

International Journal of Statistics and Applied Mathematics

ISSN: 2456-1452
Maths 2023; 8(6): 183-186
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<https://www.mathsjournal.com>
Received: 19-10-2023
Accepted: 24-11-2023

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Spatio-temporal dynamics in cotton area, production and productivity: A worldwide scenario

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DOI: <https://doi.org/10.22271/math.2023.v8.i6b.1540>

Abstract

Cotton is one of the most important fiber crops playing essential role in the history of mankind and civilization. It is called as 'White gold', due to its agricultural and industrial economic importance. Cotton is mainly grown for its fibers, which are used in textile industry. Exponential growth function was employed to estimate growth rates during the period from 2001-02 to 2020-21 in the major cotton-producing countries worldwide, namely India, USA, Egypt, and China. The results found that, during last two decades, only India has achieved positively higher growth rate in cotton area, production and productivity, but USA, China and Egypt shown declining trend, and at world level, it remained almost stagnant, with lower growth in production and yield. Worldwide growth dynamics helps in better understanding of global trade and also helps in worldwide policy making.

Keywords: Cotton, growth, worldwide, exponential function

Introduction

Cotton has been used as a fabric since time immemorial. It has been cultivated in the Indus valley more than 5000 years. It provides the basic raw material (cotton fiber) to cotton textile industry. India had the monopoly in manufacturing cotton textiles since 1500 BC. Then the cultivation of cotton spread from India to Egypt and to Spain and Italy. Cotton is grown in about 75 countries across the world, out of which, India, United States and China contribute nearly 60 percent of the total world production (ICAC, 2022) ^[4].

Cotton is one of the most traded commodities globally. Countries with significant cotton production contribute to international trade, and exports of cotton and cotton-based products form a substantial portion of their economy. United States is largest exporter of cotton followed by Brazil. Whereas, Egyptian cotton being by far the best cotton in the world, because fabrics made of Egyptian cotton are softer, finer and last longer than any other cotton. So, Egyptian cotton have greater impression on world textile markets. Over the last decade, textiles utilisation has risen steadily mainly driven by population and income growth mostly in developing countries, particularly in Asia. Moreover, demand for natural fibres has expanded quite markedly in recent years, sustained by a growing trend for sustainability. (FAO, 2023).

Methodology and Data collection

The data on cotton area, production and productivity of major cotton producers worldwide (India, USA, China and Egypt) were collected for period from 2001-02 to 2020-21 from the various public sources; ICAC and USDA.

Growth rate analysis

Growth rate can be defined as the rate of change per unit time. It is used to measure the past performance of the economic variables in question and describe the trends in those variables over time. The normal statistical procedure to obtain a measure of growth dynamics of crops over a period is to postulate a hypothetical function which would adequately describe the series of economic variables over time and estimate their parameters. Growth rate is generally expressed in two forms, viz., linear and compound. The linear form is obtained by fitting a straight line to the yearly data and estimating the parameters. The compound growth rate is obtained by fitting a straight line to the logarithms of the data and estimating the slope of the

line (Acharya *et al.*, 2012) ^[1]. In the present study, the compound growth rate was calculated using the following formula.

Compound growth rate

The compound growth rates (CGRs) of cotton was calculated by using the exponential function of the following specification:

$$Y_t = ab^t u_t \quad (1)$$

Where,

Y_t = Dependent variable (Area, Production and productivity of cotton crop in the year 't').

t = Time variable in years taking the value of 1, 2, 3, .., n

a = Intercept;

b = Regression coefficient (1+r)

r = Compound growth rate

u_t = Error term

For the purpose of estimation, the equation was expressed in logarithmic form.

$$\text{Log } Y_t = \text{Log } a + t \text{ log } b + \text{log } e \quad (2)$$

The value of log b in equation (2) was computed using the formula,

$$\text{Log } b = \frac{(\sum t \text{ Log } Y - (\sum t)(\sum \text{Log } Y / N))}{\sum t^2 - (\frac{\sum t^2}{N})} \quad (3)$$

Where,

N = Number of years.

