

**IDENTIFYING APPROPRIATE STATISTICAL GROWTH
MODELS FOR COMPUTATION OF COMPOUND GROWTH
RATES OF MAJOR OILSEEDS AND PRINCIPAL CROPS OF
CHHATTISGARH**

M.Sc. (Ag) Thesis

By

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CHHATTISGARH**

Thesis

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by

Umesh Kumar Kashyap

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CERTIFICATE – I

This is to certify that the thesis entitled “Identifying appropriate statistical growth models for computation of compound growth rates of major oilseeds and principal crops of Chhattisgarh” submitted in partial fulfillment of the requirements for the degree of Master of Science in Agriculture of the Indira Gandhi Krishi Vishwavidyalaya, Raipur is a record of the bonafide research work carried out by **Umesh Kumar Kashyap** under our guidance and supervision. The subject of the thesis has been approved by the Student’s Advisory Committee and the Director of Instructions.

No part of the thesis has been submitted for any other degree or diploma or certificate course. All the assistance and help received during the course of the investigations have been duly acknowledged.


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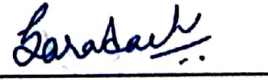
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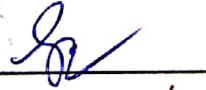
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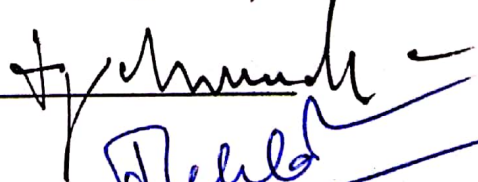

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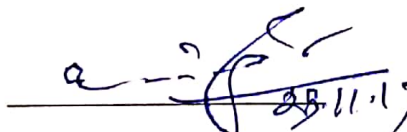
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4.2.6.3	Urd production ('000 MT) in Chhattisgarh (1998-99 to 2017-18)	100
4.2.6.5	Urd productivity (Kg/ha) in Chhattisgarh (1998-99 to 2017-18)	100

LIST OF ABBREVIATIONS/NOTATIONS

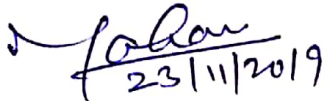
%	Percent
<i>et al</i>	And others
i.e.,	That is
etc.	Et cetera
Ha	Hectare
MT	Metric ton
Kg	Kilogram
MSE	Mean Square Error
RMSE	Root Mean Square Error
AIC	Akaike's information criteria
BIC	Bayesian Information criteria
GR	Growth Rate
CGR	Compound Growth Rate
CAGR	Compound Annual Growth Rate
TMO	Technology Mission Oilseed
HYV	High Yielding Variety
GOI	Government of India
MOA&F	Ministry of Agriculture and Farmers Welfare
TRFA	Targeting Rice Fallow Areas

THESIS ABSTRACT

- a) Title of the Thesis : Identifying appropriate statistical models for computation of compound growth rate of major oilseeds and principals crops in Chhattisgarh
- b) Full Name of the Student : Umesh Kumar Kashyap
- c) Major Subject : Agricultural Statistics
- d) Name and Address of the Major Advisor : Dr. M.L. Lakhera
Department of Agricultural Statistics and Social Science(L.), College of Agriculture, Raipur (C.G.)
- e) Degree to be Awarded : Master of Science in Agriculture (Agricultural Statistics)

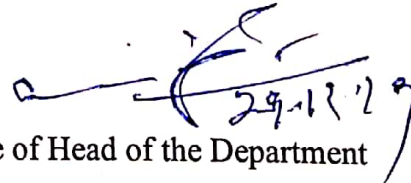


Signature of the Student



Signature of the Major Advisor

Date: 23/11/2019

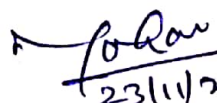


Signature of Head of the Department

ABSTRACT

Oilseed crops occupy a predominant place in an Indian economy next to food grains. In this study, an attempt made to identifying appropriate statistical models for computation of compound growth rate of major oilseeds and principals crops in Chhattisgarh State using non linear statistical models with a view to study trends of major oilseed crops and principal crops of Chhattisgarh; fitting appropriate statistical growth models for area, production and yield of major oilseeds crops and principal crops and Computation of compound growth rate based on suitable growth model for area, production and yield.

The study was based on time series data pertaining to the area, production and productivity of oilseeds, cereals and pulses for the period of 20 years (i.e. 1998-99 to 2017-18) is obtained from department of agriculture, Chhattisgarh. Attempts have been made using four statistical growth models Monomolecular, Logistic, Gompertz and Exponential models. The best model selection is based on criteria like lowest MSE, RMSE, AIC, and BIC, calculated through the Statistical Software "R: The R Project for Statistical Computing". After identifying best model compound growth rate (CGR) also calculated for oilseeds, cereals and pulses crops.


23/11/2019

Department of Agricultural Statistics and Social Sciences (L.)

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Major Advisor

थीसिस सारांश

- अ) शोध का शीर्षक : छत्तीसगढ़ में प्रमुख तिलहनों और प्रमुख फसलों की मिश्रित विकास दर की गणना के लिए उपयुक्त सांख्यिकीय मॉडल की पहचान करना
- आ) छात्र का पूरा नाम : उमेश कुमार कश्यप
- इ) मुख्य विषय : कृषि सांख्यिकी
- ई) प्रमुख मार्गदर्शक का नाम : डॉ एम.एल. लखेरा
एवं पता : प्रोफेसर,
कृषि सांख्यिकी एवं सामाजिक विज्ञान
विभाग, कृषि महाविद्यालय, रायपुर
(छ.ग.)
- उ) डिग्री : कृषि में स्नातकोत्तर

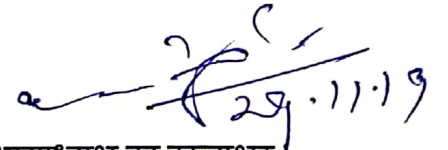


छात्र का हस्ताक्षर



प्रमुख मार्गदर्शक का हस्ताक्षर

दिनांक: 23/11/2019



विभागाध्यक्ष का हस्ताक्षर

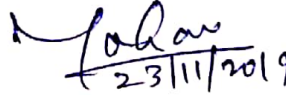
सारांश

तिलहनी फसलो का भारतीय अर्थव्यवस्था में खाद्यान के बाद में प्रमुख स्थान हैं। इस अध्ययन में, छत्तीसगढ़ राज्य के प्रमुख तिलहनों और प्रमुख फसलों की मिश्रित विकास दर (CGR) की गणना के लिए उपयुक्त सांख्यिकीय मॉडल की पहचान करने का प्रयास किया गया है, जिसमें प्रमुख छत्तीसगढ़ की तिलहनी फसलों और प्रमुख फसलों के ट्रेंड का अध्ययन करने के लिए गैर रेखीय सांख्यिकीय मॉडल (नॉन लीनियर सांख्यिकीय मॉडल) का उपयोग किया गया है। जिसमें प्रमुख तिलहनी और प्रमुख फसलों के क्षेत्र, उत्पादन और उपज के लिए उपयुक्त सांख्यिकीय विकास मॉडल तैयार करना और क्षेत्र, उत्पादन और उपज के लिए उपयुक्त विकास मॉडल के आधार पर मिश्रित विकास दर (CGR) की गणना करना है।

इस अध्ययन में तिलहन, अनाज और दाल वाली फसलो की क्षेत्र, उत्पादन, और उत्पादकता से संबंधित 20 साल की अवधि (यानी 1998-99 से 2017-18) के आंकड़ों संकलन कृषि विभाग, छत्तीसगढ़ से प्राप्त किया गया है। इस अध्ययन में चार सांख्यिकीय विकास मॉडल मोनोमोलेक्यूलर, लॉजिस्टिक, गोम्पर्टज़ और एक्सपोनेंशियल मॉडल का उपयोग किया गया है। सर्वश्रेष्ठ मॉडल का चयन सांख्यिकीय सॉफ्टवेयर "आर: आर प्रोजेक्ट फॉर स्टैटिस्टिकल कंप्यूटिंग" के माध्यम से गणना की गई न्यूनतम MSE, RMSE, AIC और BIC जैसे मापदंडों पर आधारित है। सर्वोत्तम मॉडल की पहचान करने के बाद तिलहन, अनाज और दलहन फसलों के लिए मिश्रित विकास दर (CGR) की भी गणना की गई है।

कृषि सांख्यिकी एव सामाजिक विज्ञान विभाग,

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23/11/2019

डॉ एम.एल. लखेरा

प्रमुख मार्गदर्शक

CHAPTER - I

INTRODUCTION

1.1 Background

Agriculture plays a crucial role in the economic development of any developing country, by providing food to the nation, exports to other countries, contribution to capital formation and securing markets for industrialization. It also provides raw materials for a large number of industries and provides employment to 70 to 80% rural population.

Oilseeds crops are grown all over the world and it is considered the most important crop due to their economic value. Oilseeds are mainly grown for edible oil purposes. The main source of edible oil comes from crop resources. Recently, oilseeds attracted more attention because of increasing demand for their healthy vegetable oil, biofuels, pharmaceuticals, livestock feeds, and other industrial use. In the world, India is one of the largest producers and consumers of vegetable oils. In Indian agriculture economy, oilseeds crops play important role after food grains in terms of area and production. The total area of food grain in India is 1275.24 lakh ha, production is 2850.14 lakh tons and productivity is 2235 kg/ha in 2017-18. The total oilseeds cultivable area of India is 245.08 lakh ha, the total production is 314.59 lakh tons and productivity is 1284 kg/ha in 2017-18 (**Directorate of economics and statistics**).

Oilseeds crops require a tropical climate with a temperature range of 20-30 °C. Oilseeds crops do not withstand in continuous drought it requires 50-75 cm rainfall. The well-drained light sandy loams, red, yellow and black soil are well suitable for oilseed cultivation. Indian climate is suitable for oilseeds cultivation, hence large amount of oilseeds and varieties of oilseeds are cultivated here.

The major annual oilseeds crops are cultivated in our country are Groundnut, Rapeseed and Mustard, Caster seed, Sesamum, Safflower, Sunflower, Soybean, Niger seed, and Linseed, etc. Oilseeds cultivation in the country mainly

done in small marginal lands, where no irrigation facilities are available and low inputs are used in cultivation. To improve the oilseeds situation in the country, the Indian government started several development programs like the National Oilseed and Development Project, Technology Mission Oilseeds (TMO).

Chhattisgarh is a state situated in Central India. Chhattisgarh state was separated from Madhya Pradesh on 1st November 2000. In India, Chhattisgarh is the 10th biggest state. The Chhattisgarh state is topographically situated somewhere in the range of 17^o46'N and 23^o15 North Latitude and 80^o30'E and 84^o23' East Longitude. Tropical Climate found in Chhattisgarh. It is hot and humid in view of its closeness to the Tropic of Cancer and its reliance on the storm for downpours. Summer temperature can reach 45 ^oC (113 ^oF). The period of monsoon begins from mid-June to October. Yearly precipitation of Chhattisgarh lies between 1200 to 1600 mm. The majority of the population (~ 80%) depends on agriculture.

The total geographical area of the state is 137.90 lakh ha in which 65.25 lakh is the cultivable area in which is 47.31 % of the total area. The 47.75 lakh ha region goes under Kharif crops and 17.50 lakh ha region goes under Rabi crops. The cropping intensity of Chhattisgarh is 133%. 10.47 lakh ha region comes under double area with 31 % area comes under irrigation (Net Irrigated Area-14.99 lakh ha), the mostly 70 % total cultivated area comes under rainfed conditions. Central plains of Chhattisgarh known as rice bowl of central India. Even though paddy is the principal crop of the state, recent years attention has been focused on increasing the area and production of oilseeds and pulses by Ministry of Agriculture and Farmers' welfare, GOI is identified Chhattisgarh as one of the potential states for improving the oilseeds area and production. Considering scope of growing oilseeds and pulses under rice fallows of the state MoA&F,GOI allocated funds under the scheme Targeting Rice Fallow Areas (TRFA).

The total oilseeds area in the state is 2.67 lakh ha which is 4.09 % of cultivable area and production and yield of oilseeds is 1.69 lakh tons and 461 kg/ha respectively. In Chhattisgarh, oilseeds are grown in Kharif and Rabi seasons. The major oilseeds crops are grown in the state are Soybean (36.03 %), Niger (21.67 %), Rapeseed and Mustard (15.88 %), Groundnut (7.81 %), Linseed (6.82 %),

Sesamum (6.56 %), Sunflower (0.49 %) and Safflower (0.18 %) (CG NLMT Report 2017-18). The major districts where oilseeds crops are cultivated are Raipur, Rajnandgaon, Bilaspur, Durg, Sarguja, Raigarh and Bastar. There are possibilities of the increasing area and production of oilseeds increasing in a state by irrigation facility and motivating the use of low-cost input technologies to framers.

Considering the importance of oilseeds cultivation it is essential to know the present status and scope of increasing oilseeds cultivation in comparison to other major crops grown in the state. Knowledge about the agriculture growth over the years can be known by computing the compound growth rate which is the key helps in making policies about exports/imports at the central level.

Analyzing the growth rate trends in the agricultural area, production and productivity across space and time have a significant concern for researchers as well as policymakers. Examination of compound growth rates helps us to understand land use and changing cropping pattern of a state/ region. Rate of change in the area, production and productivity for a state helps in making suitable policies for the state. However, obtaining a realistic growth rate using a suitable growth model is of utmost important. The present study attempted to obtain a suitable model and compute the compound growth rate of area, production productivity, oilseeds major cereal crops and pulses. To this end an attempt has been made to compute the growth rates of various oilseeds crops vis-à-vis other major crops with appropriate statistical models and methodology.

In the majority of the studies computation of compound growth rates was based on Malthusian function which is the log-linear model. Time series data is fitted to log linearised exponential model and then compound growth rate will be calculated by taking antilog of slope parameters. $\hat{r} = \text{antilog}(\hat{B}) - 1$. However, these computed growth rates are sometimes misleading if the data is not following linearised exponential model. Thus it is important to know the behavior of the time series data under consideration before computing the compound growth rates. To this end finding the suitable model by considering various growth models for the data under consideration is crucial. Then based on the model selected, growth

rate has to be computed for the data. The same has been emphasized by **Chandran and Prajneshu (2005)**.

A number of studies were undertaken to understand the growth pattern of crops in terms of area, production and yield using several statistical tools and techniques range from simple charts, graphs, and diagrams to complex regression analyses. To understand the growth process a sound statistical methodology is essential to know the pattern. A good amount of research has put in this line (**Chandran and Prjneshu (2005)**, **Sarada and Prjneshu (2005)**, **Ross et al (2012)**) to study the growth models especially in the area of nonlinear models and its diagnostics. Understanding the importance of nonlinear models in fitting growth pattern of the area, production and productivity of crops the present study is formulated with the following objectives:

1. To study trends of major oilseed crops and principal crops of Chhattisgarh.
2. Fitting appropriate statistical growth models for the area, production and yield of major oilseed crops and principal crops.
3. Computation of compound growth rate based on a suitable growth model for area, production, and yield.

1.2 Organisation of Thesis

The present thesis is consists of four chapters apart from these references that were presented at the end. A brief review of research done in the past is presented in Chapter II Review of Literature under following subheadings

- 2.1 Computation of growth rates of area, production, and productivity of crops in all India.
- 2.2 Computation of growth rates of area, production, and productivity of crops in Chhattisgarh.
- 2.3 Application of nonlinear growth models for modeling Area, Production and Productivity.

Chapter III deals with Materials and Methods to fulfill the objectives and it has the following subsections

- 3.1 Study area and Source of data.
- 3.2 Computation of compound growth rate using the log-linear model
- 3.3 Linear model
- 3.4 Fitting of Nonlinear models and computation of growth rates
- 3.5 Analytical tools

Chapter IV Results and Discussions presents the crop-wise trend analysis, fitting of various nonlinear growth models, selection of appropriate growth model and computation of growth rates using the selected model and it was organized with the following subsections

- 4.1 Oilseeds situation in Chhattisgarh state
- 4.2 Crop-wise situation in Chhattisgarh state

Chapter V consolidates the thesis and final conclusions. At the end of the thesis references quoted in the thesis were presented.

CHAPTER - II

REVIEW OF LITERATURE

The review of the literature gives an idea about the past research work and provides useful information to the theoretical framework in the present research work. The past review of the literature makes the researcher get an idea into the procedures and methods to be followed in present research work. Related research work done by the past researchers has been discussed under the following heads:

1. Computation of growth rates of area, production, and productivity of crops in all India.
2. Computation of growth rates of area, production, and productivity of crops in Chhattisgarh.
3. Application of nonlinear growth models for modeling Area, Production and Productivity

2.1. Computation of Growth rates of area, production, and productivity of crops at national level

Narain et al. (1984) calculated the compound growth rate (CGR) of wheat production and productivity using all India data from periods 1968-69 to 1978-79. They also computed wheat productivity of various years along with compound growth rates of selected inputs of wheat.

Chakraborty (1989) conducted a macro-level study of the inter-state variations in wheat productivity in India and Madhya Pradesh. He used Cob-Douglas production function and multiple regressions were fitted to the data to find the productivity model involving significant independent variables.

Srivastava and Singh (2003) studied time series data using area, production and productivity of sugarcane for central, eastern and western regions as well as for the whole state with for the period of 1980-81 to 1998-99 and the fitted semi-log equations to estimate compound growth in the area, production, and productivity of sugarcane

Kumar and Bhar (2005) studied the multiple linear regression techniques for developing yield forecasting models of Indian mustard. The weather variables considered for the study were temperature, bright sunshine hours, relative humidity and wind velocity.

Rajendra Prasad et al. (2012) studied the trends in the area, production, and productivity of maize crop in Andhra Pradesh during period 1969-2000. The compound function is best fitted for area and production in case of productivity S-curve is the best-fitted trend function.

Suman Parmar (2012) studied the trend in the area, production and productivity of commercial crops for two periods of data Period I (1968-60 to 1981-82) and Period II (1981-82 to 2009-10).

Chaudhari et al. (2016) estimated the compound growth rates of area, production, and productivity of summer bajra in the Banaskantha district of Gujarat. To studying the compound growth rates by exponential function is was fitted to the data of the area, production, and productivity of Banaskantha district of Gujarat state of period of 2001-02 to 2013-14. The compound growth rate of area, production, and productivity were highly significant and positive.

Arti and Chandan Kumar Rai (2017) studied the growth rate of the area, production, and productivity of Sugarcane crop in Uttar Pradesh. He used the time-series data from the period from 1990-91 to 2014-15 of Uttar Pradesh. The area of Compound annual growth rate (%) is increasing up to 1990, but there is a sharp decreasing in the compound annual growth rate (CAGR) to 0.74. The overall CAGR in area, production and yield were found to be 1.28%, 2.25%, and 0.96%.

Rajan and Palanivel (2017), studied the forecasting and growth model of cotton in Tamil Nadu state. He computed the growth pattern of cotton crops using time series data. They used different regression growth model for forecasting of cotton yield and computed the compound growth rates of the cotton crop. The most commonly used regression models viz; Linear, Cubic, Quadratic, Linear, Logarithmic, Power, etc. The cubic model is best fitted to data, followed by

exponential model for the studied yield trend and prediction of crop yield of cotton.

Parmar et al. (2017), computed the compound growth rates of maize crop in Gujrat. The maize yield data is collected for the time period of 1949-50 to 2007-08 and the annual trend of maize yield was estimated using by regression analysis. The best-fitted model selected on the basis of various criteria viz; R^2 , adjusted R^2 , RMSE, MAE, AIC and BIC values. The growth rate of maize crop and crop trend of maize yield is estimated by regression analysis. The area, production, and yield found to be positive trends of maize crops in Gujrat state.

Viswanatha Reddy K (2017), explain the area, production, yield trends and pattern of oilseeds growth in India. He concludes that the growth rate of the total oilseed area was found positive from 1980-81s to 2011-12. The growth rate of production is higher than the area due to an increase in the yield.

Sundar Rajan M (2018) studied the application of regression models for area, production and productivity growth trends of cotton crop in India. The study was carried out using different growth models viz., linear, cubic, quadratic, exponential, inverse, power, compound, logarithmic, growth and S-curve models to project the area, production, and productivity cotton crop in India for the time period from 1951 to 2013. The study revealed that through all models are significant; the cubic model is the best fitted to area, production and productivity of cotton in India.

2.2 Computation of growth rates of area, production and productivity of crops in Chhattisgarh

Azra Parveen (2013) studied the growth rate in the area, production, and productivity of maize in Surguja district of Chhattisgarh using the time series data from period of 2000 to 2010. The area and production of district are showing a positive growth rate. The growth performance of maize production in period (2000-2010) was observed significant and positive in state of Chhattisgarh.

Shaista Khan (2013) developed nonlinear statistical models for studying area, production and productivity of rice crop in Chhattisgarh. Monomolecular, Gompertz and logistic models came to be the most suitable for the production of rice in Northern hills and whole Chhattisgarh state, logistic and Gompertz models suitable for Bastar plateau.

For modeling of rice productivity, Gompertz and logistic models were found to be the most appropriate for the Northern hill, for whole Chhattisgarh logistic model is suitable. Logistic and Monomolecular models were found to be the best model for describing the area of the state.

Ajay Tegar (2016) studied growth rate in the area, production and productivity of major vegetables in Bilaspur district of Chhattisgarh state, India. The growth comparison of the vegetables between Chhattisgarh state and Bilaspur, the Bilaspur district showed additional growth in area and production as accounted to be 9.74 and 6.78 percent over Chhattisgarh but the productivity of vegetables in the state accounted incremental growth as 3.09 percent over to Bilaspur.

Dikeshwar Nishad, et al. (2016) studied the estimated models for the area, production and yield of Rapeseed-Mustard in Chhattisgarh and its constituent districts. He concluded that more area is under Rapeseed-Mustard in Chhattisgarh plain at a significant periodic partial compound growth rate of 21.086 % after the fifth year and within each fixed period at a non-significant annual partial compound growth rate (CGR).

Pradeep Kumar Ganjeer (2018) studied the trends, the prediction model of the area, production, and productivity of maize in Northern Hills of Chhattisgarh in India. The secondary time series data for maize were collected for the period from 1979-80 to 2012-13 from web sites and various governmental publications. Along with trend he also calculated the compound growth rate (CGR) of maize.

D.R. Agashe (2018) conducted a study of trend analysis of the area of linseed. He shows that the area of major linseed growing districts including Raipur, Durg, Bilaspur, and Rajnandgaon is decreasing at an alarming rate; however, area decreasing in Durg is not significant. The linseed production is increased positively

in Bastar, Raigarh and Surguja districts due to area increased in these districts. Whereas, there is decreasing trend in Bilaspur and Raipur. The linseed productivity in all districts increased significantly due to HYV (High yielding varieties).

D.R. Agashe (2018) studied the trends of the area, production, and productivity of groundnut in different districts of Chhattisgarh. He concludes that the groundnut area is positively increasing and statistically significant. But it is important to note that the groundnut area in the later period of the study is sharply increasing.

The pattern of production and productivity of groundnut is positively increasing due to increased area in these districts including Raigarh, Surguja, Raipur, Bilaspur, Durg and Rajnandgaon due to use of high yielding variety (HYV) and increased fertilizer and pesticide consumption by the farmer.

Durgesh Sagar et al. (2018) studied the growth analysis of the area, production, and productivity of okra in Chhattisgarh. The trend analysis of the area, production and yield were done using data from the period of 2009-10 to 2013-14. The compound growth rate of an area, production, and yield of okra are estimated of the five-year data.

Durgesh Sagar et al. (2019) estimated the growth analysis of the area, production, and productivity of cabbage in Dhamtari district of Chhattisgarh. The growth analysis of the area, production, and productivity of the cabbage crop was done by taking the time series data (2004-05 to 2013-14) and the growth rates were found significant at a 1% level of significance.

2.3 Application of nonlinear growth models for modeling Area, Production and Productivity

Prajneshu and Das (1993) developed three-parameter logistic models for describing the wheat production and fitted it to the data of country from period 1950-91 employing nonlinear estimation procedure.

Prajneshu and P.K. Das (2000) studied the growth models describing state-wise wheat productivity. They used data of the period 1973-74 to 1996-97 in respect of four major wheat-growing States, viz, Punjab, Haryana, Rajasthan, Uttar Pradesh as well as at the all India level. For the study, Monomolecular, Logistic, Gompertz, and Mixed- influence models are used. Gompertz and Logistic models were found to be best fitted to wheat productivity data. On the basis of the selected model, the forecast values were also computed.

Prajneshu and Chandran (2005) studied the Computation of Compound Growth Rates in Agriculture using three nonlinear models viz.; Monomolecular, Logistic and Gompertz models. Using Gompertz and Logistic models, the compound growth rates for the foodgrain production in India during the period 1980 – 2001 have been computed as 2.36% and 2.38%, respectively and the Monomolecular model was found inappropriate for describing the foodgrain production.

Sarada and Prajneshu (2005) discussed the method of appropriate reparameterization in respect to a nonlinear statistical model. The method for identifying appropriate reparameterization then discussed through the use of “Expected value parameters” and “simulation” techniques.

Sanjeev Panwar et al. (2009) studied the different statistical nonlinear models, viz Logistic, Gompertz, Quadratic models were applied for onion export of India and conducted a comparative study for these models.

T.L. Mohan Kumar (2012), discussed the Coffee production modeling in India using nonlinear statistical growth models. Based on performance MMF and Logistic models were found to be the most suitable models to describe a trend in coffee production data and Gompertz and Weibull models were found to be least suitable for describing trend of coffee production in India.

S. Pal (2014), studied forecasting groundnut production of India using nonlinear growth models. Three nonlinear growth models viz; Monomolecular, Gompertz and Logistic models are used for modeling the time series data of groundnut production of India. Under the study, all three models were fitted well in

dataset. Forecasting of India's total groundnut production for the year 2014-15 to 2019-20 has been carried out using suitable growth models.

Panwar (2014), studied the forecasting of growth rates of the yield of the wheat crop in Uttar Pradesh through using nonlinear growth models. The data is collected from various secondary sources for the period of 1970-2010. The compound growth rates are calculated by using nonlinear growth models, viz., Monomolecular, Gompertz and Logistic models. For the studied of the various goodness of fit, results indicated that logistic model was best fitted to the data, followed by Gompertz and Monomolecular growth model for forecasting of wheat production in UP.

Deep Narayan Mukherjee et al. (2016) studies the application of nonlinear growth models for estimation of annual compound growth rates of major pulse crops in Telangana state. The Nonlinear growth models were applied to the data from 1979-80 to 2012-13 of area, production and yield of moong (green gram) in Telangana state and its three regions to estimate compound annual growth rates (CAGR).

D.P. Singh, et al. (2017), developed appropriate nonlinear statistical models for wheat production trend in Madhya Pradesh. For time-series data of wheat production of 36 years (i.e. 1980-81 to 2015-16) are collected from various secondary sources. Monomolecular, Gompertz, Logistic and Richard's models are used for this study of the growth pattern of wheat in Madhya Pradesh and forecast future production.

Rajan and Palanivel (2017), studied a comparison of the nonlinear model to describe growth of cotton. They used six nonlinear growth models Gompertz, Monomolecular, Logistic, Richards, Quadratic and Reciprocal. The aims of this study are to compare goodness fit of six growth models using data of the area, production, and productivity of India. The model parameters (a, b and c), R^2 , RSS and RMSE results are also calculated. For testing of assumption of errors, they used "Run test" and "Shapiro-Wilk" test.

CHAPTER - III

MATERIALS AND METHODS

The present study is carried out with the major objective of analyzing the growth rates of area, production and productivity of oilseeds and main cereal and pluses crops of Chhattisgarh using suitable nonlinear growth models. As mentioned in the introduction computation of growth rates based on the exponential model is not always suitable and sometimes leads to erroneous conclusions. It is better to know the behavior of the time-series data and fit the appropriate model. In this section methodology for computation of compound growth rate using exponential model and selected nonlinear models have been described in detail. This chapter is organized as follows:

3.1 Study area and Source of data

3.2 Computation of compound growth rate using the log-linear model

3.3 Linear Model

3.4 Fitting of Nonlinear models and computation of growth rates

3.5 Analytical tools

3.1 Study area and Source of data:

To study the status of oilseeds, major cereals and pulses in Chhattisgarh state a compound growth rate were computed of area production and productivity for the year 1998-99 to 2017-18.

The secondary data was collected from the Agriculture Department, Chhattisgarh for sixteen years and the remaining four years data are collected from the website of <http://agriportal.cg.nic.in>, i.e. for the period 1998 to 2018. The collected data include oilseeds crops *viz.*, soybean, groundnut, rapeseed & mustard, sunflower, sesamum, and Niger. Apart from oilseeds rice, wheat, tur, urd, moong, gram also included as part of the study for comparison.

3.2 Computation of compound growth rate using the log-linear model

In general compound growth rates of area, production and productivity can be estimated with following equation 3.2.1

$$Y_t = Y_0 (1 + r)^t \quad (3.2.1)$$

Taking log both sides, we will get

$$\ln Y_t = \ln Y_0 + t \ln (1+r)$$

$$\ln Y_t = A + Bt + \varepsilon \quad (3.2.2)$$

Where, $A = \ln (Y_0)$, and $B = \ln (1 + r)$.

Estimates are obtained using "Method of least squares ". Thus, the compound growth rate (r) is estimated as

$$\hat{r} = \exp (\hat{B}) - 1 \quad (3.2.3)$$

Where \hat{B} is the slope of the linearized model fitted to the given data.

3.3 Linear Model

A mathematical model is an equation or a set of equations which represents the behaviour of a system (France and Thornley, 2006). It can be either „linear“ or „nonlinear“. A linear model is one in which all the parameters appear linearly. Some examples of linear model are:

- (a) Multiple linear regression $Y = a_0 + a_1X_1 + \dots + a_nX_n + \varepsilon$, where Y is response variable, X_i are explanatory (or predictor) variables and ε is the error term.
- (b) Polynomial models with one predictor variable $Y = a + b X + \varepsilon$ (First-order model)

3.4 Fitting of Nonlinear models and computation of growth rates

Four nonlinear models viz., Monomolecular, Logistic and Gompertz, and Exponential model were explored to study the growth pattern of each crop area production and productivity considered.

