



Impacts of *Bt* cotton adoption on agricultural land use dynamics of Nagpur district of Maharashtra

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ABSTRACT : Sustainable land management is now recognised as a major policy instrument due to severe land degradation problem in India. Understanding the temporal dynamics and trends of agricultural land use will help in planning suitable efforts to materialise the long term sustainable land management goals and improvement in life quality standards of the farmers of the region. In this perspective we analyse the temporal dynamics of agricultural land use change in Nagpur district of Maharashtra in the perspective of *Bt* cotton adoption since 2002. An extensive body of literature on economic impacts due to *Bt* cotton adoption has examined and review this literature for future research directions. This study found that a 3.84 per cent growth in area under cotton in Nagpur district for the period 1998-1999 to 2017-2018 and a 9.27 per cent growth in production for the period studied. Cotton area, production and its yield has shown a significant improvement in the state over the period of time since 2000 -2001. The study finds negative growth in area and production in case of then major crops of the district *viz.*, black gram, soyabean, green gram and sorghum. The increase in the area of cotton finds to be at the cost of other competing crops like millets and other pulses, given inelastic supply nature of land.

Key words: *Bt* cotton, CAGR analysis ; simple growth model, temporal land use change

Major cotton producing countries in the world are India, China and United States. Cotton is considered as an important cash crop in India and is cultivated under varied soils, climate and with different agricultural practices *viz.*, irrigated and rainfed system of cultivation. In India all the four types of cotton are grown commercially and during year 2000, *Gossypium hirsutum* represented 69 per cent of the total cotton in India followed by *G. arboreum* (17 %), *G. herbaceum* (11 %) and *G. barbadense* (3%). Srinivasa Rao, Ch *et al.*, 2015 reported that 65 per cent of cotton in India is being grown in rainfed conditions. After the introduction of *Bt* hybrids for commercial cultivation in India during 2002-2003, the composition of cultivation of species among farmers has got changed significantly. Consequently, more than 95 per cent of cotton grown in India is under *hirsutum* species group leaving only less than 5 per cent under *arboreum* & *herbaceum* species and negligible area under *barbadense* group (Anonymous, 2017).

There has been increase in area, production and productivity with respect to cotton cultivation in India over the past decades. International cotton advisory committee's (ICAC) data showed that on an average, cotton is planted in an area of 329.49 lakh hectares where India is contributing around 33.23 per cent in total area of the world. In India, cotton is the second largest *kharif* crop after rice, contributing 6 -7 per cent of the net sown area. India ranked first in cotton production during 2015-2016 and had occupied first position in the world cotton production since then. Cotton advisory board of India's (CAB) provisional data for the year 2018-2019 showed that cotton is produced in an area of 12.24 million hectares with a production of 613.7 million tonnes and productivity of 501 kg/ha (CAB-Press release, 2019).

Significance of cotton crop in Nagpur district of Maharashtra : During 2018-2019, Maharashtra ranked first in cotton area with

41.19 lakh hectares, which is of 33.66 per cent of area under cotton in India with a production of 81 lakh bales and productivity of 334 kg/ha (CAB - Press release, 2019). Most of the cotton grown in Maharashtra is rainfed *Bt* cotton. Nagpur district of Maharashtra, which is located in the Vidarbha region of the state, has a significant place with respect to cotton cultivation. Since year 2000, cotton had gained importance as in 1998-1999 the cotton production in Nagpur district was only 56500 hectares and in 2017-2018 the area reported under cotton was increased to 0.145 million hectares. Cotton production was increased from 11883 tonnes (during year 1998-1999) to 59092 tonnes (during year 2017-2018). Data of average cotton yield/ha of Nagpur district showed that during year 1998-1999 it was reported at 0.21/ha and it was increased to 0.41/ha in year 2017-2018.

Huge number of literature is available on *Bt* cotton impacts; while most of the studies show positive economic benefits to the farmers, along with some studies which questions the outcomes of *Bt* cotton impacts. Most of the previous studies analysed the economic impacts of *Bt* cotton adoption in different parts of India neglecting the land use impacts due to *Bt* cotton adoption. In this view, this research aims at analysing agricultural land use change due to *Bt* cotton adoption in Nagpur district of Maharashtra. In the above perspective, this paper analyse the historical change in agricultural land use and study the growth rate of area, production and yield to understand the impacts of *Bt* cotton on agricultural land use change in Nagpur district.

MATERIALS AND METHODS

Descriptive statistics of the secondary data were analyzed for mean, standard deviation and coefficient of variation *etc.* Temporal dynamics of land use change in Nagpur district for two periods (period 1 from 1998-1999 to 2005-

2006 and period 2 from 2009-2010 to 2016-2017) were studied and compared.

