A STUDY OF TIME SERIES DATA ON MAIZE PRODUCTION IN UTTAR PRADESH

Thesis
Submitted to the

Acharya Narendra Deva University of Agriculture & Technology, Kumarganj, Ayodhya - 224229, Uttar Pradesh, India

By
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Id. No. A-14715/23

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF

Master of Science (Agriculture)

IN

Agricultural Statistics

June, 2025

CERTIFICATE-I

This is to certify that the thesis entitled **"A Study of Time Series Data on Maize Production in Uttar Pradesh"** submitted in partial fulfillment of the requirements for the degree of **Master of Science (Agriculture)** with major in **Agricultural Statistics** of the college of **Agriculture** Post Graduate Studies, Acharya Narendra Deva University of Agriculture & Technology, Kumarganj, Ayodhya is a record of *bonafide* research carried out by **Mr. Abhishek Pal, Id. No. A-14715/23**, under my supervision and no part of the thesis has been submitted for any other degree or diploma.

The assistance and help received during the course of this investigation have been acknowledged.

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CERTIFICATE-III

DECLARATION FOR ANTI-PLAGIARISM

I, **Abhishek Pal,** Id No. **A-14715/23,** certify that the thesis entitled **"A Study of Time Series Data on Maize Production in Uttar Pradesh"** submitted in partial fulfillment of the requirements for the degree of **Master of Science (Agriculture)** in **Agricultural Statistics** to the College of Agriculture, Acharya Narendra Deva University of Agriculture and Technology, Kumarganj, Ayodhya (U.P.) is original work and has similarities with published work not more than minor similarities as per the UGC (Promotion of Academic Integrity and Prevention of Plagiarism in Higher Educational Institutions) Regulations, 2018, adopted by the university.

I declare that I have faithfully acknowledged, given credit to and referred to the research workers wherever their works have been cited in the text and body of the thesis. I further certify that I have not wilfully lifted up some others' work, para, text, data, results, etc. reported in the journals, books, magazines, reports, dissertations, thesis, etc., or available at web-sites and included them in this thesis and cited as my own work.

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Date: 18 ***June, 2025***

Place: Kumarganj, Ayodhya

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%	:	Per cent
&	:	and
/	:	Per
₹	:	Rupees
m	:	Meter
m ha	:	Million hectares
m t	:	Million tonnes
Kg ha^{-1}	:	Kilogram per hectare
g	:	Gram
Kg	:	Kilogram
e.g.	:	(exempli gratia) for example
et al.	:	et alia (and associates)
i.e.	:	(Ed est.) that is
Etc.,	:	And so on; and other people/things
viz.	:	(Videlicet) namely
ICAR	:	Indian Council of Agricultural Research
IARI	:	Indian Agricultural Research Institute
AICRP	:	All India Coordinated Research Project
pH	:	Potential of Hydrogen
ºC	:	degree Celsius
CV	:	Coefficient of Variation
CDVI	:	Cuddy Della Valle Index
CAGR	:	Compound Annual Growth Rate
RMSE	:	Root Mean Square Error
MAPE	:	Mean Absolute Percentage Error
FAO	:	Food and Agriculture Organizations
R^2	:	Coefficient of Determination
Adj. R^2	:	Adjusted r-squared
Qt./qt.	:	Quintals
MAPE	:	Mean Absolute Percentage Error
RMSE	:	Root Mean Squared Error
Adj R^2	:	Adjusted R^2
R^2	:	Coefficient of determination
e-NAM	:	e-National Agriculture Market
FPOs	:	Farmer Patron Organization
ML	:	Machine Learning
ANN	:	Artificial Neural Network
Govt.	:	Government
σ^2	:	Error Variance

INTRODUCTION

INTRODUCTION

Maize (*Zea mays* L.) is a member of the Poaceae family. Its chromosome (2n) number is 20. Maize is a determinate, annual C_4 plant that can grow to heights ranging from less than 1 m to over 4 m. It possesses a solid stem with large, narrow leaves arranged alternately in an opposite pattern along its length.

Maize, India's third most significant cereal crop, is grown on 188 million hectares in over 170 countries, along with 1423 million metric tons of production. India is 4th in terms of area with 9.89 million hectares of Maize cultivated. Maize was traditionally grown during the *kharif season* in northern India. However, over time, its cultivation has shifted significantly towards peninsular India, which now accounts for over 40% of total Maize-growing area and contributes its nearly 50% of the country's Maize production. In terms of usage, about 47% of the Maize produced in India is used by the feed industry, mainly for poultry and livestock. Additionally, 13% is directly fed to animals, and around 7% is consumed in the form of processed food products, such as cornflakes, snacks, and other Maize-based items. Sweet corn, baby corn, popcorn, and silage Maize are becoming increasingly popular. All India Coordinated Research Project (AICRP) on Maize has played a significant role in enhancing area and production of Maize in India. Major among these is germplasm diversification, varied inbreds, resource conservation methods, and improving resource use efficiency. Maize grain is caryopsis type, dry fruit with single seed adhering to surrounding tissue. It has two primary parts: the germ, which holds the plumule and radicle used for plant growth, and the endosperm, which acts as a source of nutrients until the seedling can sustain itself. The endosperm accounts for about two-thirds of the volume of the kernel and 86% of its dry matter, whereas the germ, which is responsible for early development, is also the source of Maize oil, representing 4% of the weight of the grain. Mostly made up of starch and 10% bound protein (gluten), the endosperm can be in white or yellow forms. In addition to serving as top-notch animal feed and man staple food, Maize is a basic raw material for producing thousands of industrial applications like food sweeteners, alcoholic beverages, starch, oil, protein, film, textiles, gum, packaging, and paper. (Source- https://iimr.icar.gov.in)

1.1 India Scenario

In India, Karnataka has the largest Maize area with 1972 thousand hectares, while Bihar leads in Production with 5709.43 thousand tonnes. West Bengal records the highest productivity of Maize at 6633 kg per hectare.

The detailed state-wise overview of area under Maize, production and productivity is shown in the following table.

Table 1.1: Major states concerning area, production and productivity for Maize in India (2023)

S. No.	Area (In 000' Ha.)		Production (In 000' Ton.)		Productivity (In Kg/hectare)	
1	Karnataka	1972	Bihar	5709.43	West Bengal	6633
2	Madhya Pradesh	1543	Karnataka	5629.24	Tamil Nadu	6239
3	Maharashtra	1326.17	Madhya Pradesh	4338.69	Andhra Pradesh	6225
4	Uttar Pradesh	1104	Tamil Nadu	2838.63	Bihar	5975
5	Rajasthan	880.52	Telangana	2778.69	Telangana	5671
6	Telangana	490	Uttar Pradesh	2668.32	Assam	5143
7	Tamil Nadu	454.97	West Bengal	2604.42	Delhi	5111
8	West Bengal	392.62	Maharashtra	2449.56	Punjab	3827

(Source - *https://www.indiastat.com/table/agriculture/selected-state-season-wise-area-production-product/1456836*)

1.2 Climate Requirements

Maize, being a warm-season crop, needs moderate to high temperature, sufficient rainfall, and an abundance of sunlight during its growing phase.

1.2.1 Temperature

Maize prefers temperatures between 18°C and 32°C. Although germination starts at a soil temperature of 10°C to 12°C, excessive heat above 35°C can adversely affect growth, pollination and grain formation.

1.2.2 Rainfall

The crop needs 500 to 800 mm of rain during its growth period. Although Maize is tolerant to short dry periods, extended drought can decrease yield, while heavy rainfall can lead to waterlogging and root rot.

1.2.3 Sunlight

Maize, being a C_4 plant, is very efficient in the process of photosynthesis and needs 6-8 hours of intense sunlight every day. Efficient sunshine favors vigorous vegetative growth and grain filling of Maize.

1.2.4 Altitude

Maize is grown from sea level to over 3,000 meters of altitude, but it grows optimally at 1,500 to 1,800 meters. The variety of Maize is important in that it determines whether it can be grown at a given altitude.

1.3 Soil Requirements

Maize grows in different types of soils, but it thrives in rich, well-drained soils that offer excellent moisture retention and aeration.

1.3.1 Soil type

Loamy and alluvial soils are good for Maize agriculture due to their moisture retention and drainage. While sandy loam and clay loam soils may also sustain Maize development, adequate soil management is required to minimize nutrient loss and water stagnation.

1.3.2 pH

pH Range for soil 5.5-7.5. Strongly acidic soils (below pH 5.0) may cause nutritional deficits, whereas strongly alkaline soils (above pH 8.0) might restrict nutrient availability and impede plant development.

1.3.3 Drainage and moisture retention

Maize is water-sensitive, thus well-drained soil is critical for root growth and nutrient absorption. However, the soil should retain sufficient moisture to support development, particularly during important periods such as Maize blooming and grain filling.

1.4 Uttar Pradesh Scenario

Uttar Pradesh, located in northern India, was formed in 1950 following the country's transition to a republic. With a population exceeding 241 million, it is the most populous state in India, accounting for 16.5% of the nation's population and about 3% of the global population. Uttar Pradesh, the fourth-largest state in India by area, spans 243,286 square kilometers, accounting for 7.3% of the country's total landmass. Bordered by Rajasthan to the west, Haryana, Himachal Pradesh, and Delhi to the northwest, Uttarakhand and Nepal to the north, Bihar to the east, and Madhya Pradesh, Chhattisgarh, and Jharkhand to the south. Administratively, the state is organized into 18 divisions and 75 districts.

(Source - https://en.wikipedia.org/wiki/uttarpradesh)

In Uttar Pradesh, Maize is cultivated throughout the year. Maize needs warm, humid weather and well-drained, rich soil for best development. Waterlogged circumstances can harm roots and reduce productivity. Maize is a multi-purpose crop grown all over the world for various purposes such as grain, fodder, and industrial purposes. Maize is produced in various agroclimatic conditions and is therefore an important global crop. In Uttar Pradesh, crops are broadly categorized into three seasonal groups: *Rabi*, *Kharif*, and *Zaid*. Although Maize is cultivated throughout the state in all these seasons, it is primarily regarded as a *Kharif* crop.

The Minimum Support Price (MSP) for Maize for the year 2025-26 has been elevated to ₹2400, reflecting a 7.86% increase from the MSP of ₹2225 in 2024-25. The Government of India determines the Minimum Support Price (MSP) based on the suggestions provided by the Commission for Agricultural Costs and Prices (CACP).

(Source - *https://www.pib.gov.in/PressReleasePage.aspx?PRID=2131983*)

Among leading Maize-producing regions, Unnao holds the top position in overall output. The table below provides insights into the extent of cultivation, total yield, and productivity of Maize across various districts.

Table 1.2: Major districts concerning area, production, and productivity for Maize in Uttar Pradesh (2022)

S. No.	Area (In ha.)		Production (In ton.)		Productivity (In ton./ha.)	
1	Bahraich	95069	Kannauj	192187	Etah	9.72
2	Kannauj	63140	Bahraich	147134	Farrukhabad	9.28
3	Gonda	59397	Jaunpur	143724	Kannauj	9.27
4	Jaunpur	54177	Kasganj	124261	Auraiya	9.26
5	Bulandshahar	53193	Bulandshahar	123851	Kanpur Dehat	9.22

(Source - *https://data.desagri.gov.in/website/crops-apy-report-web*)

1.5 Nutritional Value

A study by several governmental institutions, i.e., the ICAR and IARI, found Maize is highly rich in nutrients.

- 9-10% crude protein, required for plant and animal nutrition.
- 60-64% Neutral Detergent Fiber, affecting digestibility, 38-41% Acid Detergent Fiber, relevant to fiber analysis.
- 23-25% hemicellulose, a critical cell wall component.
- Several vitamins (A, B_6, B_1) and minerals.
- Natural antioxidants, with health benefits.

  (Source - *https://igfri.icar.gov.in*)

1.6 Objective of Study

We will examine and analyze the Maize crop in the current study with four main objectives:

1.6.1 To analyze time series Maize production data to identify overall trends and growth rates over the years in Uttar Pradesh.

1.6.2 To apply time series techniques to predict and estimate future yield.

1.6.3 To analyze the instability index and decomposition analysis for Maize production in Uttar Pradesh.

1.6.4 To suggest long-term strategies for ensuring stable Maize production in Uttar Pradesh.

1.7 Limitations of Study

This research focuses on Maize cultivation in Uttar Pradesh and is based on secondary data obtained from IndiaStat.

(Source - *https://www.indiastat.com/data/agriculture/Maize-17199*)

The study spans 73 years from 1950-1951 to 2022-2023, providing a comprehensive long-term analysis. It specifically examines Uttar Pradesh, which significantly contributes to the state's overall Maize production.

1.8 Presentation of the Study

The study undertaken has been organised as follows:

The **first chapter** discusses the economic importance of Maize, the situation in India, climate requirements, soil requirements, the scenario in Uttar Pradesh, and the nutritional values of Maize. The **second chapter** deals with the review of literature on growth rates, instability, decomposition analysis, trend analysis and forecasting of area, production and yield and policy or schemes also. **Chapter three** deals with the methods, data and statistical techniques used for the analysis. Findings based on our objectives, conclusions and comments are presented in **chapter four**. The conclusions and executive summary of the study are presented in **chapter five**.

The literature cited shall be provided at the end of the thesis.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

This chapter takes a look at the main research on the topic. It focuses on the areas that are most important for the study. The review is organized around these themes, keeping the research goals in mind.

