TIME SERIES ANALYSIS OF AREA, PRODUCTION AND PRDOUCTIVITY OF MAJOR COARSE CEREALS IN ANDHRA PRADESH

BY

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B.Sc. (Ag.)

THESIS SUBMITTED TO THE
ACHARYA N.G.RANGA AGRICULTURAL UNIVERSITY
IN PARTIAL FULFILMENT OF THE REQUIREMENTS
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MASTER OF SCIENCE IN AGRICULTURE
(AGRICULTURAL STATISTICS)

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AGRICULTURAL COLLEGE, BAPATLA
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DECLARATION

I, **Ms. VAKA NIREESHA,** hereby declare that the thesis entitled **“TIME SERIES ANALYSIS OF AREA, PRODUCTION AND PRODUCTIVITY OF MAJOR COARSE CEREALS IN ANDHRA PRADESH”** submitted to **Acharya N. G. Ranga Agricultural University** for the degree of **Master of Science in Agriculture** is the result of original research work done by me. I also declare that no material contained in the thesis has been published earlier in any manner.

Place: **(VAKA NIREESHA)**

Date: **I. D. No. BAM-12-51**

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Place ***(V. NIREESHA)***

Date

CERTIFICATE

This is to certify that thesis entitled **“TIME SERIES ANALYSIS OF AREA, PRODUCTION AND PRODUCTIVITY OF MAJOR COARSE CEREALS IN ANDHRA PRADESH”** submitted in partial fulfillment of the requirements for the degree of **Master of Science in Agriculture** of the Acharya N. G. Ranga Agricultural University, Hyderabad, is a record of the bonafide original research work carried out by **Ms. NIREESHA VAKA** under our guidance and supervision.

No part of the thesis has been submitted by the student for any other degree or diploma. The published part and all assistance received during the course of the investigations have been duly acknowledged by the author of the thesis.

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Ms**. NIREESHA VAKA** has satisfactorily prosecuted the course of research and that thesis entitled **"TIME SERIES ANALYSIS OF AREA, PRODUCTION AND PRODUCTIVITY OF MAJOR COARSE CEREALS IN ANDHRA PRADESH"** submitted is the result of original research work and is of sufficiently high standard to warrant its presentation to the examination. I also certify that neither the thesis nor its part there of has been previously submitted by him for a degree of any university.

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LIST OF SYMBOLS AND ABBREVIATIONS

%	:	Per cent
Mm	:	Millimetre
^0C	:	degree celcius
etc.,	:	and so on; and other people/things
Fig	:	Figure
i.e.	:	That is
et al.	:	and others people
e.g.	:	for example, for instance
Viz.,	:	Namely
M	:	Million
t	:	tonnes
ha	:	Hectares
AR	:	Auto Regression
MA	:	Moving Average
ARMA	:	Auto Regressive Moving Average
ARIMA	:	Auto Regressive Integrated Moving Average
MAPE	:	Mean Absolute Percent Error
Adj R^2	:	Adjusted R^2
R^2	:	Co-efficient of determination
Kg ha^{-1}	:	Kilogram per hectare
DTBES	:	Damped Trend Brown Exponential Smoothing
DBES	:	Double Brown Exponential Smoothing
Max temp	:	Maximum temperature
Min temp	:	Minimum temperature

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ABSTRACT

Name of the Author	:	**VAKA NIREEHA**
Title of the thesis	:	**TIME SERIES ANALYSIS OF AREA, PRODUCTION AND PRODUCTIVITY OF MAJOR COARSE CEREALS IN ANDHRA PRADESH.**
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University	:	**ACHARYA N. G. RANGA AGRICULTURAL UNIVERSITY**
Year of submission	:	**2014**

The Present study entitled "**Time Series Analysis of area, production and productivity of major coarse cereals in Andhra Pradesh**" has been undertaken to fit different trend equations like linear, non-linear and time series models for major coarse cereals like Maize, Sorghum, Pearl millet and Finger milet and also made the future forecasts by 2020 AD. The study was carried out for Andhra Pradesh state using time series data from 1966 to 2012.

For forecasting purpose ten linear and non-linear growth models viz., linear, logarithmic, inverse, quadratic, cubic, compound, power, s-curve, growth and exponential and time series models like ARIMA and Exponential Smoothing models were fitted to the area, production and productivity of selected crops and influence of weather parameters like Maximum temperature (^{0}C), Minimum temperature (^{0}C), Rainfall (mm), Morning Relative Humidity (RH1) (%), Evening Relative Humidity (RH2) (%) on productivity were calculated by using statistical analysis like Karl Pearson's Correlation analysis and Multiple Linear Regression Analysis. the best-fitted model for future projection was chosen based upon highest Theil's U-Statistic, coefficient of determination (R^2) and significant Adjusted R^2 with least MAPE values.

The study revealed that the area, production and productivity of maize marked increasing trend during the study period 1966-2012 the same trend was continued for the forecasted period i.e up to 2020. In sorghum there was an increasing trend followed by decreasing trend in area and production whereas productivity showed an increasing trend; the forecasts also exhibited an increasing trend. The pearl millet crop revealed that area showed decreasing trend but production and productivity showed slightly increasing trend. Whereas finger

millet crop area and production showed decreasing trend and productivity showed slightly increasing trend during the study period. Forecasts also exhibited the same trend.

From correlation analysis where RH2 showed significant correlation with productivity of Maize crop. In sorghum crop, only RH1 showed significant correlation with productivity. In pearl millet, RH1 and RH2 showed significant correlation with productivity. In case of finger millet for productivity only RH1 showed significant correlation.

The Multiple Linear Regression Analysis revealed that the predicted models for all the crops were significant in RH1. It was also identified that other than weather parameters many factors are influencing Productivity of these crops.

Chapter I

INTRODUCTION

In India, agriculture and other allied activities contribute significantly to the Gross Domestic Product (GDP), accounting for nearly 14 per cent of the GDP. It provides employment to around 64 per cent of the total work force and contributing 18 per cent of the total exports. India, with only 2.3 per cent of world's total land area supports 18 per cent of human and 15 per cent of livestock population in the world. The country has made an impressive progress on the food front, which has resulted an increased production of food grains (Anon, 2010).

Forecasting is one of the main objectives of time series analyses having the art of saying "what will happen in the future" rather than "why". There are various forecasting models in use now a days. Forecaster can choose his own method based on his knowledge and available external information. As the process goes on, this procedure can be modified to meet the conditions and to satisfy the current situation. Different forecasting models may be fitted more or less equally well to a set of data, but they forecasts different future.

Forecasting provides an important and useful input for proper, foresighted and informed planning, more so, in agriculture which is full of uncertainties. Now a day's agriculture has become highly input and cost intensive. Under the changed scenario today, forecasting of various aspects relating to agriculture are become essential.

Crop yield forecasts are extremely useful in formulation of policies regarding stock distribution and supply of agricultural produce to different areas in the country. It is also used for forewarning of incidence of crop pests and diseases, weather forecasts, price forecast etc. Forecasting is central in making food policy decisions in developing countries.

The reason that forecasting is so important is that prediction of future events is a critical input in many types of planning and decision making process with application to areas such as operation management, marketing, finance and risk management, economics, industrial process control and demography. In the computer era, forecasting can be done with the help of sophisticated statistical software more efficiently.

Coarse cereals have been traditionally the main components of the food basket of the poor in India. Predominantly grown in the resource fragile agro-climatic regions of the country, these crops include maize, sorghum, finger millet, pearl millet, varagu, harka and other small millets. These are cultivated more in Karnataka, Maharashtra, Tamil Nadu, Madhya Pradesh, Andhra Pradesh, Rajasthan and Gujarat. When it comes to research on technology and promotion, coarse cereals as a crop group has received little attention in agriculture sciences as well as social sciences, hence also in the policy matrix. The area under coarse cereals has been declining in most of the region's growing these crops and as a result the crop group is relegated as 'inferior crops'. The neglect of this crop group is also quite strong on the economic front as the relative price structures as well as the market conditions are not very favourable for it. Above all, these crops are grown by the small and marginal farmers residing in such regions having repercussions of changes upon their household economy.

Coarse cereals have been known for their rich nutrient contents and drought resistance quality and are less amenable to common diseases and pests. These crops are the lowest priced cereals and thus are affordable by the poor (comparable to the fine cereals supplied through the Public Distribution System. It is well known that coarse cereals provide the richest source of calories among the cereals and hence can provide at the lowest cost, the same units of nutrients as rice or wheat. In addition to these factors, coarse cereals also form an important component of feed for livestock. Despite these factors and mainly due to the absence of economic incentives, coarse cereals have remained neglected crops in the country. (Ashok and Sasikala, 2011)

As these crops tolerate longer moisture stress, they are preferred as well as predominated the cropping pattern of drought-prone areas in Central India. Ecologically these are well suited to the drought-prone regions of Deccan plateau. Above all, the cost of production has also been quite low and thus they become affordable for consumption as well as production for the rural poor. The crops also offer a good potential in food processing industry and as a promising exportable commodity. Therefore, the risk factor being low, small and marginal farmers show preference towards these crops and cultivate them with traditional ease. The resource requirement of these crops has also been extremely frugal as they require minimum cash component in their total cost of cultivation.

In India there had been a decline in the area coverage under coarse cereals from 29.03 Mha in 2004-05 to 26.37 Mha in 2011-12. However, the productivity of coarse cereals had increased significantly from 1153 kg ha^{-1} in 2004-05 to 1593 kg ha^{-1} in 2011-12. The states showing a major increase in the productivity of coarse cereals are Uttar Pradesh, Maharashtra and Karnataka. The total production of coarse cereals was 33.47 Mt in 2004-05 had jumped to the level of 40.04 Mt in 2008-09. Due to severe drought in various parts of the country in 2009-10, the production of coarse cereals declined to 33.55 Mt but improved to 43.40 Mt in 2010-11 and again declined marginally to 42.01 Mt in 2011-12. (Ministry of Agriculture, Government of India, 2011)

In Andhra Pradesh the area under total coarse cereals had increased from 1254 thousand hectares in 2011-12 to 1405 thousand hectares in 2012-13, the production also increased from 4227 thousand tonnes in 2011-12 to 5519 thousand tonnes in 2012-13 and productivity also increased from 3371 kg ha^{-1} in 2011-12 to 3928 kg ha^{-1} in 2012-13.

Maize (*Zea mays* L.) is one of the most versatile emerging crops having wider adaptability under varied agro-climatic conditions. Globally, maize is known as queen of cereals because it has the highest genetic yield potential among the cereals. The area under maize was 972 thousand hectares, production was 4855 thousand tonnes and productivity was 4994 kg ha^{-1} during 2012-13 in Andhra Pradesh.

Sorghum (*Sorguhm bicolor* L.) is an important world crop used for food, fodder, the production of alcoholic beverages and bio fuels. It is the fifth most important cereal crop grown in the world. The area under sorghum was 287 thousand hectares, production was 472 thousand tonnes and productivity was 1643 kg ha^{-1} during 2012-13 in Andhra Pradesh.

Pearl millet (*Pennisetum glaucum* L.) is one of the major coarse grain crops and is considered as poorman's food. It provides staple food for the poor in a short period in the relatively dry tracts of the country. The area under pearl millet was 67 thousand hectares, production was 111 thousand tonnes and productivity was 1657 kg ha^{-1} during 2012-13 in Andhra Pradesh.

Finger millet (*Eleusine coracana* (L.) geartin.) is important minor millet grown in India. It is a staple food crop in many hilly regions of the country and predominantly grown as a dry land crop in Karnataka, Andhra Pradesh and Tamil Nadu. The area under finger millet was 10 thousand hectares, production was 12 thousand tonnes and productivity was 1200 kg ha^{-1} during 2012-13 in Andhra Pradesh.

Keeping in view of the above context, the present study has been undertaken to evaluate the growth in area, production and productivity of major coarse cereals in Andhra Pradesh by using different linear, non-linear growth models, time series models and also to project the same. This study has been undertaken to throw light on the policy decision to invest accordingly for the short and long-term plans and also to provide a direction of research which would bring sustainable development in agriculture.