This study analysed trend in area, production, productivity of cotton and other major crops grown in Nagpur district for the historical period between 1998-1999 to 2017-2018 using secondary data which were collected from various sources *viz*, website of Directorate of Economics and Statistics, Ministry of Agriculture and Farmers Welfare, published reports of government departments, reports of taluk agricultural offices in Nagpur district etc.

To study the trend in area, production and productivity of cotton in Nagpur over period from 2000-2001 to 2017-2018 both simple and compound growth rates were estimated using simple growth model and least square growth model for computing the compound growth rate respectively.

Simple growth model : This is simple one period growth rate, where simple method of using two periods Y_t and Y_{t-1} are used. The following formula is applied to find the growth.

$$g_{t-1} = \left\{ \frac{Y_t - Y_{t-1}}{Y_{t-1}} \right\} \times 100;$$

where g_{t-1} is percentage growth or relative change in variable Y from period $t-1$ to t

Compound annual growth rate : The compound annual growth rate (CAGR) was calculated by fitting exponential function of the form mentioned below for cotton area, yield and production values for the period 2000-2001 to 2017-2018.

The below mentioned exponential functional form was used to represent the time series growth in cotton area, yield and production. It is estimated by fitting a log-linear transformed model of the below functional form, which was further estimated using Ordinary Least Square regression method.

$$Y_t = Y_0(1+g)^t U_t \dots \dots \dots (1)$$

Where,

Y_t = Value of area, production or yield of cotton for the year 't'

t = Time variable (1,2,...,n) for each period/year

Y_0 = Constant term

g = Compound growth rate.

Taking Natural logarithm of the equation it can be rearrange as follows

$$\ln Y_t = \ln Y_0 + t \ln(1 + g) \dots \dots \dots (2)$$

now

$$\alpha = \ln Y_0; \beta = \ln(1 + g)$$

then

$$\ln Y_t = \alpha + \beta t \dots \dots \dots (3)$$

adding disturbance term to the equation (3) we get

$$\ln Y_t = \alpha + \beta t + u_t \dots \dots \dots (4)$$

This model is linear regression model which is linear in parameters α and β .

We can compute the average annual compound growth rate using the following formula which use estimate of parameter β which is obtained from fitting an OLS regression to the values).

The compound growth rate in percentage (CGR) = $[\text{antilog}(\beta) - 1] \times 100 \dots \dots (5)$.

RESULTS AND DISCUSSION

Since 2002, there is a growing trend in mass adoption of *Bt* cotton among farmers in Nagpur district of Maharashtra. In this perspective, present study analysed how historical changes such as *Bt* technology introduction in agriculture alters the crop choices among the farmers which also impacting on agricultural land use pattern over time. From perusal of Table 1 it is known that the share of cotton area of both the net cropped area and gross cropped area doubled within eight years from it's initial share during 2009 -2010.

Compound growth rates for area, production and productivity for the period of eighteen years starting from 2000-2001 to 2017-2018 were worked out for Nagpur district, Maharashtra and India.

Compound annual growth rates of area, production and productivity of cotton in Nagpur

Table 1: Status of cotton cultivation in Nagpur district of Maharashtra from 2009-2010 to 2016-2017

Year	Cotton area (ha)	Per cent share in net cropped area	Per cent share in gross cropped area
2009-2010	63600	11.58	9.83
2010-2011	80800	14.71	12.35
2011-2012	102100	18.59	15.93
2012-2013	89400	16.26	13.94
2013-2014	92400	16.76	14.27
2014-2015	111300	20.15	17.15
2015-2016	126400	22.85	19.45
2016-2017	136500	24.37	20.72

From Fig. 1 it is evident for the period between 2013-2014 to 2017-2018, Nagpur district showed higher cotton yield as compared to the state average yield obtained for these years. During year 2013-2014, the average cotton yield realised was 341 kg/ha in Nagpur as state average yield was only 277 kg/ha. During 2017-2018 the average cotton yield of Nagpur district was 407 kg/ha as compared to state average yield of 345 kg/ha which is low.