2.1 Overall trends and growth rates over the years in Uttar Pradesh.

2.2 Fitting of time series models to predict and estimate future yield.

2.3 Analysis of instability index and decomposition analysis for maize production in Uttar Pradesh.

2.4 Suggestions for long-term strategies for ensuring stable maize production in Uttar Pradesh.

2.1 Overall Trends and Growth Rates Over the Years in Uttar Pradesh

Mhaskey *et al.* (2025) examined the composite periodic growth rate, insecurity indicators, trend models, and corruption analysis in the production of groundnut, rapeseed, and mustard in Rajasthan using secondary data from 2000-01 to 2021-22.

Kumari and Singh (2024) analyzed the growth and instability of maize production in Himachal Pradesh during 30 years from 1992-93 to 2021-22, separated into three sub-periods. The analysis showed a slight increase in emulsion growth rates for area, production, and productivity from 1992-93 to 2001-02 and from 2002-03 to 2011-12.

Prakash and Venkataramana (2023) examined the growth in area, production, and productivity of maize in India and Karnataka, as well as the risks associated with maize production in Karnataka were analyzed. Primary data for the study was collected from major maize-growing districts of Karnataka. Secondary data on the area, production, and productivity of India and Karnataka were gathered from Indiastat.com and the Directorate of Economics and Statistics, Government of Karnataka.

Prioty *et al.* (2023) estimated by applying an exponential growth function, while instability was assessed using the Cuddy Della Valle Index. The study examined growth and instability in the area, production, and productivity of black gram, along with the key factors influencing production fluctuations, using secondary data spanning the last 40 years (1981-2020). For analytical purposes, the study period was divided into four sub-periods: 1981-1990, 1991-2000, 2001-2010, 2011-2020 and various statistical tools were employed for the analysis.

Soumya (2022) employed the Ordinary Least Squares (OLS) method, along with Compound Annual Growth Rate (CAGR) and decomposition analysis as key analytical tools.

All necessary data for the research were sourced from the Indiastat.com website. The impact of climatic variables on maize yield was examined using data spanning 28 years, from 1992-93 to 2019-20. For the calculation of CAGR and decomposition analysis, the dataset covered a longer period, from 1950-51 to 2019-20.

Sharma *et al.* (2022) investigated the key factors driving the strong growth performance of rapeseed and mustard in Rajasthan. Time series data on area, production, productivity, and farm harvest prices of rapeseed-mustard in the region were collected and organized. The analysis divided the data into two decadal periods: Period I (1997-98 to 2007-08) and Period II (2008-09 to 2017-18) as well as an overall period spanning 1997-98 to 2017-18. Descriptive statistics, including the Coefficient of Variation (CV) and Compound Growth Rate (CGR), were employed to analyze the dataset.

Kumar *et al*. (2022) analyzed time series data on rapeseed-mustard production in India for the period 1967-68 to 2019-20. The overall period was divided into three sub-periods: Period I, Period II, and Period III to examine trends, the Compound Annual Growth Rate (CAGR), decomposition analysis, instability, and the impact of technological change on production. The decomposition results revealed that production growth was driven by both yield and area effects in Period I, by area expansion in Period II, and by a combination of area and yield effects in Period III.

Kolhe *et al.* (2022) examined the growth in maize area, production, productivity, and export performance in India using secondary data for the period 1999-2019. The Compound Growth Rate (CGR) served as the main analytical tool for estimating growth trends in these parameters.

Patel *et al.* (2022) analyzed the fluctuation, trend, and growth rate in area, production, and productivity of maize during the study period 2000-01 to 2019-20 with the percent contribution of area, yield, and their interaction effect towards the production of maize across major producing states of India.

Unjia *et al.* (2021) carried out on the area, production, and productivity of maize in India, with the collected data examined using descriptive statistics and linear growth rates estimated through the Compound Annual Growth Rate (CAGR) method.

Joshi *et al.* (2021) assessed the compound growth rate and instability index of maize, potato, sugarcane, oilseeds, lentil, rice, and vegetable crops in Nepal. Time-series data spanning 29 years (1990-91 to 2018-19) were analyzed by dividing the study period into three decadal sub-periods. Findings revealed that the instability in the area, production, and productivity of most crops decreased during the second sub-period but increased again in the third sub-period.

Kalia *et al.* (2021) examined time series data from 1996 to 2019 to analyze trends in the area, production, and productivity of mustard in India, Uttar Pradesh, and the Bundelkhand region. Growth trend analysis revealed that the area under mustard cultivation declined in India and Uttar Pradesh, with compound growth rates (CGR) of -0.2% and -2% per annum, respectively, while in the Bundelkhand region it increased at a CGR of 4% per annum. A similar pattern was observed in production: India recorded a CGR of 1.5%, Uttar Pradesh -0.5%, and the Bundelkhand region 8%. Productivity trends showed positive growth across all regions, with CGRs of 1.7% at the national level, 1.6% in Uttar Pradesh, and 4.3% in Bundelkhand.

Singh and Bansal (2020) analyzed trends, variability, and conducted a decomposition analysis of rapeseed and mustard cultivation in major producing states and at the national level in India over the period 1992-93 to 2017-18. Compound growth rates were estimated using an exponential growth function, while variability was measured through the coefficient of variation. The results indicated a positive and statistically significant growth in production (1.84%) and yield (1.86%) of rapeseed and mustard at the national level during the study period.

Dey *et al.* (2020) examined the growth and instability in the area, production, and productivity of wheat and rice in India over the period 1950-51 to 2015-16. It employed time series data analysis and decomposition methods to identify the key factors contributing to production growth.

Chavhan *et al.* (2020) studied the Growth rate and instability of area, production, and productivity of selected cereal crops. It was undertaken to study to growth rate in area, production and productivity of important cereal crops viz, wheat and rice for the period from 1995-96 to 2014-15. The study also focused attention on the inter-district variation of selected crops and instability was also estimated in the study. The data were analyzed by fitting an exponential function to estimate the compound growth rate. The decomposition analysis model (Minhas 1964) was used in the present study.

Adhale *et al.* (2019) studied district-wise growth rates of area, production and production of sugarcane for each district as well as region-wise as a whole year of study period of 56 years, viz., 1960-61 to 2015-16, using log log-linear production function.

Selvi *et al.* (2015) studied the growth trends have been estimated for the area, production and productivity of maize in India. The secondary data between 1970-71 and 2013-14 were collected. Trend equations were fitted to examine the pattern of growth dimensions.

2.2 Fitting of Time Series Models to Predict and Estimate Future Yield

Singh and Kumar (2025) analyzed the trend patterns in the area, production, and yield of pigeon pea in India. This was carried out using secondary time series data on the area, production, and yield of pigeon pea in India for the period 2001-2023. It involved fitting well-known statistical models, such as the linear model, exponential model, quadratic model, and cubic model.

Singh *et al.* (2025) examined the trend patterns in area, production, and yield of lentil in India. The analysis is based on secondary time series data spanning the period from 2001-2023. Trend values have been determined by applying well-known statistical models, namely the linear model, exponential model, quadratic model, and cubic model.

Kumar *et al.* (2024) analyzed Cuddy-Della Valle (CDV) instability indices and compound growth rates (CGRs) were computed using secondary time series data on the area, production, and yield of major pulses (viz., chickpea, pigeon pea, urdbean, and mungbean) for the period 2000-2021.

Gohil *et al.* (2023) demonstrated the utility of price forecasting of farm prices and validated the same for castor crops in Gujarat state for 2022 using the time series data from 2007 to 2021. While for price data of castor was collected from AGMARKNET (www.agmarknet.gov.in). Looking at the seasonal indices, the lowest and highest seasonal indices of castor price occurred in May and August, respectively, for all the castor markets except the Patan market.

Patil and Sharma (2019) analyzed the period from 2001 to 2015. Kendall's coefficients of concordance were estimated for analyzing the change in cropping pattern and tested for their significance. The coefficient of concordance for the Ganganagar district was estimated as 0.50, which was significant at the 1 percent level of significance.

Jain *et al.* (2018) investigated secondary data collected from different sources were used for the research work, for the period 2000-01 to 2014-15. Paddy is the principal crop in Chhattisgarh, and along with paddy, maize and wheat are also studied in this investigation, to know the position of these crops at present as compared to paddy. Examined the trend using linear and exponential models for three major cereal crops, paddy, maize, wheat and assessed their variation in area, production and productivity.

Gautam and Sisodia (2018) aimed to analyze the growth and trends in the area, production, and productivity of wheat in Uttar Pradesh. Time series data covering the period 1970-71 to 2010-11 were utilized to assess growth patterns, examine trends, and make projections. The required secondary data were sourced from the Bulletins of the Directorate of Agricultural Statistics and Crop Insurance, Krishi Bhawan, Lucknow, under the Government of Uttar Pradesh.

Yadav *et al.* (2016) projected that by 2025, India will need 50 million metric tonnes (MMT) of maize grain, comprising 32 MMT for the feed industry, 15 MMT for industrial use, 2 MMT for food, and 1 MMT for seed and other purposes. In addition, the country is expected to have an export potential of around 10 MMT. This scenario underscores both the need and the opportunity to double India's current maize production of about 25 MMT within the next decade.

2.3 Analysis of Instability Index and Decomposition Analysis for Maize Production in Uttar Pradesh

Kumar *et al.* (2025) analyzed the growth trend and instability of Lentil in India from 2000-2021. By using compound growth rates (CGRs) for growth trend and Cuddy-Della Valle (CDV) instability index for instability in area, production and yield.

Tripathi *et al.* (2023) computed the coefficient of Variation and the Cuddy-Della Valle Index to determine the degree of instability. The relative importance of acreage and yield to the expansion of sesame production was determined by calculating the area effect, yield effect, and interaction effect.

Supriya *et al.* (2023) used yearly data collected from Agriculture Statistics at a glance, 1970 to 2019 were used to forecast up to 2029. While in the decomposition analysis, the area effect was an essential factor for the change in lentil production in Bihar, Madhya Pradesh, West Bengal, and India, but in Uttar Pradesh, the yield effect was responsible during the overall periods. Besides, this research will be essential to determining the future gap between pulse production and demand.

Ramoliya *et al.* (2022) conducted to estimate the growth and instability of major oilseed production from the period 1990-91 to 2019-20 in India. Statistical tools like compound rate of growth for calculating annual rate of growth and Cuddy-Della Valle Index for instability index were used. The period 1990-91 to 2019-20 has been further sub-divided into three sub-period, viz., period I (1990-91 to 1999-00), period II (2000-01 to 2009-10) and period III (2010-11 to 2019-20) to bring out the trends in the more recent periods.

Salunkhe *et al.* (2021) analyzed the compound growth rates and instability index for area, production and productivity of chickpea to the district-wise, region-wise, and for the entire state of Maharashtra and the secondary time series data were collected from various published sources viz., i) Season and crop reports, Departments of Agriculture, Government of Maharashtra, Pune, (ii) Statistical Abstract of Maharashtra State, Directorate of Economics and Statistics, Government of Maharashtra, Mumbai, (iii) Epitomes of Agriculture in Maharashtra, Part–II (iv) Socio- economic Review and District Statistical Abstracts of all districts in Maharashtra, Directorate of Economics and Statistics, Government of Maharashtra, Mumbai and (v) Census report viz., agricultural census.

Pusadekar *et al.* (2020) analyzed the growth trends and conducted a decomposition analysis of the area, production, and productivity of groundnut in Gujarat. It utilized secondary data spanning 20 years (1996-97 to 2015-16), which was divided into two sub-periods: Period I (1996-97 to 2005-06) and Period II (2006-07 to 2015-16). Growth rates were estimated using an exponential function, while instability was measured through the Coefficient of Variation (CV) and the Cuddy Della Valle Instability Index.

Baba *et al.* (2019) analyzed the trends in maize production in the state employing chronological data from 1980-81 to 2015-16, collected from various issues of the Digest of Statistics, GoJK. The decomposition analysis has shown that while the area effect has a positive contribution to an increase in maize production, the productivity and interaction of area and productivity effects have negatively contributed to the production differential of maize between 1980-81 and 2015-16.

Agam *et al.* (2019) examined the growth and instability in the area, production, and productivity of wheat in the Amravati district, using secondary data sourced from various government publications. The decomposition analysis revealed that the area effect was the primary factor contributing to the increase in wheat production in the district.

Dhokar *et al.* (2019) conducted a decomposition analysis of the area, production, and productivity of pigeon pea and chickpea in the Marathwada region of Maharashtra. It is based primarily on secondary data concerning these parameters for the selected pulse crops. The research also examined growth and instability trends in the area, production, and productivity of pigeon pea and chickpea. Data were sourced from various publications, including the *Epitome of Agriculture*, covering 30 years from 1986-87 to 2015-16.

Kiran *et al.* (2018) attempted to estimate the growth rate and identify the sources of instability in maize production in India. It is based on time-series data for 60 years (1950-51 to 2009-10) on area, production and productivity of maize in India. Exponential growth rate, Instability index, and Hazel's decomposition analysis were used.

Anjum and Madhulika (2018) analyzed the growth and instability in wheat, maize, sugarcane, cotton, rice, and fruits in India. Cuddy Della Valle Index and Coppock's instability index have been calculated for all the crops. The entire study period is divided into three sub-periods: 1990-91 to 1999-2000, 2000-01 to 2009-10, and 2009-10 to 2016-17. Several fluctuations in the growth pattern of area, production and productivity of the crops were observed in the study. Also, different pattern of instability was observed in the area, production and productivity of the crops over the period.

Ahmad *et al.* (2018) investigated was found that it was positive in all the states except Uttar Pradesh and for the last few years, lentil growth in area, production and productivity have been registered negative. In decomposition analysis, the interaction effect for all the states and nation as a whole was estimated high resulted better productivity of the lentil.