Subsequently, the compound growth rate (%) was computed using the formulation,

$$\text{Compound growth rate (r)} = [(\text{Antilog of log } b) - 1] * 100 \quad (4)$$

Student 't' test was used to determine the significance of the growth rates obtained for which the following formulation was employed,

$$t = \text{Log } b / \text{SE} (\text{Log } b) \quad (5)$$

$$\text{SE} = \sqrt{\frac{\sum(Y - \bar{Y})^2 - \text{Log } b * (\sum(Y * t) - \sum(Y) * \bar{t})}{(N-2) \sum(t - \bar{t})^2}} \quad (6)$$

The calculated 't' values, from equation (6), was compared with the table 't' values and the significance was tested at 1, 5 and 10 percent levels.

Results and Discussion

Temporal changes in cotton area, production and productivity in major countries of world

To comprehend the trends in area, production and productivity of cotton, country wise growth rates were computed for the three periods: Period - I (2001-02 to 2010-11) Period-II (2011-12 to 2020-21) and Overall Period (2001-02 to 2020-21). Exponential growth functions were employed to estimate growth rates during three distinct periods in the major cotton-producing countries worldwide, namely India, USA, Egypt, and China. The ranges of growth rates given by Das *et al.* (2016) ^[2] are as follows.

Low growth rate = between 0 to 5

Medium growth rate = greater than 5 and up to 10

High growth rate = greater than 10

The ensuing discussion on growth rates is presented on a country-by-country basis for each period. Additionally, a comprehensive analysis of global cotton statistics, encompassing area, production, and productivity, has been conducted. The detailed findings are systematically presented in Table 1 and graphically depicted in Figure 1.

Table 1 reveals noteworthy trends in cotton cultivation across major producing countries during Period-I. India experienced the most substantial increase in cotton cultivation area, recording a growth rate of 3.16 percent, followed closely by China with a growth rate of 1.61 percent. Conversely, Egypt and the USA reported significantly negative growth rates in cotton cultivation area during this period, declining at rates of -9.07 percent and -5.23 percent per annum, respectively. At the global level, the area under cotton cultivation exhibited a non-significant negative growth rate during Period-I.

Turning to cotton production in the same period, India demonstrated the highest growth rate at 14.20 percent per annum, followed by China at 3.92 percent. In contrast, Egypt and the USA reported significantly negative growth rates of -11.16 percent and -3.51 percent per annum, respectively. Globally, cotton production exhibited a significant annual increase of 1.84% during Period-I. These findings align with those observed by Pangayar *et al.* (2015) ^[6] in the context of maize area, production, and productivity in India during the period from 1970-71 to 2013-14.

During Period-I, India exhibited the highest annual growth rate in cotton yield at 10.69 percent, followed by China at 2.28 percent. The USA observed a lower but significant growth rate in cotton productivity, increasing by 1.81 percent per annum. However, Egypt experienced an annual decrease in cotton yield at a rate of -2.30 percent. Globally, cotton productivity significantly increased at 2.27 percent per annum during Period-I.

In Period-II, the USA recorded the highest positive growth rate in cotton cultivation area at 1.48 percent per annum. India also demonstrated a positive but non-significant growth rate of 1.03 percent per annum in cotton area. Conversely, Egypt and China witnessed significant decreases in cotton area, declining at rates of -7.96 percent and -5.92 percent per annum, respectively. For cotton production in Period-II, only the USA showed a significant positive growth rate of 1.96 percent per annum, while Egypt and China reported significant negative growth rates of -8.01 percent and -3.02 percent per annum, respectively. India recorded a non-significant and negative growth rate (-0.57%) in cotton production during this period. Regarding cotton productivity in Period-II, China exhibited the highest growth rate at 3.09 percent per annum, while the USA had a positive but non-significant growth rate of 0.47 percent. Egypt experienced a decrease in cotton productivity at a rate of -0.05 percent per annum, and India also showed a non-significant negative growth rate. At the global level in Period-II, cotton area, production, and productivity all decreased at rates of -0.53, -0.83, and -0.31 percent per annum, respectively, with non-significant negative growth rates observed.

Over the overall period from 2001-02 to 2020-21, India was the only country to record a positive and significant growth rate in cotton cultivation area, at 2.90 percent per annum. Egypt, China, and the USA, on the other hand, reported significantly negative growth rates of -6.88, -3.31, and -1.81 percent per annum, respectively. At the global level, cotton cultivation area decreased at a rate of -0.05 percent per annum over the overall period.