OBJECTIVES

1. To apply different linear, non linear and time series models to area, production and productivity of major coarse cereals in Andhra Pradesh.
2. To study the influence of weather parameters on productivity of major coarse cereals in Andhra Pradesh.
3. To forecast the area, production and productivity of major coarse cereals in Andhra Pradesh by using best fitted model.

LIMITATIONS OF THE STUDY

The study was confined only to the major coarse cereals include Maize, Sorghum, Pearl millet and Finger millet in Andhra Pradesh. The analysis of the data has been carried out by using secondary data available from Statistical Abstracts, Andhra Pradesh, www.Indiastat.com and Ministry of Agriculture, Govt of India. And is based on forty seven years of the data from 1966-67 to 2012-13.

PRESENTATION OF THE STUDY

The report of the study is presented in five chapters.

In the first chapter, it deals with importance of coarse cereals and objectives of the study. The second chapter deals with a brief review of literature relevant to measurement of trend, fitting correlation and multiple linear regression analysis to influence of weather parameters on productivity of major coarse cereals and forecasting area, production and productivity, projections is presented. Material and methods followed with statistical procedures used are presented in the third chapter. Results and discussions with respect to the objectives of the study are presented in the chapter four. Finally, the brief summary and conclusions of the study are presented in the fifth chapter.

Literature cited is presented at the end of the thesis.

Chapter II

REVIEW OF LITERATURE

A review of the past research helps the researchers for identifying the conceptual and methodological issues related to the study. This will enables the researchers to collect relevant data and carry out their research in proper meaningful interpretations and enables them to draw conclusions. This chapter attempts a brief review of the relevant research literature related to the present study. Keeping in view, the objectives of the study, reviews are presented under the following headings.

2.1. Forecasting of area, production and productivity through linear and non-linear growth models.
2.2. Influence of weather parameters on productivity of major coarse cereals.
2.3. Forecasting through time series models.

2.1. FORECASTING OF AREA, PRODUCTION AND PRODUCTIVITY THROUGH LINEAR AND NON-LINEAR MODELS

Shah *et al*. (2014) analyzed growth and trend in area, production and yield of major crops of Khyber Pakhtunkhwa by using a time series data from 1980-81 to 2011-12 of major crops (wheat, maize, rice and sugarcane). The compound growth rates as well as trend analysis indicated that the area under wheat crop has decreased over the time due to shifting of area to other rabi crops. The production of wheat during 1981-85 to 2011-12 was increased due to the corresponding increase in per hectare yield of wheat crop in Khyber Pakhtunkhwa. The results showed that area, production and yield of maize was increased over the time due to more area was brought under hybrid and improved open pollinated maize varieties. The area under rice crop has decreased whereas their production increased due the corresponding increase in per hectare yield of rice crop. It was revealed from the data that area, production and yield of sugarcane crop was increased at a rate of 0.24 percent, 0.85 percent and 0.60 percent per annum, respectively.

Hossain and Hassan (2013) studied the growth pattern of milk, meat and egg production in Bangladesh during the time period from 1991-92 to 2011-12. By using appropriate deterministic type growth model using latest model selection criteria. They revealed that the cubic model was the best fitted model for milk, meat and linear model was the best for egg production. The selected model was used for succeeding four years forecast with a 95% confidence interval of milk, meat and egg production. The analysis found that if the present growth rates continue then the production of milk, meat and egg would be 4.55, 3.77, and 7544.67 million tons, respectively, in the year 2015-16.

Sudha *et al.* (2013) studied to measure the growth trends of area, production and productivity of maize between 1970-71 to 2008-09 and to estimate the future projections up to 2015 AD by using the growth functions like linear, logarithmic, inverse, quadratic, cubic, compound, power And exponential. Based on highest coefficient of determination (R^2) and its adjusted R^2 they concluded that among all the models cubic function was found to be best fitted model for future projections of maize area, production and productivity. The results revealed that the maize production in Guntur district may reach to 962.22 thousand tonnes in 2015 AD and the productivity also increasing from 8.85 t ha^{-1} in 2008 to 17.39 t ha^{-1} in 2015.

Khan *et al*. (2013) was made an attempt to develop nonlinear statistical models *viz.*, monomolecular, logistic, Gompertz, Richards and MMF for studying area, production and productivity of rice for three agro-climatic zones as well as whole Chhattisgarh State level for the period of 1975-76 to 2000-01. Various goodness of fit statistics *viz.*, R^2, RMSE, MAE, MSE were considered. The results revealed that for modeling production of rice, logistic, Gompertz and

Monomolecular models came to be the most appropriate for the Northern hills and whole Chhattisgarh State. Gompertz and logistic models for Bastar plateau. For modelling productivity of rice logistic and Gompertz models were found to be the most suitable for the Northern hill, logistic for whole Chhattisgarh. Monomolecular and logistic models were found to be the best model for describing the area data of Chhattisgarh State. They found that, for all state monomolecular and logistic model came out to be the best fitted models.

Naik *et al.* (2013) studied growth and instability of minor millets in the northern part of Karnataka. He observed that the growth in savi area was negative and significant for both sample district (-1.93%) and the state (-5.62%) as a whole. Accordingly the production of savi also showed declining trend as indicated by their negative growth rates in case of both district and state level savi production. Growth in navane area, production and productivity was negative for both the sample districts. The decline in area (8.62%) and production (8.69%) was found to be significant in Bellary district. For the state as a whole, the growth rates of navane area (-8.92%) and production (-8.46%) showed significantly declining trend, while growth rate of navane productivity (0.39%) was found to be positive and statistically significant at one per cent level of probability. The average savi production for the state as a whole was predominant due to change in mean area (160.79%) followed by change in mean productivity (86.33%). At the state level the stability of navane production was largely attributable to change in mean yield (69.54%).

Acharya *et al*. (2012) estimated growth in the area, production and productivity of different crops in Karnataka using the compound growth function on the basis of 26 years data from 1982-83 to 2007-08. They concluded that the Growth rates showed a significant positive growth in area under pulses, vegetables, spices, fruits and nuts, while cereals showed significant negative growth. The area under jowar, bajra, ragi and minor millets are experiencing a substantial annual decrement. The area under rice has recorded a mild annual increment. The growth in area under oilseeds and commercial crops was negative and insignificant. Similarly the production of cereals, pulses, vegetables and fruits showed a significant positive growth. The production of oilseeds and commercial crops registered insignificant positive growth. The productivity of different crops recorded significant growth in the case of cereals, pulses and fruits. Productivity of oilseeds recorded moderately positive growth. The productivity of commercial crops registered insignificant positive growth and for vegetables the growth in productivity was insignificant and negative.

Arunachalam and Balakrishnan (2012) made an attempt to study the trends in area, production and productivity of wheat crop grown during the period from 1950-1951 to 2009-2010 in India by fitting of Different non-linear models. The results indicated that none of the non-linear model was found suitable to fit the trends in area data. The Sinusoidal model was found suitable to fit the trends in production as well as productivity of wheat crop. And area, production and productivity had been shown in the increasing trend. The area of cultivation had played a major role in increasing the trend in production.

Bharti *et al*. (2012) estimated the time series data on area, production and productivity of oilseeds crop in Uttar Pradesh pertaining to the period of 1970-71 to 2005-06 were used for the investigation of trend and growth of oilseeds and also impact of technological changes on oilseeds production. Relevant statistical tools and techniques like regression analysis etc. have been used for the purpose of investigation. They observed that the production gains in oilseeds were largely due to the expansion in area during the first period (before the launch of technological mission) rather than in productivity. And the absence of growth in productivity was a result of adequate technological progress and or poor adoption of yield enhancing technologies. In addition favorable price situation created through the technological mission on oilseeds resulted in expansion of marginal areas. Thereby, causing a decline in average yields developing location specific technologies that enhance oilseeds productivity.

Kumar *et al.* (2012) made an attempt to develop appropriate nonlinear statistical growth models with a view to provide analytical approach to describe trends in Area under coffee production in India. For this purpose six nonlinear statistical growth models are used. The two best fitted models are selected based on the performance of several goodness of fit criteria *viz.*, MAE, MSE, RMSE, MAPE, AIC and BIC. Logistic and MMF models were found to be quite successful for describing the Area under coffee production. The study revealed that the series had upward trend in Area under coffee production. Forecast values were also computed using two best fitted models; result revealed that forecasted values of Logistic model are slightly larger than the MMF.

Prasad *et al.* (2012) studied growth rates in area, production and productivity of Maize crop in Telangana region of Andhra Pradesh by using 41 years of data from 1969 to 2009. Besides, growth rates the projections were also estimated up to 2014 AD by using different growth models. Among these models the model with least residual mean square (RMS) and significant Adj R^2 was considered to be the best fitted model for the projection purpose. The study revealed that in case of maize area and production compound model was found to best trend equation and in productivity s-curve function was best fitted model for future projections.

Sudha *et al.* (2012) made an attempt to study the growth rates and trends of paddy area, production and productivity in Guntur district of Andhra Pradesh for the period from 1970-71 to 2011-12 and to estimate the future projections upto 2020 AD by using linear, logarithmic, inverse, quadratic, cubic, compound, power and exponential. Based on significant adjusted R^2 and least residual mean sum of squares they concluded that in case of paddy area future projections were not calculated because no model was found to be fitted well due to non-significant adjusted R^2 values for all the fitted models. Regarding the production quadratic function was found to be best fitted model and in productivity cubic function was found to be best fitted models for future projections.

Ashok and Sasikala (2011) estimated the compound growth rates (CGR) of area, production and productivity of major coarse cereals (bajra, maize, ragi, jowar) and analyze the trends in cost of production of coarse cereals and the Minimum Support Price (MSP) during the period from 1970-71 to 2007- 08. The study revealed that the area under bajra declined throughout the period from 1970-71 to 2007-2008 in India. But the production of bajra registered significant positive growth due to growth in productivity. In maize there is significant positive growth in the area, production and productivity both in Tamil Nadu and India unlike in other coarse cereals. In case of ragi production declined in India and in Tamil Nadu due to decline in area under cultivation of ragi but Productivity registered significant positive growth rate. The area under jowar declined consistently in the last few decades both in India and Tamil Nadu. The difference between MSP and cost of production was the highest in ragi followed by cumbu, maize and jowar.

Hassan *et al*. (2011) fitted appropriate deterministic time series model using the latest model selection criteria that could best describe the coarse rice price pattern in Bangladesh during the period from July 1975 to December 2011. They revealed that among the entire models cubic model was selected as the best fitted model. And cubic growth rates varied from 0.68% to 4.03%. By using the cubic growth model coarse rice prices were forecasted.

Barakade and Lokhande (2011) studied trends in area, production and productivity of onion crop in Maharashtra for the period 2000-01 to 2008-09. It has been observed that the growth in area of onion in the State revealed trend. For the overall period of the study, very previous year's onion crop has shown continuously increasing trends for all the decades. The onion crop recorded during the year 2000-01 cultivated 121 thousand hectare increasing the year 2006-07 under the onion cultivation 229.84 thousands hectares area. The production of onion has been lowest during the year 2001-02 i.e. 1307 thousand million tonnes as compared to 2812 thousand million tonnes during the year 2006-07. The decrease in productivity due to drought and or insufficient monsoon rains, excess of rainfall during the pods formation.

Sonnad *et al.* (2011) analyzed the temporal growth rate in area, production and productivity of major oilseed crops in India during pre and post WTO periods. The results of this study showed that area under rapeseed, mustard, soya bean, sunflower and castor increased with an overall annual compound growth rate of 2.13, 17.61, 9.15 and 1.85 percent respectively. The increase in productivity of all nine selected oilseed crops put together from pre-WTO period to post-WTO period was 140 kg ha^{-1}. They concluded that the overall growth of productivity was positive in all the oilseed crops except sunflower. The mean production of the nine oilseeds put together had increased from 9.99 Mt during pre technology mission on oilseeds period to 17.68 Mt in pre-WTO period and to 22.33 Mt in post-WTO period.