Sanjay (2018) examined continuous changes and confrontations invariably affect the trend, growth and stability of the economic performances of cotton. Hence, based on secondary data from 1966-67 to 2013-14, the study assessed the trends, growth and instability in area, production and yield of cotton in Haryana using semi log linear function, compounded annual growth rate and Cuddy Della Valle Index.

Dhunde *et al.* (2018) based on secondary data on the area, production, and productivity of pigeon pea in the Marathwada region. Complete district-wise data for pigeon pea from 1996-97 to 2015-16 were utilized and divided into two sub-periods: Period I (1996-97 to 2005-06) and Period II (2006-07 to 2015-16). Growth rates were estimated using an exponential growth function, while instability in area, production, and productivity was assessed using the Coefficient of Variation (CV) and the Cuddy Della Valle Instability Index (CDVI).

Kumar and Paul (2017) estimated the patterns of growth, measured the extent of instability, and evaluated the impact of explanatory variables on maize production in Andhra Pradesh over the last two decades. Time series data on area, production, and productivity for the period 1990-91 to 2014-15 were utilized. For the inter-district analysis, Compound Growth Rates (CGR), Coppock's Instability Index (CII), and decomposition of changes in average production were applied.

Teja *et al.* (2017) examined time series data collected from 1949-50 to 2014-15. Nine annual oilseeds, which include seven edible oilseeds, viz., groundnut, rapeseed-mustard, soybean, sunflower, sesame, safflower and niger, along with two non-edible crops, viz., castor and linseed are grown in the country, constitute the total oilseeds in the study. The total period from 1949-50 to 2014-15 was divided into four sub-periods, i.e., period I, II, III, and IV. An attempt was made to analyze the trends, Compound Annual Growth Rate (CAGR), decomposition analysis, instability analysis in the area, production, and yield of total oilseeds.

Snehdeep *et al.* (2017) analyzed the trends and growth rates of rapeseed and mustard production in Uttar Pradesh using time series data on area, production, and productivity for the period 1980-81 to 2010-11. Findings revealed that the cultivated area had declined by approximately 50% in 2010-11 compared to 1980-81.

Ayalew and Sekar (2016) investigated trends, instability, and regional variations of maize production in major producing states of India. Compounded Annual Growth Rate (CAGR), Cuddy Della Valley Index (CDVI), and decomposition analysis were used to examine the data ranging from 1980 to 1981 and 2011 to 2012.

Patil and Yeledhalli (2016) analyzed the growth and instability in the area, production and productivity of different crops in the Bengaluru Division. The results revealed that Bengaluru urban had the highest CAGR, which was 24.26% in productivity, in aware was significant at the 5% level.

Ammani (2015) examined growth trends in maize output, cultivated area (hectareage), and productivity in Nigeria between 1990 and 2011. Its objectives were to estimate both instantaneous and compound growth rates for these parameters and to assess whether their growth patterns showed acceleration, stagnation, or deceleration over time.

Kumar *et al.* (2014) analyzed the growth and instability of maize production across the major districts in key maize-producing states. It also attempted to forecast maize output for the near and mid-term under various scenarios.

Sahu and Mishra (2014) attempted to measure the change, instability, and trend in area, production and yield of maize in India and the major States of India using information from 1950 to 2009. The study reveals spectacular simple growth rates for area, production and productivity of maize, accompanied by differential instability over the major growing States and periods.

Sihmar (2014) examined 12 major districts of Haryana from 1980-81 to 1990-91. Different methods can measure the Agricultural instability index, such as the coefficient of variation (C.V.), dispersion, Cuddy Della Valle Index (CDVI), etc.

Mahal *et al.* (2013) studied based on secondary data collected from 1960-61 to 2009-10. Yield increased both in oilseeds and food grains, but the increase was more in the yield of food grains (2.95%) than that of oilseeds (1.97 %) over fifty years.

2.4 Suggestions for Long-Term Strategies for Ensuring Stable Maize Production in Uttar Pradesh

The State governments focused on several development programmes for maize cultivation.

Quick Maize Development Scheme (2023-24)

To enhance agricultural productivity, the Government of Uttar Pradesh has launched the “Quick Maize Development Scheme” with a financial allocation of ₹27.68 crore for the fiscal year 2023-24, aiming to improve maize farming techniques and boost production efficiency across the state. Currently, the state records a maize production of 21.16 lakh metric tonnes, cultivated over approximately 8.30 lakh hectares. With support from the Indian Maize Institute, affiliated with IARI, the government has set an ambitious target to double maize output to 27.30 lakh metric tonnes by 2027 by increasing both yield per hectare and cultivation area.

As the third most important food crop after paddy and wheat, maize holds strategic value due to its nutritional richness, being a vital source of carbohydrates, proteins, and essential nutrients, and its role in combating malnutrition. Experts highlight that with the adoption of advanced farming methods, maize yield in the state can potentially reach up to 100 quintals per hectare. This initiative underscores the significance of maize in sustainable agriculture, food security, and future-focused crop planning in Uttar Pradesh.

MATERIALS AND METHODS

MATERIALS AND METHODS

To effectively achieve the study's objectives, it is important to follow a clear and structured approach to data collection and analysis. This chapter gives an overview of the materials that form the study's database and the key statistical techniques used. The following sections explain the specific data sources and methods applied in this research.

3.1 Description of the study area

3.2 Selection of crop

3.3 Collection of data

3.4 Statistical tools employed in the analysis

3.1 Description of the Study Area

The study was undertaken in Uttar Pradesh.

3.2 Selection of Crop

The present study is confined to Maize production in Uttar Pradesh.

3.3 Collection of Data

The study uses 73 years of data on the area, production, and productivity of Maize in Uttar Pradesh from 1950 to 2023. This secondary data is collected from the Indiastat, 2022 website. (*https://www.indiastat.com/uttar-pradesh-state/data/agriculture/maize-17199*), for the period 1950-51 to 2023-24.

3.4 Statistical Tools Employed in the Analysis

We have used the following statistical tools and methods to achieve the study's objectives.

3.4.1 Trend analysis of area, production and yield of Maize

3.4.2 Growth rate and instability index analysis

3.4.3 Decomposition analysis

3.4.4 Root mean square error (RMSE)

3.4.5 Relative mean absolute percentage error (RMAPE)

3.4.1 Trend analysis of area, production and yield of Maize

In this study, we explore different linear and non-linear models to find the best one for our data. Growth models help us see how a variable changes over time. With this, we can forecast Maize production and identify its growth trends.

3.4.1.1 Linear regression model

The function is given by,

$$Y_t = \alpha + \beta t + \varepsilon_t$$

where,

'Y_t' is the dependent variable, i.e., area or production or productivity.

'α' is the intercept.

'β' the regression coefficient.

't' is the independent variable, Time in years.

'ε_t' is the error term, $\varepsilon_t \sim N(0, \sigma^2)$.

3.4.1.2 Quadratic regression model

The Function is useful when there is a peak or trough in the data of past periods. A quadratic function is,

$$Y_t = \alpha + \beta t + \gamma t^2 + \varepsilon_t$$

where,

'Y_t' is the dependent variable, i.e., area or production or productivity.

'α' is the intercept.

'β', and 'γ' the regression coefficient.

't' is the independent variable, Time in years.

'ε_t' is the error term, $\varepsilon_t \sim N(0, \sigma^2)$.

3.4.1.3 Cubic regression model

This function is useful when there are two peaks or two troughs in the data of past periods. The cubic fit, or third-degree curve, is given by the equation,

$$Y_t = \alpha + \beta t + \gamma t^2 + \theta t^3 + \varepsilon_t$$

where,

'Y_t' is the dependent variable, i.e., area or production or productivity.

'α' is the intercept.

'β', 'γ', and 'θ' the regression coefficient.

't' is the independent variable, Time in years.

'ε_t' is the error term, $\varepsilon_t \sim N(0, \sigma^2)$.

3.4.1.4.Quintic regression model

The function is useful when there are more than four peaks or four through in the data of past periods. The quintic fit, or 5th degree curve, is given by the equation,

$$Y_t = \alpha + \beta t + \gamma t^2 + \theta t^3 + \delta t^4 + \omega t^5 + \varepsilon_t$$

where,

'$\boldsymbol{Y_t}$' is the dependent variable, i.e., area or production or productivity.

'$\boldsymbol{\alpha}$' is the intercept.

'$\boldsymbol{\beta}$', '$\boldsymbol{\gamma}$', '$\boldsymbol{\theta}$', '$\boldsymbol{\delta}$' and '$\boldsymbol{\omega}$ ' the regression coefficient.

'$\boldsymbol{t}$' is the independent variable, Time in years.

'$\boldsymbol{\varepsilon_t}$' is the error term, $\varepsilon_t \sim N(0, \sigma^2)$.

3.4.1.5 Logarithmic regression model

It is used when there is a relationship between variables that grows quickly at first and then gradually slows down. In other words, the growth starts fast and then becomes slower over time. The function is given by,

$$\boldsymbol{Y_t = \alpha + \beta ln(t) + \varepsilon_t}$$

where,

'$\boldsymbol{Y_t}$' is the dependent variable, i.e., area or production or productivity.

'$\boldsymbol{\alpha}$' is the intercept.

'$\boldsymbol{\beta}$', '$\boldsymbol{\gamma}$', and '$\boldsymbol{\theta}$' the regression coefficient.

'$\boldsymbol{t}$' is the independent variable, Time in years.

'$\boldsymbol{\varepsilon_t}$' is the error term, $\varepsilon_t \sim N(0, \sigma^2)$.

3.4.1.6 Power regression model

This model is used when the relationship between variables follows a pattern where one variable is expressed as a power of the other. In simple terms, it is useful when the data exhibits proportional change, and the growth or decline follows a consistent pattern, such as a fixed ratio or an exponential-like trend.

The function is given by,

$$\boldsymbol{Y_t = \alpha t^{\beta}. e^{\varepsilon_t}}$$

or,

$$\boldsymbol{ln(Y_t) = ln(\alpha) + \beta\, ln(t) + \varepsilon_t}$$

where,

'$\boldsymbol{Y_t}$' is the dependent variable i.e., area or production or productivity.

'$\boldsymbol{\alpha}$' is the intercept.

'$\boldsymbol{\beta}$' the regression coefficient.

'$\boldsymbol{t}$' is the independent variable, Time in years.

'$\boldsymbol{\varepsilon_t}$' is the error term, $\varepsilon_t \sim N(0, \sigma^2)$.

3.4.1.7 Exponential regression model

This model is used when one variable increase or decreases at a changing rate rather than a constant rate. In other words, the growth accelerates over time, or the decline gradually slows down, following an exponential trend.

The function is given by,

$$\boldsymbol{Y_t = \alpha e^{\beta t} . e^{\varepsilon_t}}$$

or,

$$\boldsymbol{ln\, Y_t = ln\, \alpha + \beta t + \varepsilon_t}$$

where,

'$\boldsymbol{Y_t}$' is the dependent variable i.e., area or production or productivity.

'$\boldsymbol{\alpha}$' is the intercept.

'$\boldsymbol{\beta}$' the regression coefficient.

'$\boldsymbol{t}$' is the independent variable, Time in years.

'$\boldsymbol{\varepsilon_t}$' is the error term, $\varepsilon_t \sim N(0, \sigma^2)$.

3.4.2 Growth rate and instability index analysis

Growth rate is measured by the compound annual growth rate and instability is measured by the coefficient of variation and Cuddy Della Valle Index.

3.4.2.1 Compound annual growth rate (CGAR)

To compute the annual compound annual growth rate (CAGR), the following model is used compound growth

$$\boldsymbol{Y_t = a(1 + r)^t}$$

first linearized by taking the natural logarithm on both sides and then we get,

$$\log \boldsymbol{Y_t = log\, a + t\ \ log(1 + r_l\ )}$$

or,

$$\boldsymbol{Y_t^* = a^* + bt}$$

where,

$Y_t^* = log\, Y_t\ , a^* = log\, a\, and\, b =\ log(1 + r_l\ )$

The above-linearised function was fitted by the least square method and an estimate of *b* ($\hat{b}$) was obtained.

The compound annual growth rate is then computed as,

$$\boldsymbol{CAGR\ = \left(antilog\ of\ \hat{b} - 1\right) \times 100}$$

This gives the percentage growth rate per year. All growth rates are expressed in percentages. The best-fitted model is selected based on the coefficient of determination (R^2), which measures the goodness of fit.

3.4.2.2 Instability index

The level of instability in the area, production, and productivity of various maize crops will be assessed using appropriate statistical tools. The simple coefficient of variation (C.V.) often includes a trend component, which can lead to an overestimation of the true level of instability in time series data with long-term trends. To address this issue, instability will be measured using the Cuddy-Della Valle Index, which adjusts the coefficient of variation. This index is calculated as follows:

$$\boldsymbol{Instability\ index = C.V.\sqrt{1 - R^2}}$$

$$\boldsymbol{C.V. = \frac{\sigma}{\mu} \times 100}$$

$$\boldsymbol{R^2 = \frac{Explained\ Variation}{Total\ Variation} = 1 - \frac{\sum_{i=1}^{n}(Y_i - \hat{Y}_i)^2}{\sum_{i=1}^{n}(Y_i - \bar{Y})^2}}$$

$$\boldsymbol{Adjusted\ R^2 = 1 - \frac{(1 - R^2)\ (n-1)}{n-p-1}}$$

where,

$\boldsymbol{n}$ is the total sample size.

$\boldsymbol{p}$ is the number of independent variables.

$\boldsymbol{C.V.}$ is the coefficient of variation.