Initially, the trend of the time series data (area/production/productivity) was graphically observed by plotting area/production/productivity against time and discussed the pattern over the years.

3.4.1 Nonlinear Models

Prajneshu and Chandran (2005) described the nonlinear models by “A nonlinear model is one in which at least one of the parameters appears nonlinearly. More formally, in a nonlinear model, at least one derivative with respect to a parameter should involve that parameter. If the derivative of the model depends on one or more parameter it is called a non-linear model.” Some examples of a nonlinear model are:

$$Y(t) = \exp (At + Bt^2) \quad (3.3.1.1)$$

$$Y(t) = At + \exp (-Bt) \quad (3.3.1.2)$$

3.4.2 Growth Models:

Prajneshu and Chandran (2005) described the growth models by a rule as an individual pursues a sigmoid (S-formed growth curve) growth pattern. Such curves begin at some fixed point of time and increment their growth rate monotonically to arrive at an affectation point; after this the growth rate balances out or diminishes to approach asymptotically to some last value. For studying this type of complex process simple linear models are not sufficient and this type of complex process is well explained by nonlinear statistical models. Some important non-linear statistical growth models considered were described below.

3.4.2.1 Monomolecular Model

Monomolecular model is represented by differential equation

$$\frac{dy}{dt} = r (K - Y) \quad (3.3.2.1)$$

Where r is the intrinsic growth rate and K is the carrying capacity of the system. Integrating Eq. (3.3.2.1), we get

$$Y (t) = K - (K - Y_0) \exp (-rt) \quad (3.3.2.2)$$

Where, Y_0 is the value of $Y (t)$ at $t = 0$

3.4.2.2 Logistic Model

The Logistic model is represented by the differential equation

$$\frac{dy}{dt} = r Y (1 - Y/K) \quad (3.3.2.3)$$

Where r is the intrinsic growth rate and K is the carrying capacity of the system. Integrating equation (3.3.2.3), we get

$$Y (t) = K / [1 + (K / Y_0 - 1) \exp (-rt)] \quad (3.3.2.4)$$

Where, Y_0 is the value of $Y (t)$ at $t = 0$

3.4.2.3 Gompertz Model

The Gompertz model is represented by equation

$$\frac{dy}{dt} = r Y \ln (K / Y) \quad (3.3.2.5)$$

Where r is the intrinsic growth rate and K is the carrying capacity of the system. Integration of equation we get

$$Y (t) = K \exp [\ln (Y_0 / K) \exp (-rt)] \quad (3.3.2.6)$$

Where, Y_0 is the value of $Y (t)$ at $t = 0$

3.4.2.4 Exponential Model

The exponential model is represented by the differential equation

$$\frac{dy}{dt} = rY \quad (3.3.2.7)$$

Where r is the intrinsic growth rate. Integration of equation we get

$$Y(t) = Y_0 \exp(-rt) \quad (3.3.2.8)$$

Where, Y_0 is the value of $Y(t)$ at $t = 0$

3.4.3 Computation of compound growth rate:

Computing the growth of any entity over a time period is essential for understanding the past behavior and for future planning. ‘Compound growth rate’ is one of the most frequently used methods for calculating the growth rate models. After identifying the best model for a given data set, the last step is to compute the ‘compound growth rate’, which is given as followings:

$$\frac{d \ln(y)}{dt}, \text{ i.e. } y^{-1} \frac{dy}{dt}$$

For monomolecular, logistic, Gompertz and exponential model, the annual growth rate pertaining periods (t_i, t_{i+1}) [$i = 0, 1, \dots, k-1$, where k denotes the number of data points], using equation (3.3.2.1), (3.3.2.3), (3.3.2.5), and (3.3.2.7) respectively we will get

$$R_t^M = r [K / y(t) - 1] \quad (3.3.3.1)$$

$$R_t^L = r [1 - y(t) / K] \quad (3.3.3.2)$$

$$R_t^G = r \ln [K / y(t)] \quad (3.3.3.3)$$

$$R_t^E = r \quad (3.3.3.4)$$

Where, R_t^M , R_t^L , R_t^G and R_t^E are the compound growth rate of monomolecular, logistic, Gompertz and exponential.

3.5 Analytical tools

In this section brief description of analytical techniques used in the analysis in the present study is presented below.

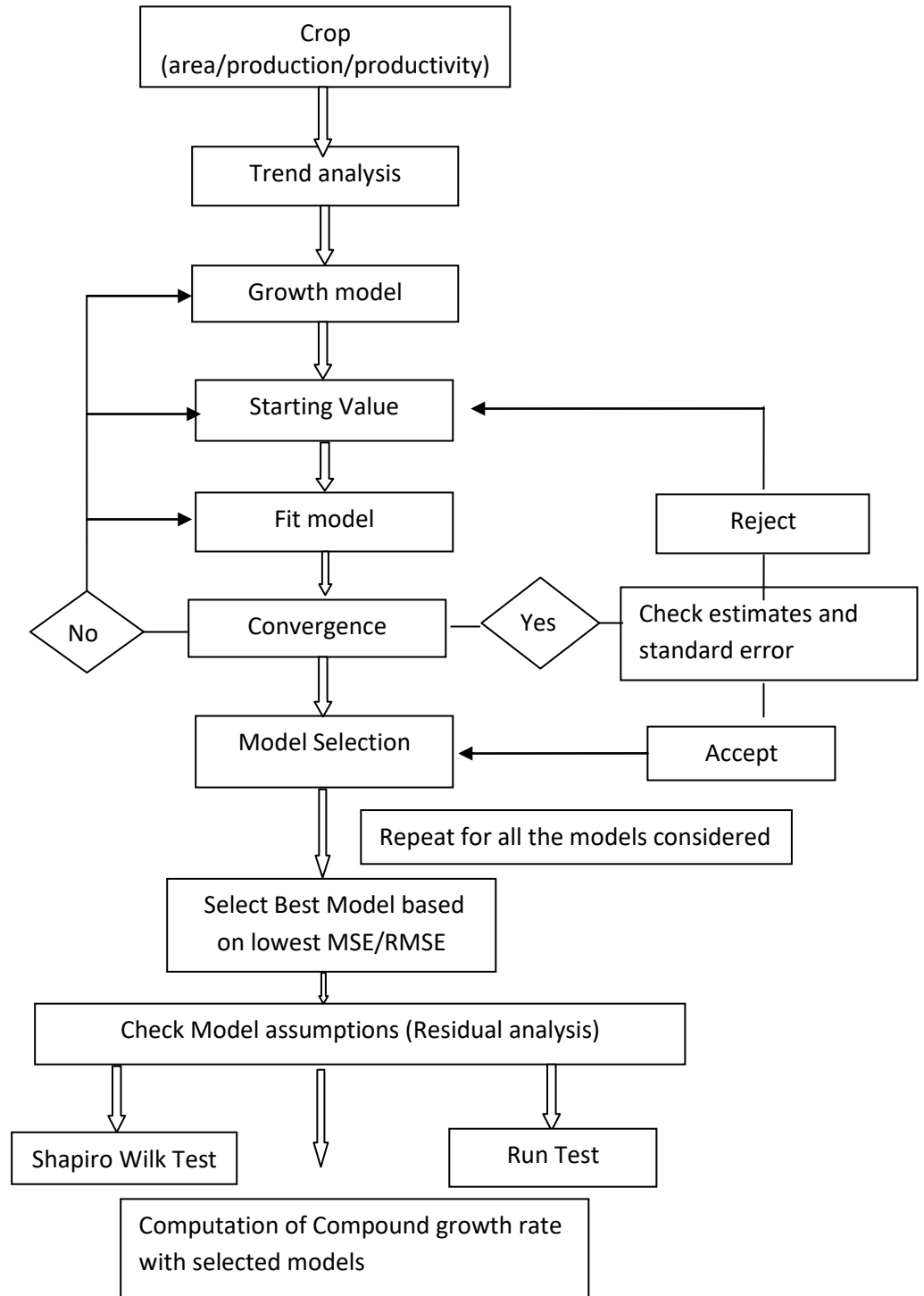


Fig 3.5: Model Selection Procedure

3.5.1 Model Selection Criteria:

Selection of best growth model we used MSE, RMSE, AIC and BIC criteria. The brief discussion of the following methods is described below. These methods are followings:

3.5.1.1 Mean Square Error (MSE)

Mean square error is a single value that provides information about the goodness of the fit of the regression line. The smaller the MSE value, the closer you are to finding the line of best fit.

$$\text{Mean Square Error:} \quad \text{MSE} = \frac{\sum(y-\hat{y})^2}{n} \quad (3.5.1.1)$$

3.5.1.2 Root Mean Square Error (RMSE)

The regression line predicts the average y value associated with a given x value.

$$\text{Root Mean Square Error:} \quad \text{RMSE} = \sqrt{\frac{\sum(y-\hat{y})^2}{n}} \quad (3.5.1.2)$$

3.5.1.3 Akaike's Information Criteria (AIC)

Akaike's information criteria (AIC) is a function of the number of observation n, the SSE and the number of independent variables $k \leq p + 1$, where k includes the intercept

$$\text{Akaike's Information criteria:} \quad \text{AIC} = \frac{(n) \log ((\text{SSError}) / n)}{2k} \quad (3.5.1.3)$$

The first term in the equation is a measure of the model lack of fit while the second term (2k) is a penalty term for additional parameters in the model. Therefore as the number of independent variables k included in the model, the lack of fit term decreases while the penalty term increases.

Conversely, as variable dropped from the model the lack of fit term increases while the penalty term decreases. The model with the smallest AIC is termed the best model since it minimizes the difference from the given model to the true model.

3.5.1.4 Bayesian Information Criteria (BIC)

BIC is a function of the number of observations n , the SSE, the pure error variance fitting the full model (σ^2), and the number of independent variables $k \leq p + 1$, where k includes the intercept

$$\text{Bayesian Information criteria: BIC} = \frac{n \log(SSE/n) + 2(k+2)^2}{SSE} \quad (3.5.1.4)$$

3.5.2 Examination of Residuals

As a measure of goodness of fit, the residual analysis of the models is carried out. The main assumptions made in the models are

- (i) Error is random
- (ii) Errors are normally distributed

3.5.2.2 Shapiro-Wilk test (Test for Normality)

To test whether the residuals are normally distributed Shapiro-Wilk test has been used. The procedure for carrying out the Shapiro-Wilk test has been explained in brief. Commonly used to test the normality of the given observation. The Null hypothesis is given by,

H_0 : The residuals are normally distributed

H_a : The residuals are not normally distributed

The test statistics are given by the following formula $W = S^2 / b$

$$\text{Where, } S^2 = \sum a(k)\{X_{(n+1-k)} - X_{(k)}\} \text{ and } b = \sum (X_i - \bar{X})^2$$

In the above, the parameter k takes values

$$K = \begin{cases} 1, 2, \dots, n/2 \text{ when } n \text{ is even} \\ 1, 2, \dots, (n-1)/2 \text{ when } n \text{ is odd} \end{cases}$$

H_0 is rejected at α the level if W is less than the table value.

3.5.2.3 Run test (Test for Randomness)

The run test is based on the number of runs (r), where a run is defined as a sequence of symbols of one kind separated by symbols of another kind. The residuals are replaced by '+' or '-' accordingly they are positive or negative. The Null hypothesis is given by,

H_0 : The residuals are random

H_a : The residuals are not random

The test statistics are given by, let m be a number of pluses and n be a number of minus in the series of residuals.

The mean is given by, $\mu = \frac{2mn}{(m+n)+1}$ and

Variance $\sigma^2 = 2mn(2mn - m - n)(m + n)^{-2}(m + n - 1)^{-1}$

The test statistics is

$$Z = \frac{(r + h - \mu)}{\sigma \sim N(0,1)}$$

Where, $h = \begin{cases} 0.5, & \text{if } r < \mu \\ -0.5 & \text{if } r > \mu \end{cases}$

H_0 is rejected at α the level if $Z < Z_\alpha$

3.5.3 Software used

In the present study, Statistical analyses have been done by using the powerful open-source software “**R: The R Project for Statistical Computing**” .R is a command-driven statistical package available as open-source software available at <https://www.r-project.org> In the present study analysis is done by using **nls ()** function for a nonlinear growth model.

CHAPTER - IV

RESULTS AND DISCUSSIONS

The present study is analyzed trends of the area, production, and productivity of oilseeds and other major crops and computation of growth rates using an appropriate growth model. For statistical modeling of growth analysis, four nonlinear models were used *viz.*, monomolecular, logistic, Gompertz, and exponential model were fitted to the time series data. Crop wise results and discussions presented combining both objectives. This chapter is organized as follows:

4.1 Oilseeds situation in Chhattisgarh state

4.2 Crop-wise situation in Chhattisgarh state

4.1. Oilseeds situation in Chhattisgarh state

Overall oilseed area, production, and productivity are presented in Fig 4.1 it can be observed that the maximum oilseeds area is 338.30 ('000 ha) in the year 1998-99 and to a minimum of 249.04 ('000ha) in the year of 2017-18. The maximum production of oilseed was observed 226.424 ('000 MT) in the year 2012-13 and to a minimum production is observed of 98.750 ('000 MT) in the year of 2002-03. The maximum productivity of oilseeds was observed 735 (Kg/ha) in the year 2012-13 and minimum production is observed in 374 (Kg/ha) in the year 1998-99.

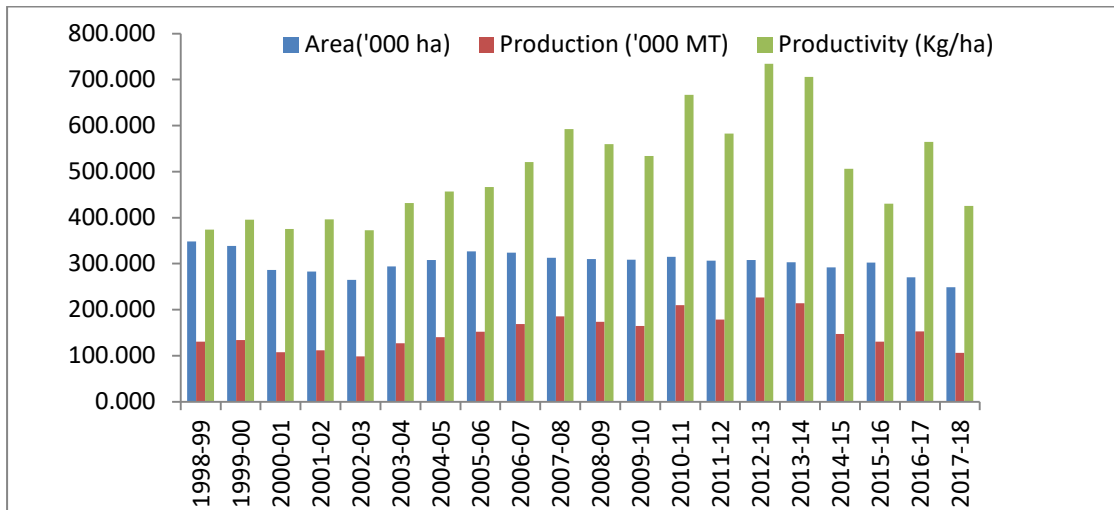


Fig 4.1: Oilseeds area, production, and productivity in Chhattisgarh (1998-99 to 2017-18)

4.1.1. Total Oilseeds

4.1.1.1 Trend analysis of oilseeds area in Chhattisgarh

It can be observed that in Fig.4.1.1.1 it can be observed a declining trend of oilseeds area from 338.30 ('000 ha) in the year 1998-99 and to a minimum of 249.04 ('000 ha) in the year of 2017-18. Initially, it decreased to 264.89('000 ha) in 2003-04 and it started increased and almost the area is stabilized and oscillated between 290-326 thousand hectares till 2015-16. It may be observed that for the last two years it started declining again. Hence it can be inferred that there is no monotonous increase and a decrease in the area was observed over the last two decades. The last five years area is decreasing due to area shifting in cereals and pulses crops.

4.1.1.2 Nonlinear growth analysis of oilseeds area in Chhattisgarh

As described in the methodology choice of good initial values plays a crucial role in the fitting of nonlinear models. To begin with first data point is taken as the initial value for analysis (for oilseeds area initial values are $(y_0 = 250, r = 0.1, K = 320)$). If convergence was met with these values then analysis was done tried with another set of values likewise large number of separated initial values

tried to get the global convergence and ensured that parameter estimates were the same for various initial values. Similarly, all the models were fitted to the data.

The first step is to identify the best-fitted model that describes this area of data of total oilseeds. The results are the models are presented below in table 4.1.1.2. From the table it was clear data set was fitted to all the models attempted. Based on minimum MSE (475.51), RMSE (20.10) and AIC (184.8) values. Gompertz model was found to be better for describing the area of total oilseeds of Chhattisgarh state. The examination of residuals reveals that errors are randomly and normally distributed. The run test statistic and Shapiro-Wilk test statistic values are not significant. The results of the residual test are presented in the table.

The best fitted Gompertz growth model equation is given by (Eq 4.1.1.2) and the computed compound growth rate was -1.10 %.

$$Y(t) = 298.613 \exp(\log(352.355 / 298.613) \exp(-1.08t)) \quad (4.1.1.2)$$

Table 4.1.1.2: Fitting of nonlinear growth models of the total area of oilseeds ('000 ha) crop during 1998-99 to 2017-18.

	Monomolecular	Logistic	Gompertz	Exponential
Parameter Estimates				
Y0	323.13 (18.06)***	352.13 (21.74)***	352.35 (21.70)***	318.66 (9.94)***
r	0.16(0.30)	1.05 (1.08)	1.09 (0.99)	-0.005 (0.002)
K	292.58 (18.22)**	298.64 (18.22)***	298.61 (5.46)***	
CGR	-0.43 %	-1.38 %	-1.10 %	-0.55 %
Diagnosis of models				
MSE	563.06	476.63	475.51	507.59
RMSE	21.88	20.13	20.10	21.37
AIC	188.17	184.84	184.79	185.24
BIC	192.16	188.42	188.7	188.23
Non-Parametric Tests				
Run Test	113 (0.79)	117 (0.67)	116 (0.70)	112 (0.81)
Shapiro Wilk Test	0.87(0.01)	0.93(0.15)	0.89 (0.16)	0.8891 (0.03)

*-significant at 5% **- Significant at 1%, ***- Significant at 0.1% and Figures in the parentheses indicate corresponding standard errors. *In residual test figures in the parentheses indicate corresponding p-values.

4.1.1.3 Trend analysis of oilseeds production in Chhattisgarh

From Fig.4.1.1.3, it can be observed an increasing trend of oilseed production. The maximum production of oilseed was observed 226.424 ('000 MT) in the year 2012-13 and to a minimum production is observed of 98.750 ('000 MT) in the year of 2002-03. Initially, it decreased to 98.750 ('000 MT) and started increasing 226.424 ('000 MT) till 2012-13. It may be observed that the last five years started declining again. Hence it can be inferred that there is no monotonous increase and a decrease in production was observed over the last two decades.

4.1.1.4 Nonlinear growth analysis of oilseeds production in Chhattisgarh

The data was fitted to the growth models with the initial values $y_0 = 100$, $r = 0.1$, $K = 180$. Final parameter estimates along with diagnosis of models and residual analysis (non-parametric tests) were presented in table 4.1.1.4. Selection of model based on minimum MSE (1088.51), RMSE (30.42), AIC (201.36) and BIC (205.34) values. Thus, the Logistic model was considered for describing the growth of the oilseeds production in Chhattisgarh state. The examination of residuals reveals that errors are randomly and normally distributed. The run test statistic and Shapiro-Wilk test statistic values are not significant. The results of the residual test are presented in the table.

The best-fitted model is the logistic model equation is given by (Eq 4.1.1.4) and the compound growth rate was 2.71 %.

$$Y(t) = 173.83 / (1 + (173.83 / 104.40) \exp(-0.169t)) \quad (4.1.1.4)$$

Table 4.1.1.4: Fitting of nonlinear growth models of production of total oilseeds (000 MT) crop during 1998-99 to 2017-18.

	Monomolecular	Logistic	Gompertz	Exponential
Parameter Estimates				
Y0	106.73 (25.71)***	104.40 (23.33)***	105.49 (24.51)***	132.49 (14.17)***
r	0.17 (0.20)	0.24 (0.21)	0.20 (0.20)	0.01 (0.01)
K	173.90 (23.63)***	172.83 (17.79)***	173.25 (20.24)***	
CGR	3.39 %	2.71 %	3.06 %	1.47 %
Diagnosis of Models				
MSE	1118.77	1088.50	1103.73	1235.93
RMSE	30.84	30.42	30.63	33.35
AIC	201.91	201.36	201.64	203.04
BIC	205.89	205.34	205.62	206.03
Non-parametric Tests				
Run Test	105 (1.00)	108 (0.93)	107 (0.96)	101 (0.89)
Shapiro Wilk Test	0.9807 (0.94)	0.9838 (0.97)	0.9818 (0.96)	0.9851 (0.98)

*-significant at 5% **- Significant at 1%, ***- Significant at 0.1% and Figures in the parentheses indicate corresponding standard errors. *In residual test figures in the parentheses indicate corresponding p-values.

4.1.1.5 Trend analysis of oilseeds productivity in Chhattisgarh

From Fig.4.1.1.5 it can be observed an increasing trend of oilseeds productivity in Chhattisgarh. For seen the graph it was clear the maximum productivity of oilseeds was observed 735 (Kg/ha) in the year 2012-13 and minimum production is observed in 374 (Kg/ha) in the year 1998-99. Initially, productivity is increasing and productivity is almost stabilized between 374 – 593 kg/ha till 2007-08. After 2007-08 productivity started decreasing and increasing till 2012-13 and after 2012-13 productivity is decreasing till 2015-16. It may be observed that for the last year productivity decline again.

4.1.1.6 Nonlinear growth analysis of oilseeds productivity in Chhattisgarh

The data was fitted to the growth models with the initial values $y_0 = 374$, $r = 0.1$, $K = 650$). Final parameter estimates along with a diagnosis of models and residual analysis (non-parametric tests) were presented in table 4.1.1.6. It is observed that the logistic model fitted better than other models with minimum MSE (7394.91), RMSE (79.28), AIC (239.68) and BIC (243.66) values. The logistic growth model was found to be better for describing the oilseed productivity in Chhattisgarh state. The examination of residuals reveals that errors are randomly and normally distributed. The run test statistic and Shapiro-Wilk test statistic values are not significant. The results of the residual test are presented in the table.

The fitted logistic model equation is given by (Eq 4.1.1.6) and the compound growth rate was 3.12 %.

$$Y(t) = 582.709 / (1 + (582.709 / 325.567 - 1) \exp(-0.23t)) \quad (4.1.1.6)$$

Table 4.1.1.6: Fitting of nonlinear growth models of productivity of oilseeds (Kg/ha) crop during 1998-99 to 2017-18.

	Monomolecular	Logistic	Gompertz	Exponential
Parameter Estimates				
Y0	327.43 (66.60)***	325.57 (59.06)***	326.18 (62.62)***	417.10 (37.83)***
r	0.16 (0.13)	0.23 (0.14)	0.19 (0.135)	0.02 (0.01)*
K	590.61 (67.73)***	582.71 (48.65)***	585.85 (56.26)***	
CGR	3.53 %	3.12 %	3.34 %	1.95 %
Diagnosis of Models				
MSE	7673.01	7394.91	7531.06	9229.28
RMSE	80.76	79.28	80.01	91.14
AIC	240.42	239.68	240.04	243.25
BIC	244.40	243.66	244.03	246.24
Non-Parametric Tests				
Run Test	97 (0.78)	100 (0.87)	99 (0.84)	98 (0.81)
Shapiro Wilk Test	0.97 (0.70)	0.97 (0.68)	0.96 (0.70)	0.96 (0.65)

*-significant at 5% **- Significant at 1%, ***- Significant at 0.1% and Figures in the parentheses indicate corresponding standard errors. *In residual test figures in the parentheses indicate corresponding p-values.

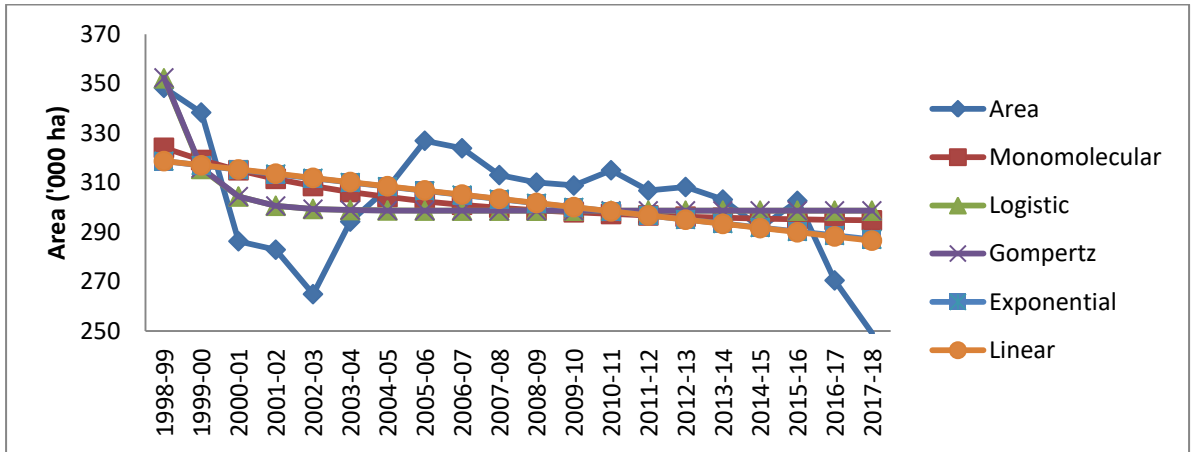


Fig 4.1.1.1: Oilseeds area ('000 ha) in Chhattisgarh (1998-99 to 2017-18)

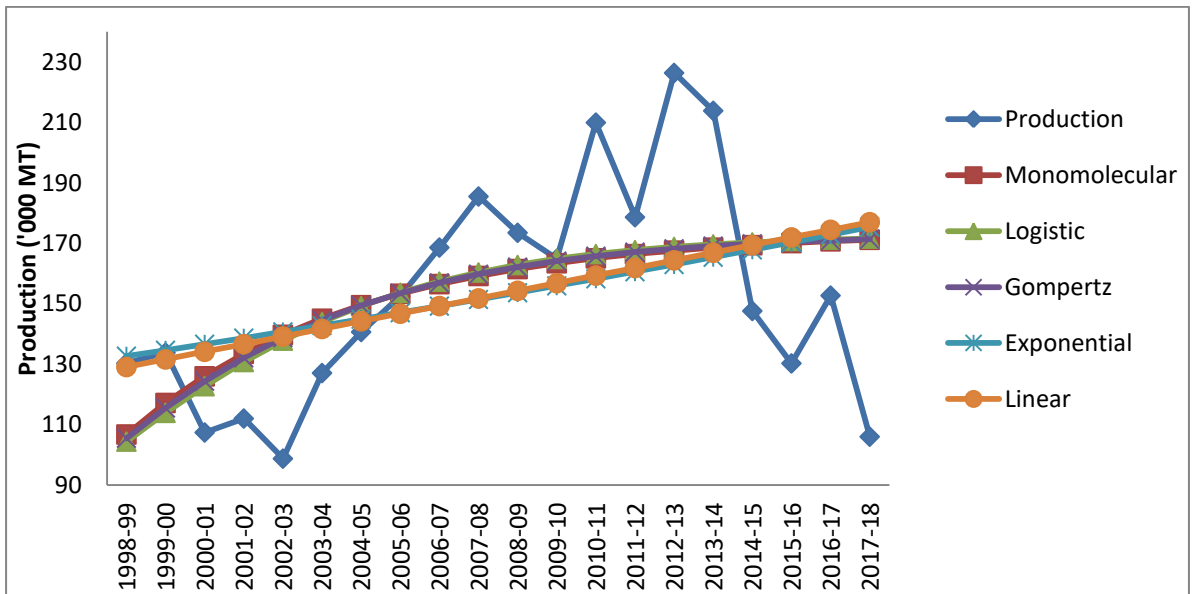


Fig 4.1.1.3: Oilseed production ('000 MT) in Chhattisgarh (1998-99 to 2017-18)

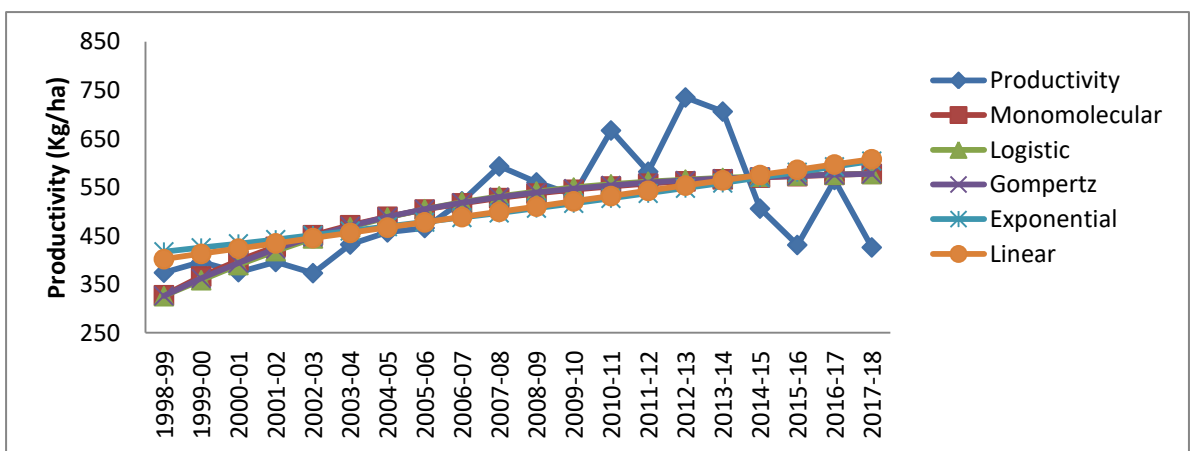


Fig 4.1.1.5: Oilseed productivity (Kg/ha) in Chhattisgarh (1998-99 to 2017-18).