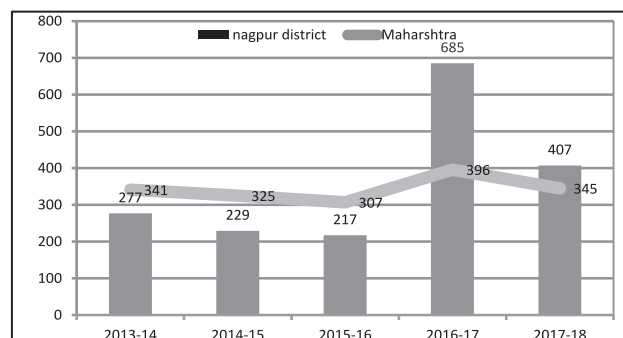


Fig. 1. Comparison cotton yield(kg/ha) of Nagpur district and Maharashtra from 2013-2014 to 2017-2018

District of Maharashtra are presented in Table 2. It shows that the average cotton area for the study period from 2000-2001 to 2017-2018 is 84498.4 hectares. Results obtained from analysis of relative change showed that 113.65 per cent increase in the area cultivated under cotton from the year 2000-2001, which implies a significant conversion of available cultivable area into cotton cultivation during the study period. Similarly the average production of cotton over the period was 24229.25 tonnes with an average productivity of 0.2 t/ha. Simple growth analysis results showed that the production showed a 347.49 per cent, growth over the studied period but the growth trend in productivity was 104.83 per cent. Similarly, the CAGR of cotton area, production and yield showed 3.84, 9.27 and 3.56 per cent, respectively. The estimated growth equation for cotton area using semi log function was $\log Y = 10.95 + 0.039 t$ with R^2 value of 54 per cent. CAGR of 3.84 per cent in cotton area indicates a significant increase in the area at the rate of 3.84 per cent/annum.

Table 3 shows the simple and compound annual growth rates of area, production and yield of cotton in Maharashtra state. Results revealed that the average cotton area, production and

yield for the study period from 2000-2001 to 2017-2018 is 35 lakh hectares, 9.75 lakh tonnes and 0.27 t/ha, respectively. The CAGR for cotton area, production and yield showed 2.11, 8.25 and 6.01 per cent growth, respectively in Maharashtra.

Perusal of Table 4 showed 101.2 lakh hectares of cotton area with production of 39.43 lakh tonnes with average yield of 0.37 tonnes /ha in India during 2000-01 to 2017-18. Increment in cotton area, production and yield obtained were 34.3, 186.13 and 112.83 per cent, respectively. The CAGR results showed that area, production and yield of cotton showed 2.45, 7.96 and 5.35 per cent growth, respectively during this period.

Perusal of Table 5 showed the results of growth analysis for the periods *viz.*, 2000-2001 to 2008-2009, 2009-2010 to 2017-2018 and 2000-2001 to 2017-2018. CAGR of - 4.54 per cent was obtained for area for first period *i.e.* 2000-2001 to 2008-2009. Similarly, results showed a CAGR value of 1.98 per cent in the case of cotton production and for yield CAGR was 6.85 per cent. First period results of cotton land use in Nagpur showed a negative trend in area under cotton and

Table 2: Compound annual growth rates of area, production and yield of cotton in Nagpur district of Maharashtra from 2000-2001 to 2017-2018

Description	Mean	CV (%)	Relative Change (%)	Compound Growth Rate (%)
Area(ha)	84498.4	32.05	113.65	3.84**(54.04)
Production (t)	24229.25	80.58	347.49	9.27**(63.45)
Yield(t/ha)	0.27	43.02	104.83	3.56*(38.79)

Note: Figures in parentheses show R^2 (%) values.

** t-ratio is significant at 1% level of significance. * t-ratio is significant at 5% level of significance.

Table 3: Compound annual growth rates of area, production and yield of cotton in Maharashtra from 2000-2001 to 2017-2018

Description	Mean	CV (%)	Compound Growth Rate (%)
Area('000ha)	3502	15.77	2.11***(67.93)
Production (000t)	974.82	40.98	8.25***(83.53)
Yield(t/ha)	0.270	32.36	6.01***(71.02)

Note: Figures in parentheses show R^2 (%) values.

** t-ratio is significant at 1% level of significance. * t-ratio is significant at 5% level of significance and NS is Non significant t ratio

Table 4: Compound annual growth rates of area, production and yield of cotton in India from 2000-2001 to 2017-2018

Description	Mean	CV (%)	Relative Change (%)	Compound Growth Rate (%)
Area (000, ha)	10122.4	16.43	34.3	2.45***(72.3)
Production (000, t)	3943.51	42.88	186.13	7.96***(82.8)
Yield(t/ha)	0.3752	31.16	112.83	5.35***(72)

Note: Figures in parentheses show R^2 (%) values.