$\boldsymbol{R^2}$ is the coefficient of determination from the trend regression.

$\boldsymbol{\sigma}$ is the standard deviation.

$\boldsymbol{\mu}$ is the Overall mean.

$\boldsymbol{Y_i}$ is the actual value of the dependent variable.

$\boldsymbol{\hat{Y}_i}$ is the predicted value of the dependent variable.

$\boldsymbol{\bar{Y}}$ is the mean of the actual value of the dependent variable.

This index provides a more accurate estimate of instability by accounting for the trend component present in time series data

3.4.3 Decomposition analysis

To estimate the contributions of area, productivity, and their interaction to the change in production of the Maize crop between two periods of time series. The following additive decomposition scheme can be applied.

$$\Delta P = A_o(Y_n - Y_o) + Y_o(A_n - A_o) + \Delta A \Delta Y$$

$$1 = \left[\frac{(A\Delta Y)}{\Delta P}\right] + \left[\frac{(Y\Delta A)}{\Delta P}\right] + \left[\frac{(\Delta A\Delta Y)}{\Delta P}\right]$$

where,

ΔP = Change in production.

A_o = Area in the base year.

A_n = Area in the current year.

Y_o = Yield in the base year.

Y_n = Yield in the current year.

ΔA = Change in the area $(A_n - A_o)$.

ΔY= Change in the Yield $(Y_n - Y_o)$.

By applying this decomposition, we can quantify how much of the change in total production is attributable to changes in area, changes in productivity, and the combined effect of both.

3.4.4 Root mean square error (RMSE)

The root mean square error (RMSE) is given by:

$$RMSE = \sqrt{\frac{1}{n} \sum_{t=1}^{n} (y_t - \hat{y}_t)^2}$$

where,

n represents the number of years for the time-series data on the variable Y.

y_t is the actual value of the dependent variable (area, production and yield).

$\hat{y}_t$ is the predicted value of dependent variable (area, production and yield).

3.4.5 Relative mean absolute percentage error (RMAPE)

The relative mean absolute percentage error (RMAPE) is a measure of prediction accuracy of the statistical model used for forecasting, and is given by the formula:

$$RMAPE = \frac{1}{n}\sum_{t=1}^{n} \left|\frac{y_t - \hat{y}_t}{y_t}\right| \times 100$$

where,

n represents the number of years for the time-series data on the variable Y.

y_t is the actual value of the dependent variable (area, production and yield).

$\hat{y}_t$ is the predicted value of dependent variable (area, production and yield).

RESULTS AND DISCUSSION

RESULTS AND DISCUSSION

This chapter employs various statistical methods, including linear, non-linear, and time series models, as well as growth rate analysis, instability assessment, and decomposition techniques, to estimate and forecast Maize production, area and yield in Uttar Pradesh. The key findings are elaborated on in detail in the following sections.

4.1 Overall trends and growth rates over the years in Uttar Pradesh.

4.2 Fitting of time series models to predict and estimate future yield.

4.3 Analysis of instability index and decomposition analysis for maize production in Uttar Pradesh.

4.4 Suggestions for long-term strategies for ensuring stable maize production in Uttar Pradesh.

For the investigation of growth rates, instability, and decomposition analysis, time-series data spanning 73 years, from 1950-51 to 2022-23, were utilized to ensure that the specified objectives were met. Additionally, for time series techniques aimed at predicting and estimating future yield data, a period of 63 years, from 1950-51 to 2012-13, was covered.
The secondary information was gathered from the IndiaStat.
(Source - *https://www.indiastat.com/data/agriculture/Maize-17199*)

In this study, various models are explored, including both linear and non-linear approaches (Ratkowsky, 1990; Bard, 1974; Draper & Smith, 1998), along with time-series models. Also conducted decomposition analysis and instability index analysis to better understand trends and variations in the data. To identify the best-fitting model, evaluated performance using key metrics such as Root Mean Squared Error (RMSE), Mean Absolute Percentage Error (MAPE) and value of R^2. The results are discussed in a structured and logical manner.

4.1 Overall Trends and Growth Rates Over the Years In Uttar Pradesh

To analyze the trend and growth rate of Maize production, use the compound annual growth rate.

4.1.1 Compound annual growth rate (CAGR)

Compound annual growth rates of area, production and yield of Maize in Uttar Pradesh for three periods and overall were carried out and given in Table 4.1.

Table 4.1: Compound annual growth rates (CAGR) percentage of area, production and yield of Maize in Uttar Pradesh

Particulars	Area	Production	Yield
Overall period (1950-51 to 2022-23)	-0.66*	0.95*	1.62*
I Period (1950-51 to 1973-74)	2.63*	2.97*	0.33
II Period (1974-75 to 1997-98)	-0.92*	2.86*	3.81*
III Period (1998-99 to 2022-23)	-1.03*	1.53*	2.59*

* Indicate significance at a 5% level of probability.

The data given in Table 4.1 revealed that, overall, the Compound Annual Growth Rates of Area (-0.66%) were negative, except for Production (0.95%) and Yield (1.62%) in Uttar Pradesh. Production and Yield were positively significant at the 5% level, except area of Maize in Uttar Pradesh.

Table 4.1 explain period I, positive growth rates of area (2.63%), production (2.97%) and yield (0.33%) of Maize in Uttar Pradesh. Area and Production showed positive and significant results at the 5% level, but Yield showed non-significant results.

Table 4.1 explain period II, Production (2.86%) and Yield (3.81%) exhibited positive growth rates, except for the area, which showed a decline of (-0.92%). Production and Yield were positively significant at the 5% level, except area of Maize in Uttar Pradesh.

Table 4.1 explain period III, the growth rates were the same as those in period II. Production (1.53%) and yield (2.59%) demonstrated positive growth rates, except for area (-1.03%). Production and yield were statistically significant at the 5% level, excluding the area of Maize in Uttar Pradesh.

4.2 Fitting of Time Series Models to Predict and Estimate Future Yield

For predicting and estimating future yield, different linear and non-linear models were applied, and the cubic model is the best for area, production, and yield estimation.

4.2.1 Maize area of Uttar Pradesh

Maize is the foodgrain crop most widely cultivated in India. Kannauj is the highest producing district in Uttar Pradesh. Maize is cultivated in districts of Unnao, Sultanpur, Sonbhadra, Sitapur, Farrukhabad, Kannauj, etc., which contribute area under cultivation in Maize.

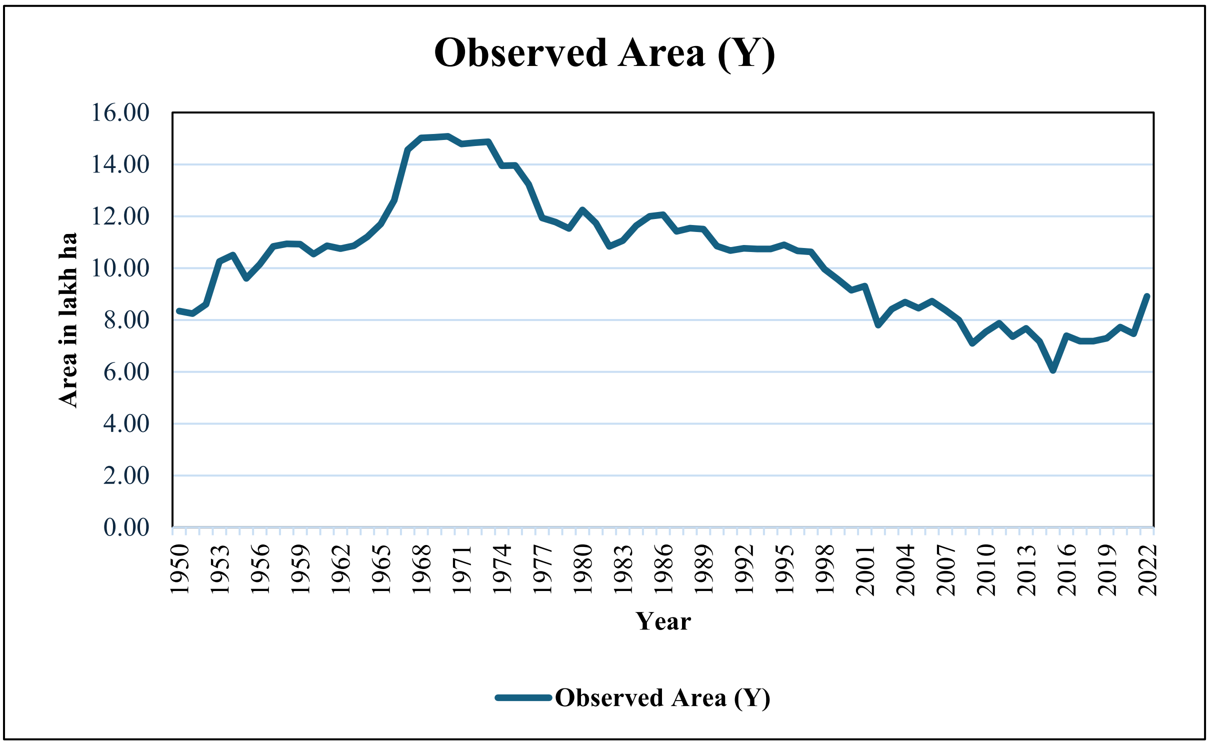

Figure 4.1: Observed area of Maize in Uttar Pradesh (1950-2022)

The average area of the Maize crop was 10.41 over the research period (1950-51 to 2022-23), as shown in Figure 4.1. The Greatest area was 15.08 lakh hectares in the year 1970, and the lowest was 6.05 lakh hectares in the year 2015.

Table 4.2 shows the results of applying appropriate linear, non-linear growth, and time series models to the time-series dataset of Maize cultivated area from 1950-51 to 2022-23.

Table 4.2: Statistical models for area of Maize in Uttar Pradesh

Parameter	Models						
	Linear	Logarithmic	Exponential	Power	Quadratic	Cubic	Quintic
α	139.43*	985.702*	5.3×10^6*	1.7×10^{44}*	-1.26×10^4*	**-1.06×10^6***	-1.08×10^5*
β	-0.065*	-128.43*	-0.007*	-13.107*	12.7632*	**1.59×10^3***	0
γ					-0.0032*	**-0.7982***	0
θ						**0.00013***	1.37×10^{-4}*
δ							-1.03×10^{-7}*
ω							2.10×10^{-11}*
Criteria							
R^2	0.3589	0.3557	0.3969	0.3934	0.6738	**0.8576**	0.8580
$Adj. R^2$	0.3499	0.3466	0.3884	0.3849	0.6644	**0.8514**	0.8228
RMSE	1.8296	1.8342	1.9016	1.9065	1.3052	**0.8624**	0.8611
MAPE	0.1434	0.1440	0.1464	0.1469	0.0959	**0.0601**	0.0600

1. Source: Secondary data collected from Indiastat. (https://www.indiastat.com/data/agriculture/Maize-17199)
2. A criterion value highlighted in bold indicates the superiority of a particular model over others in that specific criterion.
3. * Indicate significance at a 5% level.

Table 4.2 reveals that among the growth models examined, the cubic model demonstrates the highest maximum R^2 (0.8576) and Adj. R^2 (0.8514) scores, along with the lowest RMSE (0.8624) and MAPE (0.0601) scores. As a result, the cubic model is selected as the most suitable for forecasting future values of area dedicated to Maize cultivation in Uttar Pradesh.

The forecasted cubic area model is:

$$\hat{Y}_{Area} = -1057578.5786 + 1591.4977t - 0.7982t^2 + 0.00013t^3$$

The ideal cubic model was used to generate future forecasts for Maize cultivation in the region up to the year 2027, with the results given as follows.

Using data on criterion selection, such as maximum R^2, Adj. R^2With minimal RMSE and MAPE, the cubic model was used to forecast the future area dedicated to Maize cultivation in Uttar Pradesh.

According to this model, the estimated cultivated area of Maize in Uttar Pradesh by the year 2027-28 is projected to be 8.57 lakh hectares.

Furthermore, it was observed that the trend in Maize cultivation has shown a beginning in 1950, followed by continuous fluctuations in subsequent years.

Using this model, the most accurate forecasted values of Maize cultivation area up to 2027-28 were obtained, as presented in Table 4.3 and Figure 4.2.

