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Application of Regression Models for Area, Production and Productivity Growth Trends of Bt. Cotton in Odisha, India

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ABSTRACT

The study analyses the trends in area, production, and productivity of cotton in Odisha, using secondary time series data divided into two periods: before (1985–2002) and after (2002–2018) the introduction of Bt cotton. A semi-log growth model was used to calculate the Compound Annual Growth Rate (CAGR), while instability was assessed using the Cuddy-Della Valle Index (CDVI). Results show a notable rise in cotton area, production, and productivity after the adoption of Bt cotton in Odisha and in India and for its highest adjusted R^2 on increasing future projection trends with respect to area, production and productivity of cotton in India. Despite these gains, farmers continue to face challenges such as poor seed quality, pest infestations, and limited awareness of modern technologies. The study emphasizes the need to strengthen agricultural extension services to address these constraints and enhance the benefits of Bt cotton adoption.

Introduction

Cotton, often referred to as "White Gold," is a vital cash crop for India, occupying the largest area under cultivation globally. It is the primary raw material for the cotton textile industry, fulfilling around 65% of its fibre requirement. In 2012–13, global cotton production was estimated at 118.95 million bales (480 lb each), marking a 4% decrease from the previous year, while the total cultivated area declined by about 4.62%. Despite this decline, India maintained its status as the country with the largest area under cotton cultivation and ranked second in production after China, accounting for 34% of the global cotton area and 21% of global output. In Brazil, production witnessed a sharp decline of around 43%, largely due to a 40% fall in the cotton-growing area compared to the previous year. In contrast, the United States recorded a 3.41% decrease in cotton acreage but achieved a 7.85% rise in output compared to 2011–12. China was expected to be the largest importer, projecting around 14 million bales of cotton imports, representing a

34% share in global cotton imports. Among the prominent cotton-producing nations, Australia led in productivity with 2,055 kg/ha, followed by Brazil and Turkey, both reaching 1,415 kg/ha. Within India, the leading cotton-producing states include Punjab, Haryana, Rajasthan, Madhya Pradesh, Gujarat, Maharashtra, Andhra Pradesh, Tamil Nadu, and Karnataka. Odisha, while not traditionally a major cotton producer, experienced notable progress after Bt cotton's introduction in the early 2000s. Prior to its adoption, cotton yields were low, primarily due to pest infestations—especially from bollworms. Post-introduction, there was a significant increase in the area under cultivation, production levels, and overall productivity. Farmers experienced benefits from reduced pesticide applications and improved yields.

However, challenges still persist, such as seed quality issues, emergence of secondary pests, and limited awareness among farmers about modern agricultural practices. Although Bt cotton has contributed positively to production, its success in Odisha is limited by insufficient extension support and poor training. Therefore, enhancing farmer education and promoting integrated pest management techniques are crucial for sustaining cotton productivity in the region. Growth models can provide efficient data summaries and are valuable tools for forecasting future trends. Numerous studies have used various growth modelling techniques across crops. For instance, Karim *et al.*, (2010); Rimi *et al.*, (2009); Finger (2007), and Chengappa (1981) applied such models to different crops. Singh *et al.*, (2014) used statistical growth analysis for paddy using multiple growth models. Martin and Yeh (1965) and Ahuja (1987) worked on future production projections for various crops. Dhakre and Amod Sharma (2009) evaluated ginger growth in the northeast using exponential models. Aparna *et al.*, (2008) analyzed vegetable trends in Visakhapatnam using compound growth functions. Srinivasulu and Srinivasa Rao (2006) employed regression models for turmeric trend analysis, while Borthakur and Bhattacharya (1998) studied potato trends in Assam. The core objective of the present study is to assess historical trends and make future projections for cotton area, production, and productivity in Odisha and India by applying suitable forecasting and growth trend models. Such insights are vital for researchers and policymakers in making informed decisions to enhance cotton sector performance.

Materials and Methods

The present study has been conducted on area, production and productivity of cotton crop in India during the period 1985 to 2018. The cotton crop secondary data were collected from Cotton Corporation of India (CCI). In his study we have compared different models viz., linear, quadratic, cubic, exponential, compound, logarithmic, inverse, power, and growth model for estimating the growth of cotton on area, production, and productivity to find the best fit using the statistical methods such as highest R^2 and adjusted R^2. Subsequently forecasted the cotton growth using the same statistical methods.

Growth Analysis

The period of analysis is 1985 to 2018. The entire period was sub divided into two sub periods of eighteen years each. i. Pre Bt Cotton Introduction (Period I - 1985 to 2002) ii. Post Bt Cotton Introduction (Period II – 2002 to 2018).

To analyze the bt-cotton cultivation in Odisha and in Kalahandi district, it is proposed to estimate the growth and instability in area, production and yield of Bt.cotton.

