

International Journal of Statistics and Applied Mathematics

ISSN: 2456-1452
 Maths 2024; SP-9(5): 12-14
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www.mathsjournal.com
 Received: 08-06-2024
 Accepted: 12-07-2024

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A worldwide growth dynamics in area, production and productivity of maize

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Abstract

The growth dynamics of area, production, and productivity of maize from 2001-02 to 2021-22 were analysed to have better insights in strategic decisions of international trade using exponential growth functions across major maize-producing countries worldwide. These dynamics have shown significant variation among key producers in which India and Brazil demonstrated positive growth the USA and China experienced fluctuations or modest declines in growth rates of maize production. These trends reflect shifts in agricultural practices, climate impacts and economic influences.

Keywords: Maize, growth, worldwide, exponential function

Introduction

Maize known as the 'Queen of Cereals,' is a versatile grain renowned for its multiple uses and high genetic yield potential. Globally, it holds immense agricultural and economic importance serving as a staple food crop and playing a crucial role in various industrial applications such as livestock feed and ethanol production. Globally, maize production is massive, with over 1482.99 million metric tons across 167 countries. Most of this maize is used for animal feed, making it vital for agriculture worldwide. The top producers are the USA, China, Brazil, and India, with the USA leading production (FAOSTAT, 2024) [2].

Methodology and Data collection

The data on maize area, production and productivity of worldwide major maize producers of India, USA, China, Brazil and Argentina were collected for period the from 2001-02 to 2021-22 from the various public sources; ICAC and USDA.

Growth rate analysis

The growth rate is the rate of change of economic variables over time reflecting their past performance and trends. The growth dynamics was analyzed using a common statistical approach of exponential function involves fitting a straight line to the logarithms of the data and determining the slope of that line (Acharya *et al.*, 2012) [1].

The compound growth rates (CGRs) were calculated by using the exponential function:

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

Where,

- Y_t = Dependent variable (Area, Production and productivity of maize 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

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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 (4) was computed using the formula,

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

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,

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

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

The calculated 't' values, from equation (7), was compared with the table 't' values and the significance was tested at 1, 5 and 10 per cent levels.

Results and Discussion

Changes in maize area, production

To comprehend the trends in area, production and productivity of maize, country wise growth rates were computed for the three periods: Period-I (2001-02 to 2010-11) Period-II (2011-12 to 2021-22) and Overall Period (2001-02 to 2021-22) for the USA, China, Brazil, Argentina, and India. Country-specific growth rates and discussions are presented for each period, alongside a comprehensive analysis of global maize area, production, and productivity in Table 1.

During the 2000s, the USA led with a mean maize cultivation area of 31,144 thousand hectares in Period-I, increasing to 33,760 thousand hectares in Period-II. The China followed with 28,574 thousand hectares in Period-I, expanding to 41,035 thousand hectares in Period-II. The area in Brazil grew from 12,906 to 16,785 thousand hectares, while in India it increased from 7,878 to 9,362 thousand hectares. The area in Argentina also saw growth from 2,757 to 6,265 thousand hectares over the same period. All five countries showed an increase in maize cultivation area over the last two decades.

In terms of mean production, the USA achieved the highest at 293,105 thousand tonnes in Period-I, rising to 355,883 thousand tonnes in Period-II, followed by China with 151,085 thousand tonnes in Period-I, increasing to 250,700 thousand tonnes in Period-II. The production Brazil grew from 47,662 to 87,617 thousand tonnes, while in Argentina's it grew from 18,299 to 44,343 thousand tonnes. Despite India having a smaller area than Argentina, its production increased significantly from 16,901 to 26,730 thousand tonnes in Periods I and II, respectively. The USA led in mean yield at 9,394 kg/ha in Period-I, followed by Argentina, China, Brazil, and India, all showing upward trends over the years. These findings align with those observed by Pangayar *et al.* (2015)

[4] in the context of maize area, production, and productivity in India during the period from 1970-71 to 2013-14.

At the global level in Period-I, maize cultivation covered 154,642 thousand hectares, yielding 758,461 thousand tonnes with an average productivity of 4,889 kg/ha. These figures increased steadily in Period-II. Significantly, China and Argentina reported the highest increases in maize area at 3.89% each in Period-I, followed by India (2.68%), USA (2.08%), and Brazil (1.30%). Globally, maize cultivation showed a positive growth rate of 2.30% in Period-I.

India recorded the highest annual growth rate in production at 6.60%, followed by China (5.55%), Brazil (4.72%), Argentina (4.44%), and USA (3.25%) in Period-I. Globally, maize production increased by 4.07% annually in Period-I.

During Period-I, India also led in annual yield growth at 3.82%, followed by Brazil (3.38%), China (1.60%), the USA (1.14%), and Argentina (0.54%). Globally, maize yield increased by 1.73% per annum in Period-I. In Period-II, Argentina led with an 8.5% annual growth rate in maize area, followed by Brazil (3.39%) and China (1.69%). India also showed growth at 0.85% per annum, while the USA saw a decrease of -0.61% annually. Globally, maize area increased by 1.10% per annum in Period-II.

