} = r_{51}P_{y1} + r_{52} Py_2 + r_{53} Py_3 + r_{54} Py_4 + Py_5$ .....(5)

The generalized formula may be written as

$r_{yi} = r_{1i}P_y{}^1 + r_{2i} Py^2 + r_{3i} Py^3 + \ldots\ldots\ldots + r_{ni} Py^n$ .....(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

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

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

obtained by

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

Where,

$$R^2 = \sum_{i=1}^{n} P_{yj}^2 + \sum \sum_{\substack{i=1 \\ i=j}} P_{yj} P_{yj\, rij}$$

.....(10)

RESULTS AND DISCUSSION

Growth performance of cotton

Growth in area, production and productivity: In this study, the compound growth rates in area, production and productivity of cotton was estimated by using exponential function with time normalization on area, production and productivity. The growth performance of the cotton pertaining to three periods and overall is discussed and presented in Table 1. The findings of the table reveal that during period I, the compound growth rate of production and productivity of cotton was positive and significant. Only the growth rate in area of cotton in Amravati was negative and decreased (i.e.-0.52 per cent per annum) over the period of study. In period II also the compound growth rate of area under cotton in Amravati was negative i.e. -3.89 per cent per annum. During period III growth rates in area, production and productivity of cotton were found to be stagnant.

At overall level, the Table 1 shows that, during period 1986-87 to 2015-16, the area of cotton in Amravati district had declined (*i.e.* -2.95%/annum) and was significant while production (*i.e.* 2.52%/annum) and productivity (*i.e.* 5.65%/annum) of cotton shows positive and significant growth.

Table 1, Growth performance of cotton

Sr. No.	Particulars	Period I	Period II	Period III	**Overall**
1	Area	-0.52	-3.89***	0.95	**-2.95*** **
2	Production	12.09***	2.26	6.13	**2.52****
3	Productivity	12.71***	6.44	5.15	**5.62*** **

(Note:***, ** and * denotes significant at 1%, 5% and 10% level of significance)

Coefficient of variation in area, production and productivity: One should not obvious of coefficient of variation by taking the growth rates only. Because the growth rates will explain only the rate of growth over the period, whereas, instability will judge whether the growth performance is stable or unstable for the period for the pertinent variable.

In order to know the instability in area, production and yield of cotton fluctuation was measured with the help of coefficient of variation. The results are presented in Table 2 and discussed as under for the three time periods P_1, P_2, and P_3 and for the study period as a whole ten years breakage and overall also. Fluctuation in area, production and productivity due to the uncontrollable factors like climatic conditions can cause upward bias in coefficient of variation.

As seen from Table 2 the coefficient of variation in area for overall period was 27.12 per cent, there was highest variation as compared to period I and period II (*i.e.* 4.91 and 12.53%)

Table 2. Coefficient of variation in area, production and productivity of cotton in Amravati district.

Sr. No.	Particulars	Coefficient of variation (%)			**Over-all**
		Period I	Period II	Period III	
1	Area	4.91	12.53	16.63	**27.12**
2	Production	37.55	30.70	45.35	**46.28**
3	Productivity	28.62	31.45	43.68	**69.71**

respectively.

During period III Amravati district recorded highest variation (*i.e.* 16.63%) as compared to I and II period.

It is cleared that this district exhibited less variation in first period and highest variation in area during third period of study. As revealed from Table 2 the district witnessed very high instability of production as indicated by highest coefficient of variation of 46.28 per cent for overall period due to introduction of *Bt* cotton in 2002 in Vidarbha and high yielding varieties of *Bt* cotton the production was increased and the cost of production is comparatively less hence farmers were attracted towards the soybean due to high cost of cultivation of cotton. Due to less Rainfall and heavy infestation of insect pest, drought condition the production of cotton were instable in Vidarbha.

Among periods under study the period III has highest coefficient of variation (*i.e.* 45.35%) in production. While during the second period it was 30.70 per cent and in first period it was 37.55 per cent. Thus, it is clear from the study that the productivity of cotton in Amravati district has increased during the period of study.

Data in Table 3 reveals that, the productivity of cotton over the entire period shows highest coefficient of variation of 69.71 per cent. During first period the coefficient of variation of 28.62 per cent while in second period, the coefficient of variation witnessed 31.45 per cent and third period the coefficient of variation in productivity of cotton was increased to 43.68 per cent.