4.1.2 Soybean

4.1.2.1 Trend analysis of soybean area in Chhattisgarh

From Fig.4.1.2.1 it can be observed an increasing trend of soybean area in Chhattisgarh. In 1998-99 soybean was cultivated nearly 48.1 ('000 ha) but it drastically to 12.66 ('000 ha) decreased in the year 2000-01. But a tenfold increase in area from mere 12.66 ('000 ha) in 2000-01 to 115 ('000 ha) has been observed in two decades. Area of soybean in-state increase due to MSP (Minimum Support Price) of soybean and demand of oil manufactures company.

4.1.2.2 Nonlinear growth analysis of soybean area in Chhattisgarh

The data were fitted to the growth models with the initial values $y_0 = 48$, $r = 0.1$, $K = 100$, apart from this various wide range of initial values and confirmed for global convergence. Final parameter estimates along with goodness of fit statistics and residual analysis were presented in table 4.1.2.2. It is observed that the monomolecular model fitted better than other models with minimum MSE (159.40), RMSE (11.64), AIC (162.94) and BIC (166.92) values. Thus, the monomolecular model was considered for describing the growth of the soybean area in Chhattisgarh state. The examination of residuals reveals that errors are randomly and normally distributed. The run test statistic and Shapiro-Wilk test statistic values are not significant. The results of the residual test are presented in the table.

The best fitted monomolecular growth model equation is given by (Eq 4.1.2.2) and the compound growth rate was 9.09 %.

$$Y(t) = 151.33 - 117.81 \exp(-0.060t) \quad (4.1.2.2)$$

Table 4.1.2.2: Fitting of nonlinear growth models of the total area of Soybean ('000 ha) crop during 1998-99 to 2017-18.

	Monomolecular	Logistic	Gompertz	Exponential
Parameter Estimates				
Y0	33.52 (8.45)***	37.30 (6.84)***	35.36 (7.4)***	48.92 (4.74)***
<i>r</i>	0.06 (0.05)	0.174 (0.06)*	0.12 (0.05)*	0.05(0.1)***
K	151.33 (55.33)*	121.12 (16.97)***	128.52 (24.40)***	
CGR	9.09 %	5.84 %	6.73 %	4.86 %
Diagnosis of Models				
MSE	159.40	163.35	160.76	197.59
RMSE	11.64	11.79	11.69	13.34
AIC	162.94	163.43	163.11	166.37
BIC	166.92	167.41	167.09	169.36
Non-Parametric Tests				
Run Test	111 (0.84)	112 (0.81)	114 (0.76)	128 (0.41)
Shapiro Wilk Test	0.95 (0.42)	0.96 (0.51)	0.96 (0.49)	0.83 (0.02)

*-significant at 5% **- Significant at 1%, ***- Significant at 0.1% and Figures in the parentheses indicate corresponding standard errors. *In residual test figures in the parentheses indicate corresponding p-values.

4.1.2.3 Trend analysis of soybean production in Chhattisgarh

Overall an increasing trend was observed for production. However, stagnated till 2006-07 and there was a fillip in production from 13.11 to 83.61 ('000 MT) in the next year 2007-08. And it continued to increased 2012-13. It may be observed that the last three-year production is started increasing.

4.1.2.4 Nonlinear growth analysis of soybean production in Chhattisgarh

The data were fitted to the growth models with the initial values are $y_0 = 12$, $r = 0.1$, $K = 98$. Final parameter estimates along with the diagnosis of models and residual analysis (non-parametric tests) were presented in table 4.1.2.4. Only monomolecular and exponential models were converged and logistic and Gompertz models were failed to converge. The model selection is based on minimum MSE (888.33), RMSE (27.48), AIC (197.29) and BIC (201.28) values. The monomolecular model was considered for describing the growth of the

soybean area in Chhattisgarh state. The examination of residuals reveals that errors are randomly and normally distributed. The run test statistic and Shapiro-Wilk test statistic values are not significant. The results of the residual test are presented in the table.

The best fitted monomolecular growth model equation is given by (Eq. 4.1.2.4) and the compound growth rate is 27.61 %.

$$Y(t) = 143.14 - 152.59 \exp(-0.05t) \quad (4.1.2.4)$$

Table 4.1.2.4: Fitting of nonlinear growth models of the total production of Soybean ('000 MT) crop during 1998-99 to 2017-18.

	Monomolecular	Logistic	Gompertz	Exponential
Parameter Estimates				
Y0	-9.45 (25.77)	Parameters did not	Parameters did not	22.35 (8.97)*
r	0.054 (0.10)	Converge	Converge	0.07 (0.03)**
K	143.14 (159.24)			
CGR	27.61 %			7.44 %
Diagnosis of Models				
MSE	888.33			1002.56
RMSE	27.48			30.04
AIC	197.29			198.86
BIC	201.28			201.84
Non-Parametric Tests				
Run Test	104 (0.99)			101 (0.89)
Shapiro Wilk Test	0.96 (0.61)			0.92 (0.09)

*-significant at 5% **- Significant at 1%, ***- Significant at 0.1% and Figures in the parentheses indicate corresponding standard errors. *In residual test figures in the parentheses indicate corresponding p-values.

4.1.2.5 Trend analysis of soybean productivity in Chhattisgarh

From the in Fig.4.1.2.5 it can be observed that productivity showed an almost similar pattern of production to productivity was overall an increasing trend was present maximum productivity of soybean was 1243 (Kg/ha) in the year 2012-13 and minimum production was 160 (Kg/ha) in the year of 2002-03. Initially, the productivity is increased to 721 (Kg/ha) in 1999-2000 and it started decreased 191

(Kg/ha) in 2001-02 and after that productivity is stagnating till 2006-07 and after 2006-07 rapid jump in productivity till 2012-13. Again productivity started to decline after 2012-13. It may be observed that the last three-year productivity is started increasing.

4.1.2.6 Nonlinear growth analysis of soybean productivity in Chhattisgarh

The data was fitted to the growth models with the initial values $y_0 = 160$, $r = 0.1$, $K = 1155$). Final parameter estimates along with the diagnosis of models and residual analysis (non-parametric tests) were presented in table 4.1.2.6. It is observed that the logistic model fitted better than other models with minimum MSE (125813.1), RMSE (327.02), AIC (296.36) and BIC (300.34) values. The logistic growth model was found to be better for describing the soybean productivity in Chhattisgarh state. The examination of residuals reveals that errors are randomly and normally distributed. The run test statistic and Shapiro-Wilk test statistic values are not significant. The results of the residual test are presented in the table.

The best fitted logistic growth model equation is given by (Eq 4.1.2.6) and the compound growth rate is 6.38 %.

$$Y(t) = 1250.674 / (1 + (1250.674 / 323.103 - 1) \exp(-0.044t)) \quad (4.1.2.6)$$

Table 4.1.2.6: Fitting of nonlinear growth models of the total productivity of Soybean (Kg/ha) crop during 1998-99 to 2017-18.

	Monomolecular	Logistic	Gompertz	Exponential
Parameter Estimates				
Y0	323.10 (235.58)	246.39 (186.91)	290.80 (214.61)	415.78 (126.16)**
<i>r</i>	0.04 (0.20)	0.21 (0.23)	0.12 (0.21)	0.03 (0.2)
K	1250.67 (2929.66)	878.66 (313.52)	961.31 (706.99)	
CGR	10.42 %	6.38 %	7.87 %	3.92 %
Diagnosis of Models				
MSE	130030.0	125813.1	128283.6	126096.2
RMSE	332.45	327.02	330.21	336.88
AIC	297.02	296.36	296.74	295.55
BIC	301.01	300.34	300.73	298.53
Non-Parametric Tests				
Run Test	103 (0.96)	108 (0.93)	104 (0.98)	102 (0.92)
Shapiro Wilk Test	0.88 (0.02)	0.89 (0.03)	0.89 (0.02)	0.89 (0.02)

*-significant at 5% **- Significant at 1%, ***- Significant at 0.1% and Figures in the parentheses indicate corresponding standard errors. *In residual test figures in the parentheses indicate corresponding p-values.

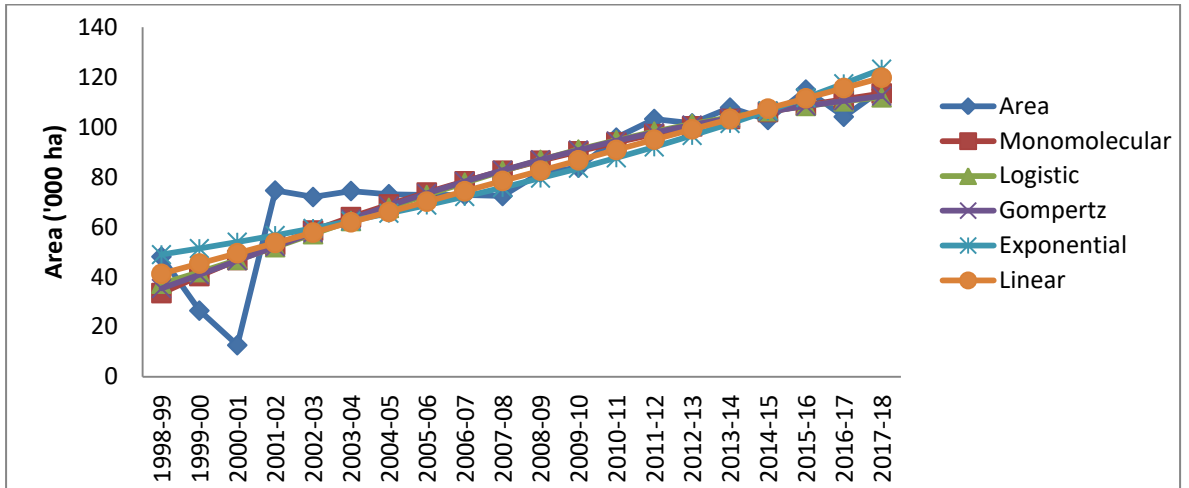


Fig 4.1.2.1: Soybean area ('000 ha) in Chhattisgarh (1998-99 to 2017-18)

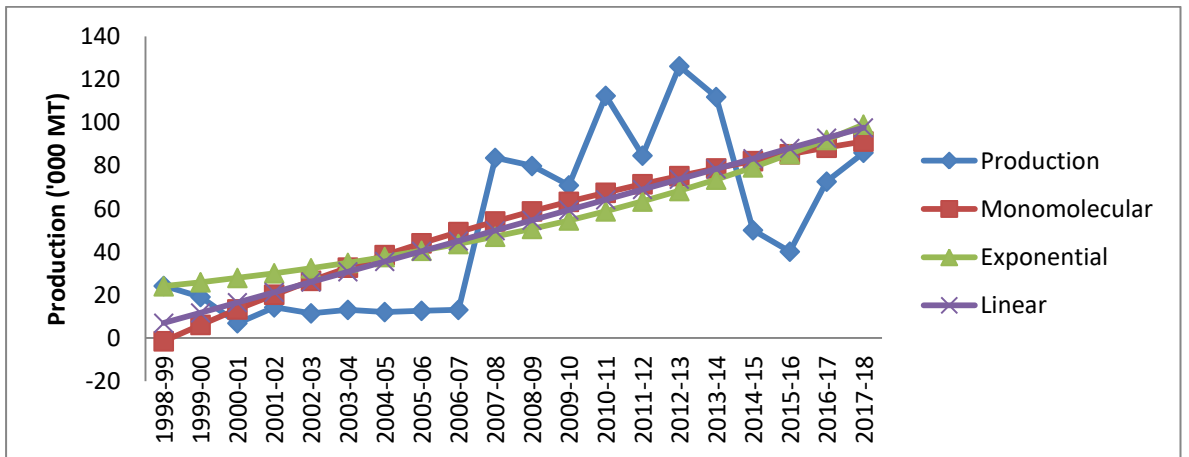


Fig 4.1.2.3: Soybean production ('000 ha) in Chhattisgarh (1998-99 to 2017-18)

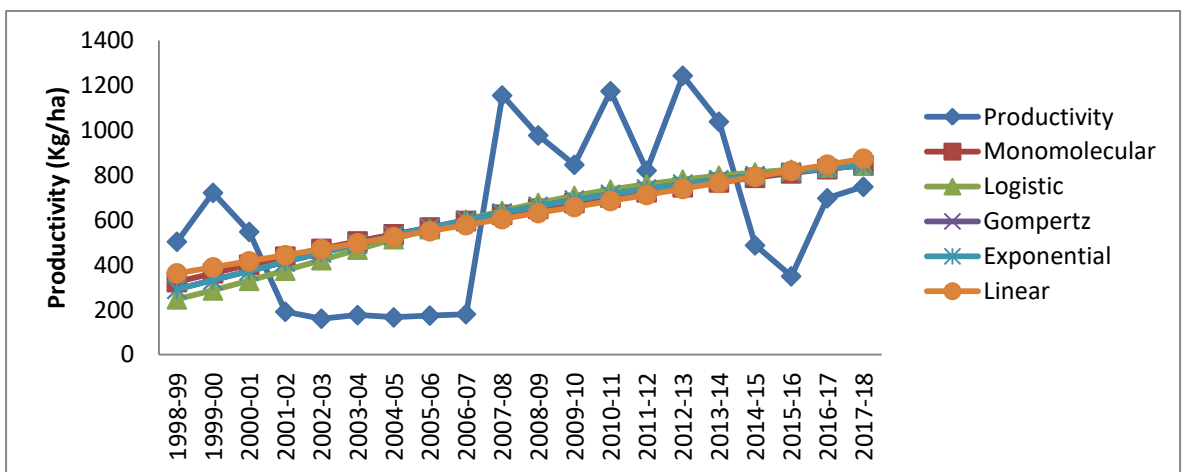


Fig 4.1.2.5: Soybean productivity (Kg/ha) in Chhattisgarh (1998-99 to 2017-18)

4.1.3 Groundnut

4.1.3.1 Trend analysis of groundnut area in Chhattisgarh

From the in Fig 4.1.31, it was observed a declining trend of groundnut area in Chhattisgarh. Seen the graph it was clear the maximum area of the groundnut was observed to be 36.32 ('000 ha) in the year of the 2003-04 and minimum area was observed to be 20.32 ('000 ha) in the year of 2017-18. Initially, area decreased to 20.41 ('000 ha) in 2011-12 and started increased to 27.71 ('000 ha) in 2015-16. It may be observed that last two years it started decreasing again.

4.1.3.2 Nonlinear growth analysis of groundnut area in Chhattisgarh

The data was fitted to the growth models with the initial values $y_0 = 34$, $r = 0.1$, $K = 20$. Final parameter estimates along with the diagnosis of models and residual analysis (non-parametric tests) were presented in table 4.1.3.2. Selection of model based on minimum MSE (7.99), RMSE (2.68), AIC (102.23) and BIC (105.22) values. An exponential model was considered for describing growth of the groundnut area in Chhattisgarh state. The examination of residuals reveals that errors are randomly and normally distributed. The run test statistic and Shapiro-Wilk test statistic values are not significant. The results of the residual test are presented in the table.

The best fitted exponential growth model equation is given by (Eq 4.1.3.2) and the compound growth rate is -2.19 %

$$Y(t) = 32.452 \exp (- 0.022t) \quad (4.1.3.2)$$

Table 4.1.3.2: Fitting of nonlinear growth models of the total area of groundnut ('000 ha) crop during 1998-99 to 2017-18.

	Monomolecular	Logistic	Gompertz	Exponential
Parameter Estimates				
Y0	33.90 (2.26)***	32.79 (2.47)***	Parameters did not	35.45 (1.33)
<i>r</i>	0.06 (0.09)	0.049 (0.15)	Converge	-0.02 (0.01)
K	18.16 (15.63)	22.52 (14.24)		
CGR	-2.06 %	-1.42 %		-2.19 %
Diagnosis of Models				
MSE	11.11	12.31		7.99
RMSE	3.07	3.24		2.68
AIC	109.66	111.72		102.23
BIC	113.64	115.70		105.22
Non-Parametric Tests				
Run Test	157 (0.05)	131 (0.35)		112 (0.81)
Shapiro Wilk Test	0.98 (0.89)	0.9650 (0.65)		0.94 (0.83)

*-significant at 5% **- Significant at 1%, ***- Significant at 0.1% and Figures in the parentheses indicate corresponding standard errors. *In residual test figures in the parentheses indicate corresponding p-values.

4.1.3.3 Trend analysis of groundnut production in Chhattisgarh

From in the Fig 4.1.3.3. It can be observed a declining trend of groundnut production in Chhattisgarh state. Seen the graph it was clear the maximum production of groundnut was observed 41.75 ('000 MT) in the year 2001-02 and minimum production is observed in 24.68 ('000 MT) in the year of 2016-17. Initially, production is decreased to 30.30 ('000 MT) in 1999-2000 and it started increasing to 41.75 ('000 MT) in 2001-02 and it was started to decline again till 2011-12. Production is again started increasing and decreasing in last six years. It may be observed that for the last year it started increasing again. Hence it can be inferred that there is no monotonous increase and decrease in production was observed over the last two decades.

4.1.3.4 Nonlinear growth analysis of groundnut production in Chhattisgarh

The data was fitted to the growth models with the initial values $y_0 = 26$, $r = 0.1$, $K = 37$. Final parameter estimates along with the diagnosis of models and residual analysis (non-parametric tests) were presented in table 4.1.3.4. Selection of model based on minimum MSE (16.34), RMSE (3.83), AIC (116.52) and BIC (119.51) values. An exponential model was considered for describing growth of the groundnut area in Chhattisgarh state. The examination of residuals reveals that errors are randomly and normally distributed. The run test statistic and Shapiro-Wilk test statistic values are not significant. The results of the residual test are presented in the table.

The best fitted exponential growth model equation is given by (Eq 4.1.3.4) and the compound growth rate is -0.64 %.

$$Y(t) = 36.409 \exp(-0.01t) \quad (4.1.3.4)$$

Table 4.1.3.4: Fitting of nonlinear growth models of total production of groundnut ('000 MT) crop during 1998-99 to 2017-18.

	Monomolecular	Logistic	Gompertz	Exponential
Parameter Estimates				
Y0	32.16 (4.34)***	32.66 (4.31)***	32.69 (4.35)***	36.409 (1.790)***
r	1.06 (5.23)	0.96 (5.29)	0.95 (5.35)	-0.01 (0.05)
K	34.27 (1.09)***	34.43 (1.11)***	34.43 (1.11)***	
CGR	1.57 %	0.41 %	1.09 %	-0.64 %
Diagnosis of Models				
MSE	19.10	19.04	19.05	16.34
RMSE	4.03	4.02	4.02	3.83
AIC	120.50	120.44	120.44	116.52
BIC	124.49	124.43	124.43	119.51
Non-Parametric Tests				
Run Test	117 (0.67)	113 (0.78)	113 (0.78)	111 (0.84)
Shapiro Wilk Test	0.97 (0.75)	0.97(0.76)	0.97 (0.76)	0.95 (0.53)

*-significant at 5% **- Significant at 1%, ***- Significant at 0.1% and Figures in the parentheses indicate corresponding standard errors. *In residual test figures in the parentheses indicate corresponding p-values.

4.1.3.5 Trend analysis of groundnut productivity in Chhattisgarh

The trend of groundnut productivity is presented in the fig 4.1.3.5. It was clearly seen the graph trend of groundnut productivity in Chhattisgarh is increasing trend from the period of 1998-99 to 2017-18. The maximum productivity of groundnut was observed in 1562 (Kg/ha) in the year 2017-18 and minimum production is observed in 935 (Kg/ha) in the year 2000-01. The productivity is increasing continuously in the starting years up to 2013-14 and after 2013-14 productivity is decreased up to 2016-17.

4.1.3.6 Nonlinear growth analysis of groundnut productivity in Chhattisgarh

The data was fitted to the growth models with the initial values $y_0 = 1500$, $r = 0.1$, $K = 990$. Final parameter estimates along with the diagnosis of models and residual analysis (non-parametric tests) were presented in table 4.1.3.6. Selection of model based on minimum MSE (16806.20), RMSE (119.52), AIC (256.10) and BIC (260.08) values. The logistic model was considered for describing growth of the groundnut productivity in Chhattisgarh state. The examination of residuals reveals that errors are randomly and normally distributed. The run test statistic and Shapiro-Wilk test statistic values are not significant. The results of the residual test are presented in the table.

The best fitted logistic growth model is given by equation (Eq 4.1.3.6) and the compound growth rate is 1.71 %.

$$Y(t) = 1435.199 / (1 + (1435.199 / 974.2 - 1) \exp(-0.068t)) \quad (4.1.3.6)$$

Table 4.1.3.6: Fitting of nonlinear growth models of the total productivity of groundnut (Kg/ha) crop during 1998-99 to 2017-18.

	Monomolecular	Logistic	Gompertz	Exponential
Parameter Estimates				
Y0	974.20 (87.93)***	976.25 (83.85)***	975.2 (85.82)***	1028 (51.67) ***
r	0.07 (0.11)	0.10 (0.11)	0.09 (0.12)	0.02 (0.01)**
K	1492 (442.8)**	1435.2 (278.99)***	1459 (342.6)***	
CGR	1.82 %	1.71 %	1.77 %	1.58 %
Diagnosis of Models				
MSE	16836.51	16806.20	16821.29	16618.62
RMSE	119.63	119.52	119.58	122.30
AIC	256.13	256.09	256.12	255.01
BIC	260.12	260.08	260.10	258.01
Residual Tests				
Run Test	111 (0.84)	111(0.84)	111 (0.84)	118 (0.65)
Shapiro Wilk Test	0.93 (0.13)	0.93 (0.13)	0.93 (0.13)	0.89 (0.03)

*-significant at 5% **- Significant at 1%, ***- Significant at 0.1% and Figures in the parentheses indicate corresponding standard errors. *In residual test figures in the parentheses indicate corresponding p-values.

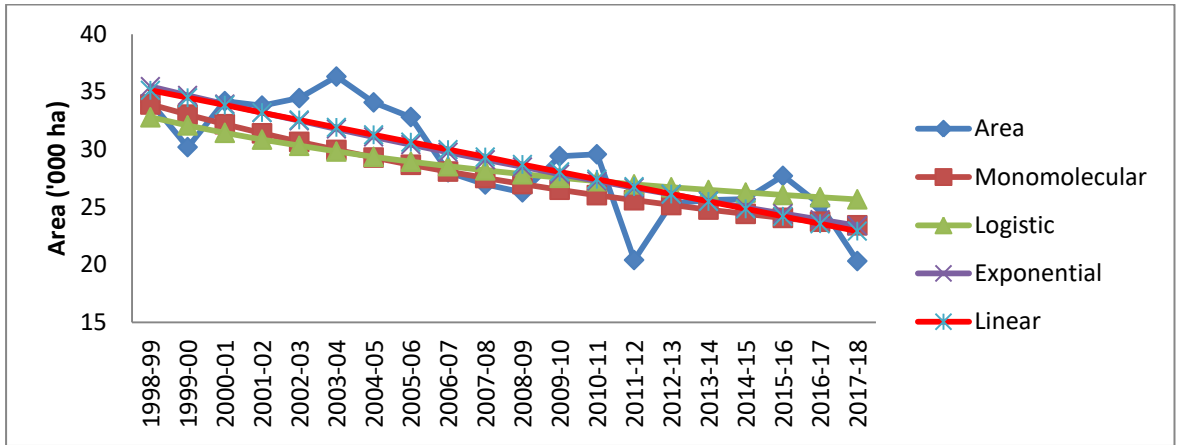


Fig 4.1.3.1: Groundnut area ('000 ha) in Chhattisgarh (1998-99 to 2017-18)

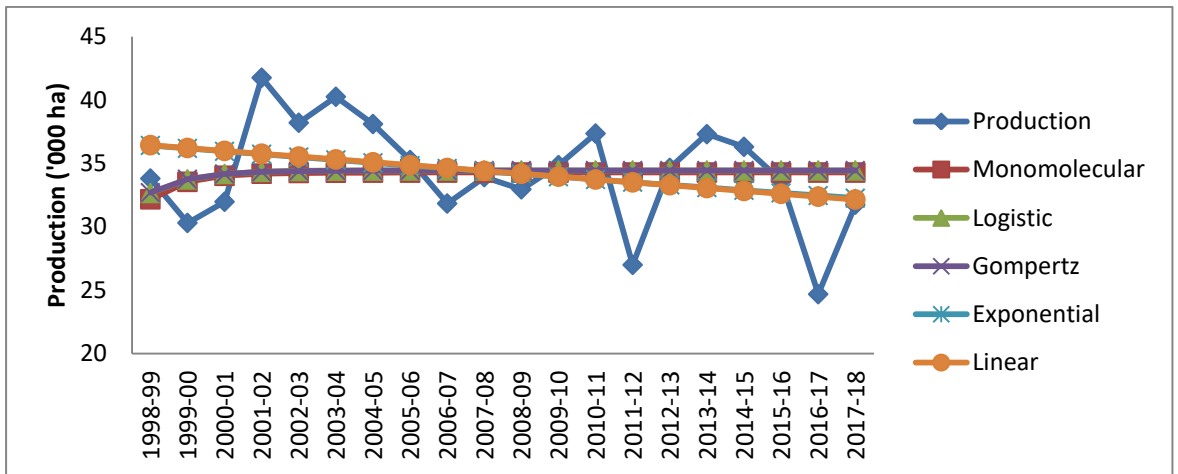


Fig 4.1.3.3: Groundnut production ('000 MT) in Chhattisgarh (1998-99 to 2017-18)

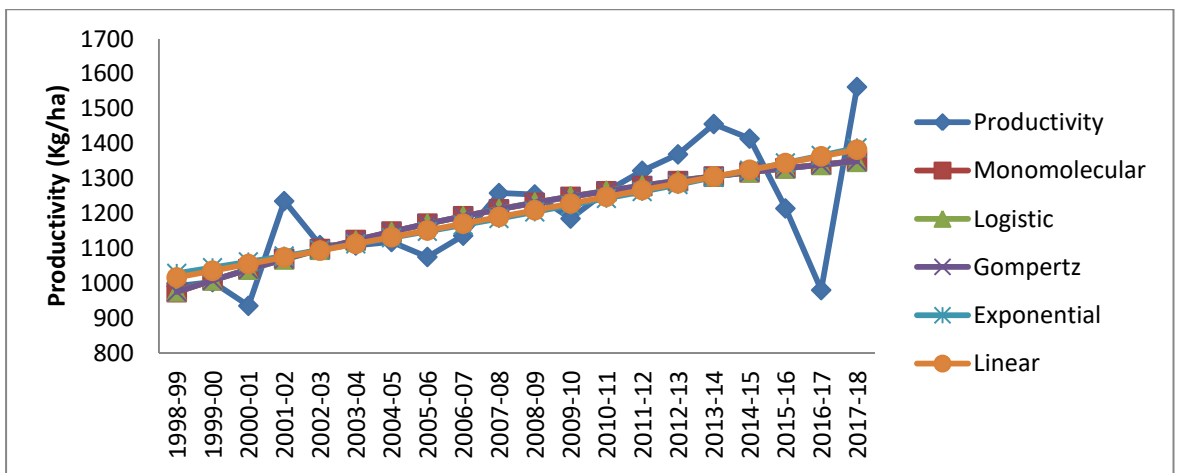


Fig 4.1.3.5: Groundnut productivity (Kg/ha) in Chhattisgarh (1998-99 to 2017-18)

4.1.4 Niger

4.1.4.1 Trend analysis of Niger area in Chhattisgarh

Niger area is presented in fig 4.1.4.1. It was clearly seen the graph the trend of an area of Niger in Chhattisgarh is decreasing trend from the period of 1998-99 to 2017-18. The maximum area of the Niger was observed to be 77.80 (000'ha) in the year 1998-99 and the minimum area was observed to be 56.35 (000'ha) in the year of 2017-18. The trend of the area of niger is continuously decreasing.

4.1.4.2 Nonlinear growth analysis of Niger area in Chhattisgarh

The data were fitted to the growth models with the initial values $y_0 = 76$, $r = 0.1$, $K = 57$, apart from this various wide range of initial values and confirmed for global convergence. But convergence was not for the models even for different values tried for the data

4.1.4.3 Trend analysis of Niger production in Chhattisgarh

Niger production is presented in the fig 4.1.3.3. It was clearly seen the graph trend of Niger production in Chhattisgarh is decreasing trend from the period of 1998-99 to 2017-18. The maximum production of Niger was observed 14.74 ('000 MT) in the year 1999-2000 and minimum production is observed in 9.80 ('000 MT) in the year of 2015-16. Initially, production is increased to 14.74 ('000 MT) in 1999-2000 and started decreasing and almost stabilized production between 14-9 ('000 MT) till 2015-16. It may be observed that last year production is decline. Hence it can be inferred that there is no monotonous increase and decrease in production was observed over the last two decades.

4.1.4.4 Nonlinear growth analysis of niger production in Chhattisgarh

The data were fitted to the growth models with the initial values are $y_0 = 13$, $r = 0.1$, $K = 10$. Final parameter estimates along with the diagnosis of models and residual analysis (non-parametric tests) were presented in table 4.1.4.4. The model selection is based on minimum MSE (0.62), RMSE (0.73), AIC (51.98) and BIC (55.99) values. The logistic growth model was considered for describing the growth of the Niger production in Chhattisgarh state. The examination of residuals

reveals that errors are randomly and normally distributed. The run test statistic and Shapiro-Wilk test statistic values are not significant. The results of the residual test in the table.