Table 1: Period wise growth rates of cotton area, production and productivity of major countries in world

Periods	State/ Items	India			USA		
		A	P	Y	A	P	Y
Period-I (2001-02 to 2010-11)	Mean	9119	19509	356	4619	23925	883
	CGR%	3.16***	14.20***	10.69***	-5.23***	-3.51***	1.81*
	SE	0.070	0.167	0.172	0.153	0.215	0.077
Period-II (2011-12 to 2020-21)	Mean	12402	33487	460	3814	21259	945
	CGR%	1.03	-0.57	-1.59*	1.48*	1.96**	0.47
	SE	0.060	0.084	0.088	0.115	0.148	0.058
Overall Period (2001-02 to 2020-21)	Mean	10760	26498	408	4216	22592	914
	CGR%	2.90***	6.38***	3.39***	-1.81**	-1.01	0.81
	SE	0.076	0.241	0.220	0.182	0.202	0.067

Periods	State/ Items	China			Egypt		
		A	P	Y	A	P	Y
Period-I (2001-02 to 2010-11)	Mean	5587	39561	1200	229	1214	884
	CGR%	1.61*	3.92**	2.28**	-9.07***	-11.16***	-2.30**
	SE	0.107	0.115	0.071	0.217	0.245	0.086
Period-II (2011-12 to 2020-21)	Mean	3902	36671	1622	121	540	741
	CGR%	-5.92***	-3.02***	3.09***	-7.96***	-8.01***	-0.05
	SE	0.098	0.118	0.041	0.346	0.455	0.162
Overall Period (2001-02 to 2020-21)	Mean	4744	38116	1411	175	877	812
	CGR%	-3.31***	-0.45	2.96***	-6.88***	-8.40***	-1.64*
	SE	0.163	0.165	0.057	0.272	0.343	0.123

Periods	Items	World		
		A	P	Y
Period-I (2001-02 to 2010-11)	Mean	327	1411	734
	CGR%	-0.42	1.84**	2.27**
	SE	0.068	0.113	0.052
Period-II (2011-12 to 2020-21)	Mean	330	1506	776
	CGR%	-0.53	-0.83	-0.31
	SE	0.057	0.083	0.045
Overall Period (2001-02 to 2020-21)	Mean	328	1458	755
	CGR%	-0.05	0.64	0.68
	SE	0.061	0.097	0.060

Note: 1. *, ** and *** indicate significance at 10%, 5% and 1% levels, respectively.

2. CGR – Compound Growth Rate and SE – Standard Error

3. A = Area (000’ ha), P = Production (000’ bales) and Y = Yield (Kg/ha)

Over the overall period, India achieved the highest and significant growth rate in cotton production at 6.38 percent per annum, making a substantial contribution to global cotton production and supporting the growth of the textile industry. Egypt, however, experienced a significant negative growth rate of -8.40 percent per annum in cotton production. The USA and China exhibited negative but non-significant growth rates in cotton production during the overall period. At the global level, cotton production increased at a lower rate of 0.64 percent per annum. Cotton productivity growth rates were found to be the highest in India at 3.39 percent, followed by China at 2.96 percent. Despite the higher growth rate in cotton yield, India still lagged behind in cotton productivity compared to other countries, indicating the need for new research methodologies to enhance cotton yield. In Egypt, cotton productivity significantly decreased at a rate of -1.64 percent per annum over the last two decades, possibly due to technological deterioration and a lack of new developments to meet the demands of the textile industry. The USA registered a positive but non-significant growth rate in cotton yield, while at the global level, cotton yield increased at a lower rate of 0.68 percent per annum

During the period from 2001-02 to 2010-11, India achieved the highest growth rates in cotton area, production, and productivity, followed by China, primarily due to the introduction of Bt. Cotton cultivation in India from 2003-04 onwards. In the USA, although cotton area and production

declined in the first decade of the 2000s, productivity remained positive. At the global level, despite a marginal decline in cotton area, production and productivity increased. In the 2010s, India showed positive growth in cotton area but experienced a decline in production and yield, particularly since 2017-18 when Bt. Cotton yield started decreasing. This suggests that Bt. Cotton technology may have lost its viability, highlighting the need to develop new high-yielding varieties. Jadhav *et al.* (2020) [5] noted similar results and concluded that The area expansion during the study period was mainly due to introduction of Bt cotton and implementation of crop development programs, supply of large scale Bt cotton varieties to the farmers. Shaikh and Joshi (2013) [7] also noted similar results in this line and mentioned that there is significantly increased in cotton growing area but less yield appear to other state districts. Only the USA exhibited a positive trend in area and production in the 2010s, while its productivity remained positive but stagnant. At the global level, cotton area, production, and productivity declined in the 2010s.