Table 4.3: Forecasted values of Maize area for Uttar Pradesh by cubic model

Year	2023-24	2024-25	2025-26	2026-27	2027-28
Forecasted Area	7.83	7.98	8.15	8.35	8.57

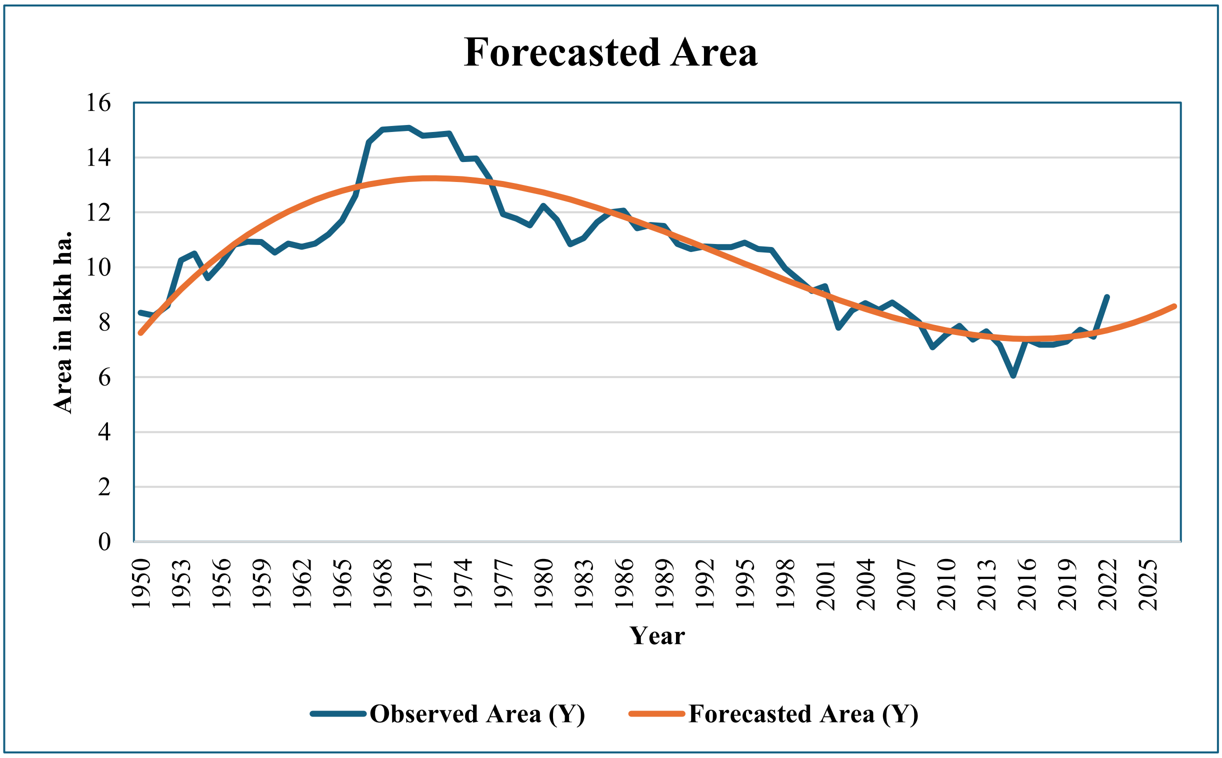

Figure 4.2: Observed and forecasted trends of Maize area in Uttar Pradesh (1950-2027)

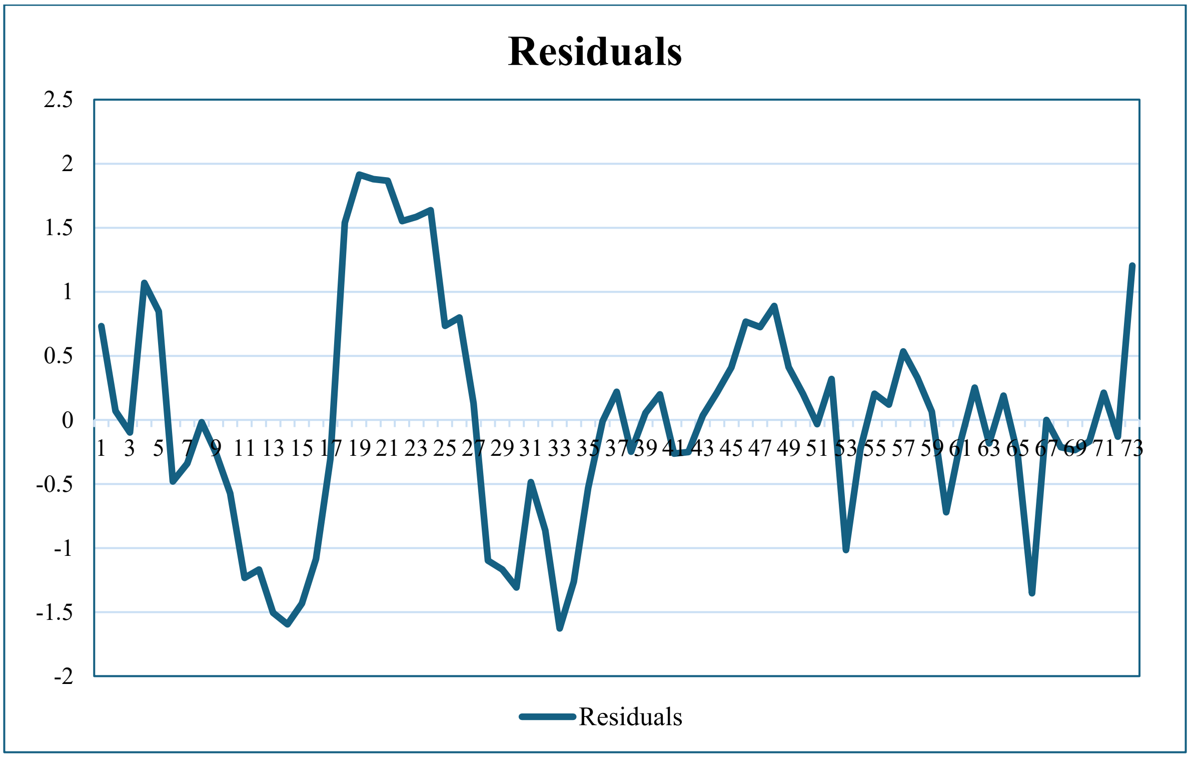

Figure 4.3: Cubic model plots of the residuals of forecasted Maize area data (1950 - 2022)

4.2.2 Maize production of Uttar Pradesh

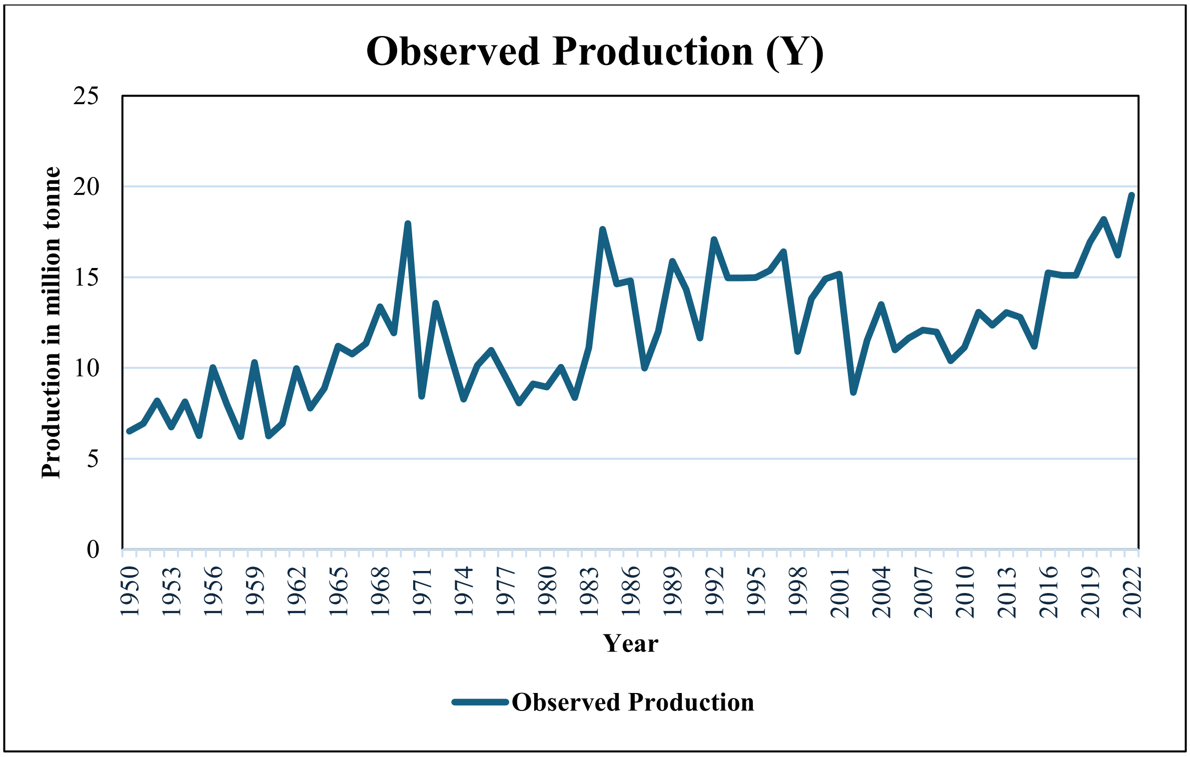

Figure 4.4: Observed production of Maize in Uttar Pradesh (1950-2022)

Figure 4.4 shows that from 1950 to 2022, Uttar Pradesh produced an average of 11.80 million tonnes of Maize grains. The production of Maize in Uttar Pradesh shows different trends over the study period. The highest production was recorded in 2022, at 19.52 million tonnes, whereas the lowest was in 1958, at 6.21 million tonnes.

Table 4.4 presents the results obtained for Maize production during the study after performing linear and non-linear models.

Table 4.4: Statistical models for production of Maize in Uttar Pradesh

Parameter	Models						
	Linear	**Logarithmic**	**Exponential**	**Power**	**Quadratic**	**Cubic**	**Quintic**
α	-193.18*	-1546.03*	7.6×10^{-8}*	8.0×10^{-62}*	-4253.2*	**-6.41×10^{5}***	-6.62×10^{4}*
β	0.1032*	205.144*	0.0095*	18.846*	4.1922*	**966.8773***	0
γ					-0.0010*	**-0.4858***	0
θ						**0.0001***	8.38×10^{-5}*
δ							-6.32×10^{-8}*
ω							1.27×10^{-11}*
Criteria							
R^2	0.4385	0.4393	0.4741	0.4753	0.4540	**0.4870**	0.4882
$Adj. R^2$	0.4306	0.4314	0.4667	0.4680	0.4384	**0.4647**	0.4370
RMSE	2.4611	2.4594	2.5144	2.5123	2.4269	**2.3523**	2.3496
MAPE	0.1796	0.1794	0.1754	0.1751	0.1772	**0.1757**	0.1756

1. Source: Secondary data collected from Indiastat. *https://www.indiastat.com/data/agriculture/Maize-17199*
2. A criterion value highlighted in bold indicates the superiority of a particular model over others in that specific criterion.
3. * Indicate significance at a 5% level.

Table 4.4 reveals that among the growth models examined, the cubic model demonstrates the highest maximum R^2 (0.4870) and Adj. R^2 (0.4647) scores, along with the lowest RMSE (2.3523) and MAPE (0.1757) scores. As a result, the cubic model is selected as the most suitable for forecasting future values of production dedicated to Maize production in Uttar Pradesh.

The forecasted cubic production model is:

$$\hat{Y}_{Production} = -641464.5833 + 966.8773t - 0.4858t^2 + 0.0001t^3$$

The best-fitted cubic model was used to generate future forecasts for Maize production in the region up to the year 2027-28, with the results presented as follows.

Based on the criteria selection data, including maximum R^2, Adj. R^2. The cubic model, with the lowest RMSE and MAPE, was used to forecast future production dedicated to Maize in Uttar Pradesh.

The forecast suggests a decrease in Maize production from 2022, with production expected to reach 17.70 million tonnes by 2027-28. The forecasted Maize production is presented in Table 4.5 and Figure 4.5 using the cubic model, which is the best-fitted model.

Table 4.5: Forecasted values of Maize production for Uttar Pradesh by cubic model

Year	2023-24	2024-25	2025-26	2026-27	2027-28
Forecasted Production	16.38	16.68	17.00	17.34	17.70

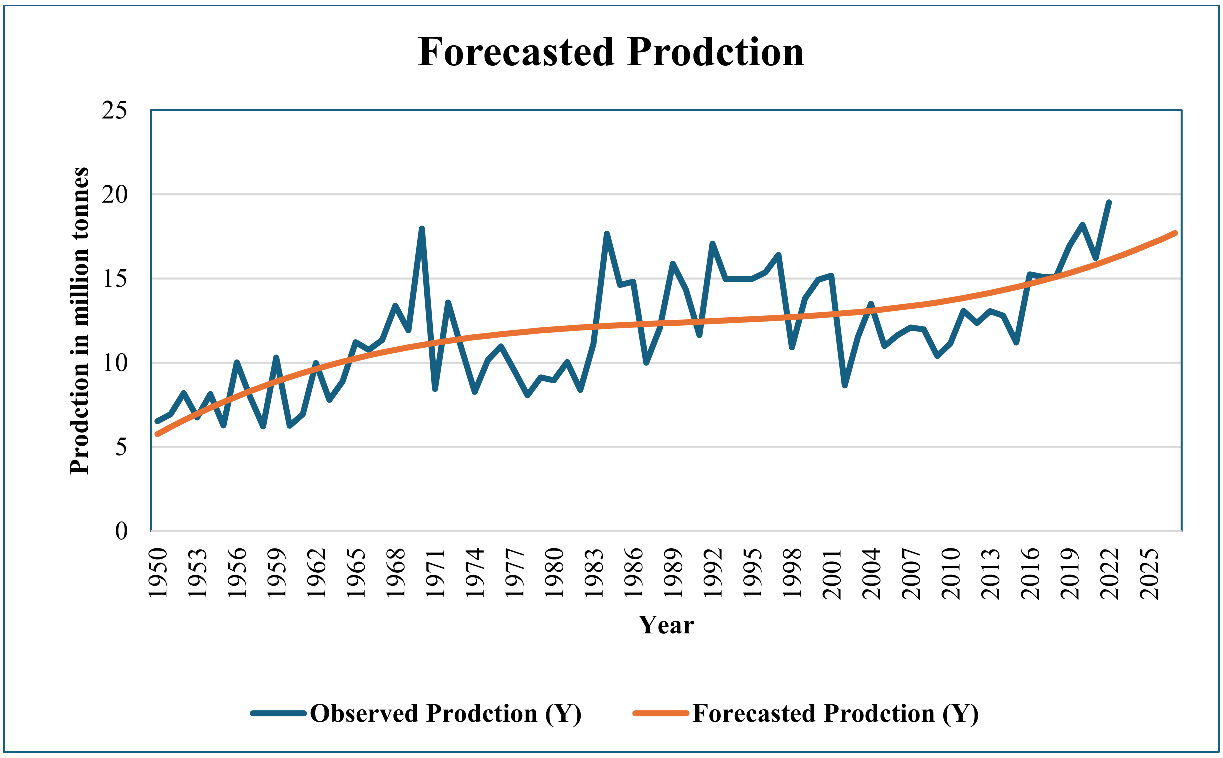

Figure 4.5: Observed and forecasted trends of Maize production in Uttar Pradesh (1950-2027)