Table 3. Coppock's Instability Index of area, production and productivity of cotton in Amravati district.

Sr. No.	Particulars	Coppock's Instability index (%)			**Over-all**
		Period I	Period II	Period III	
1	Area	4.66	3.61	16.43	**14.07**
2	Production	22.78	30.02	18.84	**39.98**
3	Productivity	17.53	26.91	40.87	**44.15**

From above it is clear that the instability in cotton was increased during third period and productivity were increased over period at time. At overall level coefficient of variation was 69.71 per cent/annum.

It is clear from Table 3 that the instability index of area under cotton for overall was 14.07 per cent. During first period instability index was 4.66 and second period the instability in area was comparatively low which means that there was instability in area under cotton. This was increased during period III (16.43%).

The instability index of production for the overall period was 39.98 per cent. During first period the instability index was 22.78 per cent while in second period the instability index witnessed 30.02 per cent and third period instability index was 18.84 per cent.

The data in the table revealed that the instability index of productivity for overall period was 44.15 per cent. During first period instability index was 17.53 per cent while in second period

instability index was 26. 91 per cent and in third period instability index was 40.87 per cent.

Yield gaps in cotton production : The study was undertaken with the overall objective of estimating the magnitude of yield gaps and factor contributing to yield gap in cotton production. The results obtained are presented in Table 4.

Table 4. Cotton yield levels realized and estimated yield gap under different field situation

(kg/ha)

Sr. No.	Particulars	Yield
1	Potential yield	2200
2	Potential farm yield	2000
3	Actual yield	
	Small farmers	1748
	Medium farmers	1670
	Large farmers	1565
	Overall	**1680**
4	**Yield gap I**	
	Small farmers	451
	Medium farmers	529
	Large farmers	634
	Overall	**519**
5	**Yield gap II**	
	Small farmers	251
	Medium farmers	329
	Large farmers	434
	Overall	**319**

It could be observed from the Table 4, that there is a wide gap in the cotton productivity between the research station, the potential farm (demonstration plots) and the sample farmers fields.

The magnitude of yield gap I worked out to be 519 kg/ha which observed relatively higher size of yield gap II 319 kg/ha (similar result were found for cotton in Akola District by Warade *et al.,* (2010). The higher magnitude of yield gap II may be attributed to the significant experimental difference and partly to the non transferable component of technology like cultural practices between the demonstration plot and the research stations. Farm size group wise analysis observed that the highest in magnitude of yield gap was recorded on the large farm (634 kg/ha) and medium farms (529 kg/ha) while the lowest magnitude was notice on small farms (451 kg/ha). In yield gap II it has been noticed that highest magnitude was notice on large farm (434 kg/ha), and the lowest in small farm (251 kg/ha).

Farm size group wise analysis showed that the medium and large farmers obtained relatively better yield levels than small farmers. This resulted comparatively higher yield levels and narrower yield gap on medium and large farms than on their medium counterparts. Due to better knowledge of new technology and proper cultural practices should manage their farms efficiently resulted in higher yield levels on the other hand comparatively lower yield level realized on small farms. This was due to their poor economical condition and unawareness.

Table 5. Magnitude and direction of yield gap for cotton

Sr. No.	Intercept	Coefficient		
		X	X^2	R^2
	305.70	-2.62	0.04	0.46

The analysis of yield gap II for cotton shows that the quadratic function fitted for yield gap data for Amravati district had positive R^2 value. This indicates that yield gaps for cotton is showing acceleration and increased i.e. yield gap is increasing at increasing rate.

Factor contributing to the yield gap path analysis : The direct and indirect effects measured both in terms of correlation coefficient and percentage of input use gaps on yield gaps are presented in Table 6.

Data in Table 5 presents the information on yield gap which were the result of gap in the quantity of input used and a composite variable that included all other factor affecting yield gap not included in the model. These could be differences in the climatic conditions, various cultural and crop management practices between the farmers and demonstration plots.

Results of correlation coefficient between the yield gap and input use gaps revealed that the total effect of bullock labour was found to be highest (0.62) followed by the machinery labour (0.59) in small farmers.

On overall category of farmers fertilizer was found to be the most important variable conditioning yield gap as indicated by its correlation coefficient (0.55) and direct and indirect effect 56.36 per cent and 43.63 per cent respectively.