The best fitted logistic growth model equation is given by (Eq 4.1.4.4) and the compound growth rate is -1.32 %.

$$Y(t) = 9.266 / (9.266/14.159 - 1) \exp (- 0.04t) \quad (4.1.4.4)$$

Table 4.1.4.4: Fitting of nonlinear growth models of production of Niger (000 MT) crop during 1998-99 to 2017-18.

	Monomolecular	Logistic	Gompertz	Exponential
Parameter Estimates				
Y0	14.13 (0.53)***	14.16 (0.55)***	14.15 (0.54)***	13.88 (0.35)***
r	0.06 (0.08)	0.04 (0.08)	0.05 (0.08)	-0.01 (0.003)***
K	9.76 (2.96)**	9.27 (4.26)*	9.55 (3.46)*	
CGR	-1.29 %	-1.32 %	-1.30 %	-1.31 %
Diagnosis of Models				
MSE	0.62	0.62	0.63	0.60
RMSE	0.72	0.73	0.74	0.74
AIC	52.02	51.98	51.99	50.49
BIC	56.01	55.96	55.98	53.47
Non-Parametric Tests				
Run Test	110 (0.90)	109 (0.89)	109 (0.89)	111 (0.84)
Shapiro Wilk Test	0.95 (0.38)	0.95 (0.37)	0.95 (0.38)	0.97 (0.83)

*-significant at 5% **- Significant at 1%, ***- Significant at 0.1% and Figures in the parentheses indicate corresponding standard errors. *In residual test figures in the parentheses indicate corresponding p-values.

4.1.4.5 Trend analysis of Niger productivity in Chhattisgarh

The trend of Niger productivity is presented in the fig 4.1.4.5. It was clearly seen the graph trend of Niger productivity in Chhattisgarh is decreasing trend from the period of 1998-99 to 2017-18. The maximum productivity of Niger was observed 194 (Kg/ha) in the year 1999-2000 and minimum production is observed in 160 (Kg/ha) in the year of 2015-16.

4.1.4.6 Nonlinear growth analysis of Niger productivity in Chhattisgarh

The data was fitted to the growth models with the initial values $y_0 = 165$, $r = 0.1$, $K = 185$. Final parameter estimates along with the diagnosis of models and residual analysis (non-parametric tests) were presented in table 4.1.4.6. It is observed that the monomolecular model fitted better than other models with minimum MSE (101.60) and RMSE (09.29) values. The monomolecular growth model was found to be better for describing the niger productivity in Chhattisgarh state. The examination of residuals reveals that errors are randomly and normally distributed. The run test statistic and Shapiro-Wilk test statistic values are not significant. The results of the residual test are presented in the table.

The best fitted monomolecular growth model equation is given by (Eq 4.1.4.6) and the compound growth rate is -0.26 %.

$$Y(t) = 174.61 - (-11.11) \exp(-0.44t) \quad (4.1.4.6)$$

Table 4.1.4.6: Fitting of nonlinear growth models of productivity of Niger (Kg/ha) crop during 1998-99 to 2017-18.

	Monomolecular	Logistic	Gompertz	Exponential
Parameter Estimates				
Y0	185.72 (9.28)***	185.60 (9.33)***	185.66 (9.30)***	176.70 (4.42)***
r	0.45 (0.76)	0.43 (0.76)	0.44 (0.76)	-0.001 (0.002)
K	174.61 (3.05)***	174.62 (3.08)***	174.61 (3.06)***	
CGR	-0.26 %	-0.38 %	-0.32 %	-0.03 %
Diagnosis of Models				
MSE	101.60	101.74	101.67	104.79
RMSE	9.29	9.30	9.30	9.71
AIC	153.92	153.96	153.94	153.69
BIC	157.91	157.94	157.93	156.68
Non-Parametric Tests				
Run Test	105 (1.00)	105(1.00)	105 (1.00)	107 (0.96)
Shapiro Wilk Test	0.96 (0.62)	0.96 (0.61)	0.96 (0.61)	0.95 (0.39)

*-significant at 5% **- Significant at 1%, ***- Significant at 0.1% and Figures in the parentheses indicate corresponding standard errors. *In residual test figures in the parentheses indicate corresponding p-values.

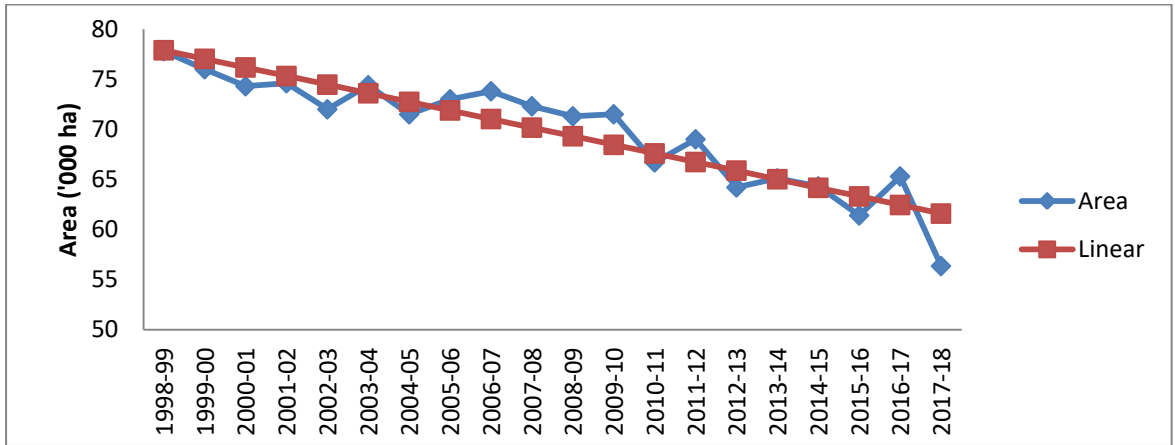


Fig 4.1.4.1: Niger area ('000 ha) in Chhattisgarh (1998-99 to 2017-18)

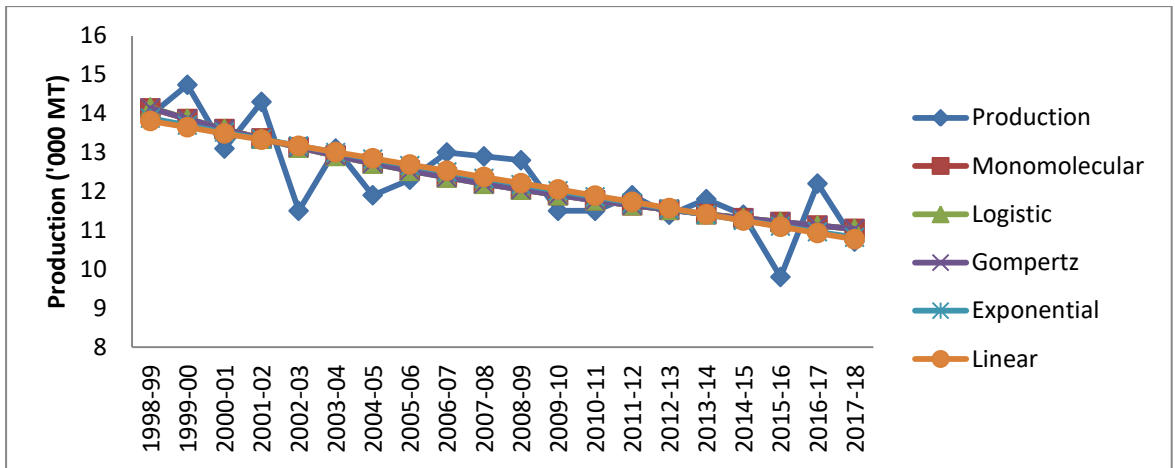


Fig 4.1.4.3: Niger production ('000 MT) in Chhattisgarh (1998-99 to 2017-18)

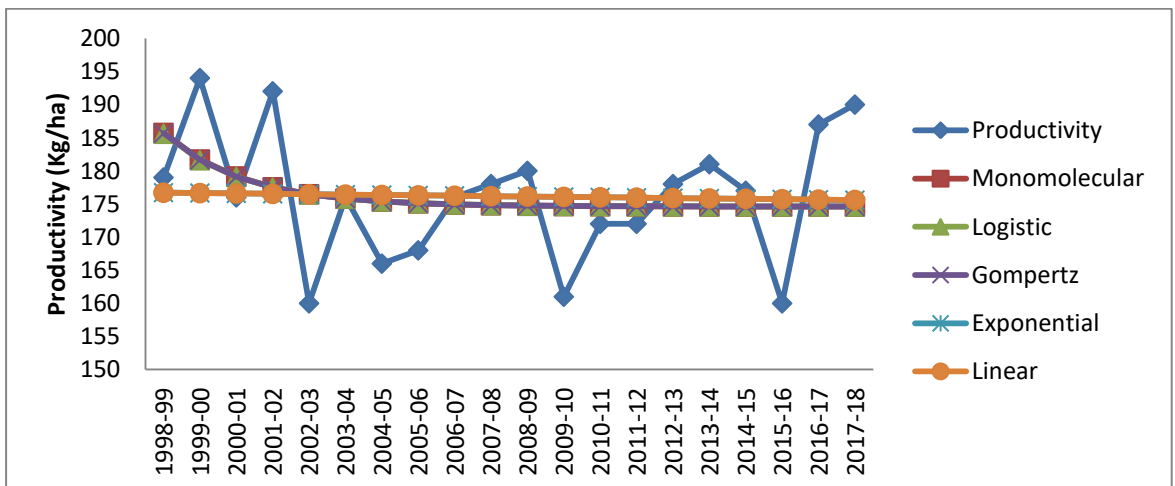


Fig 4.1.4.5: Niger productivity (Kg/ha) in Chhattisgarh (1998-99 to 2017-18)

4.1.5 Rapeseed and Mustard

4.1.5.1 Trend analysis of rapeseed and mustard area in Chhattisgarh

The trend of rapeseed and mustard area is presented in fig 4.1.5.1. It was clearly seen the graph the trend of an area of rapeseed and mustard in Chhattisgarh is decreasing trend from the period of 1998-99 to 2017-18. The maximum area of the rapeseed and mustard was observed to be 57.18 (000'ha) in the year 2005-06 and the minimum area was observed to be 41.31 (000'ha) in the year of 2017-18 which is below the area cultivated 20 years ago.

4.1.5.2 Nonlinear growth analysis of rapeseed and mustard area in Chhattisgarh

The data were fitted to the growth models with the initial values $y_0 = 51.40$, $r = 0.1$, $K = 31.31$, but convergence was not for the models even for different values tried for the data.

4.1.5.3 Trend analysis of rapeseed and mustard production in Chhattisgarh

From Fig 4.1.5.3 it can be observed a decreasing trend of rapeseed and mustard production from 33.10 (000 MT) in the year 1999-2000 and to a minimum production is observed in 15.63 (000 MT) in the year of 2002-03. Initially, production started to increase in 1999-2000 and it started decreasing in 1999-2000 to 2002-03. It may be observed that production is again started increasing and the last three years production is decline.

4.1.5.4 Nonlinear growth analysis of rapeseed and mustard production in Chhattisgarh

The data were fitted to the growth models with the initial values are $y_0 = 15$, $r = 0.1$, $K = 30$. Final parameter estimates along with a diagnosis of models and residual analysis (non-parametric tests) were presented in table 4.1.5.4. The model selection is based on minimum MSE (12.17), RMSE (3.22), AIC (111.48) and BIC (115.47) values. The monomolecular growth model was considered for describing

the growth of the rapeseed and mustard production in Chhattisgarh state. The examination of residuals reveals that errors are randomly and normally distributed. The run test statistic and Shapiro-Wilk test statistic values are not significant. The results of the residual test are presented in the table.

The best fitted monomolecular model equation is given by (Eq 4.1.5.4) and the compound growth rate was -1.50 %.

$$Y(t) = 21.312 - (-11.916) \exp(-0.065t) \quad (4.1.5.4)$$

Table 4.1.5.4: Fitting of nonlinear growth models of the total production of Rapeseed and Mustard ('000 MT) crop during 1998-99 to 2017-18.

	Monomolecular	Logistic	Gompertz	Exponential
Parameter Estimates				
Y0	33.23 (3.37)***	32.88 (3.48)***	33.07 (3.42)***	24.66 (1.96)
r	0.65 (0.38)	0.51 (0.34)	0.57 (0.36)	0.01 (0.01)
K	21.31 (0.95)	21.34 (1.00)***	21.32 (0.97)***	
CGR	-1.50 %	-2.92 %	-2.25 %	0.95 %
Diagnosis of Models				
MSE	12.17	12.64	12.40	19.04
RMSE	3.22	3.28	3.25	4.14
AIC	111.48	112.24	111.86	119.58
BIC	115.46	116.23	115.84	122.57
Non-Parametric Tests				
Run Test	102 (0.93)	101 (0.90)	101 (0.90)	102 (0.93)
Shapiro Wilk Test	0.98 (0.90)	0.98 (0.95)	0.98 (0.91)	0.98 (0.73)

*-significant at 5% **- Significant at 1%, ***- Significant at 0.1% and Figures in the parentheses indicate corresponding standard errors. *In residual test figures in the parentheses indicate corresponding p-values.

4.1.5.5 Trend analysis of rapeseed and mustard productivity in Chhattisgarh

From in Fig 4.1.5.5, it can be observed decreasing trend of rapeseed and mustard productivity in Chhattisgarh. Seen the graph it was clear the maximum productivity of rapeseed and mustard was observed 606 (Kg/ha) in the year 1999-2000 and minimum productivity is observed in 319 (Kg/ha) in the year of 2005-06. Initially, productivity started to decrease to 329 (Kg/ha) in 2002-03 and

productivity started to increase to 568 (Kg/ha) in 2013-14. It may be observed that for the last three-year productivity decline again.

4.1.5.6 Nonlinear growth analysis of rapeseed and mustard productivity in Chhattisgarh

The data was fitted to the growth models with the initial values $y_0 = 329$, $r = 0.5$, $K = 606$. Final parameter estimates along with a diagnosis of models and residual analysis (non-parametric tests) were presented in table 4.1.5.6. It is observed that the monomolecular model fitted better than other models with minimum MSE (6091.29), RMSE (71.96), AIC (235.80) and BIC (239.78) values. The monomolecular growth model was found to be better for describing the rapeseed and mustard productivity in Chhattisgarh state. The examination of residuals reveals that errors are randomly and normally distributed. The run test statistic and Shapiro-Wilk test statistic values are not significant. The results of the residual test are presented in the table.

The best fitted monomolecular model equation is given by (Eq 4.1.5.6) and the compound growth rate was -0.70 %.

$$Y(t) = 432.141 - (-204.49) \exp(-0.71t) \quad (4.1.5.6)$$

Table 4.1.5.6: Fitting of nonlinear growth models of the total productivity of Rapeseed and Mustard of (Kg/ha) crop during 1998-99 to 2017-18.

	Monomolecular	Logistic	Gompertz	Exponential
Parameter Estimates				
Y0	636.63 (75.85)***	631.27 (77.60)	634.12 (75.76)***	450.0 (39.33)
r	0.71 (0.56)	0.60 (0.53)	0.65 (0.54)	-0.001 (0.01)
K	432.14 (20.79)***	433.16 (21.44)	432.63 (21.10)***	
CGR	-0.70 %	-1.72 %	-1.72 %	-0.05 %
Diagnosis of Models				
MSE	6091.30	6228.05	6158.71	8370.47
RMSE	71.96	72.76	72.35	86.80
AIC	235.80	236.24	236.02	241.30
BIC	239.78	240.23	240.00	244.29
Non-Parametric Tests				
Run Test	97 (0.78)	97 (0.78)	97 (0.78)	100 (0.86)
Shapiro Wilk Test	0.95 (0.39)	0.95 (0.31)	0.95 (0.35)	0.92 (0.08)

*-significant at 5% **- Significant at 1%, ***- Significant at 0.1% and Figures in the parentheses indicate corresponding standard errors. *In residual test figures in the parentheses indicate corresponding p-values.

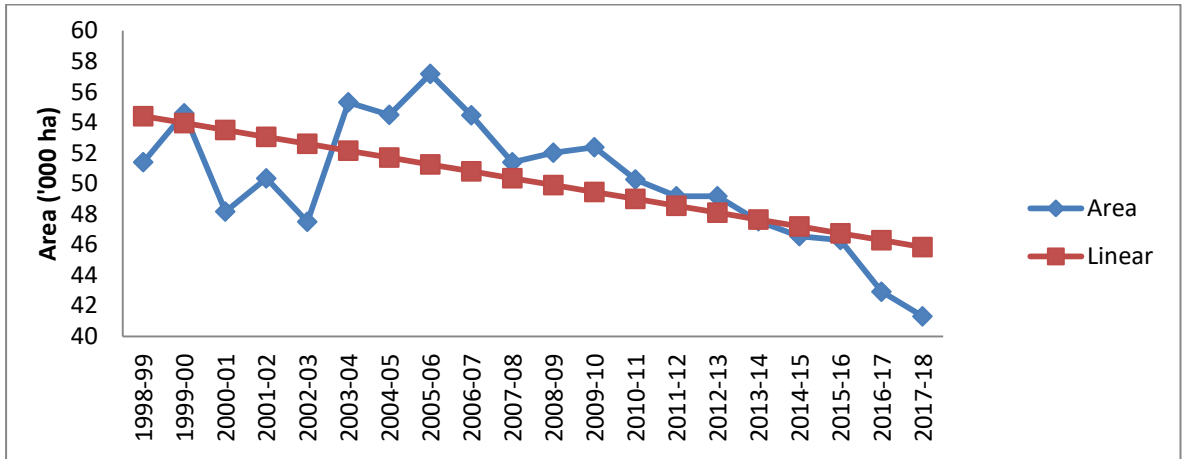


Fig 4.1.5.1: Rapeseed and Mustard area ('000 ha) of Chhattisgarh (1998-99 to 2017-18)

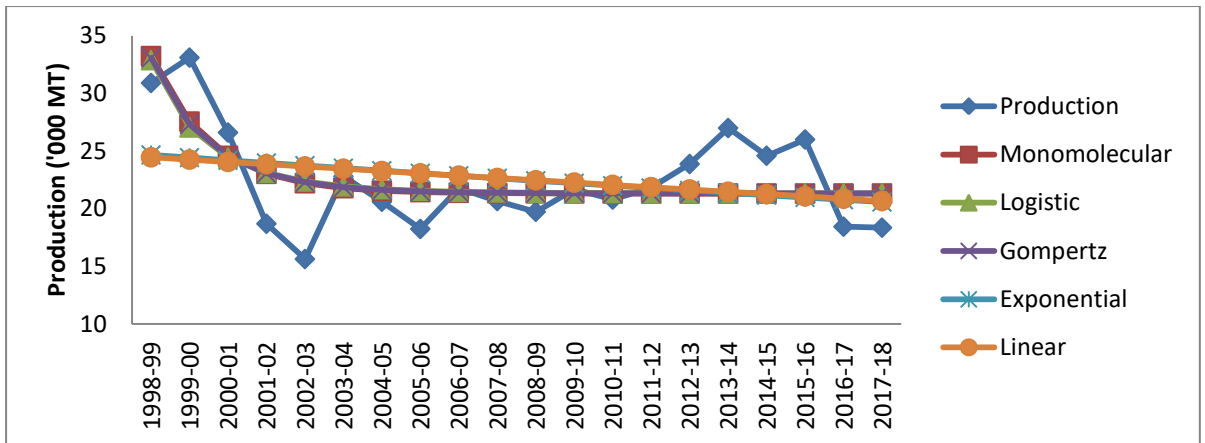


Fig 4.1.5.3: Rapeseed and Mustard production ('000 MT) of Chhattisgarh (1998-99 to 2017-18)

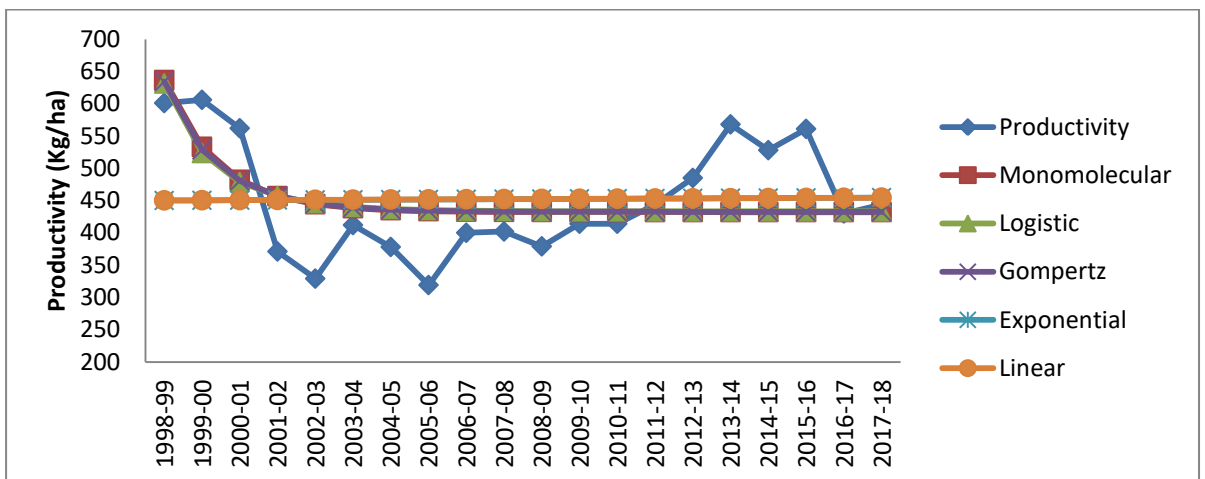


Fig 4.1.5.5: Rapeseed and Mustard productivity (Kg/ha) of Chhattisgarh (1998-99 to 2017-18)

4.1.6 Sunflower

4.1.6.1 Trend analysis of sunflower area in Chhattisgarh

The sunflower area in 1998-99 is be 0.70 ('000 ha) and increased up to 7.79 ('000 ha) in the year of 2005-06 there after it started decreasing drastically and presently only 1.28('000 ha) which almost near to the area 20 years back.

4.6.2 Nonlinear growth analysis of sunflower area in Chhattisgarh

To begin with first data point is taken as the initial value for analysis (for sunflower area initial values are ($y_0 = 01$, $r = 0.1$, $K = 07$)). The results are the models are presented below in table 4.1.6.2. From the table it was clear data set was fitted to monomolecular, logistic and exponential models are converged and Gompertz model did not converge. Selection is based on minimum MSE (2.93), RMSE (1.57), AIC (82.98) and BIC (86.96) values. The logistic model was found to be better for describing the area of sunflower of Chhattisgarh state. The examination of residuals reveals that errors are randomly and normally distributed. The run test statistic and Shapiro-Wilk test statistic values are not significant. The results of residual tests are presented in the table.

The best fitted logistic growth model equation is given by (Eq 4.1.6.2) and the computed compound growth rate was 22.25 %.

$$Y(t) = 4.305 \exp (\log(4.305 / 0.081) \exp (-1.56t)) \quad (4.1.6.2)$$

Table 4.1.6.2: Fitting of nonlinear growth models of an area of sunflower ('000 ha) crop during 1998-99 to 2017-18.

	Monomolecular	Logistic	Gompertz	Exponential
Parameter Estimates				
Y0	-0.17 (1.74)	0.08 (0.35)	Parameters did not	3.70 (0.91)
r	0.54 (0.43)	1.56 (1.70)	Converge	0.01(0.02)
K	4.22 (0.52)***	4.31 (0.445)		
CGR	44.58 %	22.25 %		22.25 %
Diagnosis of Models				
MSE	3.29	2.93	Converge	4.43
RMSE	1.67	1.56		1.99
AIC	85.35	82.98		90.41
BIC	89.33	86.96		93.40
Residual Tests				
Run Test	102 (0.93)	110 (0.86)		98 (0.81)
Shapiro Wilk Test	0.97 (0.72)	0.98 (0.97)		0.96 (0.53)

*-significant at 5% **- Significant at 1%, ***- Significant at 0.1% and Figures in the parentheses indicate corresponding standard errors. *In residual test figures in the parentheses indicate corresponding p-values.

4.1.6.3 Trend analysis of sunflower production in Chhattisgarh

From the fig (4.1.6.3) it can be observed that there is an increasing trend of sunflower production in Chhattisgarh up to 2005-06 and thereafter it decreased drastic. It was clear that maximum production of sunflower was observed 2.92 (000 MT) in the year 2005-06 and minimum production is observed in 0.22 (000 MT) in the year of 1998-99. Initially production started increasing to 2005-06 and suddenly started decline to 2011-12 and it started again increasing to 2012-13. It may be observed that last year production started declining again.

4.1.6.4 Nonlinear growth analysis of sunflower production in Chhattisgarh

To begin with first data point is taken as the initial value for analysis (for sunflower production initial values are $y_0 = 0.5$, $r = 0.1$, $K = 2.5$). The results are the models are presented below in table 4.1.6.4. Form the table it was clear Monomolecular, logistic and exponential model parameters are converged and the Gompertz model failed to converge. Selection of model based on minimum MSE

(31.32), RMSE (0.52), AIC (38.61) and BIC (42.60) values. The logistic model was found to be better for describing the sunflower production of Chhattisgarh state. The examination of residuals reveals that errors are randomly and normally distributed. The run test statistic and Shapiro-Wilk test statistic values are not significant. The results of residual tests are presented in the table.

The best-fitted model is the logistic model equation is given by (Eq 4.1.6.4) and the compound growth rate was 21.98 %.

$$Y(t) = 1.75 / (1 + (1.75 / 0.03) \exp(-1.40t)) \quad (4.1.6.4)$$

Table 4.1.6.4: Fitting of nonlinear growth models of production of sunflower ('000 MT) crop during 1998-99 to 2017-18.

	Monomolecular	Logistic	Gompertz	Exponential
Parameter Estimates				
Y0	-0.13 (0.57)	0.03 (0.12)	Parameters did not converge	1.32 (0.31)
r	0.47 (0.30)	1.40 (1.19)	Converge	0.01 (0.02)
K	1.72 (0.18)***	1.75 (0.15)***		
CGR	43.62 %	21.98 %		21.98 %
Diagnosis of Models				
MSE	0.38	0.32	Converge	0.59
RMSE	0.57	0.52		0.73
AIC	42.08	38.61		50.04
BIC	46.06	42.59		53.03
Non-Parametric Tests				
Run Test	100 (0.87)	106 (0.98)		102 (0.92)
Shapiro Wilk Test	0.93 (0.16)	0.95 (0.041)		0.93 (0.16)

*-significant at 5% **- Significant at 1%, ***- Significant at 0.1% and Figures in the parentheses indicate corresponding standard errors. *In residual test figures in the parentheses indicate corresponding p-values.

4.1.6.5 Trend analysis of sunflower productivity in Chhattisgarh

From in the fig (4.1.6.5) it can be observed a increasing trend of sunflower productivity of Chhattisgarh. Seen the graph the maximum productivity of sunflower was observed 786 (Kg/ha) in the year 2017-18 and minimum

productivity is observed in 305 (Kg/ha) in the year of 2000-01. Initially productivity started increasing to 525 (Kg/ha) in 2013-14 and it started decreasing to 352 (Kg/ha) in 2014-15. It may be observed that despite of decrease in area and production last four years the productivity is started increasing again owing to the productivity potential of the sunflower hybrids.

4.1.6.6 Nonlinear growth analysis of sunflower productivity in Chhattisgarh

To begin with, the first data point is taken as the initial value for analysis for sunflower productivity initial values are $y_0 = 374$, $r = 0.1$, $K = 650$. The results of the models are presented below in table 4.1.6. Seen in the table it was clear that the data set fitted to all the models attempted. Selection is based on minimum MSE (6886.04), RMSE (78.72), AIC (237.39) and BIC (240.38) values. The exponential growth model was found to be better for describing the oilseed productivity in Chhattisgarh state. Examinations of assumptions of residuals were also calculated. The examination of residuals reveals that errors are randomly and normally distributed. The run test statistic and Shapiro-Wilk test statistic values are significant for monomolecular, logistic and Gompertz model, for exponential model not significant. The results of residual tests are presented in the table.

The best fitted exponential model equation is given by (Eq 4.1.6.6) and the compound growth rate was 3.25 %.

$$Y(t) = 297.55 \exp(-0.03t) \quad (4.1.6.6)$$

Table 4.1.6.6: Fitting of nonlinear growth models of productivity of sunflower (Kg/ha) crop during 1998-99 to 2017-18.

	Monomolecular	Logistic	Gompertz	Exponential
Parameter Estimates				
Y0	327.17 (66.17)***	310.0 (59.88)	326.4 (56.12)	297.55 (30.58)
<i>r</i>	0.05 (0.14)	0.100 (0.13)	0.042 (0.15)	0.032 (0.01)
K	701.91 (759.77)	655.0 (342.89)	741.1 (1411.0)	
CGR	3.55 %	3.70 %	2.56 %	3.25 %
Diagnosis of Models				
MSE	10202.35	10273.85	8484.49	6886.04
RMSE	93.12	93.45	84.93	78.72
AIC	246.11	246.25	242.43	237.39
BIC	250.10	250.24	246.41	240.38
Non-Parametric Tests				
Run Test	42 (0.02)*	43 (0.02)*	70 (0.02)*	106 (0.98)
Shapiro Wilk Test	0.87 (0.02)*	0.89 (0.04)*	0.85 (0.01)*	0.92 (0.08)

*-significant at 5% **- Significant at 1%, ***- Significant at 0.1% and Figures in the parentheses indicate corresponding standard errors. *In residual test figures in the parentheses indicate corresponding p-values.