Argentina had the highest production growth rate at 10.00% per annum in Period-II, followed by India (3.86%), Brazil (3.63%), China (2.66%), and the USA (1.30%). Globally, maize production increased by 2.38% annually in Period-II.

In overall 2001-02 to 2021-22, Argentina led in maize area growth at 7.56% per annum, followed by China (3.31%), Brazil (2.49%), India (1.67%), and USA (0.73%). Globally, maize area increased by 2.06% annually. Argentina also led in overall maize production growth at 8.31% per annum, followed by Brazil (5.52%), India (4.69%), China (4.73%), and USA (1.95%). Globally, maize production increased by 3.47% annually. Maize yield growth rates were highest in India (2.97%), Brazil (2.95%), China (1.38%), USA (1.21%) and Argentina (0.70%). Despite India's higher growth rate, it lags in maize productivity compared to other countries, indicating the need for enhanced yield through advanced research and crop improvement. Similar results were noted by Kolhe *et al.* (2022) [3] in case of maize area, production and yield in India during 1999 to 2019. They estimated that area, production and productivity observed the growth rate of 11.90 per cent, 4.93 per cent and 2.97 per cent at one per cent level of significance during overall period of study, respectively.

Conclusion

The growth dynamics of major countries have shown varying trajectories in maize cultivation area, production and productivity. The USA and China have maintained substantial production volumes although with fluctuations in growth rates, while Brazil and India have demonstrated consistent increases in both area and production. Despite having smaller initial areas, Argentina has shown remarkable growth rates particularly in production and yield. Globally, maize cultivation has expanded steadily, supported by positive growth rates in both area and production across the analyzed periods. These findings underscore the significance of maize as a pivotal crop in global agriculture, influencing food security, economic stability and industrial applications. The findings highlight the adaptation of agricultural practices to changing climates and economic conditions, reflecting the resilience and adaptability of maize farming globally. Understanding these dynamics is crucial for shaping sustainable agricultural policies, enhancing productivity, and ensuring food security in an evolving global landscape.

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

Periods	State/Items	USA			China		
		A	P	Y	A	P	Y
Period-I (2001-02 to 2010-11)	Mean	31144	293105	9394	28574	151085	5262
	CGR%	2.08***	3.25***	1.14***	3.89***	5.55***	1.60***
	SE	0.051	0.077	0.055	0.021	0.036	0.029
Period-II (2011-12 to 2020-22)	Mean	33760	355883	10555	41035	250700	6103
	CGR%	-0.61***	1.30***	1.92***	1.69***	2.66***	0.96***
	SE	0.030	0.096	0.097	0.070	0.062	0.015
Overall Period (2001-02 to 2020-22)	Mean	32514	325989	10002	35102	203265	5702
	CGR%	0.73***	1.95***	1.21***	3.31***	4.73***	1.38***
	SE	0.054	0.086	0.080	0.060	0.066	0.024

Periods	State/Items	Brazil			Argentina		
		A	P	Y	A	P	Y
Period-I (2001-02 to 2010-11)	Mean	12906	47662	3673	2757	18299	6606
	CGR%	1.30***	4.72***	3.38***	3.89***	4.44***	0.54***
	SE	0.064	0.134	0.087	0.120	0.211	0.123
Period-II (2011-12 to 2020-22)	Mean	16785	87617	5209	6265	44343	7016
	CGR%	3.39***	3.63***	0.23***	8.50***	10.00***	1.39***
	SE	0.041	0.126	0.100	0.075	0.108	0.088
Overall Period (2001-02 to 2020-22)	Mean	14938	68591	4478	4595	31941	6821
	CGR%	2.49***	5.52***	2.95***	7.56***	8.31***	0.70***
	SE	0.055	0.132	0.108	0.128	0.180	0.102

Periods	State/Items	India			World		
		A	P	Y	A	P	Y
Period-I (2001-02 to 2010-11)	Mean	7878	16901	2127	154642	758461	4889
	CGR%	2.68***	6.60***	3.82***	2.30***	4.07***	1.73***
	SE	0.025	0.102	0.088	0.021	0.040	0.027
Period-II (2011-12 to 2020-22)	Mean	9362	26730	2848	194139	1094435	5629
	CGR%	0.85***	3.86***	2.99***	1.10***	2.38***	1.26***
	SE	0.039	0.055	0.039	0.016	0.044	0.036
Overall Period (2001-02 to 2020-22)	Mean	8655	22049	2505	175331	934447	5277
	CGR%	1.67***	4.69***	2.97***	2.06***	3.47***	1.38***
	SE	0.042	0.087	0.064	0.028	0.044	0.031

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’ tonnes) and Y = Yield (Kg/ha)

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