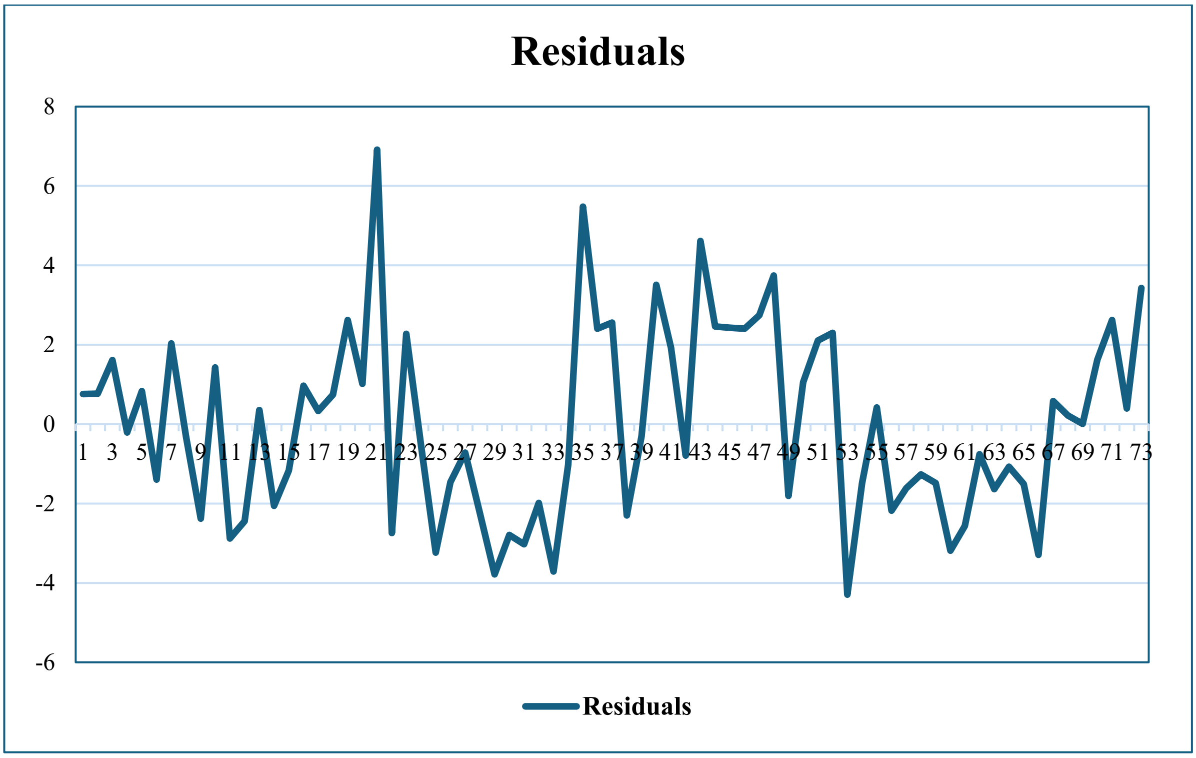

Figure 4.6: Cubic model plots of the residuals of forecasted Maize production data (1950 - 2022)

4.2.3 Maize yield of Uttar Pradesh

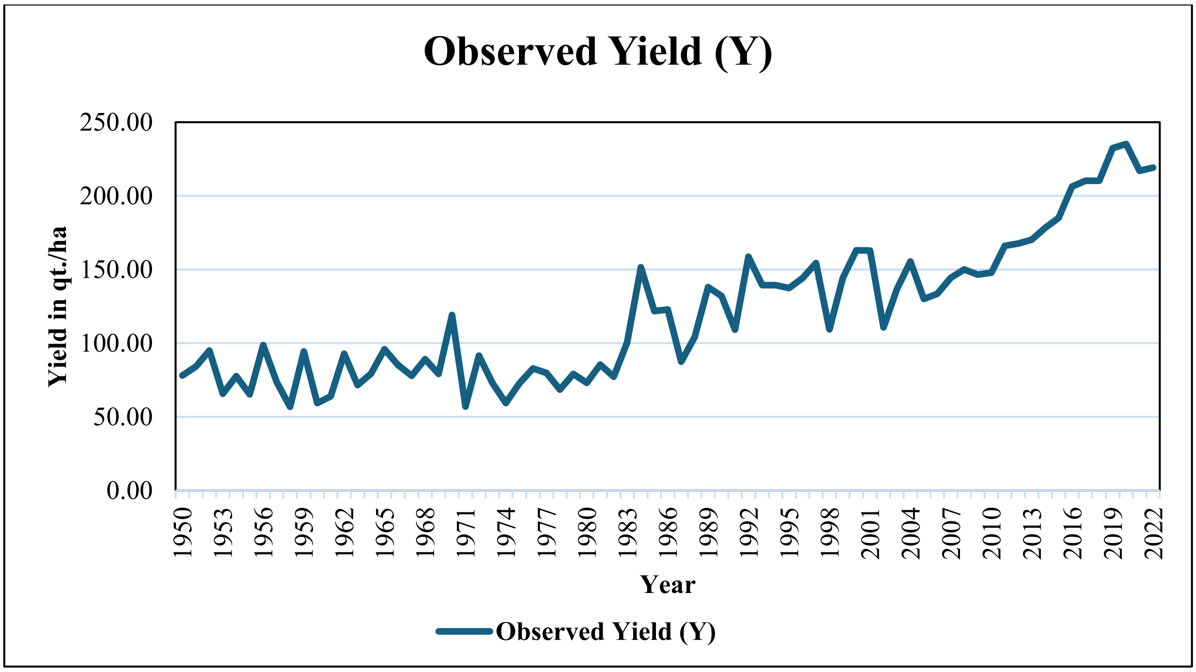

Figure 4.7: Observed yield of Maize in Uttar Pradesh (1950-2022)

Figure 4.7 shows that from 1950 to 2023, Uttar Pradesh produced an average of 120.22 quintals/hectare of Maize. The yield of Maize in Uttar Pradesh shows different trends over the study period. The highest yield was recorded in 2020, at 235.20 quintals/hectare, whereas the lowest was in 1958, at 56.82 quintals/hectare.

Table 4.6 presents the results obtained for Maize yield during the study after performing linear and non-linear models.

Table 4.6 Statistical models for yield of Maize in Uttar Pradesh

Parameter	Models						
	Linear	Logarithmic	Exponential	Power	Quadratic	Cubic	Quintic
α	-3776.6*	-29421.8*	1.4×10^{-12}*	4.7×10^{-104}*	131932.8*	**-3.76×10^{5}**	-1.9×10^{4}
β	1.9621*	3890.27*	0.0161*	31.953*	-134.72*	**632.2304**	0
γ					0.0344*	**-0.3518**	0
θ						**0.000065**	4.03×10^{-5}
δ							-3.4×10^{-8}
ω							7.8×10^{-12}
Criteria							
R^2	0.7695	0.7671	0.7665	0.7649	0.8536	**0.8537**	0.8537
$Adj. R^2$	0.7663	0.7638	0.7632	0.7616	0.8494	**0.8473**	0.8184
RMSE	22.625	22.744	19.8618	19.9599	18.0344	**18.0281**	18.0267
MAPE	0.1796	0.1804	0.1564	0.1570	0.1418	**0.1423**	0.1424

1. Source: Secondary data collected from Indiastat.
   https://www.indiastat.com/data/agriculture/Maize-17199
2. A criterion value highlighted in bold indicates the superiority of a particular model over others in that specific criterion.
3. * Indicate significance at a 5% level.

Table 4.6 reveals that among the growth models examined, the cubic model demonstrates the maximum R^2 (0.8537) and Adj. R^2 (0.8473) scores, along with the lowest RMSE (18.0281) and MAPE (0.1423) scores. As a result, the cubic model is selected as the most suitable for forecasting future values of yield dedicated to Maize yield in Uttar Pradesh.

The forecasted cubic yield model is:

$$\hat{Y}_{Yield} = -375719.2811 + 632.2304t - 0.3518t^2 + 0.000065t^3$$

The best-fitted cubic model was used to generate future forecasts for Maize production in the region up to the year 2027, with the results presented as follows.

Using the criteria selection data, such as the highest values of R^2 and $Adjusted\ R^2$, along with the lowest RMSE and MAPE, the cubic model was identified as the most suitable for forecasting Maize yield in Uttar Pradesh. The projections indicate an increase in yield starting from 2022, reaching approximately 245.57 quintals/hectare by 2027. Table 4.7 and Figure 4.8 present the forecasted Maize yield based on this best-fitting cubic model.

Table 4.7: Forecasted values of Maize yield for Uttar Pradesh by cubic model

Year	2023-24	2024-25	2025-26	2026-27	2027-28
Forecasted Yield	226.01	230.78	235.62	240.56	245.57

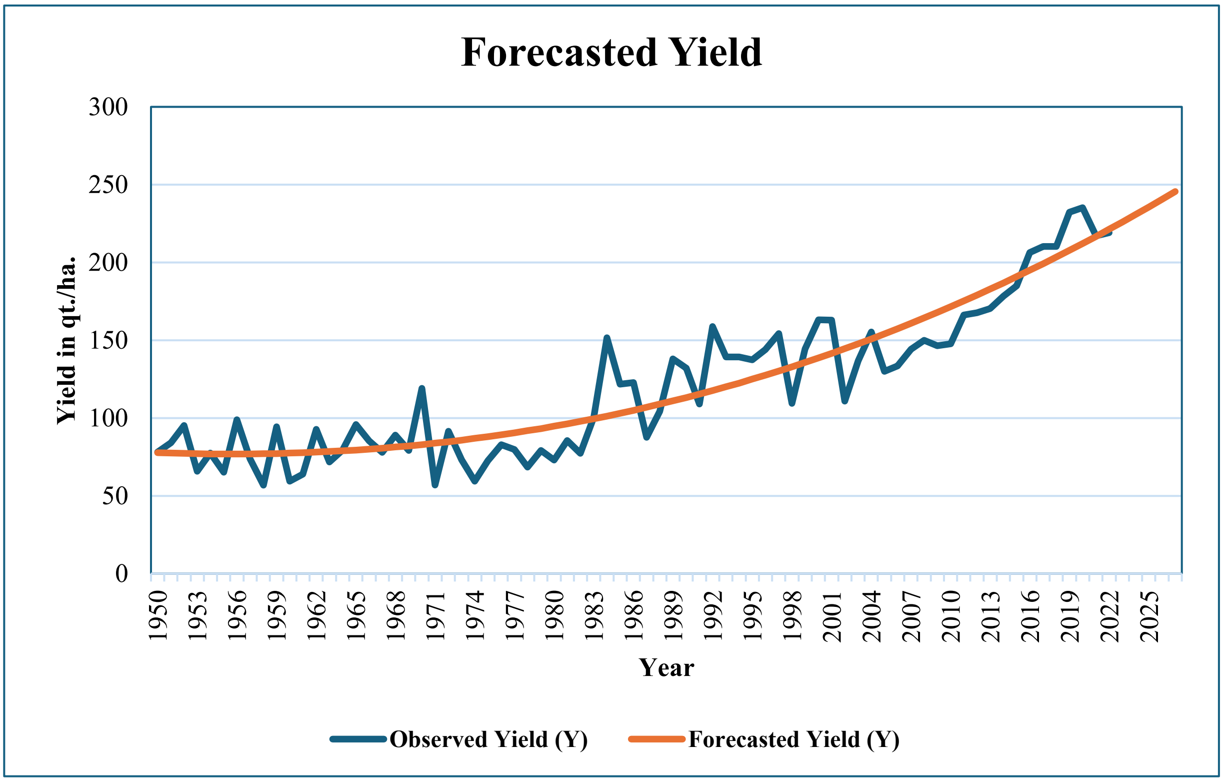

Figure 4.8: Observed and forecasted trends of Maize production in Uttar Pradesh (1950-2027)

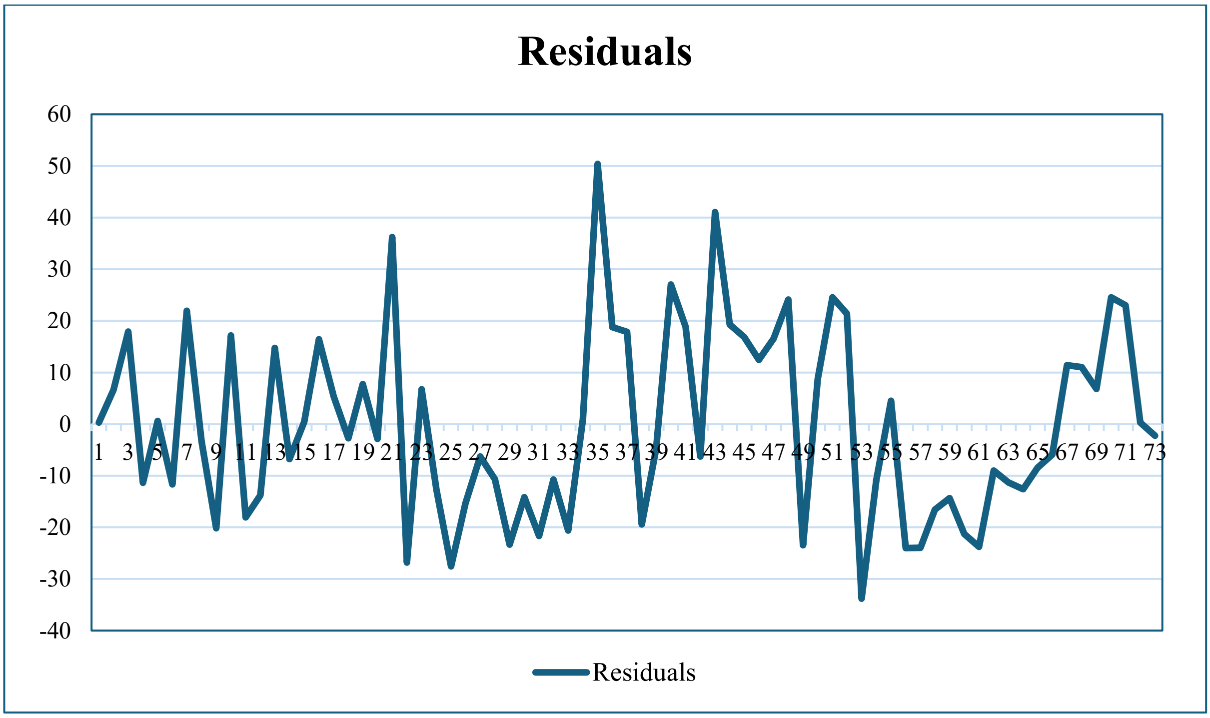

Figure 4.9: Cubic model plots of the residuals of forecasted Maize production data (1950-2022)

4.3 Analysis of Instability Index and Decomposition Analysis for Maize Production in Uttar Pradesh

For the instability index and decomposition analysis using Excel software.