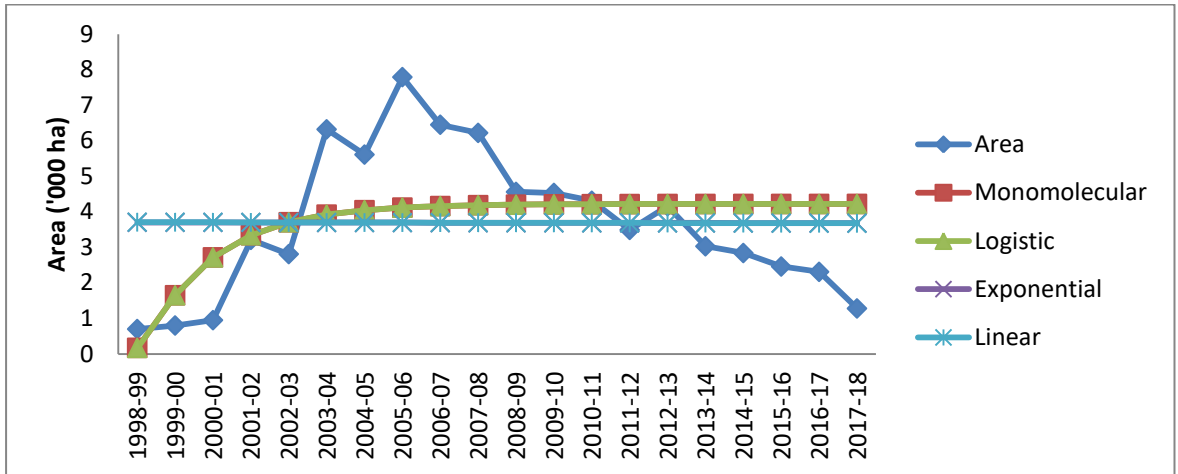


Fig 4.6.5: Sunflower area ('000 ha) in Chhattisgarh (1998-99 to 2017-18)

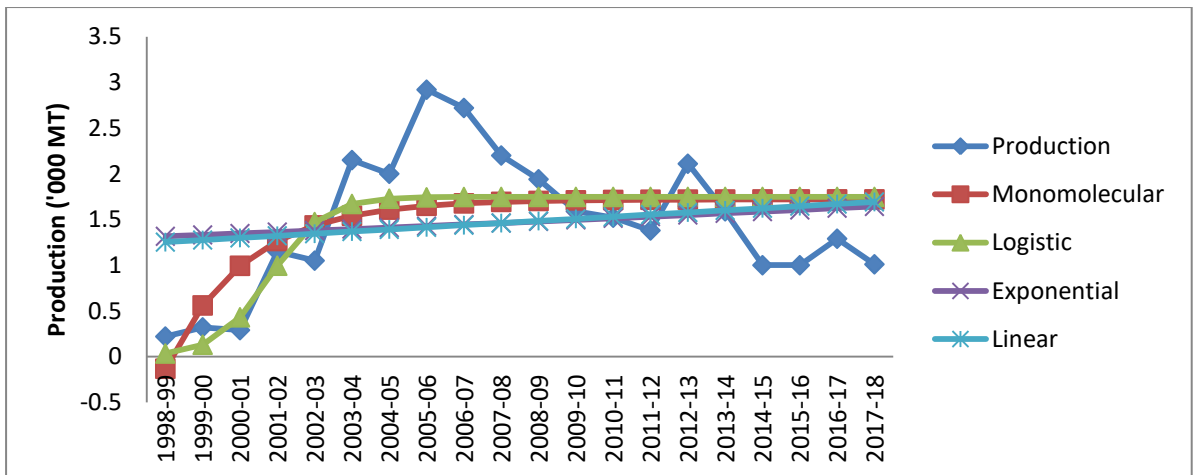


Fig 4.1.6.3: Sunflower production ('000 MT) in Chhattisgarh (1998-99 to 2017-18)

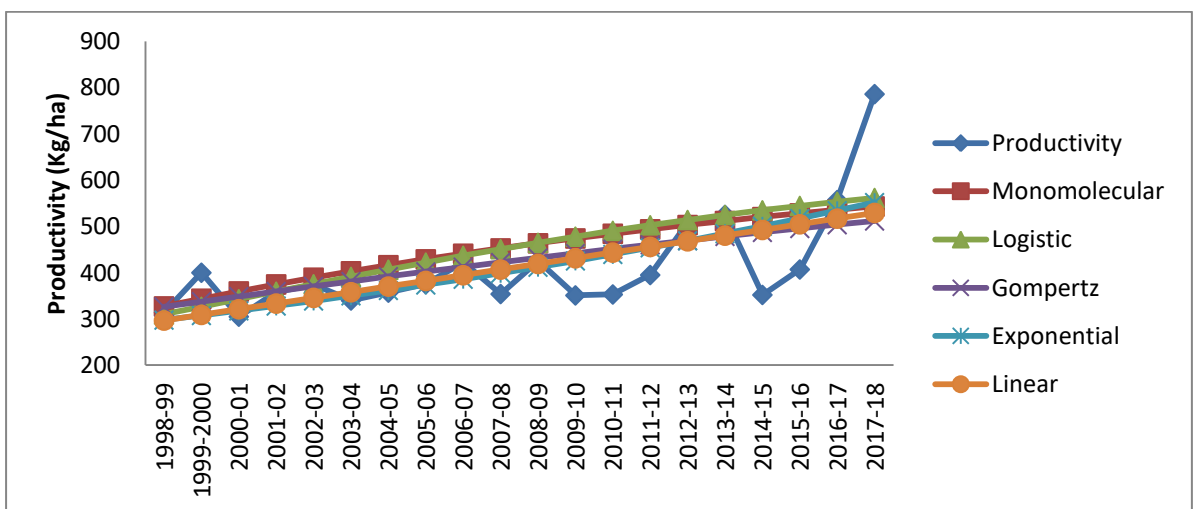


Fig 4.1.6.5: Sunflower productivity (Kg/ha) in Chhattisgarh (1998-99 to 2017-18)

4.1.7 Sesamum

4.1.7.1 Trend analysis of sesamum area in Chhattisgarh

From the fig (4.1.7.1), it can be observed a decreasing trend of sesamum area in Chhattisgarh. Seen the graph it was clear the maximum area of the sesamum was observed to be 25.80 ('000 ha) in the year 1999-2000 and the minimum area was observed to be 16.70 ('000 ha) in the year of 2013-14. Initially, production is started to decrease to 16.70 ('000 ha) in 1999-2000 and it started to increase to 19.07 ('000 ha) in 2015-16. It may be observed that for last two years it started declining again. An over all slow decreasing trend was observed for sesamum area in Chhattisgarh state.

4.1.7.2 Nonlinear growth analysis of sesamum area in Chhattisgarh

To begin with, the first data point is taken as the initial value for analysis for sesamum area initial values are $y_0 = 10$, $r = 0.1$, $K = 25$. The results are the model is presented in table 4.1.7.2 from the table it was clear data set was fitted to three models and Gompertz model did not converge. Selection is based on minimum MSE (1.30), RMSE (1.05), AIC (66.71) and BIC (70.69) values. The logistic model was found to be better describing the area of sesamum of Chhattisgarh state. The examination of residuals reveals that errors are randomly and normally distributed. The run test statistic and Shapiro-Wilk test statistic values are not significant. The results of residual tests are presented in the table.

The best fitted logistic growth model equation is given by (Eq 4.1.7.2) and the compound growth rate was -2.28 %.

$$Y(t) = 48.54 / (1 + (48.54 / 25.86) \exp (0.04t)) \quad (4.1.7.2)$$

Table 4.1.7.2: Fitting of nonlinear growth models of an area of sesamum (‘000 ha) crop during 1998-99 to 2017-18.

	Monomolecular	Logistic	Gompertz	Exponential
Parameter Estimates				
Y0	25.93 (0.71)***	25.86 (0.72)	Parameter did not	26.10 (0.52)***
r	0.01 (0.04)	-0.04 (0.04)	Converged	-0.02 (0.002)***
K	-29.63 (194.30)	48.54 (54.97)		
CGR	-2.28 %	-2.28 %		-2.25 %
Diagnosis of Models				
MSE	1.31	1.30		1.25
RMSE	1.05	1.05		1.06
AIC	66.87	66.71		65.06
BIC	70.85	70.69		68.05
Non-Parametric Tests				
Run Test	105 (1.00)	104 (0.98)		105 (1.00)
Shapiro Wilk Test	0.96 (0.49)	0.96 (0.46)		0.96 (0.66)

*-significant at 5% **- Significant at 1%, ***- Significant at 0.1% and Figures in the parentheses indicate corresponding standard errors. *In residual test figures in the parentheses indicate corresponding p-values.

4.1.7.3 Trend analysis of sesamum production in Chhattisgarh

From fig (4.1.7.3) it was observed an increasing trend of sesamum production in Chhattisgarh. Seen the graph it was clear the maximum production of sesamum was observed 8.63 (000 MT) in the year 2009-10 and minimum production is observed in 3.95 (000 MT) in the year 0-01. Initially it was started decreasing to 3.95 (000 MT) in year 2000-01 and it started increasing to 8.63 (‘000 MT) in year 2009-10 and it was again started decreasing and increasing. It may be observed that last year it started declining again.

4.1.7.4 Nonlinear growth analysis of sesamum production in Chhattisgarh

To begin with, the first data point is taken as the initial value for analysis for sesamum production initial values are $y_0 = 4$, $r = 0.1$, $K = 8$. The results are the models are presented below in table 4.1.7.4. Form the table it was clear data set

was fitted to all the models attempted. The selection of model is based on minimum MSE (1.24), RMSE (1.02), AIC (65.73) and BIC (69.71) values. The logistic model was found to better for describing the production of sesamum of Chhattisgarh state. The examination of residuals reveals that errors are randomly and normally distributed. The run test statistic and Shapiro-Wilk test statistic values are not significant. The results of residual tests are presented in the table.

The best fitted logistic growth model equation is given by (Eq 4.1.7.4) and the compound growth rate was 3.47 %.

$$Y(t) = 6.86 / (1 + (6.86 / 3.70) \exp (-0.39t)) \quad (4.1.7.4)$$

Table 4.1.7.4: Fitting of nonlinear growth models of production of sesamum ('000 MT) crop during 1998-99 to 2017-18.

	Monomolecular	Logistic	Gompertz	Exponential
Parameter Estimates				
Y0	3.78 (0.95)***	3.74 (0.86)***	3.76 (0.91)***	5.34 (0.51)***
r	0.28 (0.19)	0.39 (0.21)	0.33 (0.21)	-0.02 (0.01)
K	6.89 (0.45)***	6.86 (0.38)***	6.87 (0.41)***	
CGR	4.45 %	3.47 %	3.97 %	-1.61 %
Diagnosis of Models				
MSE	1.27	1.24	1.25	1.60
RMSE	1.04	1.02	1.03	1.20
AIC	66.33	65.73	66.02	70.05
BIC	70.31	69.71	70.00	73.04
Non-Parametric Tests				
Run Test	115 (0.73)	115 (0.73)	115 (0.73)	105 (1.0)
Shapiro Wilk Test	0.92 (0.11)	0.92 (0.09)	0.92 (0.10)	0.96 (0.30)

*-significant at 5% **- Significant at 1%, ***- Significant at 0.1% and Figures in the parentheses indicate corresponding standard errors. *In residual test figures in the parentheses indicate corresponding p-values.

4.1.7.5 Trend analysis of sesamum productivity in Chhattisgarh

The trend of sesamum productivity is presented in the fig (4.1.7.5). It was clearly seen the graph trend of sesamum productivity in Chhattisgarh is increasing trend from the period of 1998-99 to 2017-18. The maximum productivity of

sesamum was observed 448 (Kg/ha) in the year 2014-15 and minimum productivity is observed in 168 (Kg/ha) in the year 2002-03.

4.7.6 Nonlinear growth analysis of sesamum productivity in Chhattisgarh

To begin with, the first data point is taken as the initial value for analysis for sesamum productivity initial values are $y_0 = 180$, $r = 0.1$, $K = 400$. The results are the model is presented in table 4.7.6. From the table it was clear data set was fitted to all three models attempted. Selection is based on minimum MSE (2683.96), RMSE (47.76), AIC (219.40) and BIC (223.39.) values. The logistic model was found to be better describing the productivity of the sesamum of Chhattisgarh state. The examination of residuals reveals that errors are randomly and normally distributed. The run test statistic and Shapiro-Wilk test statistic values are not significant. The results of residual tests are presented in the table.

The best fitted logistic growth model equation is given by (Eq 4.1.7.6) and the compound growth rate was 5.04 %.

$$Y(t) = 379.02 / (1 + (379.02 / 147.28) \exp (-0.25t)) \quad (4.1.7.6)$$

Table 4.1,7.6: Fitting of nonlinear growth models of productivity of sesamum (Kg/ha) crop during 1998-99 to 2017-18.

	Monomolecular	Logistic	Gompertz	Exponential
Parameter Estimates				
Y0	143.88 (38.59) **	147.28 (31.70)***	145.06 (34.65)***	213.2 (21.84)***
<i>r</i>	0.12 (0.08)	0.25 (0.10)*	0.19 (0.09)*	0.04 (0.01)***
K	405.29 (60.67)***	379.02 (30.20)***	388.02 (39.49)***	
CGR	5.83 %	5.04 %	5.44 %	3.49 %
Diagnosis of Models				
MSE	2793.93	2683.96	2730.11	3603.98
RMSE	48.73	47.76	48.17	56.95
AIC	220.21	219.40	219.75	224.45
BIC	224.19	223.39	223.73	227.43
Non-Parametric Tests				
Run Test	112 (0.81)	110 (0.87)	111 (0.84)	105 (1.0)
Shapiro Wilk Test	0.94 (0.23)	0.95 (0.31)	0.94 (0.26)	0.96 (0.45)

*-significant at 5% **- Significant at 1%, ***- Significant at 0.1% and Figures in the parentheses indicate corresponding standard errors. *In residual test figures in the parentheses indicate corresponding p-values.

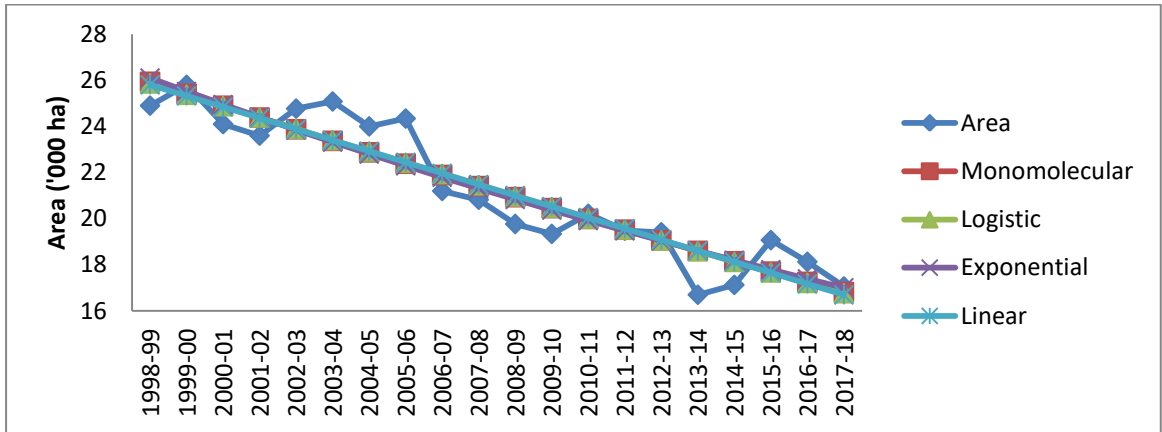


Fig 4.1.7.1: Sesamum area ('000 ha) of Chhattisgarh (1998-99 to 2017-18)

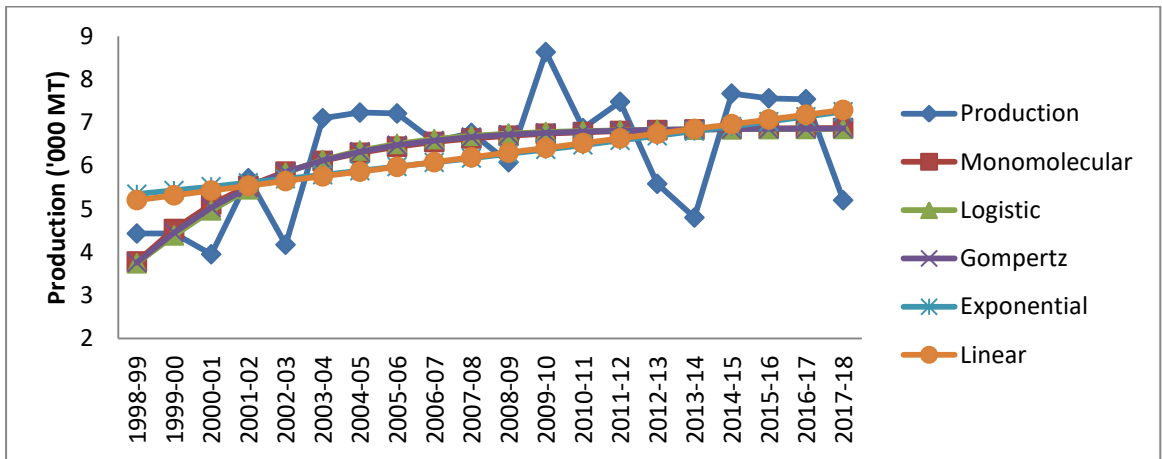


Fig 4.1.7.3: Sesamum production ('000 MT) of Chhattisgarh (1998-99 to 2017-18)

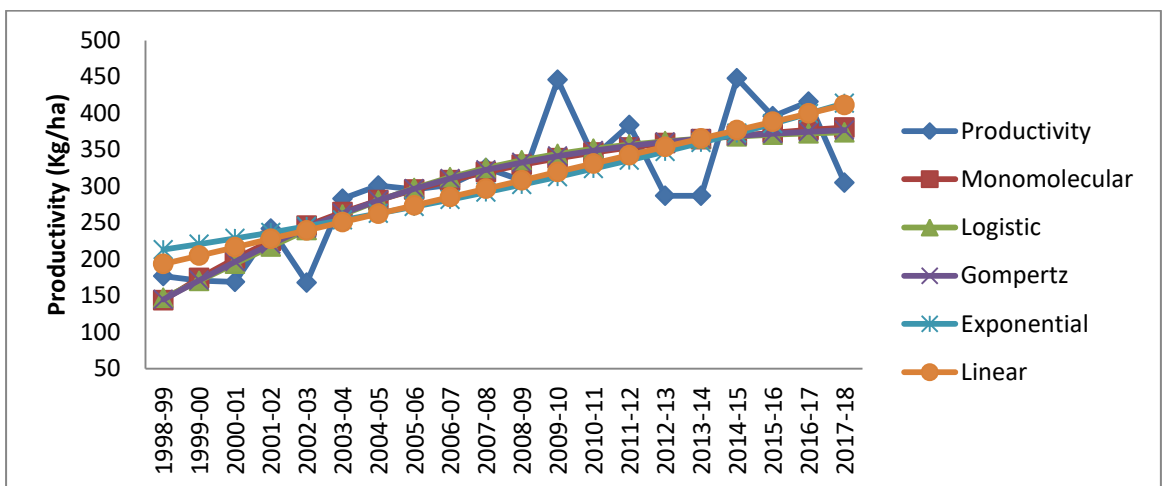


Fig 4.1.7.5: Sesamum Productivity (Kg/ha) of Chhattisgarh (1998-99 to 2017-18)

4.1.8 Linseed

Linseed is an important industrial and edible oil and fiber producing the crop. Linseed is grown as a rabi crop of eastern Uttar Pradesh, Madhya Pradesh, Chhattisgarh, Maharashtra, Odisha, and Bihar. It has a high percentage of essential fatty acids, 75 % polyunsaturated fatty acids, 57 % alpha-linolenic acid, which is an omega-3 fatty acid, and 16 % linoleic acid, which is an omega-6 fatty acid (Morris, 2005).

4.1.8.1 Trend analysis of linseed area in Chhattisgarh

The trend of the linseed area is presented in fig 4.1.8.1. It was clearly observed from the graph the area of linseed in Chhattisgarh showed a drastically decreasing trend from the period of 1998-99 to 2017-18. The maximum area of linseed was observed to be 123.10 ('000 ha) in the year 1999-2000 and minimum area was observed to be 17.74 ('000 ha) in the year 2017-18. The decreasing in area may be due per capita availability area is decreasing owing to population increase and farmer has to shift to other crops for their sustenance (Santhosh Kumar, 2018)

4.1.8.2 Nonlinear growth analysis of linseed area in Chhattisgarh

The data were fitted to the growth models with the initial values $y_0 = 118$, $r = 0.1$, $K = 17.74$. Final parameter estimates along with diagnosis of models and residual analysis (non-parametric tests) were presented in table 4.1.8.2. Selection of model based on minimum MSE (44.69), RMSE (6.16), AIC (137.50) and BIC (141.49) values. The monomolecular model was found to be better for describing the area of Linseed of Chhattisgarh state. The results of residuals test (non-parametric tests) were also presented in the table. Results reveals that run test and Shapiro Wilk test statistic values are not significant.

The best fitted monomolecular growth model equation is given by (Eq 4.1.8.2.) and the computed compound growth rate was -9.29%.

$$Y(t) = 753.73 - 645.99 \exp(-0.07t) \quad (4.1.8.2)$$

4.1.8.2; Fitting of nonlinear growth models of area of Linseed ('000 ha) crop during 1998-99 to 2017-18.

	Monomolecular	Logistic	Gompertz	Exponential
Parameter Estimates				
Y0	113.74 (4.56)***	114.84 (7.98)***	113.90 (4.82)***	115.47 (3.86)
r	0.07 (0.02)**	-0.01 (0.04)	-0.01 (0.02)	-0.08 (0.01)
K	-11.72 (19.99)	-8.61 (37.29)	63840 (815000)	
CGR	-9.29 %	-7.82 %	-9.06 %	-8.78 %
Diagnosis of Models				
MSE	44.69	89.85	45.16	43.34
RMSE	6.16	8.74	6.19	6.25
AIC	137.50	151.47	137.71	136.03
BIC	141.49	155.45	141.70	139.01
Non-Parametric Tests				
Run Test	99 (0.84)	126 (0.47)	96 (0.75)	93 (0.67)
Shapiro Wilk Test	0.90 (0.04)	0.94 (0.24)	0.91 (0.06)	0.94 (0.23)

*-significant at 5% **- Significant at 1%, ***- Significant at 0.1% and Figures in the parentheses indicate corresponding standard errors. *In residual test figures in the parentheses indicate corresponding p-values.

4.1.8.3 Trend analysis of linseed production in Chhattisgarh

The trend of linseed production is presented in Fig 4.1.8.3. Seen the graph it was clear linseed production in Chhattisgarh is also showed a decreasing trend from the period of 1998-99 to 2017-18. The maximum production of linseed was observed 31.20 ('000 MT) in 1999-2000 and minimum production was observed in 4.58 ('000 MT) in the year of 2017-18.

4.1.8.4 Nonlinear growth analysis of linseed production in Chhattisgarh

The data were fitted to the growth models with the initial values $y_0 = 20$, $r = 0.1$, $K = 5$. Final parameter estimates along with diagnosis of models and residual analysis (non-parametric tests) were presented in table 4.1.8.4. Monomolecular, logistic, and exponential models were converged and Gompertz model failed to converge. Selection of model based on minimum MSE (6.53), RMSE (2.36), AIC (99.02) and BIC (103.00) values. The monomolecular model was found to be better for describing the production of Linseed of Chhattisgarh state. The results of

residuals test (non-parametric tests) were also presented in a table. Results reveals that run test and Shapiro Wilk test statistic values are not significant.

The best fitted monomolecular growth model equation is given by (Eq 4.1.8.4) and the computed compound growth rate was -6.50%.

$$Y(t) = 110.93 - 84.32 \exp(-0.05t) \quad (4.1.8.4)$$

4.1.8.4; Fitting of nonlinear growth models of production of Linseed ('000 ha) crop during 1998-99 to 2017-18.

	Monomolecular	Logistic	Gompertz	Exponential
Parameter Estimates				
Y0	26.61 (1.67)	23.36 (2.68)	Parameters did not	26.99 (1.35)
R	0.05 (0.04)	-0.03 (0.08)	Converge	-0.06 (0.01)
K	-5.32 (18.24)	-21.45 (114.98)		
CGR	-6.50 %	-5.90 %		-6.18 %
Diagnosis of Models				
MSE	6.53	12.82		6.22
RMSE	2.36	3.30		2.36
AIC	99.02	112.53		97.19
BIC	103.00	116.52		100.18
Non-Parametric Tests				
Run Test	99 (0.84)	100 (0.85)		101 (0.86)
Shapiro Wilk Test	0.97 (0.67)	0.93 (0.15)		0.98 (0.86)

*-significant at 5% **- Significant at 1%, ***- Significant at 0.1% and Figures in the parentheses indicate corresponding standard errors. *In residual test figures in the parentheses indicate corresponding p-values.

4.1.8.5 Trend analysis of linseed productivity in Chhattisgarh

The trend of linseed productivity is presented in the fig 4.1.8.5. It was clearly seen the graph trend of linseed productivity in Chhattisgarh is increasing trend from the period of 1998-99 to 2017-18. The maximum productivity of linseed was observed 468 (Kg/ha) in the year 2016-17 and minimum productivity is observed in 204 (Kg/ha) in the year 1998-99.

4.1.8.4 Nonlinear growth analysis of linseed productivity in Chhattisgarh

The data were fitted to the growth models with the initial values $y_0 = 204$, $r = 0.5$, $K = 410$. Final parameter estimates along with diagnosis of models and residual analysis (non-parametric tests) were presented in table 4.1.8.6. Selection of model based on minimum MSE (2790.98), RMSE (48.61), AIC (220.19) and BIC (224.17) values. The logistic growth model was found to be better for describing the productivity of Linseed of Chhattisgarh state. The results of residuals test (non-parametric tests) were also presented in the table. Results reveals that run test and Shapiro Wilk test statistic values are not significant.

The best fitted logistic model equation is given by (Eq 4.1.8.6) and the compound growth rate was 2.78 %.

$$Y(t) = 820.60 / (1 + (820.60 / 228.2 - 1) \exp(-0.04t)) \quad (4.1.8.6)$$

4.1.8.6: Fitting of nonlinear growth models of productivity of Linseed ('000 ha) crop during 1998-99 to 2017-18.

	Monomolecular	Logistic	Gompertz	Exponential
Parameter Estimates				
Y0	227.19 (44.72)***	228.2 (26.69)***	228.9 (30.47)	232.1 (19.45)
r	0.14 (0.21)	0.04 (0.10)	0.013 (0.10)	0.027 (0.01)
K	333.15 (60.51)***	820.60 (2977.0)	2446 (36840)	
CGR	1.94 %	2.78 %	2.79 %	2.74 %
Diagnosis of Models				
MSE	3655.23	2790.98	2794.06	2643.24
RMSE	55.74	48.71	48.73	48.77
AIC	225.58	220.19	220.21	218.25
BIC	229.56	224.17	224.19	221.23
Non-Parametric Tests				
Run Test	125 (0.47)	110 (0.87)	110 (0.87)	112 (0.81)
Shapiro Wilk Test	0.95 (0.38)	0.94 (0.41)	0.91 (0.40)	0.94 (0.34)

*-significant at 5% **- Significant at 1%, ***- Significant at 0.1% and Figures in the parentheses indicate corresponding standard errors. *In residual test figures in the parentheses indicate corresponding p-values.