There are two types of growth rates viz., linear and compound growth rates. In present study both linear and compound growth rates of cotton were estimated to determine the LGR, the linear function of the form

$$Y = A + Bt ----(1)$$

$$LGR = \frac{B}{\bar{\bar{Y}}} \times 100 --- (2)$$

To determine the CGR, the exponential function of form is

$$Y = A.B^t ----(3)$$

Where, Y = Area/production/yield

t = time

A, B are the constants to be determined

The % of CGR is CGR = (B-1) × 100 $---(4)$

The coefficient of time $\hat{B}$ was tested by t-test statistic

$$t = \frac{\hat{B}}{SE\ of\ B}$$

$$S.E\ of\ B = \sqrt{\frac{\Sigma(Y-\hat{Y})^2}{N}}$$

Instability Analysis

The instability analysis was carried out as follows.

The instability measured by coefficient of variation (C.V.)

$$C.V. = \frac{\sigma}{\bar{Y}} \times 100 ------- (5)$$

Cuddy-Della Valle index (CDVI)

In this study, the instability in area, production and productivity was estimated using Cuddy-Della Valle index (CDVI) (Cuddy and Della Valle, 1978).

Though the coefficient of variation (CV) is commonly used for estimating the dispersion with comparability across various units, it cannot be used in case of time series data characterized by time trend. Any measure of instability needs to exclude the deviation in the data series that may arise due to secular trend or growth. CDVI was originally developed by John Cuddy and Della Valle for measuring the instability in time series data that is characterized by trend. The estimable form of the equation is as follows:

$$I = CV \times \sqrt{(1 - R^2)}$$

Where, I = Instability index in per cent

CV = Coefficient of variation in per cent

R^2 = *Coefficient of determination from time trend regression adjusted by the number of degree of freedom*

The value of (CDVI) has a range of 0-15 is categorized as low, 15-30 as moderate and above 30 as high.

Results and Discussion

The findings related to cotton area, production, and productivity are presented in Table 1. Descriptive statistics were computed for the cotton area, production, and productivity during the pre-bt cotton period (1985 to 2002) and the post-btcotton period (2002 to 2018). As shown in Table 1, the total cotton area during the entire study period was 1940.81 thousand hectares. Of this, 271.35 thousand hectares were planted during the pre-bt cotton era, while 1669.46 thousand hectares were planted in the post-bt cotton era. Similarly, the average cotton area during the entire study period, the pre-btcotton period, and the post-bt cotton period were 53.91 thousand hectares, 15.08 thousand hectares, and 92.75 thousand hectares, respectively. This indicates that the area allocated to cotton in Odisha increased following the adoption of bt cotton.

The total cotton production during the entire study period was 874.74 thousand bales, with 385.05 thousand bales in the pre-Bt cotton period and 4465.88 thousand bales in the post-Bt cotton period. The mean production during the overall, pre-Bt, and post-Bt periods were 24.30, 21.39, and 248.10 thousand bales, respectively. This shows a significant variation between the two periods. The area under cotton increased from 271.35 to 1669.46 thousand hectares, and with Bt cotton introduction, production rose substantially. The average productivity across the study period was 332.14 kg/ha. In the pre-Bt period, it was 228.22 kg/ha, while in the post-Bt period, it increased to 436.06 kg/ha. These figures clearly indicate that the introduction of Bt cotton led to a notable improvement in productivity.

Bt-Cotton Production in India and Odisha

Bt-Cotton production, area, and productivity in India from 2002-03 to 2018-19 are shown in Table 2. During this period bt-cotton area of India has increased from 0.29 lakh hectares to maximum 119.40 lakh hectares in the year 2014-15 with exception in the year 2012-13 and 2013-14.Later, downward tendencies in the area’s cotton were visible in the 2015-16 and 2016-17 and thereafter increase area's cotton. During the same period bt cotton area increased from 0.001 lakh hectares to 1.599 lakh hectares from 2002-03 to 2018-19 in Odisha. During that period (from 2002 to till date) saw a huge growth in cotton production, which rose by 272% throughout that time with a productivity range of 191.00 kg per hectare to 436.00 kg per hectare in India. And production and productivity increased by 135404.2 % and 52.32 respectively in Odisha during the same period. This increase may be due to more emphasis given by farmers to bt-cotton than non bt-cotton, cereals and other cash crops.

During the entire study period, total cotton production was 4815.80 lakh bales in India and 65.609 lakh bales in Odisha. The mean bt-cotton production was 267.54 lakh bales in India and 3.645 lakh bales in Odisha. Mean productivity during the period was 419.17 kg/ha in India and 815.57 kg/ha in Odisha. These figures indicate a significant rise in the area, production, and productivity of bt cotton.

This growth may be attributed to farmers giving more preference to bt cotton over non-bt varieties, cereals, and other cash crops, along with strong extension services from both government and private sectors.