Table 6. Direct and indirect effects of input use on yield gap in cotton

Sr. No	Particulars	Small	Medium	Large	**Overall**
A					
1	Direct effect of human Labour	0.24(44.44)	-0.28(-28.00)	-1.32(-130.69)	**1.18(-300.00)**
2	Indirect effect of human labour	0.30(55.55)	1.28(128.00)	2.33(230.69)	**0.25(416.66)**
3	**Total effect of human labour**	**0.54(100.00)**	**1.00(100.00)**	**1.01(100.00)**	**0.06(100.00)**
B					
1	Direct effect of bullock labour	0.30(48.38)	0.06(4.95)	-0.25(-27.17)	**0.21(37.50)**
2	Indirect effect of bullock labour	0.32(51.61)	1.14(94.21)	1.17(127.17)	**0.35(62.50)**
3	**Total effect of bullock labour**	**0.62(100.00)**	**1.21(100.00)**	**0.92(100.00)**	**0.56(100.00)**
C					
1	Direct effect of machine labour	0.07(11.86)	0.42(42.00)	0.45(46.39)	**0.10(18.86)**
2	Indirect effect of machine labour	0.51(86.44)	0.57(57.00)	0.51(52.57)	**0.43(81.13)**
3	**Total effect of machine labour**	**0.59(100.00)**	**1.00(100.00)**	**0.97(100.00)**	**0.53(100.00)**
D					
1	Direct effect of seed	-0.03(-6.81)	-0.47(-46.07)	0.48(39.02)	**-0.03(-6.25)**
2	Indirect effect of seed	0.47(106.81)	1.49(146.07)	0.74(60.16)	**0.52(108.33)**
3	**Total effect of seed**	**0.44(100.00)**	**1.02(100.00)**	**1.23(100.00)**	**0.48(100.00)**
E					
1	Direct effect of manure	0.24(54.54)	0.30(24.39)	-0.05(-5.05)	**0.26(65.00)**
2	Indirect effect of manure	0.20 (45.45)	0.93(75.60)	1.04(105.05)	**0.14(35.09)**
3	**Total effect of manure**	**0.44(100.00)**	**1.23(100.00)**	**0.99(100.00)**	**0.40(100.00)**
F					
1	Direct effect of fertilizer	0.12(23.07)	-0.29(-29.29)	1.18(132.58)	**0.31(56.36)**
2	Indirect effect of fertilizer	0.40(76.92)	1.28(129.29)	-0.29 (-32.58)	**0.24(43.63)**
3	**Total effect of fertilizer**	**0.52(100.00)**	**0.99(100.00)**	**0.89(100.00)**	**0.55(100.00)**
G					
1	Direct effect of plant protection	0.15(27.27)	0.83(67.48)	0.01(0.82)	**0.15(27.77)**
2	Indirect effect of plant protection	0.40(72.72)	0.39(31.70)	1.20(99.17)	**0.39(72.22)**
3	**Total effect of plant protection**	**0.55(100.00)**	**1.23(100.00)**	**1.21(100.00)**	**0.54(100.00)**

In small category of farmers plant protection was found to be the most important variable conditioning yield gap as indicated by its correlation coefficient (0.55) and it explained direct and indirect effect (27.27%) and (72.72%) of total effect. In medium category of farmers manure was found to be the most important variable conditioning yield gap as indicated by its correlation coefficient (1.23). In large farmers 39.02, 60.16 and 46.39, 52.57 per cent area effect is the most responsible factor of yield gap.

The positive correlation between the input use gaps and the yield gap indicated a direct association between the input use differences and yield gap. The findings 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 input need to be considered and there is a need to educate farmers about the benefits of using the recommended level of inputs.

CONCLUSIONS

It was concluded that the area under cotton decreased over a period, however the production and productivity of cotton increased with significant growth. Variability in area, production and productivity of cotton during period III was the highest as compared to period I and II. Instability in area of cotton decreased during second period. This increased during third period and productivity increased over period at time. Due to variability and instability in production and productivity, it is necessary to evolve high yielding cum stable yield varieties of cotton. The highest magnitude of yield gap was recorded on the large farmers. There is a possibility of reducing the yield gap by reducing the input use gaps. In addition to this, farmers ability to use the recommended level of input need to be considered.

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