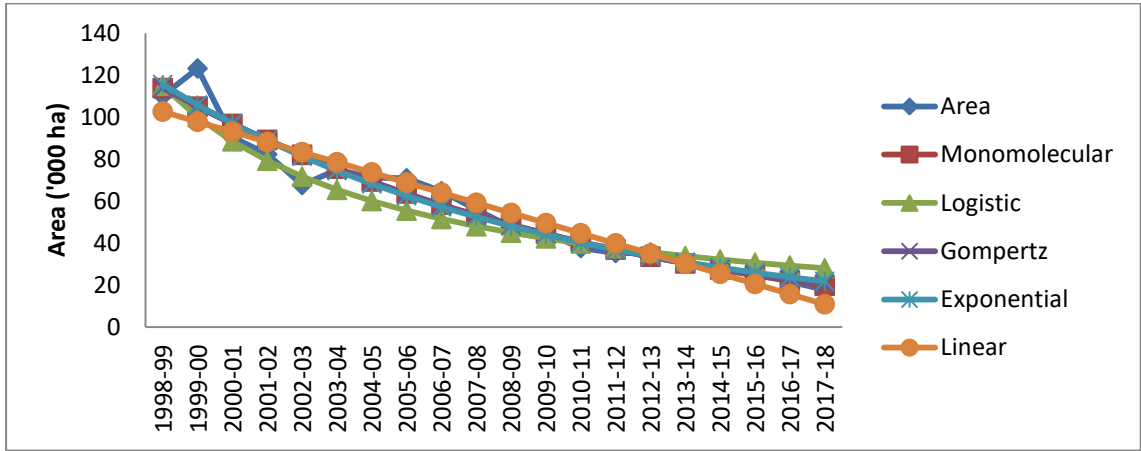


Fig 4.8.1 (a): Linseed area ('000 ha) of Chhattisgarh (1998-99 to 2017-18)

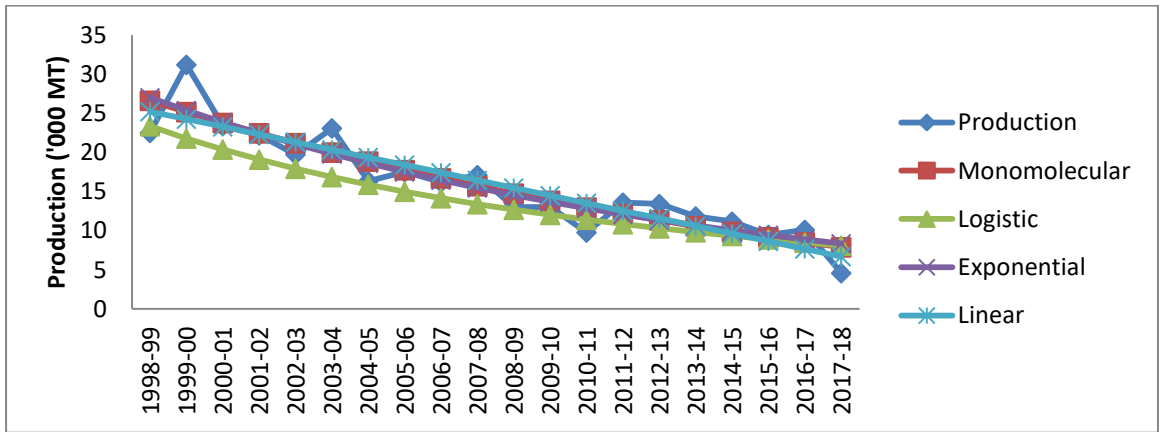


Fig 4.1.8.3: Linseed production ('000 MT) of Chhattisgarh (1998-99 to 2017-18)

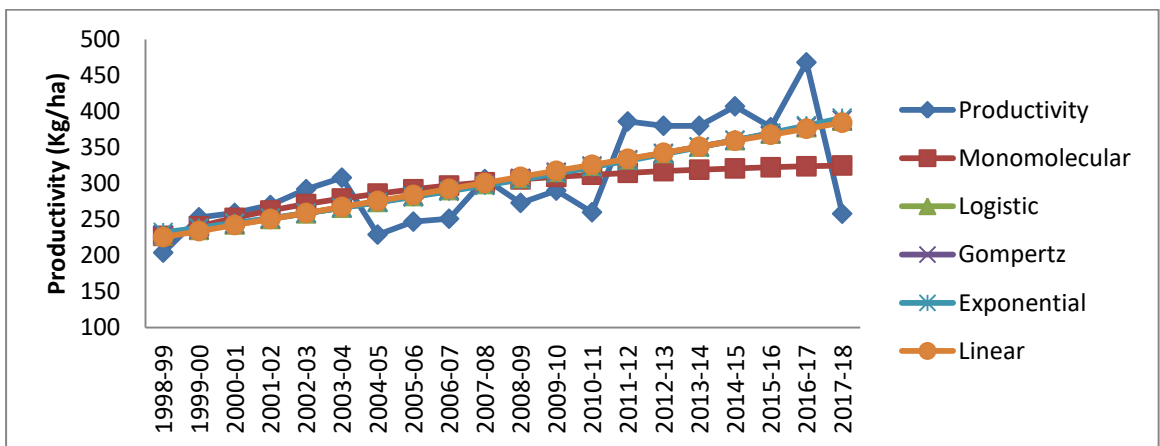


Fig 4.1.8.5: Linseed productivity (Kg/ha) of Chhattisgarh (1998-99 to 2017-18)

4.2 Crop-wise situation in Chhattisgarh state

Trend analysis and growth analysis of cereals crops like; paddy and wheat and pulses crops like tur, gram, moong, and urad are done. The results of these analyses are presented below.

4.2.1 Paddy (Rice)

4.2.1.1 Trend analysis of paddy area in Chhattisgarh

In Fig 4.2.1.1 it observed an increasing trend of paddy area in Chhattisgarh. Seen the graph it was clear the maximum area of the paddy was observed to be 3880.280 ('000 ha) in the year of 2017-18 and minimum area was observed to be 3670.60 ('000 ha) in the year of 1998-99.

4.2.1.2 Nonlinear growth analysis of paddy area in Chhattisgarh

To begin with, first data point is taken as the initial value for analysis for paddy area initial values are $y_0 = 3682$, $r = 0.5$, $K = 3820$. The results are the models are presented below in table 4.2.1.2. For seen the table it was clear data set was fitted to all the models attempted. Selection is based on minimum MSE (464.66), RMSE (19.87), AIC (184.33) and BIC (188.32) values. The monomolecular model was found to be better for describing the paddy area of Chhattisgarh state. The examination of residuals reveals that errors are randomly and normally distributed. The run test statistic and Shapiro-Wilk test statistic values are not significant. The results of residual tests are presented in table.

The best fitted monomolecular growth model equation is given by (Eq 4.2.2.2) and the compound growth rate was 0.21 %.

$$Y(t) = 4200 - 504 \exp(-0.02t) \quad (4.2.2.2)$$

Table 4.2.1.2: Fitting of nonlinear growth models of the total area of paddy (‘000 ha) crop during 1998-99 to 2017-18.

	Monomolecular	Logistic	Gompertz	Exponential
Parameter Estimates				
Y0	3696 (13.53)***	3697 (13.45)***	3696 (13.49)***	3701 (8.98)***
r	0.02 (0.04)	0.02 (0.04)	0.02 (0.04)	0.002 (0.001)
K	4200 (960.1)***	4189 (908.30)***	4194 (908.3)***	
CGR	0.21 %	0.21 %	0.21 %	0.21 %
Diagnosis of Models				
MSE	464.66	465.21	464.94	468.51
RMSE	19.87	19.89	19.88	19.96
AIC	184.33	184.36	184.35	182.50
BIC	188.32	188.34	188.33	185.49
Non-Parametric Tests				
Run Test	98 (0.81)	98 (0.81)	98 (0.81)	102 (0.92)
Shapiro Wilk Test	0.96 (0.56)	0.96 (0.57)	0.96 (0.56)	0.96 (51)

*-significant at 5% **- Significant at 1%, ***- Significant at 0.1% and Figures in the parentheses indicate corresponding standard errors. *In residual test figures in the parentheses indicate corresponding p-values.

4.2.1.3 Trend analysis of paddy production in Chhattisgarh

The trend of paddy production is presented in the fig (4.2.1.3). It was clearly seen the graph trend of paddy production in Chhattisgarh is increasing trend from the period of 1998-99 to 2017-18. The maximum production of paddy was observed 8048.460 (000 MT) in the year 2016-17 and minimum production is observed in 2337.430 (000 MT) in the year 2000-01.

4.2.1.4 Nonlinear growth analysis of paddy production in Chhattisgarh

To begin with, first data point is taken as the initial value for analysis for paddy production initial values are $y_0 = 3636.9$, $r = 0.1$, $K = 7340.29$. The results are the models are presented below in table 4.2.1.4. For seen the table it was clear data set was fitted to all the models attempted. Selection is based on minimum MSE (1194349), RMSE (1007.57), AIC (341.37) and BIC (345.35) values. The logistic model was found to be better for describing the paddy production of

Chhattisgarh state. The examination of residuals reveals that errors are randomly and normally distributed. The run test statistic and Shapiro-Wilk test statistic values are not significant. The results of residual tests are presented in table.

The best fitted logistic growth model equation is given by (Eq 4.2.2.4) and the compound growth rate was 3.62 %.

$$Y(t) = 8358 - (1 + (8358 / 3444) \exp(-0.10t)) \quad (4.2.2.4)$$

Table 4.2.1.4: Fitting of nonlinear growth models of production of paddy ('000 MT) crop during 1998-99 to 2017-18.

	Monomolecular	Logistic	Gompertz	Exponential
Parameter Estimates				
Y0	3445 (690.7)***	3444 (625.3)***	3442 (656.4)***	3765 (395.5)***
r	0.02 (0.09)	0.10 (0.10)	0.06 (0.09)	0.03 (0.01)***
K	14150 (39750)	8358 (4512)	9570 (8849)	
CGR	3.99 %	3.62 %	3.79 %	3.36 %
Diagnosis of Models				
R ²	0.72	0.72	0.72	0.71
MSE	1202172	1194349	1198208	1233196
RMSE	1010.86	1007.57	1009.19	1023.83
AIC	341.5	341.37	341.43	340.01
BIC	345.48	345.35	345.41	342.99
Non-Parametric Tests				
Run Test	111 (0.84)	111 (0.84)	111 (0.84)	109 (0.89)
Shapiro Wilk Test	0.89 (0.04)*	0.89 (0.04)*	0.89 (0.04)*	0.89 (0.02)*

*-significant at 5% **- Significant at 1%, ***- Significant at 0.1% and Figures in the parentheses indicate corresponding standard errors. *In residual test figures in the parentheses indicate corresponding p-values.

4.2.1.5 Trend analysis of paddy productivity in Chhattisgarh

The trend of paddy productivity is presented in the fig (4.2.1.5). It was clearly seen the graph trend of paddy productivity in Chhattisgarh is increasing trend from the period of 1998-99 to 2017-18. The maximum productivity of paddy was observed 2212 (Kg/ha) in the year 2016-17 and minimum production is observed in 609 (Kg/ha) in the year 2000-01.

4.2.1.6 Nonlinear growth analysis of paddy productivity in Chhattisgarh

To begin with, first data point is taken as the initial value for analysis for paddy productivity initial values are $y_0 = 669$, $r = 0.1$, $K = 2200$. The results are the models are presented below in table 4.2.1.6. For seen the table it was clear data set was fitted to all the models attempted. Selection is based on minimum MSE (94979.12), RMSE (284.13), AIC (290.74) and BIC (294.72) values. The logistic model was found to be better for describing the paddy productivity of Chhattisgarh state. The examination of residuals reveals that errors are randomly and normally distributed. The run test statistic and Shapiro-Wilk test statistic values are not significant. The results of residual tests are presented in table.

The best fitted logistic growth model equation is given by (Eq 4.2.2.6) and the compound growth rate was 3.73 %.

$$Y(t) = 2175.6 - (1 + (2175.6 / 920.59) \exp(-0.11t)) \quad (4.2.2.6)$$

Table 4.2.1.6: Fitting of nonlinear growth models of productivity of paddy (Kg/ha) crop during 1998-99 to 2017-18.

	Monomolecular	Logistic	Gompertz	Exponential
Parameter Estimates				
Y0	925.1 (197.9)***	920.59 (177.77)***	922.1 (187.4)	1031 (112.3)***
r	0.03 (0.09)	0.11 (0.10)	0.07 (0.10)	0.03 (0.01)
K	3212 (5757)	2175.6 (905.63)*	2426 (1680)	
CGR	4.17 %	3.74 %	3.93 %	3.37 %
Diagnosis of model				
MSE	96091.07	94979.12	95532.6	99601.59
RMSE	285.79	284.13	284.96	290.97
AIC	290.97	290.73	290.85	289.68
BIC	294.95	294.72	294.83	292.67
Non-Parametric Tests				
Run Test	106 (0.98)	105 (1.0)	106 (0.98)	112 (0.81)
Shapiro Wilk Test	0.89 (0.03)	0.90 (0.04)	0.89 (0.04)	0.88 (0.02)

*-significant at 5% **- Significant at 1%, ***- Significant at 0.1% and Figures in the parentheses indicate corresponding standard errors. *In residual test figures in the parentheses indicate corresponding p-values.

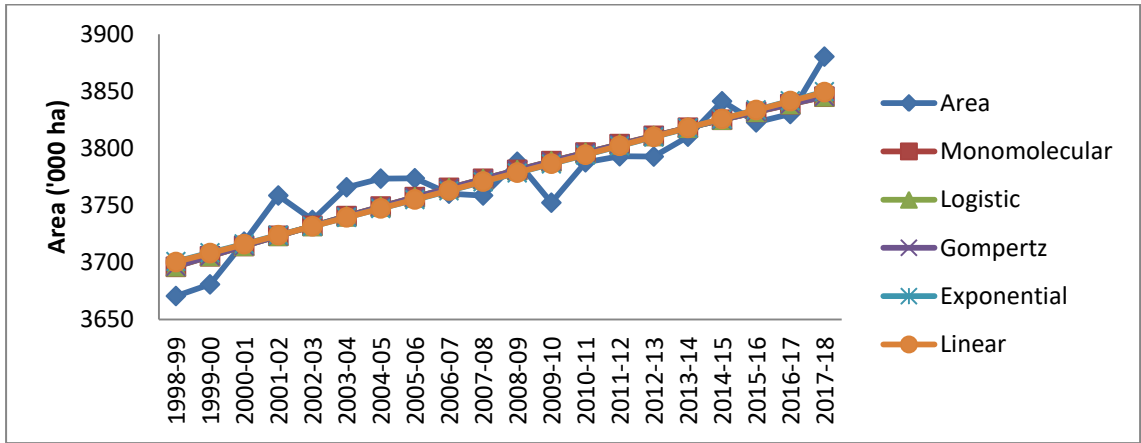


Fig 4.2.2.1: Paddy area ('000 ha) of Chhattisgarh (1998-99 to 2017-18)

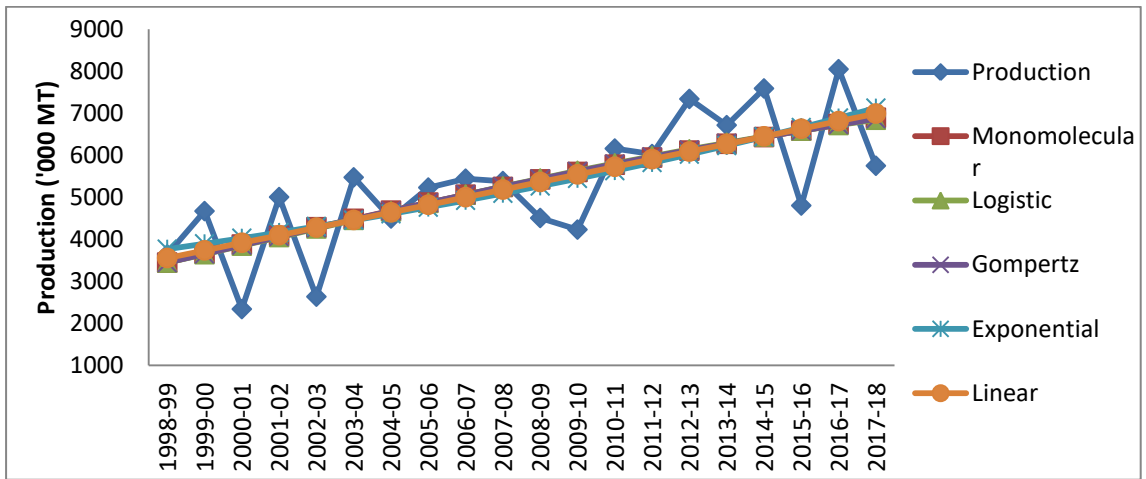


Fig 4.2.1.3: Paddy production ('000 MT) of Chhattisgarh (1998-99 to 2017-18)

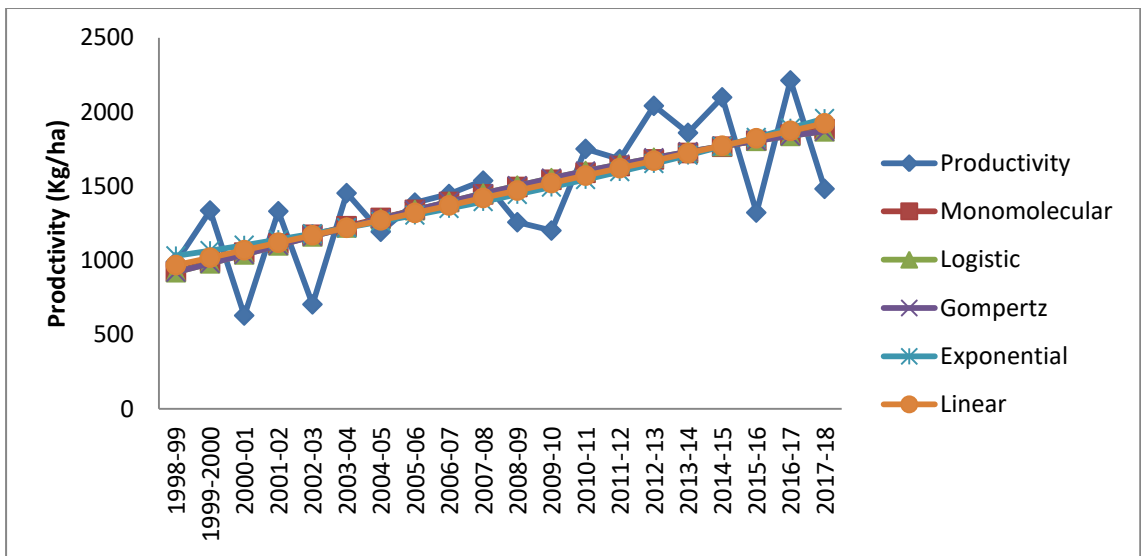


Fig 4.2.1.5: Paddy productivity (Kg/ha) of Chhattisgarh (1998-99 to 2017-18)

4.2.2 Wheat

4.2.2.1 Trend analysis of the wheat area in Chhattisgarh

The trend of wheat area is presented in fig (4.2.2.1). It was clearly seen the graph the trend of an area of wheat in Chhattisgarh is increasing trend from the period of 1998-99 to 2017-18. The maximum area of the wheat was observed to be 109.19 (000'ha) in the year 2009-10 and minimum area was observed to be 77.84 (000'ha) in the year 2000-01.

4.2.2.2 Nonlinear growth analysis of the wheat area in Chhattisgarh

To begin with, first data point is taken as the initial value for analysis for wheat area initial values are $y_0 = 80$, $r = 0.5$, $K = 105$. The results are the models are presented below in table 4.2.2.2. For seen the table it was clear data set was fitted to all the models attempted. Selection is based on minimum MSE (29.90), RMSE (5.04), AIC (129.46) and BIC (133.45) values. The monomolecular model was found to be better for describing the wheat area of Chhattisgarh state. The examination of residuals reveals that errors are randomly and normally distributed. The run test statistic and Shapiro-Wilk test statistic values are not significant. The results of the residual tests are presented in table.

The best fitted monomolecular growth model equation is given by (Eq 4.2.2.2) and the compound growth rate was 1.10 %.

$$Y(t) = 508.27 - 421.99 \exp(-0.13t) \quad (4.2.2.2)$$

Table 4.2.2.2: Fitting of nonlinear growth models of area of wheat ('000 ha) crop during 1998-99 to 2017-18.

	Monomolecular	Logistic	Gompertz	Exponential
Parameter Estimates				
Y0	86.28 (4.01)***	86.42 (3.89)***	86.35 (3.95)***	90.59 (2.33)***
r	0.13 (0.09)	0.15 (0.10)	0.14 (0.10)	0.01 (0.002)
K	106.69 (5.94)***	106.18 (5.12)***	106.42 (5.49)***	
CGR	1.10 %	1.04 %	1.07 %	0.90 %
Diagnosis of Models				
MSE	29.90	29.92	29.91	31.87
RMSE	5.04	5.05	5.04	5.36
AIC	129.46	129.48	129.47	129.88
BIC	133.45	133.46	133.45	132.87
Non-Parametric Tests				
Run Test	115 (0.73)	114 (0.75)	115 (0.73)	103 (0.96)
Shapiro Wilk Test	0.96 (0.57)	0.96 (0.57)	0.96 (0.57)	0.95 (0.38)

*-significant at 5% **- Significant at 1%, ***- Significant at 0.1% and Figures in the parentheses indicate corresponding standard errors. *In residual test figures in the parentheses indicate corresponding p-values.

4.2.2.3 Trend analysis of wheat production in Chhattisgarh

The trend of wheat production is presented in the fig (4.2.2.3). It was clearly seen the graph trend of wheat production in Chhattisgarh is increasing trend from the period of 1998-99 to 2017-18. The maximum production of wheat was observed 153.32 (000 MT) in the year 2014-15 and minimum production is observed in 76.70 (000 MT) in the year 1998-99.

4.2.2.4 Nonlinear growth analysis of wheat production in Chhattisgarh

To begin with first data point is taken as the initial value for analysis for wheat production initial values are $y_0 = 46$, $r = 0.1$, $K = 145$. The results are the models are presented below in table 4.2.2.4. For seen the table it was clear data set was fitted to logistic and exponential models are converged and monomolecular and Gompertz model did not converge. Selection is based on minimum MSE (113.61), RMSE (10.11), AIC (155.31) and BIC (158.29) values. An exponential model was found to be better for describing the wheat production of Chhattisgarh

state. The examination of residuals reveals that errors are randomly and normally distributed. The run test statistic and Shapiro-Wilk test statistic values are not significant. The results of residual tests are presented in table.

The best fitted exponential growth model equation is given by (Eq 4.2.2.4) and the compound growth rate was 3.54 %.

$$Y(t) = 79.36 \exp (- 0.04t) \quad (4.2.2.4)$$

Table 4.2.2.4: Fitting of nonlinear growth models of production of wheat ('000 MT) crop during 1998-99 to 2017-18.

	Monomolecular	Logistic	Gompertz	Exponential
Parameter Estimates				
Y0	Parameter did not	79.05 (5.86)***	Parameter did not	79.36 (3.86)***
r	Converged	0.04 (0.04)	Converged	0.04 (0.01)***
K		1514.0 (2025)		
CGR		3.55 %		3.54 %
Diagnosis of Models				
MSE		120.25		113.61
RMSE		10.11		10.11
AIC		157.31		155.30
BIC		161.28		158.29
Non-Parametric Tests				
Run Test		106 (0.98)		105 (1.00)
Shapiro Wilk Test		0.94 (0.27)		0.94 (0.25)

*-significant at 5% **- Significant at 1%, ***- Significant at 0.1% and Figures in the parentheses indicate corresponding standard errors. *In residual test figures in the parentheses indicate corresponding p-values.

4.2.2.5 Trend analysis of wheat productivity in Chhattisgarh

The trend of wheat productivity is presented in the fig 4.10.5. It was clearly seen the graph trend of wheat productivity in Chhattisgarh is increasing trend from the period of 1998-99 to 2017-18. The maximum productivity of wheat was observed 1486 (Kg/ha) in the year 2014-15 and minimum production is observed in 859 (Kg/ha) in the year 2004-05.

4.2.2.6 Nonlinear growth analysis of wheat productivity in Chhattisgarh

To begin with, the first data point is taken as the initial value for analysis for wheat productivity initial values are $y_0 = 859$, $r = 0.1$, $K = 1400$. The results are the models are presented below in table 4.2.2.6. For seen the table it was clear data set was fitted to all the models attempted. Selection is based on minimum MSE (9072.04), RMSE (90.36), AIC (242.91) and BIC (245.90) values. An exponential model was found to be better for describing the wheat productivity of Chhattisgarh state. The examination of residuals reveals that errors are randomly and normally distributed. The run test statistic and Shapiro-Wilk test statistic values are not significant. The results of residual tests are presented in table.

The best fitted exponential growth model equation is given by (Eq 4.2.2.6) and the compound growth rate was 2.68 %.

$$Y(t) = 873 \exp (- 0.03t) \quad (4.2.2.6)$$

Table 4.2.2.6: Fitting of nonlinear growth models of productivity of wheat (Kg/ha) crop during 1998-99 to 2017-18.

	Monomolecular	Logistic	Gompertz	Exponential
Parameter Estimates				
Y0	874.7 (84.26)***	865.3 (78.09)***	873.3 (79.58)***	873.0 (3.61)***
r	0.07 (0.08)	0.09 (0.09)	0.07 (0.08)	0.03 (0.01)***
K	1478.0 (438.40)**	1456.0 (467.80)**	1494.0 (544.90)*	
CGR	2.24 %	1.88 %	1.98 %	2.68 %
Diagnosis of Models				
MSE	15510.85	15971.41	15483.26	9072.05
RMSE	114.82	116.51	114.72	90.36
AIC	254.49	255.08	254.46	242.90
BIC	258.47	259.06	258.44	245.90
Non-Parametric Tests				
Run Test	115 (0.73)	146 (0.13)	135 (0.28)	109 (0.90)
Shapiro Wilk Test	0.96 (0.55)	0.97 (0.65)	0.97 (0.66)	0.97 (0.74)

*-significant at 5% **- Significant at 1%, ***- Significant at 0.1% and Figures in the parentheses indicate corresponding standard errors. *In residual test figures in the parentheses indicate corresponding p-values.

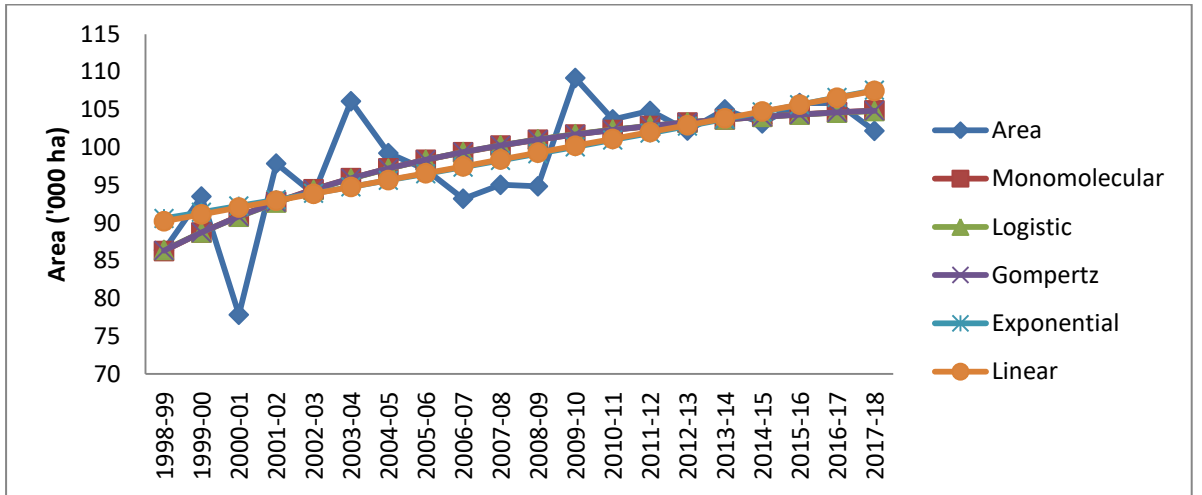


Fig 4.2.2.1: Wheat area ('000 ha) of Chhattisgarh (1998-99 to 2017-18)

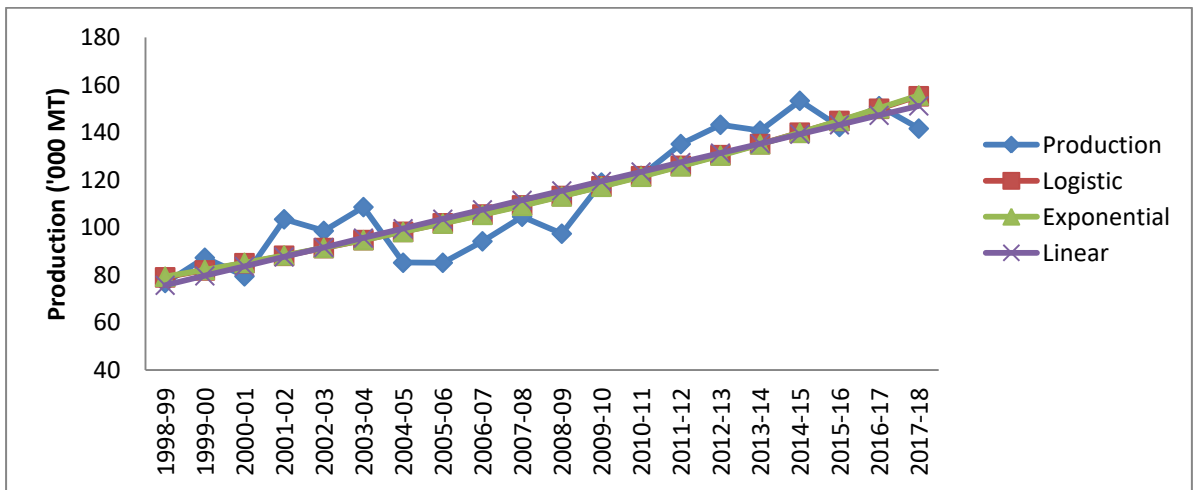


Fig 4.2.2.3: Wheat production ('000 MT) of Chhattisgarh (1998-99 to 2017-18)

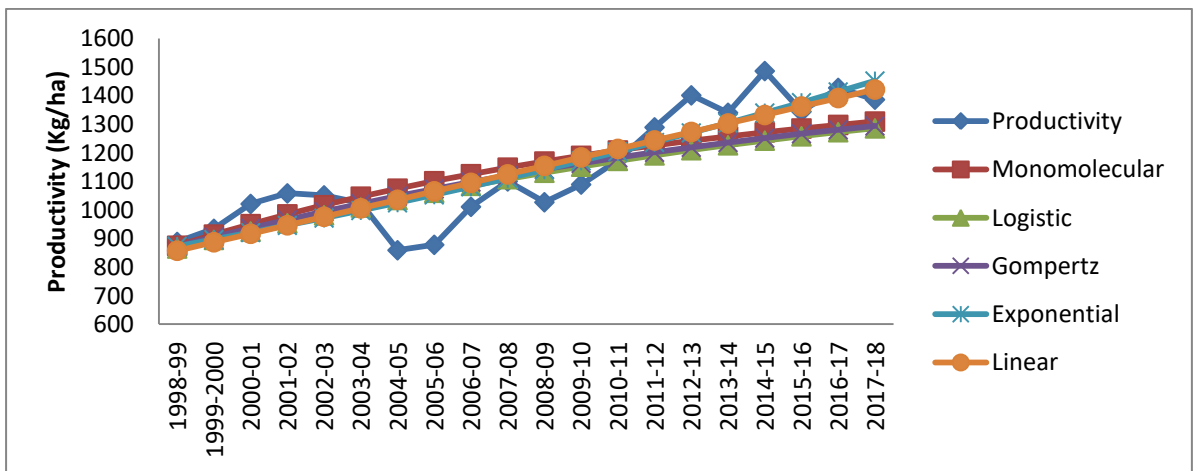


Fig 4.2.2.5: Wheat productivity (Kg/ha) of Chhattisgarh (1998-99 to 2017-18)

4.2.3 Tur (Arhar)

4.2.3.1 Trend analysis of tur area in Chhattisgarh

The trend of the tur area is presented in fig (4.2.3.1). It was clearly seen the graph the trend of an area of tur in Chhattisgarh is increasing trend from the period of 1998-99 to 2017-18. The maximum area of the tur was observed to be 66.20 (000'ha) in the year 2016-17 and minimum area was observed to be 41 (000'ha) in the year 1998-99.

