Original Research Article

Effect of Climate, Growth and Decomposition Analysis of Maize in India

ABSTRACT

Maize is third most important cereal crop in India after rice and wheat. Maize can be grown under various agro-climatic zones.

Aims:

- To study the effect of temperature, rainfall and crop are on crop yield in maize in India.
- To study Compound Annual Growth Rate of area, production and productivity of maize in India.
- To study percentage contribution of area, yield and their interaction to maize production in India.

Study design: Only secondary data has been considered for the present study. Maize in India is considered for study purpose.

Data considered: All the data required for the study is obtained from Indiastat website. The impact of climatic variables on yield is studied by using data for a period of 28 year i.e., from 1992-93 to 2019-20. For calculating CAGR and for decomposition analysis data from 1950-51 to 2019-20 were considered.

Methodology: Ordinary Least Squares method, Compound Annual Growth Rate(CAGR) and decomposition analysis were tools employed for the study.

Results: For every 1^{0}c rise in temperature, the yield of maize decreased by 1.6 units. For every 1 mm increase in rainfall, the yield increased by 0.05 units and for every thousand hectares increase in temperature, the crop yield increased by nearly 1.37 units. Temperature, Rainfall, crop area and time explain 89 per cent of variation in maize yield. Highest and significant growth rate of 3.39 per cent per annum was observed in area during the period II i.e., from 1960-61 to 1969-70. Similarly, in the case of production and yield a highest and significant growth rate of 7.32 and 4.03 per cent respectively were observed during the period I i.e., 1950-51 to 1959-60. For the entire study period i.e., from 1950-51 to 2019-20 significant and positive growth rates of 1.26, 3.34, and 2.05 per cent per annum were observed in area, production and yield respectively.For the entire period, the contribution of interaction effect is high (58.30%) followed by yield(28.73%) and area effects(12.97%). The results revealed that area and yield effect contributes more to production than their interaction when data is considered for a shorter period(10 years) whereas the interaction effect contributes more to production if the period considered is of longerduration(70 years).

Conclusion: Care should be taken by the government in the supply of hybrid maize seeds to farmers. Farmers should be educated about the effect of climatic variables on maize yield and they are also trained in following an improved package of practices.

Keywords: Area effect, Decomposition, Growth, interaction effect, yield effect.

1. INTRODUCTION

Rice, wheat and maize are important cereal crops not only in India but also in the world. These are the crops that are the reason for securing food security in recent years by developing resistant and high-yielding varieties. To feed the people all over the world there is still a need to improve yields of all these crops. Cereal production is facing challenges due to climate change, degradation of ecosystems, population growth etc.

Maizeis third most important cereal crop in India after rice and wheat.Maize can be grown under various agro-climatic zones.The estimatedproduction of maize in India for the year 2020-21 was 30.24 million tonnes approximately.Maize is cultivated for various purposes such as grains, fodder, baby and sweet corn.Andhra Pradesh, Karnataka, Rajasthan, Maharashtra, Bihar, Uttar Pradesh, Madhya Pradesh and Himachal Pradesh are major maize producing states in India.

In the year 1957, All India Coordinated Research Project (AICRP) on maize was launched to develop superior varieties and production technologies. Many new cultivars were developed and disseminated throughout the country. With the development of various varieties though maize is a kharif season crop, now winter cultivation has also started.

The main objectives of the current study are

- To study the effect of temperature, rainfall and crop are on crop yield in maize in India.
- To study Compound Annual Growth Rate of area, production and productivity of maize in India.
- To study percentage contribution of area, yield and their interaction to maize production in India.

Some of the past studies are specified below

1.1 Effect of climate on yield of crops

Isik and Devadoss [1] studied the impact of climatic factors on the mean,variance and covariance of crop yield by developing an econometric model. The results showed that climate change has modest effects on mean crop yield and reduces the variance and covariance for most of the crops considered. The present study helps in taking the decision on crop production mix.

Acquah and Kyei [2] examined the impact of climatic variables on mean and variance of maize yield in Ghana. The Just and Pope stochastic production function was used for the purpose of analysis. The results showed that average maize yield is affected positively by crop area and negatively by rainfall and temperature whereas maize yield variability is affected positively by crop area and temperature and negatively by rainfall.

Chen et al [3] assessed the effect of climate change on agricultural production in China using Ricardian approach. Data were collected from 13,379 farmers across 316 villages in 31 provinces. The results revealed that temperature has positive impact and precipitation has negative impact on net crop revenue per hectare.

Dumrul and kilicarslan [4]studied the impact of climate change on Turkey's agricultural production using time series data from 1961 to 2013. The agricultural GDP increases with increase in precipitation and decreases with increase in temperature. The study suggested the need to establish policies, plans strategies and programs to combat climate change.

Singh *et al* [5] assessed the impact of climatic variables on area, production and productivity of major cash crops in India for the period from 1971 to 2013 using marginal impact analysis technique. The results of the study showed that 1% increase in climatic variables decrease the cropped area of groundnut and sesame crops by 13.87% and 23.50%respectively,decrease the production of groundnut and cotton by 9.83% and 41.09% respectively; and decrease the yield of potato, groundnut, sesame andcotton by 3.71%, 10.31%, 4.51% and 7.20% respectively. The study helps to provide suggestions to mitigate the adverse effect of climatic factors on crop farming.