Priya and Bajpai (2011) carried out to compute the compound growth rates of area, production and productivity of sugarcane crop in India. During the period of 1930-31 to 2006-07 has been used for the computation of growth rates. The non-linear growth models have been discussed for computing the compound growth rates. The parameters of the model have been estimated using three popular Non-linear growth models like Logistic, Gompertz and Monomolecular. The results of the parameter estimates and goodness of fit measures indicated that among the three models Logistic model was appropriate for calculating the compound growth rates. The results of compound growth rates for sugarcane area, production and productivity have been estimated as 1.73%, 2.96% and 1.12% respectively.

Rajarathinam and Parmar (2011) were carried out to study area, production and productivity trends of castor crop grown in Anand district of middle Gujarat state for the period of 1949-50 to 2007-08 based on parametric and non-parametric models. Relative growth rates were estimated based on the best fitted trend function. The study revealed that non-parametric regression model was selected as the best fitted trend function for the area, production and productivity of castor crop. The percent growth rate values showed that the production had increased at a rate of 5.79% per annum which was due to combined effect of increase in area and productivity at a rate of 2.86 and 3.41% per annum respectively.

Dhakre and Sharma (2010) studied the growth analysis and trend in area, production and productivity of maize in nagaland based on index numbers and compound growth rates by fitting exponential function ($y=a.b^t$). They concluded that among area, production and productivity of maize, the instability was highest for the production.

Karadavut (2010) compared some statistical growth models like quadratic, square root, exponential and weibull for describing seedling growth in early period. As a result, quadratic model explained better than other models for seedling growth.

Rajarathinam *et al.* (2010) estimated models for area, production and productivity trends of tobacco crop grown in Anand region of middle Gujarat state for the period of 1949-50 to 2007-08 based on parametric and non parametric regression models. Relative growth rates of area, production and productivity were estimated based on the best fitted trend function. The non parametric regression was selected as the best fitted trend function for the area, production and productivity of tobacco crop based on lower values of RMS and mean absolute error.

Karim *et al.* (2010) examined the growth pattern of wheat production in Bangladesh and its three major areas Dinajpur, Rajshahi, and Rangpur districts during the time period from 1971-72 to 2004-05. They concluded that linear model was found appropriate for Dinajpur District, while cubic model was appropriate for both Rajshahi and Rangpur districts. On the other hand, quadratic model was found appropriate for Bangladesh. It meant that the annual growth rates were significantly different from time to time for wheat production. Five-year forecasts of wheat production in Bangladesh, Dinajpur, Rajshahi, and Rangpur districts during 2005-06 were 1.55, 0.31, 0.24, and 0.37 Mt, respectively. If the present growth rates continue, wheat production in Bangladesh, Dinajpur, Rajshahi, and Rangpur districts would be 1.54, 0.35, 0.31, and 0.58 Mt, respectively, in 2009-10.

Chetana (2009) examined prediction models in teak based agro forestry systems in Northern transitional zone of Karnataka. Different prediction models namely Linear, Quadratic, Cubic, Exponential, Growth, Sigmoid, vapour pressure, Hassel, Morgan Mercer Flodin (MMF), compound, Logarithmic, Logistic, Weibull, Gompertz, Power etc., have been tried to predict the diameter and height growth of teak tree. The results revealed that Morgan Mercer Flodin (MMF) model was found to be better followed by Gompertz and Weibull for diameter prediction whereas for height growth prediction Morgan Mercer Flodin (MMF) model followed by logistic and Richards were found to be better.

Karadavut (2009) examined the growth curves of some Triticale cultivars with respect to their dry weight-age relationships and to determine a suitable non-linear model explaining their growth curve. The study revealed that Richard's and Weibull models were seemed to be best suitable models for explaining triticale growth.

Masuda *et al.* (2009) studied World soybean production, area harvested, yield and long-term projections. The world soybean production increased by 4.6% annually from 1961-2007 and reached annual production of 217.6 million tons in 2005-07. World production of soybean is predicted to increase by 2.2% annually to 317.3 million tons by 2030 using exponential smoothing model with a damped trend.

Panwar *et al.* (2009) analysed export of onion from India by using different non-linear models viz., Logistic, Gompertz, Monomolecular, Richard's, Weibull and Quadratic models were applied and a comparative study was conducted for these models.

Sandika *et al.* (2009) carried the study to analyse the growth performance of rice sector and to identify the appropriate model to predict the future trend of the sector in Sri Lanka. The growth performance was analysed by considering total production and productivity. Cubic model was selected as the most suitable to predict the total production and productivity of Rice.

Gupta *et al*. (2009) has been made an attempt to forecast Jute production and compare the methods of forecasting using parametric models such as polynomial, logarithmic, inverse, and exponential, with those of Box-Jenkins techniques, such as autoregressive, autoregressive moving average, and autoregressive integrated moving average techniques of forecasting using the data for the period 1961-2002. The study also examined the nature of growth and forecasted a decline in Jute yield.

Aparna *et al*. (2008) examined the trend in growth rates of major vegetables in Visakhapatnam district with the help of compound growth rates. Compound growth rates were calculated by using exponential growth function. She concluded that the compound growth rates of area registered negative significant growth rate where as production and productivity showed positive but non-significant growth rates.

Gaddour *et al*. (2008) analysed on adjustment of the kid's growth curve in pure goat breeds and crosses under southern Tunisian conditions. Five non-linear statistical models, Gompertz, Brody, Richards, Logistic and Exponential, were tested to fit the kid's growth curve parameters and shape of indigenous goat, Alpine, Damascus and their crosses. Data from 16 years periodical weighing was used to adjust growth curve before 5 months age of 1687 suckled kids. They concluded that Gompertz model was the best fitted model to adjust kid's growth evolution.

Kalita (2008) studied trends in area, production and productivity of major fruit crops in Jammu and Kashmir based on the secondary data for the period of 1974-75 to 1999-2000. This study revealed that area, production and productivity of major fruit crops had a positive and statistically significant growth during the study period. The coefficient of variation of area, production and productivity for almost all crops were less than 50%, indicating that less risk of cultivation in the state.

Shadmehri (2008) analysed the trends in area, production and yield of Iran's agriculture production especially food grains. Compound growth rates of area, production and yield were estimated by fitting semi-log trend equation using data for 1970-71 to 1999-2000. Decomposition of output growth of main crops were examined by fitting component analysis model $\Delta P = A_0\Delta Y + Y_0\Delta A + Y\Delta A$. The performance of agricultural sector was slightly better during the pre-revolutionary period than that of post-revolutionary period. The main source of growth agricultural production in pre-revolutionary period has been the growth in yield per hectare and expansion in irrigated area.

Devraj *et al.* (2007) studied trends and growth performance in area, production and yield of chickpea in the four zones of India. The study utilized the secondary time series data of area, production and productivity of chickpea in different zones for the period of 30 years from 1975-76 to 2004-05. They observed that the maximum area and production of chickpea was in the Central Zone followed by the North West Plain Zone and North East Plain Zone while the lowest area and production was in the South Zone. The highest compound growth rate of area and production was observed in the South Zone followed by the Central Zone, while the lowest growth was registered in the North West Plain Zone followed by the North East Plain Zone.

Rao and Srinivasulu (2006) made and attempt to measure the growth rates of turmeric considering the period from 1970 to 2005 and to estimate the future projections up to 2020 AD by using the regression equations like linear, quadratic, exponential, logarithmic, compound models. They concluded that the growth rates of area, production and productivity of Turmeric were positive and showed increasing trend in the state, Andhra Pradesh. It was found that linear equation was the best fit of its highest coefficient of determination. Hence, the future projections of area, production and productivity of Turmeric in Andhra Pradesh and India were calculated based on the linear regression equation.

Shindgikar and Patil (2006) described the trend in area, production and productivity of Grapes in India for the period from 1991-92 to 2002-2003.

Mohanty *et al*. (2006) analysed the impact of puddling, tillage and residue management on wheat (*Triticum aestivum* L.) seedling emergence and growth in a rice-wheat system using nonlinear regression models. The nonlinear regression models study indicated that the Logistic model predicted the shoot growth of wheat under different tillage and residue management practices better than the Gompertz model. Whereas, for root growth the Monomolecular model fitted well with the experimental data.

Lathika and Kumar (2005) examined the growth trends in area, production and productivity of coconut in India for the past five decades (1950-51 to 2001-02). The study focused on the performance of different states in coconut production and also the relative role of area and yield in explaining the observed trend in production.

Sarkar *et al*. (2005) fitted suitable non-linear models *viz.*, exponential, Gompertz and logistic to describe the growth (body weight) of pigs. They tested the assumptions of independence and normality of errors by using run test and Shapiro-Wilk test, respectively and concluded that Gompertz model was the best fitted model for the growth of body weights in pigs.

Panwar and Kumar (2004) used five non-linear models viz., logistic, gompertz., monomolecular, Morgan Mercer-Flodin (MMF) for describing state wise yield data of Apple during 1991-92 to 2000-2001. They considered five major Apple growing states viz., Jammu and Kashmir, Arunachal Pradesh, Uttaranchal, Nagaland and Himachal Pradesh. They concluded that logistic model described quite well for the Apple productivity data and Nagaland showed good performance in yield compared to other states.

Selvan and Kumar (2004) described the trend in area under cultivation, production and productivity of spices in Meghalaya during 2002-03.

Varghese (2004) made an attempt to study the trends in area, production and productivity of cardamom in Kerala and to analyze the price behaviour and the mechanisms of price transmission for the period 1970-71 to 2002-03. He concluded that the trends in area, production and productivity of cardamom in Kerala during the initial years (1970-71 to 1978-79) does not show any increment and from 1979-80 onwards, it had shown a marginal increase.

Sreekanth and Bhaskara Rao (2003) analysed to develop a simple forecasting model for predicting the cashew yield for area and production based on secondary data from the years 1985-86 to 2000-01.

Raghuwanshi *et al.* (2001) in their attempt to evaluate the growth performance of chickpea production in Bundelkhand region of Madhya Pradesh during the period from 1970-71 to 1994-95. The study revealed that all the districts of the region experienced positive growth rates of area, production and productivity of chickpea during the reference period. Tikamgarh district showed higher growth rate under area of chickpea while Datia district ranked first in growth of yield. Coefficient of variation indicated that variability was highest in production and it was due to increased yield variability associated with nominal acreage variability of chickpea crop. Results of the component analysis showed that yield was the major contributor in production than the area in Datia and Tikamgarh district.

Chattopadhyay and Das (2000) analyzed growth rates of agricultural production in West Bengal using log-quadratic, exponential and parabolic trend equations. Best fitted model was chosen based on model selection criteria like Adjusted R^2 and Residual Mean Square (RMS). They concluded that exponential function was found to be the best fitted model.

Borthakur and Bhattacharya (1998) analysed the trends of area, production and productivity of potato in Assam for the period of 1951 to 1993 using different functional forms like linear, quadratic and exponential models.

Singh and Ranjan (1998) analysed the growth performance of principal food crops in North Bihar and in India during the period from 1970-71 to 1994-95. They revealed that production showed positive growth rates during post green revolution period. It was also observed that there is no substantial increase in area under Rice during the study period. And a declining trend in rice area has been observed during early 1990s.

Singh *et al*. (1997) analysed the trends in area, production and yield of major food grains, coarse cereals, pulses, oilseeds, sugarcane, and cotton at the state level in India and the factors responsible for determining yield and acreage of important food grain crops. Compound growth rates of area, production and yield were estimated by fitting log-linear functions using the data for 1960-61 to 1992-93. The study revealed that for total food grains, as well as for all the individual grain crops, yield witnessed a higher growth rate as compared to acreage during 1972-73 to 1992-93.

Mathur (1996) estimated the trends in area, production and yield of major pulse crops using time series data during the period of 1980-81 to 1990-91. Simple linear regression equations were fitted by the ordinary least square method.

Kalola *et al.* (1995) reported that for area the quadratic model, for production and productivity the linear model were found suitable to fit the trend of tobacco crop grown in Gujarat state during the period from 1951-52 to 1990-91.