** t-ratio is significant at 1% level of significance. * t-ratio is significant at 5% level of significance and NS is Non significant t ratio

Table 5 : Compound annual growth rates of area, production and yield of cotton in Nagpur district for periods 2000-2001 to 2008-2009 , 2009-2010 to 2017-2018 and 2000-2001 to 2017-2018

Period	CAGR of area (%)	CAGR of production (%)	CAGR of yield (%)
2000-2001 to 2008-2009	-4.54*(53)	1.98(6)NS	6.85*(62)
2009-2010 to 2017-2018	9.64**(89.5)	18.07**(68)	7.4 NS(30)
2000-2001 to 2017-2018	3.84**(54.04)	9.27**(63.45)	3.56*(38.79)

Note: Figures in parentheses show R^2 (%) values.

** t-ratio is significant at 1% level of significance. * t-ratio is significant at 5% level of significance and NS is Non significant t ratio

later in the second period *viz.*, 2009-2010 to 2017-2018 the growth with which cotton area increased was 9.64 per cent with a total growth rate of 3.84 per cent for the total period, *viz.*, 2000-2001 to 2017-2018. Similarly, second period showed a production and yield growth rates of 18 and 7.4 per cent, respectively as compared to their lower growth rate values during the first period.

It is apparent from Fig. 2 that cotton production in Nagpur district was increased constantly in spite of few years showed decreased production compared to that of previous year; for example for years 2000-2001, 2008-2009 and 2017-2018 for which cotton production was reduced compared to previous year's production. 2016-2017 was the year which realised a significant increase in cotton production *i.e.* 93534 tonnes and it reduced to 59092 tonnes in year 2017-2018. Area under cotton cultivation also showed a similar increasing and positive trend which is evident from Fig. 2. During 1998-99 the cotton area reported in Nagpur district was 56500 ha and it was increased to 145168 hectares during 2017-2018. During 2008-2009 and 2012-2013 in which area under cotton

showed decreasing trend from its previous year. Productivity increased from 210.3 kg/ha in 1998-2000 to 407 kg/ha in 2017-2018. Year 2016-2017 was a year recorded with bumper cotton yield of 685.2 kg/ha and it was the highest recorded yield of the district over the study period.

From Table 6 it is evident that CAGR of cultivated area of crops *viz.* cotton (3.84 %), rice (5.95 %), wheat (5.7 %), gram (4.78 %) and red gram (1.55 %) showed positive trend during the study period compared to crops such as

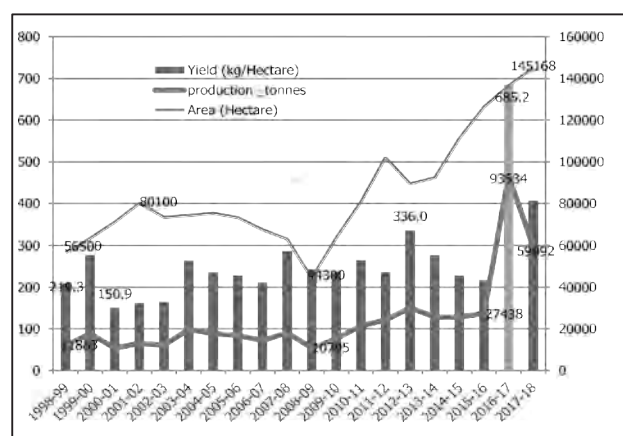
**Fig. 2.** Trend in Cotton Area, Production And Yield(Kg/Ha) of Nagpur District of Maharashtra from 1998-99 To 2017-18

Table 6: CAGR of area, production and yield of major crops in Nagpur district of Maharashtra from 2000-2001 to 2017-2018 (%)

Period	CAGR of Area (%)	CAGR of production (%)	CAGR of yield (%)
Cotton	3.84	9.27	3.56
Rice	5.95	8.1	2
Wheat	5.7	9.1	3.2
Gram	4.78	8.59	3.63
Red gram	1.55	2.26	0.7
Soybean	-0.96	-3.21	-2.21
Black gram	-5.3	-9.99	-4.32
Green gram	-5.85	-5.72	0.14
Sorghum	-16.94	-18.23	-1.55
Other kharif pulses	-10.3	-1.31	-1.11

soyabean (-0.96 %), black gram (-5.3 %), green gram (-5.85 %), sorghum (-16.94 %) and other *kharif* pulses (-10.3 %) as they showed a negative trend in their area under cultivation. From results it is apparent that sorghum area has been reduced significantly during the study period as crops such as cotton and red gram were being cultivated more in the marginal lands of Nagpur. This might be due to their better market scenario existed then for cotton due to strong price support in the form of minimum support price, expansion of existing demand for processing mills and obviously due to perceptible economic impact from *Bt* technology as less spending on pesticides along with reasonable yield outcome helped the farmers to confidently adopt more areas under cotton during the study period.