4.2.3.2 Nonlinear growth analysis of tur area in Chhattisgarh

The data were fitted to the growth models with the initial values $y_0 = 49$, $r = 0.5$, $K = 60$, apart from this various wide range of initial values and confirmed for global convergence. Final parameter estimates along with the diagnosis of model and residual analysis (non-parametric tests) were presented in table 4.2.3.2. It is observed that monomolecular model fitted better than other models with minimum MSE (20.29), RMSE (4.15), AIC (121.70) and BIC (129.69) values. Thus, monomolecular model was considered for describing growth of the tur area in Chhattisgarh state. The examination of residuals reveals that errors are randomly and normally distributed. The run test statistic and Shapiro-Wilk test statistic values are not significant. The results of residual tests are presented in the table.

The best fitted monomolecular growth model equation is given by (Eq 4.2.3.2) and the compound growth rate was 1.28 %.

$$Y(t) = 57.15 - 8.08 \exp(-0.41t) \quad (4.2.3.2)$$

Table 4.2.3.2: Fitting of nonlinear growth models of the total area of tur (‘000 ha) crop during 1998-99 to 2017-18.

	Monomolecular	Logistic	Gompertz	Exponential
Parameter Estimates				
Y0	49.23 (4.36)***	49.29 (4.30)***	49.25 (4.33)***	51.56 (1.90)***
r	0.41 (0.48)	0.44 (0.50)	0.43 (0.49)	0.01(0.01)
K	57.15 (1.67)***	57.14 (1.64)***	57.14 (1.66)***	
CGR	1.28 %	1.02 %	1.16 %	0.91 %
Diagnosis of Model				
MSE	20.29	20.50	20.35	21.18
RMSE	4.15	4.17	4.15	4.36
AIC	121.70	121.92	121.77	121.71
BIC	125.69	125.90	125.76	124.70
Non-Parametric Tests				
Run Test	98	103	98	101
Shapiro Wilk Test	0.95	0.95	0.95	0.95

*-significant at 5% **- Significant at 1%, ***- Significant at 0.1% and Figures in the parentheses indicate corresponding standard errors. *In residual test figures in the parentheses indicate corresponding p-values.

4.2.3.3 Trend analysis of tur production in Chhattisgarh

The trend of tur production is presented in the fig (4.2.3.3). It was clearly seen the graph trend of tur production in Chhattisgarh is increasing trend from the period of 1998-99 to 2017-18. The maximum production of tur was observed 39.60 (000 MT) in the year 2016-17 and minimum production is observed in 19.06 (000 MT) in the year 1998-99.

4.2.3.4 Nonlinear growth analysis of tur production in Chhattisgarh

The data were fitted to the growth models with the initial values $y_0 = 21$, $r = 0.5$, $K = 30$, apart from this various wide range of initial values and confirmed for global convergence. Final parameter estimates along with the diagnosis of model and residual analysis (non-parametric tests) were presented in table 4.2.3.4. It is observed that monomolecular model fitted better than other models with minimum

MSE (17.17), RMSE (3.82), AIC (118.38) and BIC (122.36) values. Thus, monomolecular model was considered for describing growth of the tur production in Chhattisgarh state. The examination of residuals reveals that errors are randomly and normally distributed. The run test statistic and Shapiro-Wilk test statistic values are not significant. The results of residual tests are presented in the table.

The best fitted monomolecular growth model equation is given by (Eq 4.2.3.4) and the compound growth rate was 2.48 %.

$$Y(t) = 32.24 - 10.36 \exp(-0.14t) \quad (4.2.3.4)$$

Table 4.2.3.4: Fitting of nonlinear growth models of production of tur (‘000 MT) crop during 1998-99 to 2017-18.

	Monomolecular	Logistic	Gompertz	Exponential
Parameter Estimates				
Y0	21.88 (3.33)***	22.37 (3.08)***	22.13 (3.08)***	23.9 (1.82)*
r	0.14 (0.18)	0.15 (0.19)	0.14 (0.19)	0.02 (0.01)
K	32.24 (5.52)***	32.38 (5.81)***	32.28 (5.59)***	
CGR	2.48 %	2.02 %	2.23 %	1.83 %
Diagnosis of Model				
MSE	17.17	17.31	17.24	17.76
RMSE	3.82	3.83	3.83	3.99
AIC	118.38	118.53	118.45	118.19
BIC	122.36	122.52	122.43	121.18
Non-Parametric Tests				
Run Test	103	101	101	103
Shapiro Wilk Test	0.97	0.97	0.96	0.97

*-significant at 5% **- Significant at 1%, ***- Significant at 0.1% and Figures in the parentheses indicate corresponding standard errors. *In residual test figures in the parentheses indicate corresponding p-values.

4.2.3.5 Trend analysis of tur productivity in Chhattisgarh

The trend of tur productivity is presented in the fig (4.2.3.5). It was clearly seen the graph trend of tur productivity in Chhattisgarh is increasing trend from the period of 1998-99 to 2017-18. The maximum productivity of tur was observed 636 (Kg/ha) in the year 2014-15 and minimum production is observed in 402 (Kg/ha) in the year 2001-02.

4.2.3.6 Nonlinear growth analysis of tur productivity in Chhattisgarh

The data were fitted to the growth models with the initial values $y_0 = 405$, $r = 0.5$, $K = 530$, apart from this various wide range of initial values and confirmed for global convergence. Final parameter estimates along with the diagnosis of model and residual analysis (non-parametric tests) were presented in table 4.2.3.6. It is observed that logistic model fitted better than other models with minimum MSE (6110.07), RMSE (72.06), AIC (235.86) and BIC (239.84) values. Thus, logistic model was considered for describing growth of the tur productivity in Chhattisgarh state. The examination of residuals reveals that errors are randomly and normally distributed. The run test statistic and Shapiro-Wilk test statistic values are not significant. The results of residual tests are presented in the table.

The best fitted logistic growth model equation is given by (Eq 4.11.6) and the compound growth rate was 1.48 %.

$$Y(t) = 531.84 - (1 + (531.84 / 416.93) \exp(-0.25t)) \quad (4.11.6)$$

Table 4.2.3.6: Fitting of nonlinear growth models of productivity of tur (kg/ha) crop during 1998-99 to 2017-18.

	Monomolecular	Logistic	Gompertz	Exponential
Parameter Estimates				
Y0	416.93 (68.61)***	419.09 (66..27)***	417.94 (67.44)***	461.60 (35.41)***
r	0.25 (0.38)	0.29 (0.41)	0.27 (0.39)	0.01 (0.01)
K	531.84 (41.45)***	530.92 (38.63)***	531.32 (39.84)***	
CGR	2.11 %	1.48 %	1.80 %	1.01 %
Diagnosis of Model				
MSE	6121.29	6110.07	6115.55	5945.33
RMSE	72.13	72.06	72.09	73.19
AIC	235.89	235.86	235.88	234.45
BIC	239.88	239.84	239.86	237.44
Non-Parametric Tests				
Run Test	105	105	105	107
Shapiro Wilk Test	0.95	0.95	0.95	0.96

*-significant at 5% **- Significant at 1%, ***- Significant at 0.1% and Figures in the parentheses indicate corresponding standard errors. *In residual test figures in the parentheses indicate corresponding p-values.

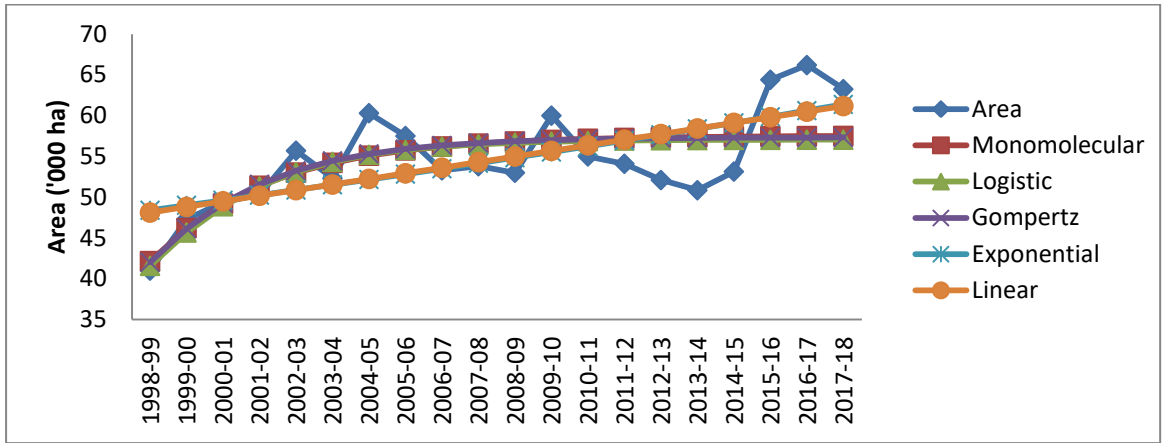


Fig 4.2.3.1: Tur area ('000 ha) of Chhattisgarh (1998-99 to 2017-18)

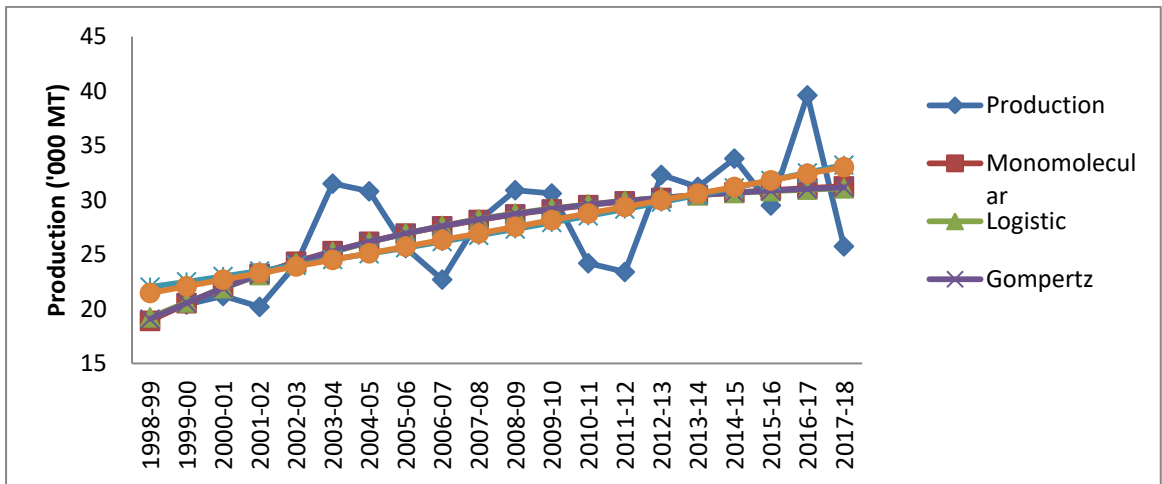


Fig 4.2.3.3: Tur production ('000 MT) of Chhattisgarh (1998-99 to 2017-18)

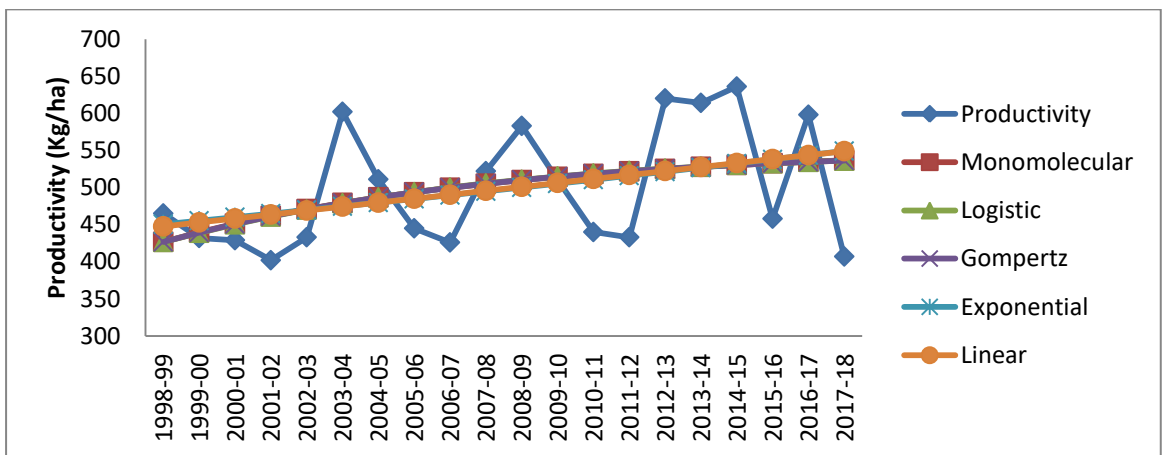


Fig 4.2.3.5: Tur productivity (Kg/ha) of Chhattisgarh (1998-99 to 2017-18)

4.2.4 Gram (Chickpea)

4.2.4.1 Trend analysis of gram area in Chhattisgarh

The trend of the gram area is presented in fig (4.2.4.1). It was clearly seen the graph the trend of area of gram in Chhattisgarh is increasing trend from the period of 1998-99 to 2017-18. The maximum area of the gram was observed to be 338.03 (000'ha) in the year of 2017-18 and minimum area was observed to be 140.07 (000'ha) in the year 2000-01.

4.2.4.2 Nonlinear growth analysis of gram area in Chhattisgarh

The data were fitted to the growth models with the initial values $y_0 = 142$, $r = 0.5$, $K = 300$, apart from this various wide range of initial values and confirmed for global convergence. Final parameter estimates along with diagnosis of model and residual analysis (non-parametric tests) were presented in table 4.2.4.2. It is observed that monomolecular model fitted better than other models with minimum MSE (272.40), RMSE (15.21), AIC (173.65) and BIC (177.63) values. Thus, monomolecular model was considered for describing growth of the gram area in Chhattisgarh state. The examination of residuals reveals that errors are randomly and normally distributed. The run test statistic and Shapiro-Wilk test statistic values are not significant. The results of residual tests are presented in table.

The best fitted monomolecular growth model equation is given by (Eq 4.2.4.2) and the compound growth rate was 3.70 %.

$$Y(t) = 630.05 - 474.49 \exp(-0.02t) \quad (4.2.4.2)$$

Table 4.2.4.2: Fitting of nonlinear growth models of the total area of gram ('000 ha) crop during 1998-99 to 2017-18.

	Monomolecular	Logistic	Gompertz	Exponential
Parameter Estimates				
Y0	156.01 (10.40)***	157.36 (9.46)***	156.59 (9.89)***	170.10 (6.38)***
r	0.02 (0.03)	0.09 (0.03)*	0.05 (0.3)	0.03 (0.01)
K	630.05 (575.09)	383.49 (76.14)***	436.48 (141.23)***	
CGR	3.70 %	3.70 %	3.63 %	3.36 %
Diagnosis of Model				
MSE	272.40	273.79	272.51	303.51
RMSE	15.21	15.26	15.22	16.53
AIC	173.65	173.75	173.66	174.96
BIC	177.63	177.74	177.64	177.95
Non-Parametric Tests				
Run Test	272.40	273.79	272.51	303.51
Shapiro Wilk Test	15.21	15.26	15.22	16.53

*-significant at 5% **- Significant at 1%, ***- Significant at 0.1% and Figures in the parentheses indicate corresponding standard errors. *In residual test figures in the parentheses indicate corresponding p-values.

4.2.4.3 Trend analysis of gram production in Chhattisgarh

The trend of gram production is presented in the fig (4.2.4.3). It was clearly seen the graph trend of gram production in Chhattisgarh is increasing trend from the period of 1998-99 to 2017-18. The maximum production of gram was observed 338.32 (000 MT) in the year 2014-15 and minimum production is observed in 72.14 (000 MT) in the year 1998-99.

4.2.4.4 Nonlinear growth analysis of gram production in Chhattisgarh

The data were fitted to the growth models with the initial values $y_0 = 72$, $r = 0.5$, $K = 300$, apart from this various wide range of initial values and confirmed for global convergence. Final parameter estimates along with diagnosis of model and residual analysis (non-parametric tests) were presented in table 4.2.4.4. It is observed that logistic model fitted better than other models with minimum MSE

(1172.90), RMSE (31.57), AIC (202.85) and BIC (206.83) values. Thus, logistic model was considered for describing growth of the gram production in Chhattisgarh state. The examination of residuals reveals that errors are randomly and normally distributed. The run test statistic and Shapiro-Wilk test statistic values are not significant. The results of residual tests are presented in table.

The best fitted logistic growth model equation is given by (Eq 4.2.4.4) and the compound growth rate was 6.49 %.

$$Y(t) = 643.60 - (1 + (643.60 / 97.67) \exp(-0.02t)) \quad (4.2.4.4)$$

Table 4.2.4.4: Fitting of nonlinear growth models of production of gram (‘000 MT) crop during 1998-99 to 2017-18.

	Monomolecular	Logistic	Gompertz	Exponential
Parameter Estimates				
Y0	97.67 (30.18)**	91.81 (16.81)***	89.96 (18.50)***	110.60 (11.14)***
r	0.02 (0.87)	0.13 (0.05)*	0.06 (0.05)	0.06 (0.01)
K	643.60 (2184)	405.57 (130.03)**	539.95 (357.99)	
CGR	5.05 %	6.49 %	6.77 %	5.86 %
Diagnosis of Model				
MSE	2311.04	1172.90	1173.75	1231.25
RMSE	44.32	31.57	31.59	33.29
AIC	216.42	202.85	202.86	202.99
BIC	220.39	206.83	206.85	205.95
Non-Parametric Tests				
Run Test	158 (0.05)	119 (0.62)	119 (0.62)	111 (0.84)
Shapiro Wilk Test	0.96 (0.61)	0.95 (0.35)	0.95 (0.31)	0.96 (0.52)

*-significant at 5% **- Significant at 1%, ***- Significant at 0.1% and Figures in the parentheses indicate corresponding standard errors. *In residual test figures in the parentheses indicate corresponding p-values.

4.2.4.5 Trend analysis of gram productivity in Chhattisgarh

The trend of gram productivity is presented in the fig (4.2.4.5). It was clearly seen the graph trend of gram productivity in Chhattisgarh is increasing trend from the period of 1998-99 to 2017-18. The maximum productivity of gram was observed 1164 (Kg/ha) in the year 2016-17 and minimum production is observed in 516 (Kg/ha) in the year 2004-05.

4.2.4.6 Nonlinear growth analysis of gram productivity in Chhattisgarh

The data were fitted to the growth models with the initial values $y_0 = 515$, $r = 0.5$, $K = 1100$, apart from this various wide range of initial values and confirmed for global convergence. Final parameter estimates along with diagnosis of model and residual analysis (non-parametric tests) were presented in table 4.2.4.6. It is observed that logistic model fitted better than other models with minimum MSE (18685.93), RMSE (126.03), AIC (258.22) and BIC (262.20) values. Thus, logistic model was considered for describing growth of the gram productivity in Chhattisgarh state. The examination of residuals reveals that errors are randomly and normally distributed. The run test statistic and Shapiro-Wilk test statistic values are not significant. The results of residual tests are presented in table.

The best fitted logistic growth model equation is given by (Eq 4.2.4.6) and the compound growth rate was 3.02 %.

$$Y(t) = 1621.0 - (1 + (1621.0 / 580.4) \exp(-0.03t)) \quad (4.2.4.6)$$

Table 4.2.4.6: Fitting of nonlinear growth models of productivity of gram (Kg/ha) crop during 1998-99 to 2017-18.

	Monomolecular	Logistic	Gompertz	Exponential
Parameter Estimates				
Y0	580.4 (87.69)***	580.3 (80.96)***	580.2 (84.18)	625.6 (50.97)***
r	0.03 (0.08)	0.09 (0.09)	0.06 (0.09)	0.03 (0.01)***
K	1621.0 (2286)	1207.0 (496.2)*	1322.0 (856.6)	
CGR	3.23 %	3.02 %	3.12 %	2.82 %
Diagnosis of Model				
MSE	18779.96	18685.93	18731.36	18286.68
RMSE	126.34	126.03	126.18	128.29
AIC	258.32	258.22	258.27	256.93
BIC	262.30	262.20	262.25	259.92
Non-Parametric Tests				
Run Test	110 (0.87)	110 (0.87)	111 (0.84)	110 (0.86)
Shapiro Wilk Test	0.97 (0.76)	0.97 (0.76)	0.97 (0.76)	0.96 (0.63)

*-significant at 5% **- Significant at 1%, ***- Significant at 0.1% and Figures in the parentheses indicate corresponding standard errors. *In residual test figures in the parentheses indicate corresponding p-values.

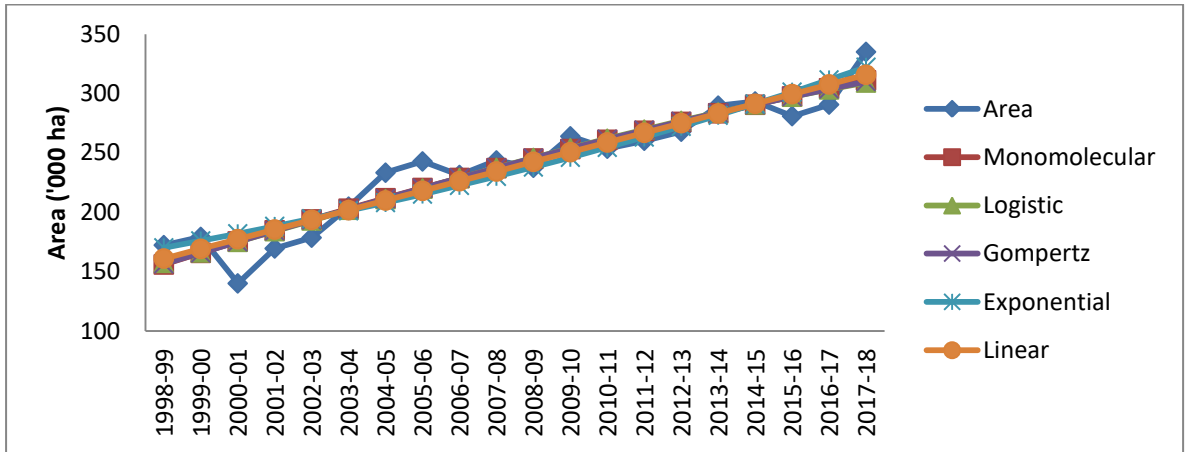


Fig 4.2.4.1: Gram area ('000 ha) of Chhattisgarh (1998-99 to 2017-18)

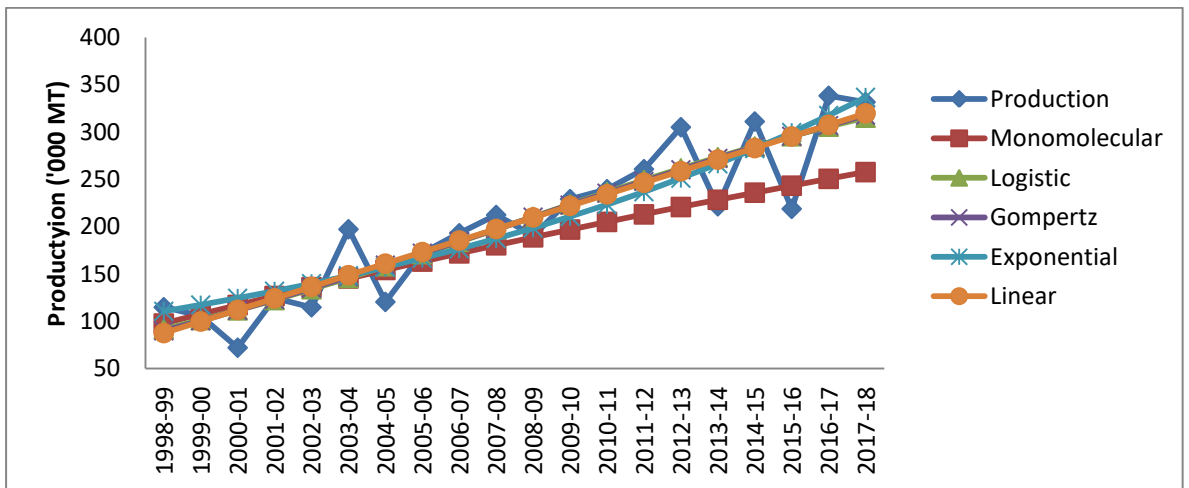


Fig 4.2.4.3: Gram production ('000 MT) of Chhattisgarh (1998-99 to 2017-18)

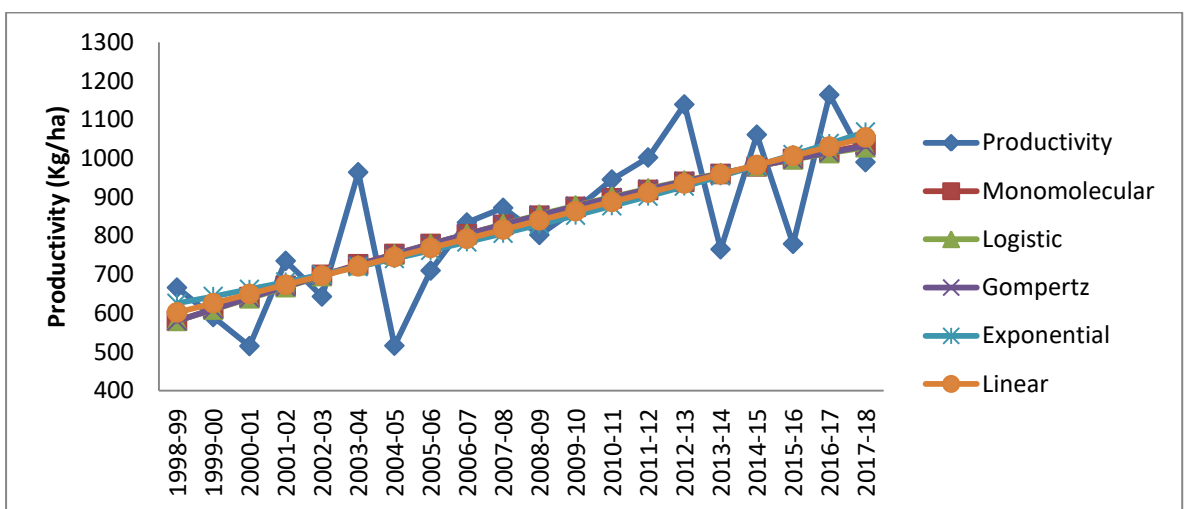


Fig 4.2.4.5: Gram productivity (Kg/ha) of Chhattisgarh (1998-99 to 2017-18)

4. 2.5 Moong (Green gram)

4.2.5.1 Trend analysis of moong area in Chhattisgarh

The trend of the moong area is presented in fig (4.2.5.1). It was clearly seen the graph the trend of area of moong in Chhattisgarh is decreasing trend from the period of 1998-99 to 2017-18. The maximum area of the moong was observed to be 10.06 (000'ha) in the year 2005-06 and minimum area was observed to be 8.40 (000'ha) in the year 1999-2000.

4.2.5.2 Nonlinear growth analysis of moong area in Chhattisgarh

The data were fitted to the growth models with the initial values $y_0 = 8.5$, $r = 0.1$, $K = 9$, apart from this various wide range of initial values and confirmed for global convergence. Final parameter estimates along with diagnosis of model and residual analysis (non-parametric tests) were presented in table 4.13.2. It is observed that exponential model fitted better than other models with minimum MSE (0.27), RMSE (0.49), AIC (34.37) and BIC (37.35) values. Thus, exponential model was considered for describing growth of the moong area in Chhattisgarh state. The examination of residuals reveals that errors are randomly and normally distributed. The run test statistic and Shapiro-Wilk test statistic values are not significant. The results of residual tests are presented in table.

The best fitted exponential growth model equation is given by (Eq 4.2.5.2) and the compound growth rate was -0.49 %.

$$Y(t) = 9.73 \exp (0.01t) \quad (4.2.5.2)$$

Table 4.2.5.2: Fitting of nonlinear growth models of an area of moong (‘000 ha) crop during 1998-99 to 2017-18.

	Monomolecular	Logistic	Gompertz	Exponential
Parameter Estimates				
Y0	9.13 (0.37)***	8.82 (0.77)***	9.11 (0.76)***	9.73 (0.23)***
r	-0.02 (2.76)	2.85 (402.88)	0.52 (2.27)	-0.01 (0.001)
K	8.99 (22.71)	8.85 (0.18)***	8.75 (0.23)***	
CGR	-0.06 %	-14.26 %	-3.06 %	-0.49 %
Diagnosis of Model				
MSE	0.40	0.60	0.66	0.27
RMSE	0.58	0.71	0.75	0.49
AIC	43.14	51.30	53.07	34.37
BIC	47.12	55.28	57.05	37.36
Non-Parametric Tests				
Run Test	132 (0.33)	177 (0.05)	185 (0.05)	116 (0.70)
Shapiro Wilk Test	0.92 (0.11)	0.92 (0.11)	0.95 (0.39)	0.95 (0.42)

*-significant at 5% **- Significant at 1%, ***- Significant at 0.1% and Figures in the parentheses indicate corresponding standard errors. *In residual test figures in the parentheses indicate corresponding p-values.

4.2.5.3 Trend analysis of moong production in Chhattisgarh

The trend of moong production is presented in the fig (4.2.5.3). It was clearly seen the graph trend of moong production in Chhattisgarh is increasing trend from the period of 1998-99 to 2017-18. The maximum production of moong was observed 4.58 (000 MT) in the year 2015-16 and minimum production is observed in 2.25 (000 MT) in the year 2002-03.