Kaushik (1993) studied the growth of oilseeds production in India by using exponential function for the period of 1968-69 to 1991-92. The period was divided into two sub periods. The study revealed that during period 1, most of the growth in oilseeds output was due to growth in area, where as in period 2 it was mainly due to improvement in productivity.

Reddy and Reddy (1983) studied the trends in agricultural growth of Andhra Pradesh and observed that the growth of area under groundnut was positive in the three regions of Andhra Pradesh and Andhra Pradesh as a whole during 1956-57 to 1977-78. The growth of area under competing crops (Jowar and Maize) was negative indicating a shift in area in favour of groundnut.

2.2. INFLUENCE OF WEATHER PARAMETERS ON PRODUCTIVITY OF MAJOR COARSE CEREALS

Sivapragasam and Prabakaran (2014) estimated the yield of rice and month wise weather parameters for Madurai district data over ten years (1995-96 to 2004-05) were used for this study. In this study, the time effect was found to be of continuous nature over time in the rice yield. There were no sub-periods (revealed by quantum jumps) in the yield of rice crop, indicating no technological changes in the study period. Crop weather relationship studies indicated that different weather parameter influenced in the yields of rice crop in different seasons. The results showed that Kharif season sowing, transplanting and vegetative stage temperature and rainfall plays important role for rice crop, but during harvesting stage rainfall plays negative correlation with rice crop yield. Rabi season humidity and rainfall played a positive role during vegetative stages. Maximum temperature showed negative and significantly correlated and morning relative humidity was positive and significantly correlated with rabi season rice crop yield. It was also revealed that study of the differential response of weather parameter is important to enhance the crops yields.

Pandey *et al.* (2013) developed models for forecasting rice yield at district level on the basis of weather variables. Weekly data (of 19 meteorological weeks) on seven weather variables over a span of 21 years period (1989-90 to 2009-10) has been used along with the annual rice production data for Faizabad district (Eastern UP). Stepwise regression was used to screen out the important weather variables and multiple regression approach was subsequently employed to estimate model parameters. The results showed that the model –I was evolved as best for yield forecasting out of five model evaluated, R^2 and RMSE of this model comes out to be 71.2%, 0.733 respectively followed by model-V with R^2 and RMSE 51.25% 1.2524 respectively.

Vijayan *et al.* (2013) studied the significance of meteorological parameters in the implementation of agriculture engineering practices in the Tabuk region of the Royal Kingdom of Saudi Arabia. Meteorological data was collected for the period 2002-2011. A trend analysis showed an increasing trend in temperature and rainfall while relative humidity showed a decreasing trend during that time of 10 years. The effect of each of the meteorological parameters on productivity of selected crops was studied using statistical tools. It was observed that among all the meteorological parameters, temperature and relative humidity greatly influences the production of crops like wheat, potato, fruits and vegetables in this region. While crops like wheat, potato and vegetables showed a positive correlation with temperature, fruit production follows relative humidity changes.

Sheng *et al.* (2011) forecasted the grain yield of Guangxi by using multiple linear regression models in order to provide references for related researches. The factors affecting the grain yield in Guangxi were analyzed by using multiple linear regression models and forecasted the grain yield of Guangxi. The results showed that the factor of grain planting area had the biggest impact on the grain yield which was 14643810 t and the grain planting area should not be decreased in order to sustain the yield and production of grains in Guangxi.

Rankja *et al*. (2010) made an attempt to study the quantitative relationship between weather parameters and district level yield of cotton and to develop pre harvest forecast models for cotton yield. For this purpose 32 years data of weather parameters and crop yield was collected. The results showed that the 26 week crop period model was recommended for pre harvest forecast due to highest coefficient of determination (R^2) and lower forecast error. The analysis also revealed that time trend, maximum temperature, morning and evening relative humidity have significantly affected on crop yield.

Guruswamy *et al*. (2008) were studied the mean annual and seasonal rainfall behavior and the effects of weather parameters on coconut productivity in Thanjavur district, Tamil Nadu, India during the period from 1996-97 to 2005-06. The results showed that southwest monsoon and winter rainfall had a negative correlation with coconut productivity whereas summer and North East Monsoon exhibited a positive correlation with coconut productivity. The percentage of barren nut production in coconut had a positive correlation with summer rainfall and negative correlation with winter, south west and north east monsoons. And the maximum temperature, minimum temperature, relative humidity, pan evaporation and rainfall had a positive correlation with coconut productivity.

Singh *et al*. (2008) analysed the effect of rainfall and temperature effect on wheat yield in south western region of Punjab. Over the past 25 years the technology trend at Bathinda indicated that wheat yield have increased at the rate of 82.1 kg ha^{-1}. Maximum, minimum temperature and rainfall from December to march for each period of five years 1977-81 to 1997-2001 were analyzed. The results revealed that temperatures during February and March showed significant effect on wheat yield. The grain yield revealed positive correlation with minimum temperature but no trends observed for other parameters.

Srivastava *et al.* (2007) developed a weather interactive model for predicting sugarcane yield for the state of Uttar Pradesh by using 20 years productivity data from 1980-81 to 1998-99. The monthly average of weather parameters such as maximum (Tmax) and minimum (Tmin) temperature, morning (RH7) and afternoon (RH 14) relative humidity, rainfall (Rain) and range of temperature (Trange) were used from April to September. Three models were developed. Model l includes weather parameters Tmin, RH7, RH14, Rain and Trange. Model 2 is based on Tmax, Tmin, RH7, RH14, Rain and Trange. Model 3 included Tmax, Tmin, RH7, RH14 and Rain. These multiple regression models were developed using generated variables for each weather parameter based on respective correlation coefficients of individual weather parameters with yield during April to September. The models were updated for each year for predicting the yield in the following year. The results showed that the coefficients of determination of these models were found to be significant at 1% .The models were validated from 2000-01to 2005-06 sugarcane crop seasons. Model 3 was found best with Root Mean Square Error (RMSE) as 11.51%.

Sanjeev *et al*. (2006) in their study on forecasting the profitability of sugarcane farming in major states of India. The study was based on the data of cost of cultivation of sugarcane in different states of India for the period 1990–2001 by multiple regression models. The study has revealed an increasing trend in sugarcane production in India.

Chen *et al.* (2004) examined the statistical investigation of potential effects of climate change on crop yield variance in the context of current observed yields and then extrapolates to the effects under projected climate change. In particular, maximum likelihood panel data estimates of the impacts of climate on year-to-year yield variability are constructed for the major U.S. agricultural crops. The estimation results indicate that changes in climate modify crop yield levels and variances in a crop specific fashion. For sorghum, rainfall and temperature increases are found to increase yield levels and variability. On the other hand, precipitation and temperature are individually found to have opposite effects on corn yield levels and variability.

Joshi (1999) studied the dependence of area and production of lead crops (pearl millet, groundnut and rain fed cotton) on rainfall in dry farming area in Gujarat, India. The study examined whether any relationship can be established to suggest optimum period of planting these cops and also forecast expected area coverage and production from 1961-62 to 1991-92. The study showed that the time of onset of monsoon becomes the deciding factor for area covering and later on in production of many lead crops. Adequate rainfall in the early period of monsoon increases area of cash crops like groundnut in Saurastra region, where as with inadequate rainfall in this period farmers, opted for coarse cereals like pearl millet. The adequate rainfall during the early growth period of cotton has a positive influence on its production. The forecast of area can’t be based on periodical rainfall received during the season of a crop.

2.3. FORECASTING AREA, PRODUCTION AND PRODUCTIVITY OF MAJOR COARSE CEREALS THROUGH TIME SERIES MODELS

2.3.1 Forecasting through ARIMA

Meena (2014) carried out a study to forecast the mustard seed and oil prices in selected Indian markets by using ARIMA model. The results indicated that for Alwar market forecast model of mustard seed was ARIMA (1, 1, 1) (2, 1, 1), for Jaipur market (1, 1, 1)(1, 1, 1) and Sriganganagar market (1, 1, 1)(0, 1, 1) was best fitted models based on lowest AIC and BIC values. Results also showed that there was slight difference between actual and forecast prices of mustard seed and mustard oil. The forecasted value of mustard seed and oil showed an increasing trend of prices in selected markets.

Prabakaran *et al*. (2014) analysed pulses area and production in India during the period from 1950-51 to 2011-12 by fitting Box-Jenkins Auto Regressive Integrated Moving Average (ARIMA) model. Validity of the model was tested using standard statistical techniques. They concluded that ARIMA (1, 1, 0) and ARIMA (2, 1, 1) models were best fitted to forecast area and production in India for four leading years. The results also showed that area forecast for the year 2015 to be about 26.74 thousand hectare with upper and lower limits of 30.53 and 22.96 thousand hectares respectively and pulses production forecast for the year 2015 to be about 15.51 thousand tonnes with upper and lower limits of 18.47 and 12.54 thousand tonnes respectively.

Hamjah (2014) made an attempt to fit the best Auto-Regressive Integrated Moving Average (ARIMA) model that could be used to forecast the rice production of Bangladesh such as in Aus, Boro, Aman season covering the whole country. They concluded that The best fitted ARIMA model for Aus and Aman productions was ARIMA (2, 1, 2) and for Boro ARIMA (1, 1, 3). It was found from the analysis that ARIMA model gives good forecasting for short term analysis.

Thirunavukkarasu and Rajarathinam (2014) analysed modelling and forecasting future milled rice production in India using time series data from 1960-61 to 2013-14. These data include trend variations which allow the use of ARIMA (Auto Regressive Integrated Moving Average), Brown exponential smoothing and Damped exponential smoothing models for predictions of future behavioural patterns. They concluded that all model forecasting accuracy degree of statistical validity based on highest R^2 with lowest RMSE, MAPE and Normalised BIC.

Manoj and Madhu (2014) attempted to study forecasting of sugarcane production in India by using time series modelling approach (Box-Jenkins ARIMA model). They found that ARIMA (2, 1, 0) model was best fitted model for forecasting of sugarcane production.

Debnath *et al.* (2013) focused on forecasting the cultivated area and production of cotton in India using Autoregressive Integrated Moving Average (ARIMA) model by using the data from 1950-51 to 2010-11. Based on model selection criteria like highest R^2 with lowest RMSE, MAPE, MAE and Normalised BIC they revealed that ARIMA (0, 1, 0) ARIMA (1, 1, 4) and ARIMA (0, 1, 1) are the best fitted model for forecasting of cotton area, production and yield in India respectively. The analysis also showed that if the present growth rates continue then the cotton area, production and yield in the year 2020 will be 10.92 million hectares, 39.19 million bales of 170 kg of each and 527 kg ha^{-1} respectively.

Prabakaran *et al.* (2013) analysed area and production of wheat in India for the period from 1950-51 to 2011-12 by using Box-Jenkins Auto Regressive Integrated Moving Average (ARIMA) model. Validity of the model was also tested using standard statistical techniques. They concluded that ARIMA (1, 1, 1) and ARIMA (1, 1, 0) models were best fitted to forecast area and production in India for five leading years. The results also showed that area forecast for the year 2015 to be about 31.46 thousand hectare with upper and lower limits 34.25 and 31.46 thousand hectares respectively. And Wheat production forecast for the year 2015 to be about 97.73 thousand tonnes with upper and lower limit 107.55 and 87.92 thousand tonnes respectively.

Kumar and Mahto (2013) studied forecasting techniques in juice production by using statistical time series modelling techniques like Moving Average, Simple Exponential Smoothing and Least Square methods. The purpose of this study is to observe whether the forecast errors are within the reasonable limit of expectations or whether these errors are irrationally large and require an improvement in the statistical models and process of producing these forecasts. Their performance evaluated by comparing the MAPE, MAD and MSE obtained from different methods. The results showed that least Square method was more accurate than the other methods.

Verma *et al.* (2013) made an attempt to study forecasting of sugarcane crop in karnal, Kurukshetra and Ambala districts of Haryana during the period from 1960-61 to 2009-10 by using Box-Jenkins Approach (ARIMA). The analysis revealed that ARIMA (0, 1, 1) for Ambala, karnal districts and ARIMA (1, 1, 0) model for kurukshetra district were fitted for pre-harvest crop yield prediction.