1.2Growth rate and decomposition analysis

Rehman *et al*[6] studied the trends in area, production and yield of selected crops such as wheat, rice, sugarcane and cotton in Pakistan. The entire period is divided into pre structural adjustment period (SAP) (1972 to 1988) and post structural adjustment period (1989-2009). The growth rates of production and area wheat, sugarcane and cotton showed better growth in pre SAP and rice showed better growth in post SAP. Yields of wheat and cotton performed better in pre SAP and rice and sugarcane performed better in post SAP. Decomposition analysis revealed that major source for change in production is yield effect in wheat, rice and cotton whereas area effect in sugarcane during pre SAP. During post SAP, change in production is mainly due to yield effect in wheat and cotton and due to area effect in sugarcane and rice. For overall study period the major source of change in production is yield effect in wheat and cotton and area effect in sugarcane and rice.

Rambabu et al[7]studied the trends in area, production and yield of groundnut in Andhra Pradesh for the period from 1995-96 to 2010-11 using Compound Annual Growth Rate(CAGR). Decomposition of production of groundnut was done using component analysis. The production and productivityof ground nut showed negative and non- significant growth. According to decomposition analysis, the change in production is due to area effect whereas the yield effect and interaction effect were negligible.

Pattnaik and shah[8]studied the factors contributing to the agricultural production in Gujarat. The results revealed that price effect increased and yield effected decreased over time. Price-area interaction and yield-price interaction has become positive in the recent years which showed that price increase cause favourable change in area as well as yield.

Changela and Devi [9] investigated trend in area, production and yield of major pulses such as pigeon pea and chicken pea in Gujarat as well as India. Compound Growth Rate(CGR) and decomposition analysis are used to analyse data from 2001-02 to 2016-17. Both Gujarat and India showed positive and significant growth in area, production and productivity in chick pea, pigeon pea and total pulses. Decomposition analysis revealed that increase in production is due to increase in area in chick pea, pigeon pea and total pulses in India whereas in case of Gujarat it is due to yield effect.

Verma *et al* [10] analysed the data of potato from 1950-51 to 2017-18 using compound growth rate and decomposition analysis. The results revealed that potato production in India increased from 1.66 to 51.31 million tonnes, area under potato cultivation increased from 0.21 to 2.14 million ha and yield increased from 6917 kg/ha to 23967 kg/ha. Area, production and yield of potato showed positive growth rate during entire period of study. Area effect contributed more to production in each decade except seventies whereas for the whole period change in production caused by area and interaction of yield and area effect. During post SAP

2. METHODOLOGY

2.1 Nature and sources of data: Only secondary data is considered for the purpose of analysis. Data on rainfall and temperatureof India and area, production and yield of maize in India are obtained from the Indiastat website.

2.2 Ordinary Least Squares Method: The ordinary least squares method is applied for multiple regression and equation is

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \varepsilon (1)$$

Where

Y=Maize yield (kg/ha)
$\beta_{0=}$ Intercept
X_1= Temperature (^{0}c)
X_2= Rainfall (mm)
X_3=Crop area('000 hectares)
X_4= Time period(represent technology change)
ε = Random error
β_1,β_2,β_3 and $\beta_4$represents coefficients ofX_1, X_2, X_3 and X_4 respectively
The data from 1992-93 to 2019-20(28 years) is analysed using eviews software.

2.3Compound Annual Growth Rate:

$$Y = ab^t (2)$$

Where Y=Area or production or yield variable for which growth rate is calculated [11]
t=time variable taking 1, 2, 3…….,n. and here they are years

$$\log Y = \log a + t \log b (3)$$

a=intercept
b=regression co-efficient of "Y" on t.
by taking log form on both sides, we

$$\ln Y = \alpha + \beta T (4)$$

Where,

Y=time series data of maize
T= trend term
α= constant coefficient
β= slope coefficient measure relative change in Y for a given absolute change in explanatory variable T.

If we multiply the relative change in Y by 100, we will get percentage change or growth rate in Y for absolute change in variable T,

Compound Annual Growth Rate (CAGR) can be calculated by following formula.

$$CAGR\% = (Antilog(\beta) - 1) \times 100 (5)$$

CAGR will be estimated by applying Ordinary Least Square (OLS) method. The t-test will be performed to test the significance of "β". The entire study period(1950-51 to 2019-20) is divided into 7 periods such as Period I(1950-51 to 1959-60), Period II(1960-61 to 1969-70), Period III(1970-71 to 1979-80), Period IV(1980-81 to 1989-90), Period V (1990-91 to 1999-2000), Period VI(2000-01 to 2009-10) and Period VII(2010-11 to 2019-20).CAGR is calculated for all the periods separately and also for total period.