Approximately 65 per cent of India's cotton is produced on dry land and 35 per cent on irrigated land (Pan, *et al.*, 2006). Cotton is optimally and efficiently grown in areas of deep soils but in the case of Nagpur rainfed cotton is grown in soils of shallow nature (less than 40 cm in depth) which is not conducive for high yield (Venugopalan, 2017). It is reported that regardless of increased land use under cotton in Nagpur district of Maharashtra, more than 50 per cent of cotton cultivation showed very low productivity of less than 2 bales/ha as against the national yield average of more than 3 bales/ha (Basu, 2017). Our

study found that 3.56 per cent growth in productivity of cotton in Nagpur even though it is lesser as compared to that of national yield trend in cotton which is found to be 5.35 per cent from the analysis. The traditional crops of Nagpur were sorghum, pearl millet and rice which has been replaced significantly by cash crops such as cotton, soyabean and oranges. Some of the past study results reported negative compound growth rates of cotton for Nagpur in area, production and productivity during the period 1999-2000 to 2008-2009 (Badole and Patil, 2013). Meanwhile, Kulkarni *et al.*, 2017 found positive compound annual growth rates in cotton area, production and yield in Maharashtra for the period 1998-2009 to 2013-2014 *i.e.* 1.92, 10.23 and 8.16 per cent, respectively. Present study revealed that negative CAGR of area under cotton for the period 2000-2001 to 2008-2009 *i.e.* -4.54 per cent and positive CAGR for the period 2009-2010 to 2017-2018 *i.e.* 9.64 per cent.

In Vidarbha region of Maharashtra, due to unprecedented crop loss in drought years along with severe pest infestation which in turn created a source of debt and economic stress, which is often quoted cause of distress among farmers and farmer suicides were reported among the cotton farmers. In recent years it also reported the use of illegal herbicide-tolerant cotton reported in Vidarbha region

(<https://www.economictimes.indiatimes.com>, 2018). This area also witnessed the extinction of many traditional cultivars and landraces of cotton which are short duration in nature and less input intensive and hardy due to the introduction of *Bt* cotton and hybrids. After the *Bt* cotton hybrids introduction and reduction in area under crops such as sorghum and millets in this shallow soils ended up in degradation of soil conditions due to input intensive agriculture (soil erosion, soil nutrient loss and salinity). Moreover, in India, there is no prescribed rules to ensure coexistence of non GM and GM crops (Suman Sahai, 2004) which also creates difficulties in growing non *Bt* cotton varieties and marketing them separately. Farmer in Nagpur face cotton crop's riskiness due to the *Bt* technology's uncertainty to protect from pests and its low profitability in drought years as severe bollworm infestation and drought in recent years affected its profitability significantly (<https://www.hindustantimes.com>, 2018).

Above discussed issues show that we need studies for measuring the implications of crop choices among farmers to ensure long term sustainability and farmer profitability in the study area. Present study tried to understand the temporal agricultural land use changes with respect to crop selection among the farmers of Nagpur and we need further studies towards agricultural land use change in Nagpur district of Maharashtra and determinants of farmers' decisions on crop choices. Likewise, we lack documented information on underlying processes which impacts land use change among farmers which should get addressed through future research endeavours.

CONCLUSION

Cotton got an utmost importance in Nagpur district over the study period as revealed by the compound growth rate (CAGR) analysis *i.e.* 3.84 per cent, 9.27 per cent and 3.56 per cent growth in area,

production and yield, respectively. Analysis showed that the share of pulse crops like black gram, soyabean, green gram, other *kharif* pulses and millets like jowar were reduced significantly due to shift of cultivable area to cotton. The results showed that major crops of Nagpur district during the study period were rice, cotton and soyabean in *kharif* season and wheat and gram during *rabi* season. Competing crops for current land use of Nagpur district are cotton, soybean and red gram based on climatic and market situations. The growth rate of area, production and productivity of most of the important pulse and oilseed crops of Nagpur district declined during the study period except gram and red gram. Among cereals, rice and wheat showed positive growth rate and sorghum growth rate in area, production and productivity showed decreasing trend.

It is evident from the results that the increase in the area of cotton was at the cost of other competing crops like millets and other pulses as crops like sorghum, black gram, green gram, soyabean and other *kharif* pulses reduced significantly. Rice, wheat, red gram and gram area in the district showed positive growth show that shifting from diversified cultivation to intensive monoculture due to land use transitions in agriculture in Nagpur district.

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