Tripathi *et al.* (2013) attempted to study trend in area, production and productivity of pearl millet in India and also focused on forecasting cultivated area and production of pearl millet by using Auto Regressive Integrated Moving Average (ARIMA) model using time series data covering the period from 1950-51 to 2010-11. The study revealed that compound trend models can adequately delineate trends in area, production and productivity of pearl millet. The model also showed that pearl millet area, production and yield would be 8.67 Mha, 9.15 Mt and 1083.12 kg ha^{-1} respectively.

Rahman *et al.* (2013) carried out a study to estimate growth pattern and examine the best ARIMA model to efficiently forecasting pigeon pea, chickpea and field pea pulse production in Bangladesh. It appeared that the time series data for pigeon pea, chickpea and field pea were 1st order homogenous stationary. Two types of models namely Box-Jenkins type Autoregressive Integrated Moving Average (ARIMA) and deterministic type growth models, are examined to identify the best forecasting models for pigeon pea, chickpea and field pea pulse production in Bangladesh. The study revealed that the best models were ARIMA (1, 1 and 1), ARIMA (0, 1 and 0) and ARIMA (1, 1 and 3) for pigeon pea, chickpea and field pea pulse production, respectively. Among the deterministic type growth models, the cubic model was the best for pigeon pea, chickpea and field pea pulse production.

Mishra *et al.* (2013) studied trends in area, production and productivity of onion in India covering the period of 1978-79 to 2008-09. And also focused on forecasting of cultivated area and production of onion in India using Auto Regressive Integrated Moving Average (ARIMA). The study revealed that among the parametric trend models cubic trend model was found to be best fitted model and forecast onion production for the year 2020 to be about 23.02 Mt.

Selvararaju *et al.* (2013) focused on forecasting model for predicting bluetongue outbreaks in North-west agro climatic zone of Tamil- Nadu by using multiple linear regression.

Biswas and Bhattacharya (2013) conducted a study for forecasting the area and production of rice in West Bengal by using ARIMA model during the period from 1947-48 to 2007-08. Based on model selection criteria like the model having highest R^2 with least RMSS and lowest AIC, BIC values having selected was best fitted model. The results showed that among all the models ARIMA (2, 1, 3) and ARIMA (2, 1, 1) was the best fitted models for forecasting of rice area and production respectively.

Sankar and Prabakaran (2012) forecasted the milk production in Tamil Nadu based on data of milk production during the years from 1978 to 2008. Based on ARIMA (p, d, q) and its components ACF, PACF, normalized BIC, Box-Ljung Q statistics and residuals estimated, ARIMA (1, 1, 0) was selected as best fitted model. The study revealed that Based on the chosen model, it could be predicted that the milk production would increase to 7.15 Mt in 2015 from 5.96 Mt in 2008 in Tamil Nadu.

Harris *et al*. (2012) estimated the behaviour of Ghana's annual coffee production by using ARIMA as well as make five years forecasts, by using the data from 1990-91 to 2010-11. The results showed that in general, the trend of Ghana's total coffee production follows an upward and downward movement. They concluded that ARIMA (0, 3, 1) was selected as the best fitted model on the basis of various diagnostics, selection and an evaluation criterion. And the forecast figures based on Box- Jenkins method showed that Ghana's annual coffee production will decrease continuously in the next five years.

Zakari and Ying (2012) forecasted Niger grain production and harvested areas and for the two main staple crops (Millet and Sorghum) using ARIMA model. The time series data of production and harvested area covering the period from 1970-71 to 2010-11 were used in the study. They concluded that the total harvested area and total grain production would be 21317.4 thousand ha and 12677.9 thousand tons in 2030, respectively. The model also showed that Millet and Sorghum production would be 4503 thousand tonnes and 1574.8 t respectively during the period.

Sivapathasundaram and Bogahawatte (2012) investigated the past, present and future trends of paddy production in Sri Lanka and develop a time series model to detect the long term trend and prediction for future changes of paddy production for the three leading years. By using Autoregressive Integrated Moving Average (ARIMA) during the period from 1952-53 to 2010-11. They concluded that ARIMA (2, 1, 0) was the most suitable model with lowest AIC and BIC values. The Mean Absolute Percentage Error (MAPE) for paddy production was 10.5. The forecasts for paddy production during 2011 to 2013 were 4.07, 4.12 and 4.22 million Mt respectively, and the production for the year 2011 and 2012 was lower than in 2010. However in later year 2013 the production was higher it was observed that overall it had an increasing trend.

Padhan (2012) applied ARIMA models for forecasting of agricultural productivity in India during the period from 1950 to 2010. Forecasted values have been obtained for another 5 years since 2011. The validity of the model is verified with various model selection criteria such as Adj R^2, minimum of AIC and lowest MAPE values. The results showed that among the selected crops, tea provides the lowest MAPE values, whereas cardamom provides lowest AIC values.

Borkar (2012) estimated modelling and forecasting of cotton yield in Maharashtra by time series models for the period of 1964-65 to 2007-08. Autocorrelation and Partial Auto Correlation functions were calculated for the data. Based on least AIC and BIC values future values were forecasted. The results showed that ARIMA (2, 1, 1) model was best appropriate for future projections of cotton yield up to 2020 AD.

Suleman and Sarpong (2012) studied modelling and forecasting production and consumption of corn in Ghana using ARIMA models. The study revealed that ARIMA (2, 1, 1) and ARIMA (1, 1, 0) were the appropriate models for forecasting production and consumption respectively. They concluded that forecast showed an increasing pattern in consumption and production of corn.

Olajide *et al.* (2012) studied to forecast the inflation rate in Nigeria using Box- Jenkins approach. The data used for this paper was yearly data collected for a period of 1961-2010. Differencing method was used to obtain stationary process. The empirical study revealed that the most adequate model for the inflation rate was ARIMA (1, 1, 1). The model developed was used to forecast the year 2011 inflation rate was 16.27%. Based on this result, we recommend effective fiscal policies aimed at monitoring Nigeria's inflationary trend to avoid the consequences in the economy.

Adil *et al*. (2012) designed a study for estimation of future projections regarding onion area, production and consumption in Punjab, Pakistan by using Auto Regressive Integrated Moving Average (ARIMA) model. They concluded that in area ARIMA (1, 1, 0) was best fitted and in production and consumption of onion ARIMA (1, 1, 1) model was best fitted based on ACF and PACF plots. Consumption and production gap of onion was also estimated for up-to the year 2025. The analysis reveals that forecasted results entail onion area and production to be 47.484 thousand hectares and 372.403 thousand tonnes in 2025 respectively.

Suresh and Priya (2011) examined forecasting the sugarcane area, production and productivity of Tamil Nadu through fitting of univariate ARIMA models during the period from 1950-2007. The results showed that ARIMA (1, 1, 1) model was found to be appropriate for sugarcane area and productivity whereas ARIMA (2, 1, 2) was suitable for sugarcane production based on minimum value of the selection criterion i.e, Akaike Information Criteria (AIC) and Schwarz Bayesian Information Criteria (SBC). He concluded that the predicated values of sugarcane area are slightly higher than the actual values and the predicted values of sugarcane productivity are much closer to the observed values.

Ahmed *et al.* (2011) forecasted milk production in Pakistan using ARIMA model covering time series data from 1990-91 to 2010-11. They concluded that ARIMA (1, 1, 1) was the best fitted model and forecasting of milk production for the year 2015 would be 47494.2 thousand tonnes with lower and upper limits 38826.3 thousand tonnes and 56162.1 thousand tonnes respectively. Forecast of milk production showed an increasing trend**.**

Sarika *et al*. (2011) conducted modelling and forecasting time-series data of pigeon pea production [*Cajanus cajan* (L.) Millsp.] In India, by using Box-Jenkins Autoregressive Integrated Moving Average (ARIMA) during the period from 1969–70 to 2007–08. RMSE, AIC and BIC were used to identify the best model. The performance of fitted model was examined using Mean Absolute Error, Mean Per cent Forecast Error, Root Mean Square Error and Theil's inequality coefficients. They concluded that ARIMA (2, 1, 0) model performed better among other models of ARIMA for modelling as well as forecasting purpose. One and two-step ahead forecast value for 2006–07 and 2007–08 for India's pigeon pea production was computed as 2.54 and 2.53 million tonnes with standard errors 0.29 and 0.31, respectively.

Sankar (2011) forecasted the fish product export in Tamil Nadu based on data on inland and marine fish product export during the years from 1969 to 2008. The study considered AR, MA and ARIMA processed to select the appropriate stochastic model for forecasting fish product export in Tamil Nadu. Based on ARIMA (p, d, q) and its components, ACF, PACF, normalized BIC, Box-Lujung Q statistics and residuals estimated, ARIMA (0,1,2) was selected. Based on the chosen model, it could be predicted that the fish product export would increase to 1,14,695 t in 2015 from 74,549 t in 2008 in Tamil Nadu.

Awal and Siddique (2011) estimated the growth pattern of rice production of different seasons in Bangladesh and to develop appropriate ARIMA models for the time series of Aus, Aman, and Boro rice production in Bangladesh. Based on model selection criteria like R^2, RMSE, AIC, BIC, MAE, and MAPE are used to select the best model. The study revealed that ARIMA (4, 1, 4), ARIMA (2, 1, 1), and ARIMA (2, 2, 3) were selected as best fitted models for forecasting of Aus, Aman, and Boro rice production, respectively.

Badmus and Ariyo (2011) focused on forecasting the cultivated area and production of maize in Nigeria using Auto regressive Integrated Moving Average (ARIMA) model. During the period from 1970-71 to 2005-06 was used for the study. The results showed maize production forecast for the year 2020 to be about 9952.72 tons with upper and lower limits of 6479.8 and 13425.64 thousand tons respectively. The model also showed that the maize area would be 9229.74 thousand hectares with lower and upper limit of 7087.67 and 11371.81

thousand hectares respectively by 2020. This projection is important as it helps to improve good policies with respect to relative production, price structure as well as consumption of maize in the country. The conclusion from the study was that, total cropped area can be increased in future, if land reclamation and conservation measures are adopted.

Devi *et al*. (2011) made an attempt to forecast the prices on sunflower and groundnut in Andhra Pradesh by using ARIMA models. ARIMA model was used to forecast prices in Kurnool market for the period from January 2010 to May 2010, from the model prices of 13 years. They observed that Forecasts were found fairly accurate when compared to real time prices.

Shukla and Jharkharia (2011) studied on applicability of ARIMA models in wholesale vegetable market, based on taking sales data of one perishable vegetable (Onion) from Ahmadabad wholesale market in India. It was found that these models applied to forecast the demand with MAPE. The model was successfully validated by using sales data of another vegetable (Potato) from the same market. The parameters of the ARIMA (2, 0, 1) model showed that sales in the last two periods were highly influencing the sales in the Current period. It was surprising to note that the price, temperature and other variables did not significantly affect the onion sales. The forecasted values of obtained showed that the model was highly efficient in forecasting the demand of vegetables on a day-to-day basis.

Kumar and Gupta (2010) used univariate time series model to forecast the exports of industrial goods from Punjab for ensuing decade till 2020 by using data of exports of industrial products for the period 1974-75 to 2007-08. He concluded that the ARIMA (2, 1, 1) model was optimal for the variable exports because of minimum standard error, minimum AIC, lowest Q. Finally, by using that model, he revealed that in the year 2008-09, the forecasted figure of exports is Rs. 11228.36 expected to rise to Rs. 12567.87 in 2011-12 and to 14032.62 (in crores) in 2015-16 and finally expected to be Rs. 15448.53 (in crores) by the year 2019-2020.

Sivaramane and Mathur (2010) forecasted the rice exports from India by ARIMA technology. Based on AIC criterion, ARIMA (0, 1, 1) was found better than others. They forecasted rice generated for three periods that were 2010, 2015 and 2020. The export of rice in the future would be about 6-7 Mt.