Growth trend of Bt-Cotton in India and Odisha

Odisha's cotton productivity showed a positive but statistically non-significant compound growth rate (CGR), likely due to the crop's recent inclusion in the state's cropping pattern and limited familiarity with some crop varieties among farmers. However, it holds significant potential to emerge as a major commercial crop in the interior regions of Odisha. Regression analysis was employed to estimate the compound growth rates of cotton area, yield, and production in India and Odisha for the period 2002–03 to 2018–19. The results indicate that CGRs for area, yield, and output were positive in both regions.

Table.1 Descriptive statistics of Cotton Crop in Odisha

S.No.	Category	Period	Total	Mean	Range	SE	Variance
1	Area (‘000 ha)	Pre Bt Cotton Period (1985 2002)	271.35	15.08	61.36	4.00	112.65
2		Post Bt Cotton Period (2002 2018)	1669.46	92.75	140.08	10.74	49.12
3		Overall Period (1985-2018)	1940.81	53.91	167.65	8.66	96.37
4	Production (’000 bales)	Pre Bt Cotton Period (1985 2002)	385.05	21.39	63.18	5.33	105.68
5		Post Bt Cotton Period (2002 2018)	4465.88	248.10	528.65	34.45	58.92
6		Overall Period (1985-2018)	874.74	24.30	103.68	4.63	114.23
7	Productivity (kg/ha)	Pre Bt Cotton Period (1985 2002)	4108.00	228.22	232.00	15.82	29.41
8		Post Bt Cotton Period (2002 2018)	7849.00	436.06	293.00	16.96	16.50
9		Overall Period (1985-2018)	11957.00	332.14	472.00	20.96	37.86

Table.2 Bt-Cotton Production in India and Odisha

Years	**Area under Bt. cotton****	**Production**	**Yield**	**Area under Bt. cotton****	**Production**	**Yield**
	(in lakh hectare)	**(in lakh bales)**	**(kg per hectare)**	**(in lakh hectare)**	**(in lakh bales)**	**(kg per ha)**
	India			**Odisha**		
2002-03	0.29	86.21	191	0.001	0.004	558.70
2003-04	0.92	137.28	307	0.006	0.022	686.28
2004-05	4.85	164.29	318	0.025	0.122	822.50
2005-06	12.34	184.99	362	0.086	0.406	802.40
2006-07	33.53	226.32	421	0.231	1.224	901.33
2007-08	54.72	258.84	467	0.306	1.734	963.96
2008-09	66.69	222.76	403	0.475	2.518	901.28
2009-10	85.52	240.22	403	0.488	2.339	814.86
2010-11	96.32	330	499	0.681	3.356	837.54
2011-12	107.58	352	491	0.929	4.617	844.80
2012-13	105.43	342.2	486	1.08	5.069	798.00
2013-14	110.35	359.02	510	1.157	5.816	854.66
2014-15	119.4	348.05	462	1.197	5.598	795.15
2015-16	106.83	300.05	415	1.151	5.001	738.99
2016-17	89.43	325.77	511	1.218	6.293	878.04
2017-18	110.76	328.05	477	1.331	6.618	845.00
2018-19	117.81	287.08	386	1.486	6.867	785.75
% increased	40406.90	274.28	128.27	159800.00	200000.00	52.32

**Source: Directorate of Economics and Statistics*
***Source: DAC and FW, State Governments and Directorate of Cotton Development, Nagpur*
****First Advancement Estimate (Directorate of Economics and Statistics)*

Table.3 Descriptive statistics of Bt-Cotton Crop in India and Odisha

S.No	Category	Period	Total	Mean	Range	SE	Variance
1	Area (in lakh ha)	India (1902-18)	1340.24	74.46	119.11	6.01	60.08
3		Odisha (1902-18)	13.446	0.747	1.598	0.130	73.91
4	Production (lakh bales)	India (1902-18)	4815.80	267.54	272.81	19.37	30.72
6		Odisha (1902-18)	65.609	3.645	8.000	0.627	73.02
7	Productivity (kg/ha)	India (1902-18)	7545.00	419.17	320.00	19.82	20.06
9.		Odisha (1902-18)	14680.24	815.57	405.26	21.08	10.97

Table.4 Growth Rate for Bt cotton crop in India and Odisha during period of 2002-18