2.4Decomposition Analysis:

To measure the relative contribution of area, yield and their interaction to change in production conventional method was used which was previously adopted by Chaudhari and Singh [12]

Change in production = Area effect + Yield effect + Interaction effect

$$\Delta P = Y_0 \Delta A + A_0\, \Delta Y + \Delta A\, \Delta Y \text{------------(6)}$$

In the above equation first term represents area effect, second term represents yield effect and third term represents interaction effect.

Where

ΔP= Change in production

ΔA=Change in area

ΔY=Change in yield

A_0= Area in initial year

Y_0= Yield in initial year

P_0= Production in initial year

A_n=Area in final year

Y_n = Yield in final year

P_n = Production in final Year

The entire study period(1950-51 to 2019-20) is divided into 7 periods as previously specified and decomposition analysis done for all the periods separately and also for total period.

3. RESULTS AND DISCUSSION

The results of the least-squares method (Table 1) revealed that temperature has a negative effect on India's maize yield whereas rainfall, crop area and time have positive effect on maize yieldin India. For every 1^0c rise in temperature, the yield of maize decreased by 1.6 units. For every 1 mm increase in rainfall, the yield increased by 0.05 units and for every thousand hectares increase in crop area,the crop yield increased by nearly 1.37 units. All the independent variables considered under the least-squares method explain 89 per cent variation in maize yield. An increase in temperature causes a decrease in pollination and thereby decrease in grain filling and at last resulting in decreased crop yield.

Table 1: Results of Least Squares method for yield

Variable	Coefficient	p-value
Intercept	0.2335	0.9624
Temperature(^{0}c)	-1.6081	0.3121
Rainfall(mm)	0.0474	0.8042
Crop area ('000 hectares)	1.3666	0.0000
Time (Years)	0.0221	0.6390
R-square	0.8907	-
F-statistic	46.8621	0.0000

As is seen from Table 2,the growth rate of area is positive for all the periods except period III and IV. The growth rate of production and yield is positive for all the periods except period III. Highest and significant growth rate of 3.39 per cent per annum was observed in area during the period II i.e., from 1960-61 to 1969-70. Similarly, in the case of production and yield a highest and significant growth rate of 7.32 and 4.03 per cent respectively was observed during the period I i.e., 1950-51 to 1959-60. For the entire study period i.e., from 1950-51 to 2019-20 significant and positive growth rates of 1.26, 3.34, and 2.05 per cent per annum were observed in area, production and yield respectively.

The area under maize cultivation increased due to an increase in demand for maize. Demand for maize is increased due to its demand both in domestic as well as export markets. Demand for maize is increasing due to its increased use as animal feed and also for human consumption. Maize production in India is increased due to the adoption of single-cross hybrids. Maize production can be increased by increasing the area for the cultivation of hybrids and improved package of practices.Though India is one of the major maize-producing countries, India's maize yield is not on par with the yield of other major maize-producing countries.

Table 2: Compound Annual Growth Rates of area, production and Yield of maize during various periods in India

Period	Compound Annual Growth Rate (CAGR%)		
	Area	Production	Yield
Period I	3.18**	7.32**	4.03**
Period II	3.39**	4.15**	0.74^{NS}
Period III	-0.13^{NS}	-0.63^{NS}	-0.50^{NS}
Period IV	-0.19^{NS}	1.87^{NS}	2.06^{NS}
Period V	0.95**	3.28**	2.32**
Period VI	2.93**	5.29**	2.28*
Period VII	1.06**	3.47**	2.39**
Total period	1.26**	3.34**	2.05**

Note: ** represents significant at 1% probability level and NS-Non significant

The contribution of area, yield and their interaction to change in the production of maize in terms of percentage during various periods are presented in Table 3. Except for period I, the contribution of Interaction of area and yield is very negligible when compared to contribution of area and yield. For the entire period the contribution of interaction effect is high (58.30%) followed by yield(28.73%) and area effects(12.97%).

The results revealed that area and yield effect contributes more to production than their interaction when data is considered for a shorter period(10 years) whereas the interaction effect contributes more to production if the period considered is of long duration(70 years).

Table 3: Decomposition analysis of maize during various periods

Period	Area effect	Yield effect	Interaction effect
Period I	27.67	52.60	19.73
Period II	84.51	11.65	3.85
Period III	8.97	93.13	-2.10
Period IV	-3.87	105.45	-1.58
Period V	30.86	63.56	5.58

Period VI	64.31	28.56	7.13
Period VII	36.66	56.62	6.73
Total period	12.97	28.73	58.30

4. CONCLUSION

Maize is one of the major cereals that is being cultivated in India. Temperature has a negative effect on India's maize yield whereas rainfall, crop area and time have positive effect on maize yield in India.The area under maize in India is increased due to demand in domestic and export markets and also due to usage as animal feed as well as for human consumption.Maize production in India is increased due to the adoption of single-cross hybrids. Though India is one of the major maize-producing countries, India's maize yield is not on par with the yield of other major maize-producing countries.The results revealed that area and yield effect contributing more to production than their interaction when data is considered for a shorter duration and the percentage of the interaction effect contribution increased if data is considered for a longer duration. Care should be taken by the government in the supply of hybrid maize seeds to farmers. Farmers should be educated about the effect of climatic variables on maize yield and they are also trained in following an improved package of practices.

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