Rahman (2010) analyzed forecasting of boro rice production in Bangladesh by ARIMA approach from 2008-09 to 2012-13. They found that the ARIMA (0, 1, 0) ARIMA (0, 1, 3) and ARIMA (0, 1, 2) are the best for local, modern and total boro rice production respectively. It was observed from the analysis that short term forecasts are more efficient for ARIMA models.

Sharma (2010) estimated forecasting of food grain production in India by ARIMA model. Based on AIC and SBC, ARIMA (0, 1, 1) was selected as the best model from the data during 1950-51to 2003-04. Food grain production for next six years was estimated. It was estimated to be 224.74 Mt in 2010.

Zakria and Muhammad (2009) studied forecasting the population of Pakistan by using ARIMA models. Population of Pakistan from 1951-2007 was used for forecasting of next 20 years. The selected model was ARIMA (1, 2, 0) based on criteria of MSE, AIC, SBC, P-value and graphical techniques like ACF and PACF plot of residuals. Finally, they concluded that forecasted population for the year 2025 was 229 millions.

Nehru and Rajaram (2009) predicted wheat production in India by ARIMA technique. ARIMA (1, 1, 0) was selected as best fitted model based on AIC and SBC criteria. The predicted values of wheat production showed that there will be steady increase from 2008-09 to 2014-15.

Nicolescu *et al.* (2009) estimated a model for urban air quality forecasting using time series of monthly averages concentrations. Sedementable dusts (SD), total suspended particulates (TSP), nitrogen dioxide (NO_2), and sulphur dioxide (SO_2) imissions recorded between 1995 and 2008 in the urban area of Targoviste city are used as inputs in the model. The measured pollutant data were statistically analysed by using ARIMA, linear trend, simple moving average of three terms and simple exponential smoothing. The results showed that ARIMA technique scores well in predicting the analysed environmental air quality parameters.

Aneja *et al.* (2008) analyzed pre-harvest forecast models for cotton yield by taking biometrical characteristics like height, girth, total number of bolls, number of opened and unopened bolls and yield of first pick etc., the yield of first picking after about five months of sowing along with number of unopened bolls was found to be fairly adequate for the use in building advance estimates of yield of cotton with the help of multiple linear regression model. They concluded that the estimated yield of cotton in mid October was 1124, 1245, 1409 and 1382 kg.ha^{-1} for the years 2003-04, 2004-05, 2005-06 and 2006-07 respectively.

Pal *et al.* (2007) attempted forecasting the milk production in India using statistical time series modelling techniques like double exponential smoothing, Auto Regressive Integrated Moving Average (ARIMA) during the period from 1980-81 to 2004-05. Based on validation forecasts from these models the model with lowest AIC, MAPE, MAE and MSE was considered as best fitted model. They concluded that ARIMA (1, 1, 1) model was performed better than the other one.

Chandran and Pandey (2007) studied whole sale monthly prices of potato in Delhi market from 1985-2005 by using seasonal ARIMA model. Seasonal indices calculated showed that generally the price was low from December to May and it picks up from June, and reaches the maximum in October. Based on Schwartz Bayes Criterion (SBC) and Akike Information Criteria, the estimated best models were ARIMA (1, 1, 1) and ARIMA (1, 0, 0).

Nochai and Nochai (2006) fitted an appropriate ARIMA Model for forecasting in three types of oil palm price by considering the minimum of mean absolute percentage error (MAPE). The results showed that for forecasting farm price of oil palm is ARIMA (2, 1, 0), for forecasting wholesale price of oil palm is ARIMA (1, 0, 1) or ARMA(1, 1) and for forecasting pure oil price of oil palm is ARIMA (3, 0, 0) or AR(3). Was best fitted models.

Iqbal *et al*. (2005) studied forecasting of wheat area and production in Pakistan by using ARIMA model. They developed models such as ARIMA (1, 1, 1) for area and ARIMA (2, 1, 2) for production by using data of 1950-2000 to forecast up to 2022. The forecasted production of wheat showed an increasing trend.

Rajaraman and Datta (2003) attempted forecasting through the univariate ARIMA models to past agricultural out comes for five states viz., Punjab, Rajasthan, Karnataka, Andhra Pradesh and Utter Pradesh. They observed broad similarity between the ARIMA process for Punjab, Rajasthan and Andhra Pradesh in terms of the auto-regressive and moving average terms which best fit the univariate process. Out of five states, Rajasthan had given the poorest fit in terms of forecast.

Krishnankutty (2001) forecasted teak prices in Kerala state, India by using ARIMA models. Annual averages current prices of teak in girth classes 1, 2, 3 were predicted based on the time series. The future prices were predicted with 95% confidence limits for the year up to 2015-16.

Balanagammal *et al*. (2000) forecasted agriculture scenario in Tamil Nadu by ARIMA models were built for the data related to the cultivable area, production and productivity of crops *viz*., finger millet, groundnut, sorghum, green gram, red gram, black gram, rice, cotton and sugarcane over the period 1956-57 to 1994-95 and to forecast for the subsequent five year, considering 1994-95 as the base year. They concluded that with regard to production, finger millet and groundnut had a decreasing level of production with a decrease in the area of cultivation whereas; sorghum, green gram and red gram the cultivable area decreased through increased production level. With regard to productivity of the crops, black gram, green gram and cotton showed a decreasing trend during the forecasting period while other crops such as rice, sorghum, pearl millet, red gram, sugarcane and groundnut showed a mild increasing trend.

Saeed *et al*. (2000) forecasted wheat production in Pakistan by using ARIMA Models. The diagnostic checking had shown that ARIMA (2, 2, 1) was appropriate. The forecasts from 1998-99 to 2012-13 were calculated based on the selected model. These forecasts would be helpful for the policy makers to foresee ahead of time the future requirements of grain storage import and export in Pakistan.

Boken. (2000) analyzed long-term forecast of average spring wheat yield for Saskatchewan without using any weather data based on time series of past yields. The 1975-93, 1975-94, 1975-95 yield data were used and six forecasting techniques (linear trend, quadratic trend, simple exponential smoothing, double exponential smoothing, simple moving averaging, and double moving averaging) were employed to model these series and their corresponding second-differenced series. They concluded that Using deterministic measure (i.e., mean squared error) of evaluating the performance of a forecasting technique, quadratic technique was found to be the best over model development periods (1975-93, 1975-94, and 1975-95) and model testing periods (1994, 1995, and 1996, respectively). However, the stochastic measures (which could be applied only on the model development periods) suggested the simple moving averaging technique to be the best one. Giving higher weightage to the model testing period compared to the model development period, quadratic trend is suggested to be the best technique.

Noble and Sathianandan (1991) studied the trend analysis in all- India mackerel catches by using ARIMA models. For forecasting by using the annual catch data from 1950 to 1989. The suitable model was identified as ARIMA (1, 0, 0). They concluded that the fitted ARIMA model was better with the spawning stock in making predictions. Catch predictions by these models also hinted at ten year cycle but seemed to lack seasonal term. The ten year cycle seen in the commercial landings may be dependent on the spawning stock and spawning success.

2.3.2 Forecasting through Exponential Smoothing

Muhammad and Abdullah (2013) studied yearly paddy production data for the period of 1970-71 to 2009-10 of Kelantan were analysed by time series methods. Several individual forecasting methods such as Brown's Double Exponential Smoothing, Linear's Double Exponential Smoothing, Winter's Multiplicative Exponential Smoothing, Damped Trend and Random Walk method were used to determine the best forecasting model for the data based on model selection criteria like least MAPE. The study revealed that the "best" forecasting model was the composite forecast model of Holt's Linear and Damped Trend Exponential Smoothing, which predicted a generally increasing pattern of Kelantan total paddy production for the next five years.

Petrevska (2013) focused on the importance of applying forecasting methods in estimation of tourism trends. In this respect, two quantitative methods were used i.e the method of exponential smoothing, through two of its variants: Double Exponential Smoothing and the Holt-Winters Smoothing; and the Box-Jenkins methodology, through several alternative specifications. The result of the research is a medium-term estimation of foreign tourism demand for destinations in the Former Yugoslav Republic of Macedonia (FYROM) by the end of 2014. They concluded that all applied methods are not capable of explaining the driving factors behind the results, the estimated values can serve as a base for identifying measures and activities necessary for creating comprehensive tourism policy.

Rani and Raza (2012) were designed a study to find out suitable forecasting method among the two forecasting methods namely trend analysis and double exponential smoothing. Measures of accuracy (MAPE, MAD and

MSD) were used as the model selection criteria that could best describe the trend of prices of major pulses such as gram, mash, masoor and mung during 1975-76 to 2009-10. They concluded that among these two methods Double Exponential Smoothing method was found to be pertinent for price estimation of major pulses in Pakistan because of smaller values of accuracy measures. Six-year's forecasts of prices of gram, mash, masoor and mung in Pakistan in 2010-11 were Rs.31.80, Rs.84.09, Rs.72.06, and Rs.47.69 per kg respectively along with 95% prediction intervals. The results showed that if the present growth rates remain the same then prices of these pulses in Pakistan would be Rs.37.64, Rs.120.26, Rs.89.55 and Rs.55.03 per kg, respectively in 2015-16.

Kumar *et.al* (2011) analysed to compare the forecasting performance of Holt Winter Exponential Smoothing and seasonal ARIMA time series methodology for forecasting onion prices in Bangalore market for the monthly average data of onion prices from April 1999 to November 2010 was used to forecast the future price. To determine the best forecasting model different selection criteria like MSE, MAE, MAPE, RMSE and Theil's inequality coefficient (U- STATISTICS) were used. This study revealed that the time series data were influenced by seasonal factors. The results showed that ARIMA model outperformed the Holt-Winter Exponential Smoothing model for forecasting onion price.

Masuda and Goldsmith (2008) analysed world Soybean production, yield and harvested area. They finalised that World production of soybeans is predicted to increase by 2.1% annually to 359.7 million tons by 2030, using an exponential smoothing model with a damped trend.

Garcia and Rodriguez (2007) attempted to study forecasting international tourist demand using Holt-Winters. They examined forecasts of international tourism arrivals to Spain. A survey was conducted on residents from 10 other major origin countries with respect to their future visits to Spain. The Holt-Winters exponential smoothing model was used to forecast the residents' demand for tourism in Spain by 2007-08.

Rancheva (2002) attempted to study trends of average yield changes of cereals in Bulgaria. Main trend in the productivity of cereals in Bulgaria was estimated by using exponential smoothing methods. Time series data for the period 1940-95 was used in the analysis.

Kumar (2002) worked on statistical evaluation of price variation in tropical Timbers. Exponential smoothing model is preferred to the multiplicative time series model for forecasting purpose. The results showed that the single parameter exponential smoothing model was used to predict the prices of teak, rosewood and yellow teak.

Chapter III

MATERIAL AND METHODS

To realize the various objectives of the study, an appropriate methodology describing data collection and tools of analysis for the conduct of the study are inevitable. The main aim of this chapter is to provide a brief description of the materials which provide the necessary database for this study along with the important statistical tools employed in the analysis. The details of the materials and the methods used for this study are discussed under following headings.

3.1. Description of the study area
3.2. Selection of crops
3.3. Collection of data
3.4. Statistical tools employed

3.1. DESCRIPTION OF THE STUDY AREA

The study was undertaken in Andhra Pradesh state.

3.2. SELECTION OF CROPS

The study pertains to the period of 47 years from 1966 to 2012. The important crops selected for the study are major coarse cereals viz., Maize, Jowar, Bajra and Ragi in Andhra Pradesh.

3.3. COLLECTION OF DATA

The data pertaining to area, production and productivity of maize, jowar, bajra and ragi have been collected for the period of 47 years from 1966 to 2012. The data has been collected from the statistical abstracts of Andhra Pradesh and Ministry of Agriculture, Govt of India and www.Indiastat.com

3.4. STATISTICAL TOOLS EMPLOYED IN THE ANALYSIS

Keeping in view of the objectives set for the study, following statistical tools and methods have been employed.

1. Statistical models to study the trend and to forecast the area, production and productivity through linear and non-linear growth models.
2. Correlation analysis, multiple linear regression analysis is used to study the influence of weather parameters on productivity of major coarse cereals.
3. Forecasting through time series models and identifying trend by using ARIMA, Exponential Smoothing techniques.