In the overall period of the last two decades, only India achieved a positively higher growth rate in cotton area, production, and productivity. In contrast, the USA, China, and Egypt exhibited declining trends in cotton area, production, and productivity, and at the global level, growth remained almost stagnant, with lower growth rates in production and yield.

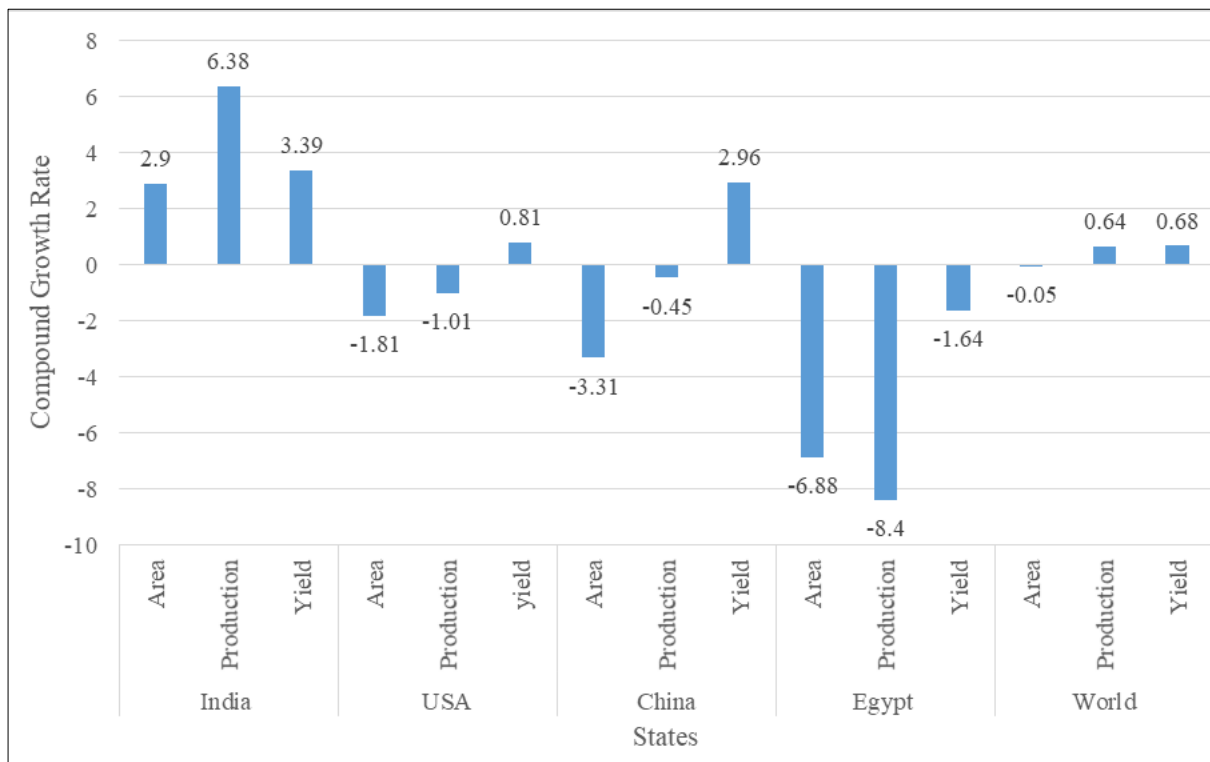


Fig 1: Overall period growth rate of cotton area, production and yield in major countries of world during 2001-02 to 2020-21

Conclusion

Over the last two decades, India significantly contributed to global cotton production, demonstrating substantial growth in cultivation area, production, and productivity. At world level, cotton production increased at the lower rate of 0.64 percent per annum in overall period. In the same period, China and the USA reported negative but non-significant growth rates in cotton production, while the global increase remained modest. In 2010s, though area under cotton in India shown positive growth, but production and yield were decreased. From the year 2017-18 onwards, Bt. cotton yield started declining. This indicates that the Bt. cotton technology has lost its viability. Notably, India stands out as the only country with a positive and significant growth rate in cotton metrics. Conversely, China, the USA, and Egypt experienced declining trends in cotton metrics, contributing to the overall stagnation in global growth.

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