4.3.1 Instability index of area, production and yield of Maize

One shouldn't be oblivious of instability by taking the growth rate only, because the growth rate will explain only the rate of growth over the period, whereas instability judges whether the growth performance is stable or unstable for the period for the material variable. To know the instability in the area, the production and yield of the crop the change is measured with the help of measures of variation and mean. The simple measure of variation (CV) constantly contains the trend element and thus overestimates the position of instability in the time series data characterized by a long-term trend. To overcome this problem, this study used the instability index given by Cuddy Della Valle (1978), which corrects the measure of variation.

Overall period (1950-2022) CV and CDVI of Maize in Uttar Pradesh were estimated and presented in Figure 4.10. For the overall period (1950–2022), the Coefficient of variation (CV) was highest, and the Cuddy Della Valle Instability Index (CDVI) was smallest were recorded as 22.11% and 17.70% for the area of the Maize crop. Coefficient of variation highest and the Cuddy Della Valle Instability Index, the smallest, were set up for production independently, 28.03%, 21.01% and yield the highest CV, 39.48% and the CDVI was the smallest 18.95%.

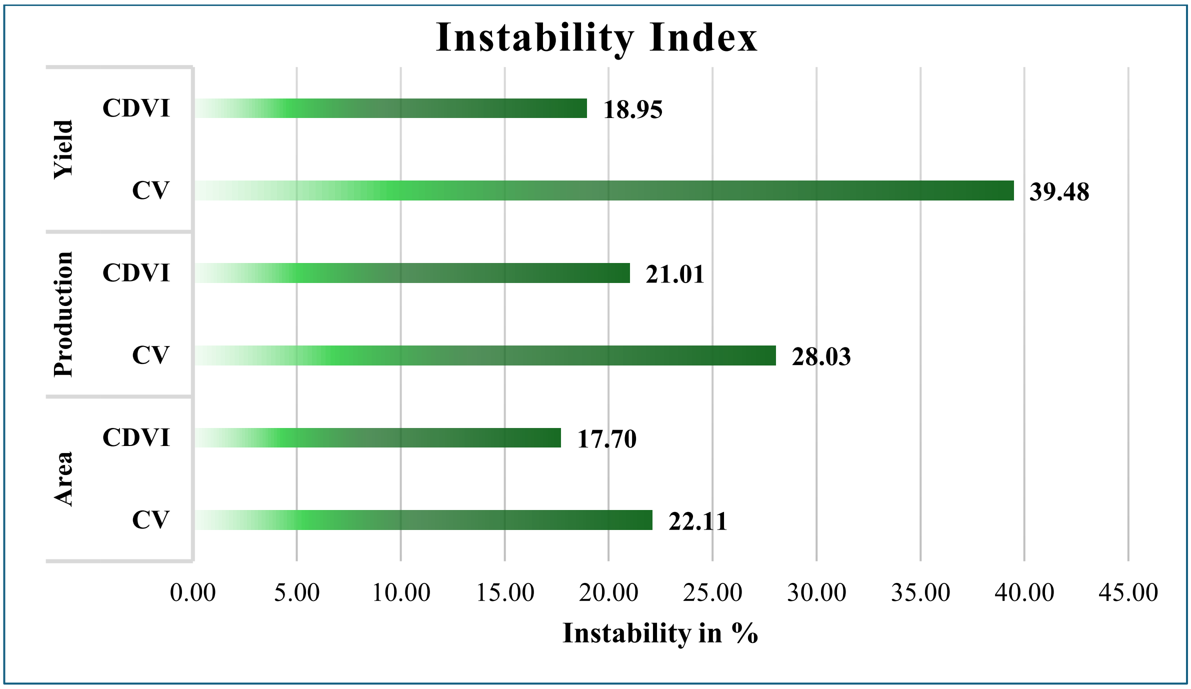

Figure 4.10: Instability index of area, production and yield of Maize in Uttar Pradesh (1950-2022)

4.3.2 Decomposition analysis of Maize production

The relative contribution of yield, area and their interaction to the change in production of Maize in Uttar Pradesh is presented in Figure 4.11.

It could be seen from the table that during the overall period, all three variables were responsible for the growth in Maize production. During the entire period, production growth was mainly achieved due to the interaction effect (6.2%), followed by the yield effect (3.4%) and area effect (90.4%).

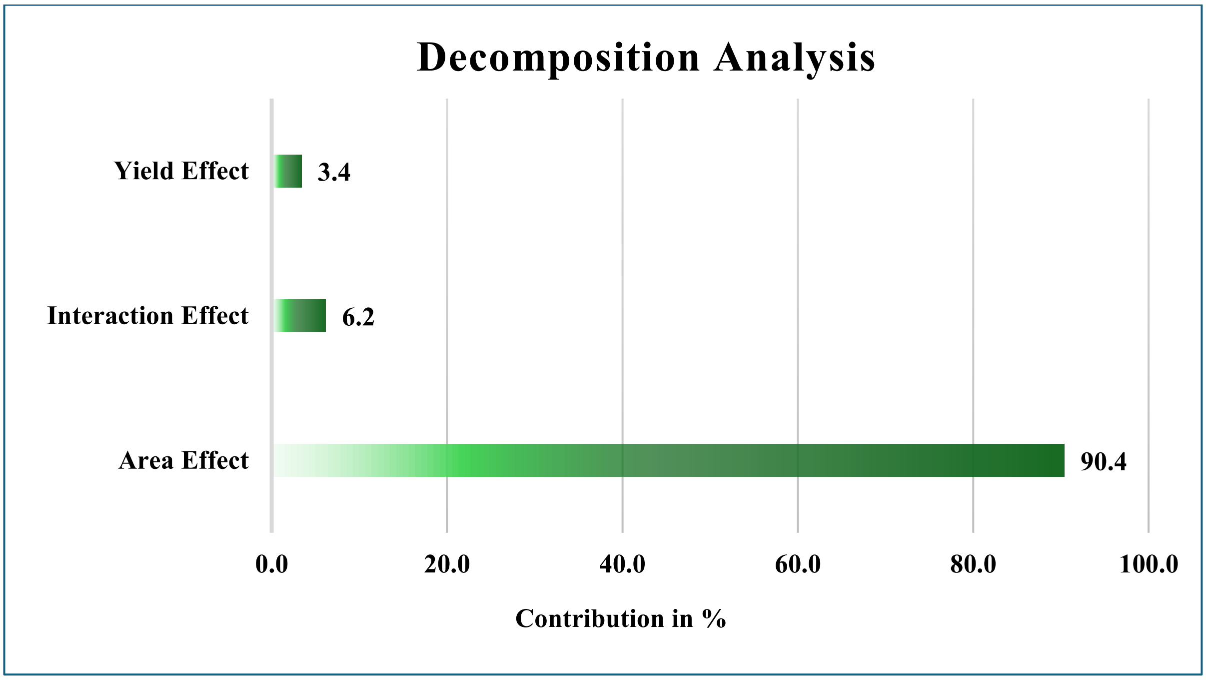

Figure 4.11: Per cent contribution of area, productivity and their interaction for the production of Maize in Uttar Pradesh (1950-2027)

4.4 Suggestions for Long-Term Strategies for Ensuring Stable Maize Production in Uttar Pradesh

The Government of Uttar Pradesh is developing a policy for the Maize crop to promote its cultivation and increase crop production, as well as the secondary products of Maize.

Quick Maize Development Scheme (2024) by the government of Uttar Pradesh. As per the aim of the government Scheme, our result will also increase the area, production and yield of Maize. The current study suggests recommendations to the state level for policymaking aimed at farmers' welfare.

4.4.1 Yield improvement as a priority

Perfecting Maize yield is pivotal for ensuring food security, enhancing profitability and perfecting planter well-being. With the rising population and shrinking agrarian land, maximizing Maize production per unit area has become essential. Advanced breeding ways, high-yielding and cold-blooded Maize kinds, bettered agronomic practices, and the use of ultramodern technologies contribute significantly to advanced productivity.

Yield improvement in Maize also reduces the input cost per unit of area, thereby adding to overall ranch profitability. Both public and private exploration institutions are focusing on particularity-grounded parentage specifically for Maize to ameliorate yield, stress tolerance, and nutritive quality. This focus aligns with public pretensions of doubling planter income and reducing pastoral poverty through sustainable and effective agrarian practices.

4.4.2 Climate-resilient agricultural practices

Climate flexible husbandry involves practices and technologies that help crops adapt to changing climate conditions, such as droughts, floods, extreme heat, and erratic rainfall. ways include the development of stress-tolerant crop kinds, conservation husbandry, water harvesting, and integrated pest management. It also involves rainfall-grounded premonitory services and crop insurance schemes to reduce climate-related pitfalls. These practices help ensure stable yields indeed during adverse rainfall. Promoting similar strategies strengthens food systems and planter rigidity in vulnerable regions.

4.4.3 Sustainable land use and area optimization

Sustainable land use means using land in a way that meets current agricultural requirements without degrading its long-term value. It includes practices like crop rotation, intercropping, agroforestry, and organic husbandry. Area optimization refers to relating and cultivating the right crops in suitable regions(agro-ecological zoning) to maximize productivity. The use of Civilians, remote sensing, and soil health mapping helps in scientific land use planning. This approach conserves natural coffers, prevents land degradation, and ensures long-term agrarian sustainability.

4.4.4 Development of market and infrastructure

Developing Effective request and structure systems is vital to connect growers to consumers, reduce post-harvest losses and ensure fair prices. Structure includes cold storehouse, transportation, pastoral roads, irrigation, storage and recycling units. Digital platforms and e-NAM also enhance request access. Strengthening FPOs (Farmer Patron Organizations) and collaborative marketing can increase growers' logrolling power. More structure leads to reduced destruction, better value creation, and further investment in husbandry, eventually supporting pastoral development.

SUMMARY AND CONCLUSION

SUMMARY AND CONCLUSION

This chapter expands on prior work and highlights specific conclusions drawn from the investigation.

5.1 Summary

The study focused on the growth rates of Maize area, production and yield from 1950 to 2022 in Uttar Pradesh. And the instability of area, production and yield of Maize throughout the year by CV and CDVI.

The study focused on the contribution of area and yield to the production of Maize by decomposition analysis.

The study aims to identify the most accurate linear and non-linear growth models for predicting future trends pattern in the Maize area, production, and yield from 1950 to 2022, with projections extended up to 2027.

The selection of the optimal model for forecasting up to 2026 relies on criteria including the maximization coefficient of determination R^2 and $Adj.R^2$ Coefficients while minimizing RMSE and MAPE values. Conducted in Uttar Pradesh, the exploration focuses on determining which model best fits the data to enhance understanding of implicit agricultural issues and inform decision-making processes.

The study focused on creating a comprehensive long-term forecast analysis of agricultural output, offering essential insights into future Maize crop production for the benefit of the general public, researchers, and decision-makers. By providing a deeper understanding of potential change in Maize crop output, the study enables informed judgments regarding agricultural management and food commerce. Its objective was to establish effective models capable of explaining predicted values using a range of linear and non-linear models, including linear, exponential, quadratic, quintic and cubic models. The required time series data regarding the area, production, and yield of Maize in Uttar Pradesh were obtained from the Indiastat.

The data period from 1950 to 2022 was collected from the Indiastat and on website. (*https://www.indiastat.com/data/agriculture/Maize-17199*)

For the projection of Maize area, production, and yield up to 2027, model with the highest R^2 and $Adj.R^2$. The model accuracy, along with the lowest RMSE and MAPE values, was selected.

Based on this study, we conclude some important values of Maize crops according to their area, production, and yield.