3.4.1. Statistical models used in the study

The trend equations were fitted by using different linear, non-linear models, exponential smoothing models and time series models for identifying the trend. Growth models are nothing but the models that describe the behaviour of a variable varying with respect to time. They are very quick to estimate and less expensive, although less efficient. They are very good in many situations for describing the growth pattern and the future movement of a time series (Pindyck and Rubinfeld, 1991) these models are widely used to estimate the growth rate of time series data. The growth models taken under consideration here are as follows.

3.4.1.1 Linear function

The mathematical equation is given by

$$Y_t = a + bt$$

Where,

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

't' is the independent variable, time in years

'a' is the intercept

'b' is the regression coefficient

The a and b are estimated by applying the ordinary least squares approach.

3.4.1.2 Quadratic function

This function is useful when there is peak or trough in the data of past periods.

Quadratic fit is given by the equation

$$Y_t = a + bt + ct^2$$

Where,

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

't' is the independent variable, time in years

'a' is the intercept

'b' and 'c' is the regression coefficients

The 'a', 'b' and 'c' can be estimated by applying the ordinary least squares approach.

3.4.1.3. Cubic function

This function is useful when there is, two peaks or two troughs in the data of past periods.

Cubic fit or third degree curve is given by the equation:

$$Y_t = a + bt + ct^2 + dt^3$$

Where,

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

't' is the independent variable, time in years

'a' is the intercept

'b' and 'c' is the regression coefficients

The 'a', 'b' and 'c' can be estimated by the method of applying the ordinary least squares (OLS).

3.4.1.4. Compound function

This function is useful when it is known that there is increasing growth or decline in past periods.

Compound fit is given by

$$Y_t = ab^t$$

(or)

$$\ln Y_t = \ln a + t \ln b$$

Where,

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

't' is the independent variable, time in years

'a' is the intercept

'b' is the regression coefficients

The 'a' and 'b' can be estimated by the method of applying the ordinary least squares (OLS).

3.4.1.5. Inverse function

Inverse fit is given by the equation

$$Y_t = a + b/t$$

Where,

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

't' is the independent variable, time in years

'a' is the intercept

'b' is the regression coefficients

The 'a' and 'b' can be estimated by the method of applying the ordinary least squares (OLS).

3.4.1.6. Logarithmic function

The mathematical equation is given by

$$Y_t = a + b \ln (t)$$

Where,

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

't' is the independent variable, time in years

'a' is the intercept

'b' is the regression coefficients

The 'a' and 'b' can be estimated by the method of applying the ordinary least squares (OLS).

3.4.1.7. Power function

The mathematical model is

$$Y_t = at^b$$

(or)

$$\ln (Y_t) = \ln (a) + b \ln(t)$$

Where,

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

't' is the independent variable, time in years

'a' is the intercept

'b' is the regression coefficients

The 'a' and 'b' can be estimated by the method of ordinary least squares (OLS).

The fit is similar to exponential fit, but produces a forecast curve that increase or decreases at different rate.

3.4.1.8. Exponential function

The function of this fit can be given by

$$Y_t = a\, e^{bt}$$

(or)

$$\ln Y_t = \ln a + (bt)$$

Where,

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

't' is the independent variable, time in years

'a' is the intercept

'b' is the regression coefficients

The 'a' and 'b' can be estimated by applying ordinary least squares (OLS).

3.4.1.9. Growth function

This Growth function is given by

$$Y_t = \text{Exp}\ (a + bt)$$

(or)

$$\ln Y_t = a + bt$$

Where,

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

't' is the independent variable, time in years

'a' is the intercept

'b' is the regression coefficients

The 'a' and 'b' can be estimated by applying ordinary least squares (OLS).

3.4.1.10. S-curve

S- Curve fit is given by

$$Y_t = \text{Exp}\ (a + b/t)$$

(Or)

$$\text{Ln}\ Y_t = a + b/t$$

Where,

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

't' is the independent variable, time in years

'a' is the intercept

'b' is the regression coefficients

The 'a' and 'b' can be estimated by applying ordinary least squares (OLS).

3.4.2. Association between weather parameters and coarse cereals productivity

Karl-Pearson's correlation coefficient, functional relationship by regression analysis is common tools to identify the association between the variables.

3.4.2.1 Karl-Pearson's correlation coefficient

Correlation coefficient is a measure of degree of linear association relationship between two variables.

Correlation coefficient between two variables X and Y

$$r\,(X,Y) = \frac{\mathrm{Cov}\,(X\,Y)}{\sqrt{\mathrm{Var}\,(x).\mathrm{Var}\,(y)}}$$

To test the significance of correlation coefficient (r) t-test is used.

Null Hypothesis (H_0): þ = 0

Alternate Hypothesis (H_1): þ ≠ 0

Test of Significance of correlation coefficient

$$t = \frac{r\sqrt{n-2}}{\sqrt{1-r^2}} \sim t_{(n-2)} \text{ degrees of freedom}$$

3.4.2.1. Multiple Linear Regression

If more than one independent variable is to be used in the model, linear regression can be extended to multiple linear regression to accommodate several independent variables (Pearson 2011)

Multiple linear regression equation is fitted by

$$Y_i = a + b_1x_1 + b_2x_2 + \ldots + b_nx_n$$

Where

a = Intercept

$b_1, b_2, \ldots b_n$ are regression coefficients,

$x_1, x_2, \ldots x_n$ are independent variables.

3.4.3. Time series models and Exponential Smoothing Methods

Time series is a set of collection of observations of state variables made sequentially in time.

$$(y_1, y_2, \dots , y_t)$$

Set of evenly spaced numerical data obtained by observing response variable at regular time periods.

Different time series models are Exponential Smoothing, AR, MA, ARMA, and ARIMA. ARIMA is a combination of both AR and MA models with suitable order of differencing. Hence before describing ARIMA model, it is essential to know AR and MA models (Damodar, 1995).

3.4.3.1 Exponential Smoothing

A simple exponential smoothing model is a very popular model used to produce a smoothed time series. Where in simple Moving Average models the past observations are weighted equally, Exponential Smoothing assigns exponentially decreasing weights as the observations get older. However, a "smoothing parameter" or "smoothing constant" – is used to determine the weights assigned to the observations (Gardner, 1985).

The time series data is Y_1, Y_2…… Y_t to forecast the next value of time series Y_{t+1} that is yet to be observed with forecast for Y_t denoted by F_t then the forecast F_{t+1} is based on weighing the most recent observations Y_t with a weight value α and weighting the most recent forecast F_t with a weight of (1- α). The weight is between 0 and 1. Thus the forecast for the period t+1 is given by

$$F_{t+1} = F_t + \alpha (Y_t - F_t)$$

Where α is a smoothing constant.

Different exponential smoothing methods are

3.4.3.1.1. Linear Holt-Winter's Exponential Smoothing

The Holt-Winters exponential smoothing is used when the data exhibits both trend and seasonality. Holt (1957) extended simple exponential smoothing to allow forecasting of data with a trend. This method involves a forecast equation and two smoothing equations (one for the level and one for the trend):

Forecast equation: $\hat{y}_t + h/t = l_t + hb_t$

Level equation: $\ell_t = \alpha\, y_t + (1-\alpha)(\ell_t - 1 + b_t - 1)$

Trend equation: $b_t = \beta(\ell_t - \ell_t - 1) + (1-\beta) * b_t - 1$

Where,

'l_t' = estimate of the level of the series at time t

'b_t' = estimate of the trend (slope) of the series at time t

'α' = the smoothing parameter for the level, $0 \leq \alpha \leq 1$ and

'β'= the smoothing parameter for the trend, $0 \leq \beta \leq 1$

As with simple exponential smoothing the level equation here shows that ℓ_t is a weighted average of observation y_t and the within-sample one-step-ahead forecast for time t, here given by $\ell_t - 1 + b_t - 1$. The trend equation shows that b_t is a weighted average of the estimated trend at time *t* based on $\ell_t - \ell_t - 1$ and $b_t - 1$, the previous estimate of the trend.

The forecast function is no longer flat but trending. The h-step-ahead forecast is equal to the last estimated level plus h times the last estimated trend value. Hence the forecasts are a linear function of h.

The error correction form of the level and the trend equations show the adjustments in terms of the within-sample one-step forecast errors:

$$\ell_t = \ell_t - 1 + b_t - 1 + \alpha e_t$$

$$b_t = b_t - 1 + \alpha\beta\, e_t$$

Where,

$$e_t = y_t - (\ell_{t-1} + b_{t-1}) = y_t - \hat{y}_{t|t-1}.$$

3.4.3.1.2. Damped-Trend Exponential Smoothing

The forecasts generated by Holt's linear method display a constant trend (increasing or decreasing) indefinitely into the future. Even more extreme are the forecasts generated by the exponential trend method which include exponential growth or decline.

Empirical evidence indicates that these methods tend to over-forecast, especially for longer forecast horizons. Motivated by this observation, Gardner and McKenzie (1985) introduced a parameter that "dampens" the trend to a flat line sometime in the future. Methods that include a damped trend have proven to be very successful and are arguably the most popular individual methods when forecasts are required automatically for many series.

3.4.3.1.3. Damped-Trend Linear Exponential Smoothing

The model equation for damped-trend linear exponential smoothing is

$$Y_t = u_t + ß_1 t + e_t$$

Exponential smoothing equations are

$$L_t = \alpha Y_t + (1 - \alpha)(L_{t-1} + ø\, T_{t-1})$$

$$T_t = \gamma (L_t - L_{t-1}) + (1 - \gamma)\phi T_{t-1}$$

The error correction form of the equation is

$$L_t = L_{t-1} + \phi T_{t-1} + \alpha e_t T_t = \phi T_{t-1} + \alpha \gamma e_t$$

For missing value $e_t = 0$.

The k-step prediction equation is

$$\hat{Y}_t(k) = L_t + \sum_{i=1}^{k} \phi^i T_t$$

The ARIMA model equivalency to damped-trend linear exponential smoothing is the ARIMA (1, 1, 2) model.

$$(1-\phi B)(1-B)Y_t = (1-\theta_1 B - \theta_2 B^2)e_t$$
$$\theta_1 = 1+\phi-\alpha-\alpha\gamma\phi$$
$$\theta_2 = (\alpha-1)\phi$$

The moving average form of the equation assuming $|\phi| < 1 \, is$

$$Y_t = \varepsilon_t + \sum_{j=1}^{\infty}(\alpha + \alpha\gamma\phi\,(\phi^j - 1)/(\phi - 1))\varepsilon_{t-j}$$

For damped-trend linear exponential smoothing, the additive-invertible region is

$$\{0 < \alpha < 2\}$$

$$\{0 < \phi\gamma < 4/\alpha - 2\}$$

The variance of the prediction errors is estimated as

$$\operatorname{var}(e_t(k)) = \operatorname{var}(\varepsilon_t)\left[1 + \sum_{j=1}^{k-1}\alpha + \alpha\gamma\phi(\phi^j - 1)/(\phi - 1))^2\right]$$

3.4.3.1.4. Double (Brown) Exponential Smoothing

This method is also called as trend adjusted exponential smoothing. This situation can be improved by the introduction of a second equation with a second smoothing constant or second weight w_2.