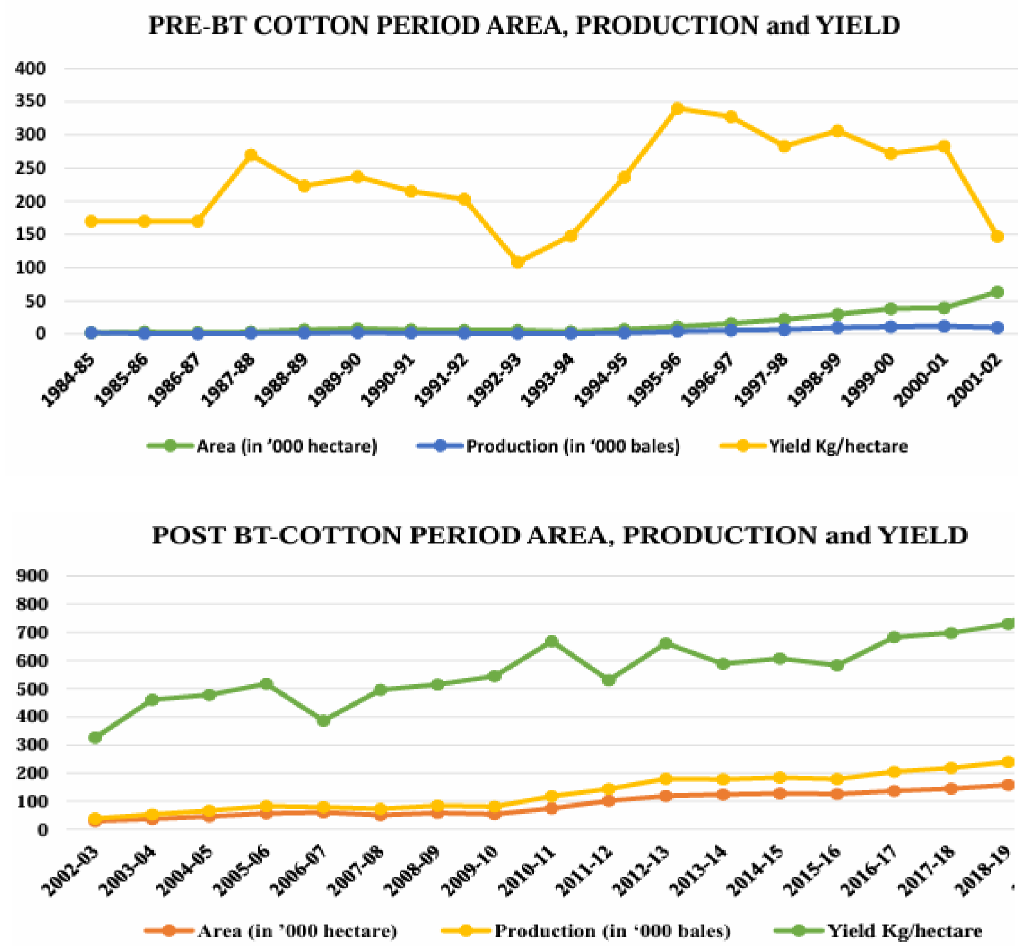
Sl. No.	Periods (2001-18)	CGR		
		Area	Production	Productivity
1	India	30.23***	6.04***	2.94***
		-0.0001	-0.00005	-0.0046
2	Odisha	39.14***	39.87***	0.73^{NS}
		-0.00001	-0.00002	-0.189

#Parenthesis indicates the P value; NS indicates non-significant *** indicates significance at 1%

Table.5 Cuddy-Della Valle index (CDVI) for area of Cotton Crop

Sl. No.	Periods (2002-18)	CDVI Value		
		Area	Production	Productivity
1	India	38.42	18.83	15.97
2	Odisha	41.21	42.04	10.69

Figure.1 Area, production and productivity of cotton in pre bt cotton-period and post bt cotton period



In India, the growth rates for area, production, and productivity were all positive and statistically significant at the 1% level of probability. Similarly, in Odisha, the growth rates for area and production were also positive and statistically significant at the 1% level.

Instability analysis

Cuddy-Della Valle index (CDVI) for Bt-cotton in India and Odisha When comparing the CDVI value in India and Odisha indicated that the productivity Instability is high in India. In terms of production and area, Odisha is more volatile than the India during the study period. The outcome also showed that area allocation during the Bt Cotton was less stable in Odisha than India. The reasons for increasing trend in Bt- cotton area and production over time may be attributed due to lack of high-quality varieties of Bt- cotton and improper managerial abilities of cotton industry in the state. It also reflects that there was a greater degree of diversification to vegetables and pulse crops because of inadequate irrigation facilities.

The present study regression parameter for estimating of cultivated bt cotton crop area, production and productivity in Odisha and India. Results show a notable rise in cotton area, production, and productivity after the adoption of bt cotton in Odisha and in India and for its highest adjusted R^2 on increasing future projection trends with respect to area, production and productivity of cotton in India. The outcome also showed that the productivity Instability is high in India. In terms of production and area, Odisha is more volatile than the India during the study period. Despite these gains, farmers continue to face challenges such as poor seed quality, pest infestations, and limited awareness of modern technologies. The study emphasizes the need to strengthen agricultural extension services to address these constraints and enhance the benefits of bt cotton adoption.

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