4.2.5.4 Nonlinear growth analysis of moong production in Chhattisgarh

The data were fitted to the growth models with the initial values $y_0 = 0.2$, $r = 0.5$, $K = 0.4$, apart from this various wide range of initial values and confirmed for global convergence. Final parameter estimates along with diagnosis of model and residual analysis (non-parametric tests) were presented in table 4.2.5.4. It is observed that logistic model fitted better than other models with minimum MSE (0.41), RMSE (0.59), AIC (43.84) and BIC (47.82) values. Thus, logistic model

was considered for describing growth of the moong production in Chhattisgarh state. The examination of residuals reveals that errors are randomly and normally distributed. The run test statistic and Shapiro-Wilk test statistic values are not significant. The results of residual tests are presented in table.

The best fitted logistic growth model equation is given by (Eq 4.2.5.4) and the compound growth rate was 0.56 %.

$$Y(t) = 3.04 - (1 + (3.04 / 2.66) \exp(-0.07t)) \quad (4.2.5.4)$$

Table 4.2.5.4: Fitting of nonlinear growth models of production of moong ('000 MT) crop during 1998-99 to 2017-18.

	Monomolecular	Logistic	Gompertz	Exponential
Parameter Estimates				
Y0	2.72 (0.48)***	2.66 (0.43)***	2.69 (0.45)***	2.19 (0.20)***
r	0.13 (0.92)	0.07 (0.70)	0.10 (0.77)	0.03 (0.01)**
K	2.99 (0.70)***	3.04 (2.18)	3.01 (1.14)*	
CGR	1.35 %	0.56 %	0.90 %	2.48 %
Diagnosis of Model				
MSE	0.43	0.41	0.42	0.28
RMSE	0.61	0.59	0.59	0.50
AIC	44.85	43.84	44.32	35.14
BIC	48.84	47.83	48.30	38.13
Non-Parametric Tests				
Run Test	59 (0.08)	62 (0.11)	61 (0.11)	103 (0.95)
Shapiro Wilk Test	0.72 (0.06)	0.73 (0.06)	0.72 (0.06)	0.95 (0.54)

*-significant at 5% **- Significant at 1%, ***- Significant at 0.1% and Figures in the parentheses indicate corresponding standard errors. *In residual test figures in the parentheses indicate corresponding p-values.

4.2.5.5 Trend analysis of moong productivity in Chhattisgarh

The trend of moong productivity is presented in the fig (4.2.5.5). It was clearly seen the graph trend of moong productivity in Chhattisgarh is increasing trend from the period of 1998-99 to 2017-18. The maximum productivity of moong was observed 485 (Kg/ha) in the year 2017-18 and minimum production is observed in 234 (Kg/ha) in the year of 2002-03.

4.2.5.6 Nonlinear growth analysis of moong productivity in Chhattisgarh

The data were fitted to the growth models with the initial values $y_0 = 251$, $r = 0.1$, $K = 360$, apart from this various wide range of initial values and confirmed for global convergence. Final parameter estimates along with diagnosis of model and residual analysis (non-parametric tests) were presented in table 4.2.5.6. It is observed that exponential model fitted to data with minimum MSE (2645.40), RMSE (48.79), AIC (218.26) and BIC (221.24) values. Monomolecular, logistic and Gompertz model parameters did not converge. An exponential model was considered for describing growth of the moong productivity in Chhattisgarh state. The examination of residuals reveals that errors are randomly and normally distributed. The run test statistic and Shapiro-Wilk test statistic values are not significant. The results of residual tests are presented in table.

The fitted exponential growth model equation is given by (Eq 4.2.5.6) and the compound growth rate was 3.02 %.

$$Y(t) = 224.4 \exp (0.03t) \quad (4.2.5.6)$$

Table 4.2.5.6: Fitting of nonlinear growth models of productivity of moong (Kg/ha) crop during 1998-99 to 2017-18.

	Monomolecular	Logistic	Gompertz	Exponential
Parameter Estimates				
Y0	Parameter did not	Parameter did not	Parameter did not	224.4 (19.18)***
r	Converged	Converged	Converged	0.03 (0.01)***
K				
CGR				3.02 %
Diagnosis of Model				
MSE	Parameter did not	Parameter did not	Parameter did not	2645.40
RMSE	Converged	Converged	Converged	48.79
AIC				218.26
BIC				221.25
Non-Parametric Tests				
Run Test	Parameter did not	Parameter did not	Parameter did not	105 (1.0)
Shapiro Wilk Test	Converged	Converged	Converged	0.95 (0.44)

*-significant at 5% **- Significant at 1%, ***- Significant at 0.1% and Figures in the parentheses indicate corresponding standard errors. *In residual test figures in the parentheses indicate corresponding p-values.

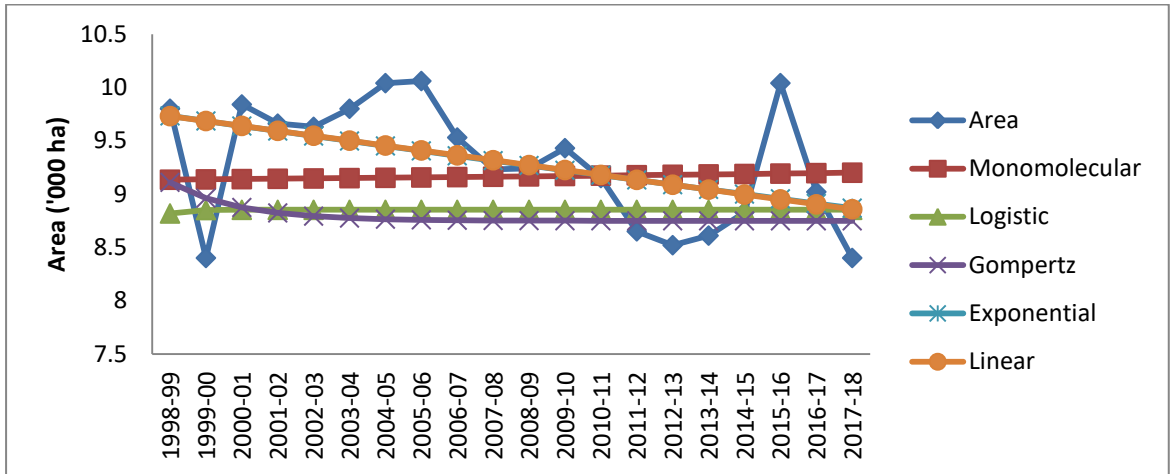


Fig 4.2.5.1: Moong area ('000 ha) of Chhattisgarh (1998-99 to 2017-18)

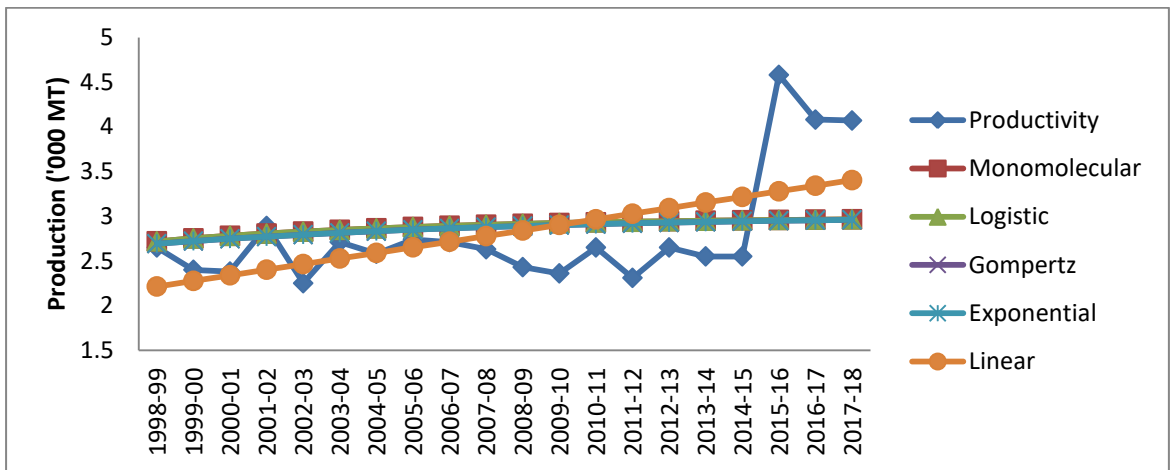


Fig 4.2.5.3: Moong production ('000 MT) of Chhattisgarh (1998-99 to 2017-18)

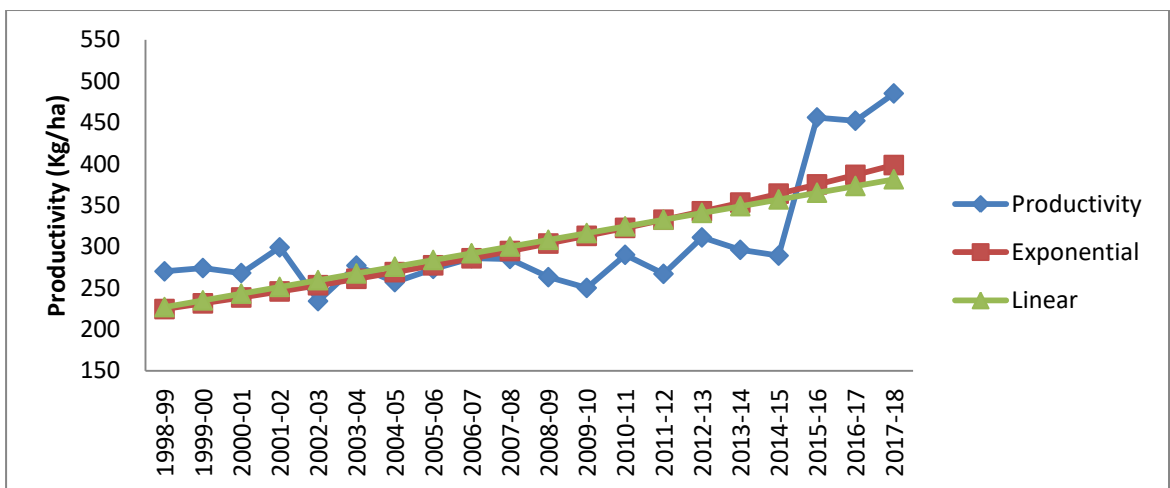


Fig 4.2.5.5: Moong productivity (Kg/ha) of Chhattisgarh (1998-99 to 2017-18)

4.2.6 Urd (Black Gram)

4.2.6.1 Trend analysis of urd area in Chhattisgarh

The trend of the urd area is presented in fig (4.2.6.1). It was clearly seen the graph the trend of area of urd in Chhattisgarh is decreasing trend from the period of 1998-99 to 2017-18. The maximum area of the urd was observed to be 119.10 (000'ha) in the year 1999-2000 and the minimum area was observed to be 85.88 (000'ha) in the year of 2017-18.

4.2.6.2 Nonlinear growth analysis of urd area in Chhattisgarh

The data were fitted to the growth models with the initial values $y_0 = 86$, $r = 0.1$, $K = 114$, apart from this various wide range of initial values and confirmed for global convergence. Final parameter estimates along with diagnosis of model and residual analysis (non-parametric tests) were presented in table 4.2.6.2. It is observed that exponential model fitted better than other models with minimum MSE (13.16), RMSE (3.44), AIC (112.20) and BIC (115.19) values. Thus, exponential model was considered for describing growth of the urd area in Chhattisgarh state. The examination of residuals reveals that errors are randomly and normally distributed. The run test statistic and Shapiro-Wilk test statistic values are not significant. The results of residual tests are presented in table.

The best fitted exponential growth model equation is given by (Eq 4.2.6.2) and the compound growth rate was -0.98 %.

$$Y(t) = 117.96 \exp (0.01t) \quad (4.2.6.2)$$

Table 4.2.6.2: Fitting of nonlinear growth models of an area of urd ('000 ha) crop during 1998-99 to 2017-18.

	Monomolecular	Logistic	Gompertz	Exponential
Parameter Estimates				
Y0	118.12	116.98	118.10	117.96
r	0.02	0.06	0.01	-0.01
K	36.14	89.65	10.32	
CGR	-0.98 %	-1.12 %	-0.98 %	-0.98 %
Diagnosis of Model				
MSE	13.9339	22.3147	13.9364	13.1679
RMSE	3.4415	4.3552	3.4418	3.4425
AIC	114.1937	123.6121	114.1973	112.2059
BIC	118.1766	127.5950	118.1802	115.1931
Non-Parametric Tests				
Run Test	112 (0.81)	172 (0.91)	112 (0.81)	111 (0.84)
Shapiro Wilk Test	0.96 (0.55)	0.96 (0.57)	0.96 (0.55)	0.96 (0.51)

*-significant at 5% **- Significant at 1%, ***- Significant at 0.1% and Figures in the parentheses indicate corresponding standard errors. *In residual test figures in the parentheses indicate corresponding p-values.

4.2.6.3 Trend analysis of urd production in Chhattisgarh

The trend of urd production is presented in the fig (4.2.6.2). It was clearly seen the graph trend of urd production in Chhattisgarh is decreasing trend from the period of 1998-99 to 2017-18. The maximum production of urd was observed 38.70 (000 MT) in the year 1999-2000 and minimum production is observed in 27.50 (000 MT) in the year 1998-99.

4.2.6.4 Nonlinear growth analysis of urd production in Chhattisgarh

The data were fitted to the growth models with the initial values $y_0 = 28$, $r = 0.1$, $K = 37$, apart from this various wide range of initial values and confirmed for global convergence. Final parameter estimates along with diagnosis of model and residual analysis (non-parametric tests) were presented in table 4.2.6.4. It is observed that exponential model fitted better than other models with minimum MSE (6.11), RMSE (2.34), AIC (96.85) and BIC (99.84) values and Gompertz model did not converge. An exponential model was considered for describing

growth of the urd production in Chhattisgarh state. The examination of residuals reveals that errors are randomly and normally distributed. The run test statistic and Shapiro-Wilk test statistic values are not significant. The results of residual tests are presented in table.

The best fitted exponential growth model equation is given by (Eq 4.2.6.4) and the compound growth rate was -0.62 %.

$$Y(t) = 33.36 \exp (0.01t) \quad (4.2.6.4)$$

Table 4.2.6.4: Fitting of nonlinear growth models of production of urd (‘000 MT) crop during 1998-99 to 2017-18.

	Monomolecular	Logistic	Gompertz	Exponential
Parameter Estimates				
Y0	33.195	32.639	Parameter did not	33.365
R	-0.029	0.037	Converged	-0.006
K	38.168	27.453		
CGR	-0.62 %	-0.56 %		-0.59 %
Diagnosis of Model				
MSE	6.4569	6.9248		6.1105
RMSE	2.3427	2.4261		2.3451
AIC	98.8103	100.2092		96.8506
BIC	102.7932	104.1921		99.8378
Non-Parametric Tests				
Run Test	110 (0.87)	139 (0.22)		109 (0.87)
Shapiro Wilk Test	0.96 (0.62)	0.96 (0.63)		0.96 (0.63)

*-significant at 5% **- Significant at 1%, ***- Significant at 0.1% and Figures in the parentheses indicate corresponding standard errors. *In residual test figures in the parentheses indicate corresponding p-values.

4.2.6.5 Trend analysis of urd productivity in Chhattisgarh

The trend of urd productivity is presented in the fig (4.2.6.5). It was clear seen the graph trend of urd productivity in Chhattisgarh is increasing trend from the period of 1998-99 to 2017-18. The maximum productivity of urd was observed 326 (Kg/ha) in the year 1999-2000 and minimum production is observed in 246 (Kg/ha) in the year of 1998-99.

4.2.6.6 Nonlinear growth analysis of urd productivity in Chhattisgarh

The data were fitted to the growth models with the initial values $y_0 = 246$, $r = 0.1$, $K = 308$, apart from this various wide range of initial values and confirmed for global convergence. Final parameter estimates along with diagnosis of model and residual analysis (non-parametric tests) were presented in table 4.2.6.6. It is observed that Exponential model fitted better than other models with minimum MSE (365.59), RMSE (18.13), AIC (178.68) and BIC (181.66) values. An exponential model was considered for describing growth of the urd productivity in Chhattisgarh state. The examination of residuals reveals that errors are randomly and normally distributed. The run test statistic and Shapiro-Wilk test statistic values are not significant. The results of residual tests are presented in table.

The best fitted monomolecular growth model equation is given by (Eq 4.2.6.6) and the compound growth rate was 0.40 %.

$$Y(t) = 282.5 \exp(-0.004t) \quad (4.2.6.6)$$

Table 4.2.6.6: Fitting of nonlinear growth models of productivity of urd (Kg/ha) crop during 1998-99 to 2017-18.

	Monomolecular	Logistic	Gompertz	Exponential
Parameter Estimates				
Y ₀	279.34	279.552	279.454	282.500
r	0.08	0.083	0.081	0.004
K	309.27	309.272	309.287	
CGR	0.46 %	0.42 %	0.44 %	0.40 %
Diagnosis of Model				
MSE	384.74	384.8102	384.7765	365.5978
RMSE	18.08	18.0856	18.0848	18.1394
AIC	180.56	180.5622	180.5604	178.6810
BIC	184.54	180.5604	184.5433	181.6682
Non-Parametric Tests				
Run Test	95 (0.73)	95 (0.73)	95 (0.73)	101 (0.90)
Shapiro Wilk Test	0.97 (0.80)	0.97 (0.81)	0.97 (0.80)	0.98 (0.93)

*-significant at 5% **- Significant at 1%, ***- Significant at 0.1% and Figures in the parentheses indicate corresponding standard errors. *In residual test figures in the parentheses indicate corresponding p-values.

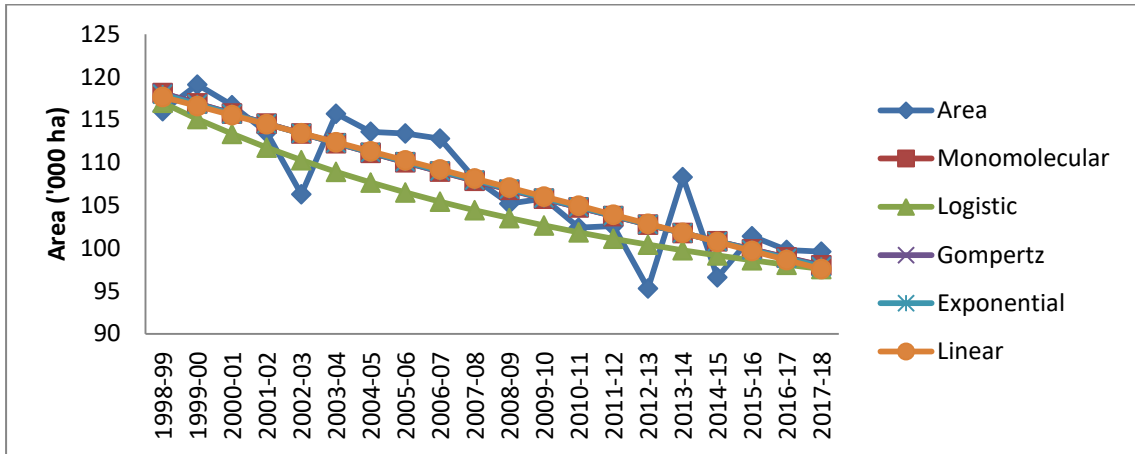


Fig 4.2.6.1: Urd area ('000 ha) of Chhattisgarh (1998-99 to 2017-18)

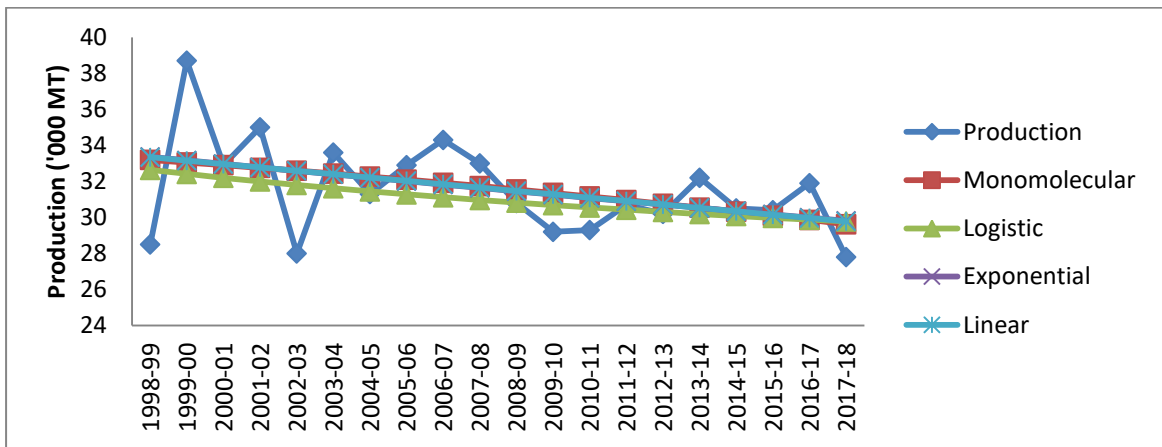


Fig 4.2.6.3: Urd production ('000 MT) of Chhattisgarh (1998-99 to 2017-18)

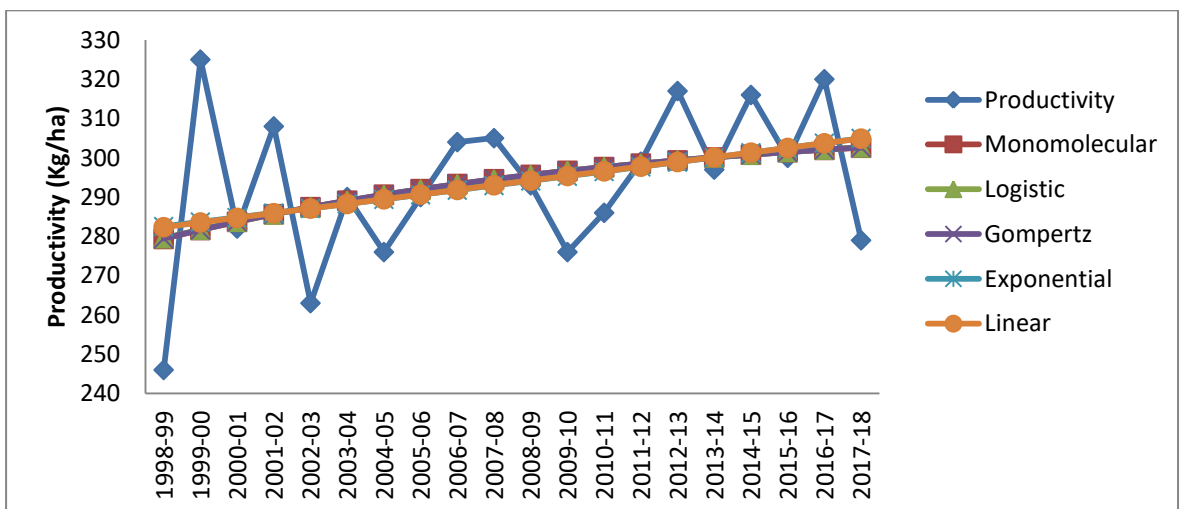


Fig 4.2.6.5: Urd productivity (Kg/ha) of Chhattisgarh (1998-99 to 2017-18)

SUMMARY AND CONCLUSIONS

5.1 Summary

Mathematical models assume a significant part of agriculture research. In this examination, different nonlinear growth models viz.; Gompertz, monomolecular, logistic, and exponential models are studied. One downside of every one of these models is that they are deterministic in nature. These models can be replaced by including an error term on the right side of the underlying equations. In spite of the fact that including an error term on the right-hand side of the model makes it progressively sensible, it additionally brings about the extensive difficulty in the estimation of parameters. For an error, the assumptions are made that these are independent and normally distributed.

The secondary data was collected from the Agriculture Department, Chhattisgarh for sixteen years and the remaining four years data are collected from the website of <http://agriportal.cg.nic.in>, i.e. for the period 1998 to 2018. The collected data include oilseeds crops viz., soybean, groundnut, rapeseed & mustard, sunflower, sesamum, and Niger. Apart from oilseeds rice, wheat, tur, urd, moong, gram also included as part of the study for comparison.

An attempt is made to identifying appropriate statistical models for computation of compound growth rate of major oilseeds and principals crops in Chhattisgarh State. To this end, four nonlinear statistical models viz.; monomolecular, logistic, Gompertz, and exponential models are considered. Parameter estimation is done using “**R: The R Project for Statistical Computing**”. Various model selection criteria based on MSE, RMSE, AIC, and BIC. Run tests and Shapiro-Wilk tests are employed to the test respectively the assumption of randomness and normality of residuals.

5.2 Conclusions

At the end of the present investigation entitled “**Identifying appropriate statistical growth models for computation of compound growth rates of major oilseeds and principal crops of Chhattisgarh**” following conclusions were made:

- Area of oilseeds in Chhattisgarh is decreasing trend, production and productivity of oilseeds showing an increasing trend in study period. Computation of compound growth rate of the total area, production, and productivity under oilseeds in Chhattisgarh state, we found that the Gompertz model for area and for production and productivity logistic model fit very well to data understudy and CGR of oilseeds area, production and productivity is -1.10%, 2.71%, and 3.12 % respectively in state.
- Area, production, and productivity of soybean are showing increasing trend in Chhattisgarh. Computation of compound growth rate of the total area, production, and productivity under soybean in Chhattisgarh state, we found that the monomolecular model for area and production, for productivity logistic model fit very well to data understudy and CGR of soybean area, production and productivity is 9.09%, 27.61%, and 6.38% respectively in state.
- Area and production of groundnut are decreasing trend and productivity is showing increasing trend in Chhattisgarh. Computation of compound growth rate of the total area, production, and productivity under groundnut in Chhattisgarh state, we found that the exponential model for area and production, and for productivity logistic model fit very well to data understudy and CGR of groundnut area, production and productivity is -2.19%, -0.64% and 1.71 % respectively in state.
- Area, production, and productivity of niger are showing decreasing trend in Chhattisgarh. Computation of compound growth rate of the total production and productivity under niger in Chhattisgarh state, we found that the logistic model for production and productivity monomolecular model fits

very well with data understudy and CGR of niger production and productivity is -1.32 % and -0.26% respectively in state.

- Area, production, and productivity of rapeseed and mustard are showing decreasing trend in Chhattisgarh. Computation of compound growth rate of the total production and productivity under rapeseed and mustard in Chhattisgarh state, we found that the for production and productivity monomolecular model fit very well to data understudy and CGR of rapeseed and mustard production and productivity is -1.50% and -0.70 % respectively in state.
- Area, production, and productivity of sunflower are showing increasing trend in Chhattisgarh. Computation of compound growth rate of the total area, production, and productivity under sunflower in Chhattisgarh state, we found that the logistic model for area and production, and for productivity exponential model fit very well to data understudy and CGR of sunflower area, production and productivity is 22.06 %, 21.98%, and 3.25 % respectively in state.
- Area of sesamum is decreasing trend, production and productivity are showing increasing trend in Chhattisgarh. Computation of compound growth rate of the total area, production, and productivity under sesamum in Chhattisgarh state, we found that the for area, production, and productivity logistic model fit very well to data understudy and CGR of sesamum area, production and productivity is -2.28%, 3.47%, and 5.04% respectively in state.
- Area and production of linseed are observed decreasing trend and productivity of linseed is showing increasing trend in Chhattisgarh. Computation of compound growth rate of the total area, production, and productivity under linseed in Chhattisgarh state, we found that the monomolecular model for area and production, and for productivity logistic model fit very well to data understudy and CGR of linseed area, production and productivity is -9.09%, -6.50% and 2.78% respectively in state.

- Area, production, and productivity of paddy are showing increasing trend in Chhattisgarh. Computation of compound growth rate of the total area, production, and productivity under paddy in Chhattisgarh state, we found that the monomolecular model for area and for production and productivity logistic model fit very well to data understudy and CGR of paddy area, production and productivity is 0.21%, 3.62%, and 3.73% respectively in state.
- Area, production, and productivity of wheat are showing increasing trend in Chhattisgarh. Computation of compound growth rate of the total area, production and productivity under wheat in Chhattisgarh state, we found that the monomolecular model for area and for production exponential model and for productivity logistic model fit very well to data understudy and CGR of wheat area, production and productivity is 1.10%, 3.54%, and 3.73% respectively in state.
- Area, production, and productivity of tur are showing increasing trend in Chhattisgarh. Computation of compound growth rate of the total area, production, and productivity under tur in Chhattisgarh state, we found that the monomolecular model for area and production, and for productivity logistic model fit very well to data understudy and CGR of tur area, production and productivity is 1.28%, 2.48%, and 1.48% respectively in state.
- Area, production, and productivity of gram are showing increasing trend in Chhattisgarh. Computation of compound growth rate of the total area, production, and productivity under gram in Chhattisgarh state, we found that the monomolecular model for area, and for production and productivity logistic model fit very well to data understudy and CGR of gram area, production and productivity is 3.70%, 6.49%, and .3.02% respectively in state.
- Area of moong showing decreasing trend and production and productivity of moong is showing an increasing trend in Chhattisgarh. Computation of compound growth rate of the total area, production, and productivity under moong in Chhattisgarh state, we found that the exponential model for area,

and for production logistic model, and productivity exponential model fit very well to data under study and CGR of moong area, production and productivity is -0.49 %, 0.56%, and 3.02% respectively in state.

- Area and production of urd are showing decreasing trend and productivity of urd is showing increasing trend in Chhattisgarh. Computation of compound growth rate of the total area, production, and productivity under urd in Chhattisgarh state, we found that the for area and production and productivity exponential model fit very well to data under study and CGR of urd area, production and productivity is -0.98%, -0.62% and 0.40% respectively in state.

5.3 Suggestions for future research work

The data is related to time series hence time series analysis, cyclic trend analysis, and forecasting may be done using time series models.

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Dear Author(s),

It is pleasure to inform you that your manuscript No. 201909327-IJCMAS entitled "**IDENTIFYING APPROPRIATE STATISTICAL GROWTH MODELS FOR COMPUTATION OF COMPOUND GROWTH RATES OF TOTAL OILSEEDS IN CHHATTISGARH**" has been accepted for publication in International Journal of Current Microbiology and Applied Sciences and published in the Vol 8 (09) to be released in September-2019.

Thank you

With Regards

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