In the research phase, Uttar Pradesh's Maize cultivation covered an average area of 10.41 lakh hectares, production of around 11.80 million tonnes, with a yield of 120.22 quintals per hectare. However, future projections using a cubic model indicate a notable anticipated growth in area, production and yield. By 2027, it's forecasted that the Maize cultivation area will increase to 8.57 lakh hectares, with production to 17.70 million tonnes, and yield reaching 245.57 quintals per hectare. As per the research, various linear regression was utilized to predict Maize production using area and yield parameters. The outcome showed statistical significance at the 5% level for the Maize crop. The model possessing the highest coefficient of determination is deemed the most effective in forecasting future output based on area and yield factors.

5.2 Conclusion

The overall growth rates of maize area, production, and yield showed a decline in area, a slight increase in production, and a moderate improvement in yield. In the first period, both area and production increased, while yield registered only a marginal rise. In the second period, area declined, but production and yield recorded significant growth. In the third period, area again declined, with moderate increases in both production and yield.

The research finding indicates that the cubic model is the most suitable for estimating the area of Maize, with projected areas showing an increasing trend. The finding indicates that the cubic model is optimal for forecasting the production of Maize, showing an increasing trend. The finding indicates that the cubic model is optimal for forecasting the yield of Maize, showing an increasing trend. By 2027, Maize is anticipated to experience an upward trend in area, production and yield.

Overall, the study revealed that the area, production and yield under cultivation of Maize crops are expressing a positive trend for the next 5 years. The research suggests that farmers expand the cultivation area of Maize to increase profitability through higher yields. Furthermore, it advocates for government initiatives and policies to encourage farmers to increase the production of the Maize crop.

The growth dynamics of maize reveal varying trends over different periods. Overall, the maize area showed a declining trend, while production and yield experienced moderate growth. In the first period, the area under maize cultivation and its production both increased, but yield showed only a slight rise. During the second period, the cultivated area declined; however, there was significant growth in both production and yield, indicating improvements in productivity despite reduced area. In the third period, the area continued to decline, but production and yield saw moderate increases, suggesting ongoing yield improvements compensating for shrinking cultivation area.

Regarding variability, maize yield exhibited the highest coefficient of variation, indicating that yield experienced the greatest relative fluctuations over time compared to production and area. Maize production had the next highest variability, while the area under cultivation showed the least variation, suggesting that acreage was relatively more stable compared to yield and production.

The instability of maize parameters, measured by the Cuddy-Della Valle Instability Index, was greatest in production, followed by yield, with area showing the least instability. This pattern reflects how production is more influenced by factors causing fluctuation, such as climate or management practices, while the area remains comparatively steady.

In terms of contribution to production changes, the effect of the area under maize cultivation was predominantly high, indicating that changes in the area contributed the most to production variability. The yield effect contributed a smaller but meaningful share, showing that improvements in yield also impacted production levels. The interaction effect between area and yield contributed a modest proportion to overall production change, highlighting the combined influence of both these factors on maize production.

This detailed examination underscores that while maize area is more stable and the main driver of production change, yield improvements and their interactions with area changes also play important roles in influencing maize production outcomes. The fluctuating nature of yield and production points to the need for targeted interventions to stabilize and enhance maize productivity.

5.3 Implications

1. A third-degree polynomial was found to be the most appropriate model for predicting upcoming trends in the pattern of Maize area, production, and yield based on secondary data collected. This model is easy to use. As a result, it may be employed to forecast future trends, which will be beneficial to policymakers.
2. Predicting crop production is highly beneficial for global commodity marketing, as well as for the exports and imports of this particular agricultural product.
3. Forecasts can assist policymakers in anticipating future demand for grain storage for importing or exporting, allowing them to implement appropriate policies in response.

5.4 Future Line of Work

The study focused on one crop and utilized a limited number of models. Therefore, it is suggested that:

1. Data from the crop may be used to fit models for predictions.
2. Predictive modeling can also be conducted using advanced algorithms like Machine Learning (ML) and Artificial Neural Networks (ANN).
3. Given that the research centered on Uttar Pradesh data for Maize, it implies that data from various regions and countries could be used to construct models and forecast yields for a range of crops.
4. Using multiple linear regression analysis showed that the expected models for Maize crop production were statistically significant. Additionally, apart from area and yield, other factors were found to influence crop production.
5. Study of the individual varietal comparison of Maize in Uttar Pradesh and India.
6. Study of Maize impact with climatic variables (rainfall, temperature, relative humidity, etc.) in Uttar Pradesh and India.

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LITERATURE CITED

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APPENDIX

APPENDIX

Time series data on area, production and yield of maize in Uttar (1950-51 to 2022-23)

Year	Area(In lakh ha.)	Production (In million tonnes)	Yield (In qt./ha.)
1950	8.34	6.51	78.06
1951	8.24	6.93	84.10
1952	8.60	8.18	95.12
1953	10.26	6.74	65.69
1954	10.50	8.14	77.52
1955	9.60	6.26	65.21
1956	10.14	10.02	98.82
1957	10.83	7.98	73.68
1958	10.93	6.21	56.82
1959	10.92	10.3	94.32
1960	10.54	6.25	59.30
1961	10.86	6.94	63.90
1962	10.75	9.97	92.74
1963	10.86	7.78	71.64
1964	11.20	8.88	79.29
1965	11.70	11.21	95.81
1966	12.61	10.76	85.33
1967	14.56	11.34	77.88
1968	15.02	13.38	89.08
1969	15.05	11.92	79.20
1970	15.08	17.96	119.10
1971	14.79	8.43	57.00
1972	14.83	13.57	91.50
1973	14.87	10.88	73.17
1974	13.94	8.27	59.33
1975	13.96	10.14	72.64
1976	13.23	10.97	82.92
1977	11.93	9.52	79.80
1978	11.77	8.06	68.48
1979	11.53	9.12	79.10
1980	12.24	8.94	73.04
1981	11.74	10.04	85.52
1982	10.84	8.37	77.21
1983	11.06	11.11	100.45
1984	11.64	17.65	151.63
1985	12.00	14.62	121.83
1986	12.06	14.81	122.80

Contd…

Year	Area(In lakh ha.)	Production (In million tonnes)	Yield (In qt./ha.)
1987	11.42	9.99	87.48
1988	11.54	12.021	104.17
1989	11.50	15.869	137.99
1990	10.85	14.322	132.00
1991	10.67	11.636	109.05
1992	10.76	17.076	158.70
1993	10.74	14.963	139.32
1994	10.74	14.963	139.32
1995	10.90	14.98	137.43
1996	10.66	15.359	144.08
1997	10.63	16.403	154.31
1998	9.96	10.9	109.44
1999	9.56	13.81	144.46
2000	9.14	14.912	163.15
2001	9.31	15.17	162.94
2002	7.80	8.64	110.77
2003	8.42	11.52	136.82
2004	8.69	13.5	155.35
2005	8.45	10.99	130.06
2006	8.72	11.639	133.47
2007	8.38	12.09	144.27
2008	7.99	11.98	149.94
2009	7.09	10.39	146.54
2010	7.54	11.14	147.75
2011	7.87	13.08	166.20
2012	7.36	12.345	167.73
2013	7.67	13.062	170.30
2014	7.17	12.79	178.38
2015	6.05	11.19	184.96
2016	7.39	15.25	206.36
2017	7.18	15.093	210.21
2018	7.18	15.093	210.21
2019	7.29	16.936	232.32
2020	7.73	18.181	235.20
2021	7.47	16.21	217.00
2022	8.91	19.52	219.08

Source: Indiastat 2022. ***(https://www.indiastat.com/data/agriculture/maize-17199)***

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COMMUNICATED RESEARCH PAPERS

1. **Pal, A.**, Mehta, V. and Deepa, V. 2025. Analysis of trends, decomposition, growth, and instability in Maize production of Uttar Pradesh. Paper contributed at *Environment and Ecology*.
2. Deepa, V., Mehta, V. and **Pal, A.** 2025. Integrative statistical modelling and policy framework for growth dynamics, production volatility, and decomposition analysis of turmeric cultivation in southern India. Paper contributed at *Proceedings of the National Academy of Sciences, India Section B: Biological Sciences*.

3. Deepa, V., Mehta, V. and **Pal, A.** 2025. Advanced time series forecasting of turmeric production using ARIMA modelling: An empirical analysis in selected southern states of India. Paper contributed at *Environment and Ecology*.
4. Shukla, S.S., Singh, V.K., Dwivedi, K. and **Pal, A.** 2025. Integrated study of leaf rust Disease Scoring, Genetic advance, and Phenotypic Correlation in Wheat Genotypes. Paper contributed at *Archives of Current Research International.*

DECLARATION

I hereby declare that all the information furnished above is true to the best of my knowledge & belief; documentary evidences will support them as and when required.

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ABSTRACT

Maize (*Zea mays* L.) is a globally cultivated cereal crop used for food, animal feed, and industrial purposes. It flourishes in hot regions with proper drainage and sufficient rainfall. In India, it is primarily cultivated in regions such as Karnataka, Madhya Pradesh, and Uttar Pradesh. Uttar Pradesh cultivates maize in Rabi, Kharif, and Zaid seasons, primarily as a Kharif crop, despite its cultivation throughout the state. The secondary time series data of maize area, production and yield collected from the indiastat website spanning 1950-51 to 2022-23. The study utilizes the coefficient of variation, instability index and growth rate for the analysis of the time series data. The growth rate was computed by Compound Annual Growth Rate, while the instability index was evaluated by Coefficient of variation (CV) and Cuddy-Della Valle Index (CDVI). For the growth rate of maize throughout the study period, divided into 4 sub-periods: Overall Period (1950 - 2022), Period I (1950 - 1973), Period II (1974-1997) and Period III (1998-2022). Trend values have been measured by applying well-known statistical linear and nonlinear regression models, likely the linear model, power model, logarithmic model, quintic model, exponential model, quadratic model, and cubic model. Furthermore, the accuracy of these fitted models has been evaluated using statistical parameters such as the coefficient of determination (R^2), Adjusted R^2 and root mean square error (RMSE), and relative mean absolute percentage error (RMAPE). Based on these statistical measures viz., coefficient of determination (R^2), Adjusted R^2 and root mean square error (RMSE), and relative mean absolute percentage error (RMAPE), the cubic model is the best-fitted model for area, production and yield of maize in Uttar Pradesh. Decomposition analysis of Maize indicates that the area effect was the most significant factor in increasing maize production in Uttar Pradesh.

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सारांश

मक्का (*जिया मेज* एल.) एक वैश्विक स्तर पर उगाई जाने वाली अनाज फसल है, जिसका उपयोग भोजन, पशुचारे और औद्योगिक उद्देश्यों के लिए किया जाता है। यह गर्म क्षेत्रों में उचित जल निकासी और पर्याप्त वर्षा की स्थिति में अच्छी तरह पनपती है। भारत में मक्का का प्रमुख उत्पादन क्षेत्र कर्नाटक, मध्यप्रदेश और उत्तरप्रदेश जैसे राज्य हैं। उत्तर प्रदेश में मक्का की खेती रबी, खरीफ और जायद तीनों मौसमों में की जाती है, हालांकि यह मुख्यतः खरीफ फसल के रूप में उगाई जाती है और पूरे राज्य में व्यापक रूप से बोई जाती है। इस अध्ययन में मक्का की क्षेत्रफल, उत्पादन और उपज से संबंधित द्वितीयक टाइम सीरीज डेटा का उपयोग किया गया है, जिसे इण्डिया स्टेट वेबसाइट से 1950–51 से 2022–23 की अवधि के लिए एकत्र किया गया है। इस टाइम सीरीज डेटा के विश्लेषण के लिए परिवर्तन शीलता गुणांकै, अस्थिरता सूचकांक और वृद्धि दर का उपयोग किया गया है। वृद्धि दर की गणना चक्र वृद्धि वार्षिक वृद्धि दर के माध्यम से की गई है, जबकि अस्थिरता सूचकांक का आकलन परिवर्तन शीलता गुणांक और कड्डी डेला वाले सूचकांक द्वारा किया गया है। पूरे अध्ययन काल के दौरान मक्का की वृद्धि दर को चार उप–अवधियों में विभाजित किया गया है: अवधि प्रथम (1950–1973), अवधि द्वितीय (1974–1997), अवधि तृतीय (1998–2022) और समग्र अवधि (1950–2022)। प्रवृत्तिमान को मापन करने के लिए प्रसिद्ध सांख्यिकीय रैखिक और अरैखिक प्रतिगमन मॉडल जैसे रैखिक मॉडल, लॉगरिदमिक मॉडल, घातांकीय मॉडल, पावर मॉडल, द्विघात मॉडल, त्रिघात मॉडल और पंचघात मॉडल का प्रयोग किया गया है। इन प्रतिरूपों की सटीकता का मूल्यांकन निर्धारण गुणांक आर स्क्वायर, समायोजित आर स्क्वायर, रूट मीन स्क्वेयर एरर, तथा सापेक्ष माध्य निरपेक्ष प्रतिशत त्रुटि जैसे सांख्यिकीय मापदंडों के आधार पर किया गया है। इन मापदंडों के अनुसार, क्षेत्रफल, उत्पादन और उपज के लिए त्रिघात मॉडल को सबसे उपयुक्त पाया गया। मक्के के उत्पादन की व्याख्या हेतु किए गए अपघटन विश्लेषण से यह ज्ञात हुआ कि उत्तर प्रदेश में मक्का उत्पादन में वृद्धि के लिए क्षेत्रफल प्रभाव सबसे महत्वपूर्ण कारक रहा।

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