Assuming monthly export value is influenced by the trend component. This must be chosen in conjunction with W1. The two equations associated double exponential smoothing given by

$$S_t = W_1 X_t + (1-W_1)(S_{t-1} + b_{t-1}) \text{ ……….. (1)}$$

$$b_t = W_2(S_t - S_{t-1}) + (1-W_2)(b_{t-1}) \text{ ……… (2)}$$

Where,

S_t = Smoothened value at time period t

S_{t-1} = Smoothened value at time period t-1

W_1 = Level smoothing constant

X_t = Actual price at time period t

b_t = Trend estimate of the time period t

b_{t-1}= Trend estimate of the period t-1

W_2= Trend smoothing constant

Taking different value for both W_1 and W_2 by trial and error method both trend factor and level factor is estimated. Hence by using both trend estimate and level estimate, forecast value for the period m is obtained by

$$F_{t+m} = S_t + mb_t$$

In relation of equation 3, forecast value for the *m* period ahead is *m* times the trend estimate of the time period t plus the level estimate of the time period t. initial value of the trend estimate (b_1) and level estimate (S_1) or first smoothened value is taken as follows.

$$S_1 = X_1$$

$$b_1 = \frac{(X_2 - X_1) + (X_4 - X_3)}{2}$$

Where, X_1, X_2, X_3 and X_4 are observed values for the initial three season of the timber time series data set. The current value of the series is used to calculate its smoothed value is replacement in double exponential smoothing. The second smoothing equation then updates the trend, which is expressed as the difference between the last two values. The equation is similar to the basic form of single smoothing, but here applied to the updating of the trend.

3.4.3.1.5. Winter's seasonal exponential smoothing method

To handle seasonality present in the time series data, the third parameter is added. Introduced third equation along with W_3 takes care of seasonality. The resulting set of equations is called the "Holt-Winters" (HW) method after the names of the inventors. There are two main HW models, depending on the type of seasonality.

Holt-winters multiplicative model

$$S_t = W_1 \frac{X_t}{SI_{t-1}} + (1 - W_1)(S_{t-1} + b_{t-1})$$

Where,

W_1 = level smoothing constant

SI = seasonality estimate

l = length of seasonal cycle.

Trend estimate is given by:

$$b_t = W_2(S_t - S_{t-1}) + (1 - W_2)b_{t-1}$$

Seasonality estimate given by:

$$SI_t = W_3 \frac{X_t}{S_t} + (1 - W_3)SI_{t-1}$$

Where, W_3 = seasonal smoothing constant

Then m-period ahead forecast is given by

$$F_{t+m} = (S_T + mb_t)SI_{t-l+m}$$

Holt-Winters additive model

Smoothing equation is given by:

$$S_t = W_1(X_t - SI_{t-1}) + (1 - W_1)(S_{t-1} + b_{t-1})$$

Trend estimate given by:

$$b_t = W_2(S_t - S_{t-1}) + (1 - W_2)b_{t-1}$$

Seasonality estimate is given by:

$$SI_t = W_3(X_t - S_t) + (1 - W_3)SI_{t-l}$$

Forecast equation for additive seasonality is:

$$F_{t+m} = S_t + mb_t + SI_{t-l+m}$$

Forecasting can be carried out by applying the Time series models involving which is based on past values, the Auto Regressive Integrated Moving Average (ARIMA) models are applied for this purpose.

Auto Regressive (AR) Model

$$Z_t = Ø_1 Z_{t-1} + U_t \quad \ldots (1)$$

Where,

Z_t = the value of variable for forecasting at time'‘t’ (rainfall, in the present case)

$Ø_1$ = Regression coefficient

U_t = Random error

This model is known as AR (1) model. The above model can be extended to any number of lags, as follows:

$$Z_t = Ø_1 Z_{t-1} + \ldots + Ø_p Z_{t-p} + U_t \quad (2)$$

The above model is then AR (P) model or AR (P) process.

Moving Average (MA) Model

Sometimes residuals with different lags may exhibit relationships with the dependent variable as follows:

$$Z_t = c + a_t - Ø_1 a_{t-1} + \ldots + Ø_q a_{t-q}$$

Where

Z_t = the value of the variable for forecasting at time t (Rainfall, in the present case)

c = Constant

e_t = Error term

$\emptyset_1$ to $\emptyset_q$ = Partial regression coefficients

This model is known as MA (q) model.

Auto Regressive Moving Average (ARMA) Model

In the model Y_t depends on AR as well as MA variables and can be specified as

$$Z_t - \text{Ø}_1 Z_{t-1} - \ldots.. - \text{Ø}_p Z_{t-p} = c + a_t - \text{Ø}_1 a_{t-1} + \ldots + \text{Ø}_q a_{t-q}$$

Where,

$$Z_t = Y_t - \overline{Y} \text{ (deviation of } Y_t \text{ from the mean of Y).}$$

The above model is ARIMA (p, q) model.

In the light of the above models let us consider the ARIMA model

Auto Regressive Integrated Moving Average (ARIMA) Model

In the above models it was assumed that the error U_t is random error (white noise) i.e., the data is stationary. However, in general, the data is not stationary. For example, the data on economic variables such as area, production, productivity often exhibit trend. Similarly, the rainfall data frequently exhibits seasonal and cyclic fluctuations. In the presence of these components the time series models described above cannot be applied. These components can be eliminated. For instance, if the data exhibits trend, it can be estimated by fitting a suitable trend equation and finally it can be eliminated from the data. Similarly, when seasonality is present, it can be removed by successive differencing. These two situations are respectively referred as trend stationary and difference stationary models.

The difference stationary models lead to ARIMA model. Here, the non-stationary time series is reduced to stationary by selecting suitable order of differencing. An ARIMA model is therefore an ARIMA model with suitable differencing (d) that reduces the data to stationarity. It is referred as ARIMA (p, d, q) model. The concept of ARIMA model was developed by Box and Jenkins. ARIMA model essentially require identification of three constants p, d, q i.e. the order of AR terms (p), order of differencing (d) and the order of MA terms (q).

Box and Jenkins established that these parameters can be obtained through trial and error approach after examining the Auto Correlation Function (ACF) and Partial Auto Correlation Function (PACF). The first step in developing ARIMA model is to examine data for stationarity. This can be identified through Auto Correlation Function (ACF) of actual data, If the auto correlation function does not die out rapidly, it indicate that the data are non-stationary. Under this situation, the auto correlation corresponding to most of lags are statistically significant. For reducing the data to stationarity, the data are therefore transformed by taking first order differences (d=1). If the auto correlation functions of differenced data indicate a rapid decrease, then it can be concluded that the transformed data is stationary. If not again the data has to be transformed by taking second order differences (d=2). Continuing in a similar way as that of d=1, the order of differencing i.e., d can be determined.

After determining the differencing order'd', the order of auto regressive (p) and moving average (q) components, can be obtained as follows :

If the auto correlation function corresponding to the transformed data decays after the q^{th} lag, then it is taken as MA (q) model; likewise, if partial auto correlation function indicates a decaying after p^{th} lag, it indicates existence of AR (p) model i.e., the characteristics p and q are determined on the basis of PACF and ACF of the stationary data. The ARIMA (p,d,q) model is then formulated as

$$Z_t - b_1 Z_{t-1} - \ldots\ldots - b_p Z_{t-p} = U_t - \varnothing_1 U_{t-1} - \ldots\ldots \varnothing q\, U_t - q$$

Where, $Z_t = Y_t - \bar{Y}$ (deviation of Y_t from mean Y).

The formulation of ARIMA model requires Auto Correlation Function (ACF) and Partial Auto Correlation Function (PACF).The ACF can be generated on the basis of auto correlation coefficients (ρ_j) corresponding to different lags (j), defined as;

$$\rho_j = \frac{\sum Y_t Y_{t-j} - \frac{1}{n}[(\sum Y_t)(\sum Y_{t-j})]}{\sum {Y_t}^2 - \frac{1}{n}(\sum Y_t)^2} \quad ; \qquad j = 1, \ldots K$$

The PACF can be obtained through the Yule-walker's equations on the basis of ρ_j's . The Yule-walker's equations can be described as

$$\rho_j = Ø\, k1\, \rho_{j-1} + \ldots + Ø\, k\, (k-1)\, \rho_{j-k+1} + Ø\, kk\, \rho_{j-k} \quad ; \qquad j = 1, \ldots K$$

Where,

Ø's = Partial Auto Correlation coefficients

ρ_j =Auto correlations corresponding to the jth lag.

Fitting of ARIMA model: It is a four step procedure.

Step 1: Identification

This involves identification of stationary, order of differencing and the order for AR and MA models. These can be obtained through ACF and PACF graphs referred respectively as correlograms and partial correlograms1* using the criteria as described earlier.

Step 2: Estimation

The parameters of ARIMA model (later identifying p, d, and q) can be estimated by applying the Grid-Search procedure as advocated by Box and Jenkins (1978). This procedure, which is iterative, help in estimating the MA coefficients in addition to the AR coefficients (which is not possible with the least squares method). The procedure can be illustrated in the context of ARIMA (2,2)2*.The ARMA(2,2) can be specified as:

$$Z_t - b_1 Z_{t-1} - b_1 Z_{t-1} = U_t - Ø_1 U_t - Ø\, 2U_t \quad \ldots(1)$$

1*: Correlograms are obtained by plotting ρ_j's against its lags and partial correlograms are obtained when Ø kk's are plotted against its lags.

2*: ARMA (2,2) is also ARIMA(2,0,2).

Step 3: Diagnostic checking

Having chosen a particular ARIMA model and having estimated its parameters, the next step is to check whether the chosen model fits the data reasonably well, as it is possible that another ARIMA model might do the job well. Here selection of model will be done by criteria like R-square, Adjusted R-square, MAPE (Mean Absolute Percent Error) and Theil's U-Statistic (model accuracy).

R^{2}- Criteria

R^2 is a statistic that will give some information about the goodness of fit of a model. In regression, the R^2 or coefficient of determination is a statistical measure of how well, the regression line approximates the real data points. An R^2 of 1.0 indicates that the regression line perfectly fits the data. It provides a measure of how well future outcomes are likely to be predicted by the model.

The most general definition of the coefficient of determination is

$$R^2 = 1 - \frac{SS_{err}}{SS_{reg}}$$

In some cases the total sum of squares equals the sum of the two other sums of squares defined above,

$$TSS = SS_{err} + SS_{reg}$$

See sum of squares for a derivation of this result for one case where the relation holds. When this relation does hold, the above definition of R^2 is equals to

$$R^2 = \frac{SS_{reg}}{SS_{tot}}$$

Adjusted R^2:

Adjusted R^2 is a modification of R^2 that adjusts for the number of explanatory terms in a model. The adjusted R^2 can be negative, and will always be less than or equal to R^2.

It is the coefficient of determination adjusted for degrees of freedom.

The adjusted R^2 is defined as

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

Where, n = no of observations

P = no of parameters in the model

Mean Absolute Percentage Error (MAPE)

The mean absolute percentage error (MAPE), also known as mean absolute percentage deviation (MAPD), is a measure of accuracy of a method for constructing fitted time series values in statistics, specifically in trend estimation. It usually expresses accuracy as a percentage, and is defined by the formula:

$$MAPE = \left(\sum_{t=1}^{n}\left(\left|\frac{A_t - F_t}{A_t}\right|\right)\times 100\right)/n$$

Where,

A_t is the actual value and

F_t is the forecast value

The difference between A_t and F_t is divided by the actual value A_t again. The absolute value in this calculation is summed for every fitted or forecasted point in time and divided again by the number of fitted points n. multiplying by 100 makes it a percentage error.

Theil's U- Statistic

The relative measures give equal weight to all errors in contrast to the MSE, which squares the errors and there by emphasizes large errors. It would be helpful to have a measure that considers both the disproportionate cost of large errors and provides a relative basis for comparison with naive methods. One measure that has these characteristics is the U–Statistics developed by Theil (1966).

This statistics allows a relative comparison of normal forecasting methods with naive approaches and also squares the errors involved so that large errors are given much more weight than small errors. The positive characteristic that is given up in moving to Theil's U-Statistic as a measure of accuracy is that of intuitive interpretation. The difficulty will become apparent as the computation of this statistic and its application are examined. Mathematically,

Theil's U-Statistic is defined as,

$$U = \sqrt{\sum_{t=1}^{n-1} \frac{\left(\frac{F_{t+1} - Y_{t+1}}{Y_t}\right)^2}{\left(\frac{Y_{t+1} - Y_t}{Y_t}\right)^2}} \ *100$$

Where,

F_{t+1} is the forecasted value at time period t+1,

Y_{t+1} is the actual value at time period t+1,

Y_t is the actual value of a point for a given time period *t*,

F_t is the forecasted value of a point for a given time period *t*,

n is the number of data points, and

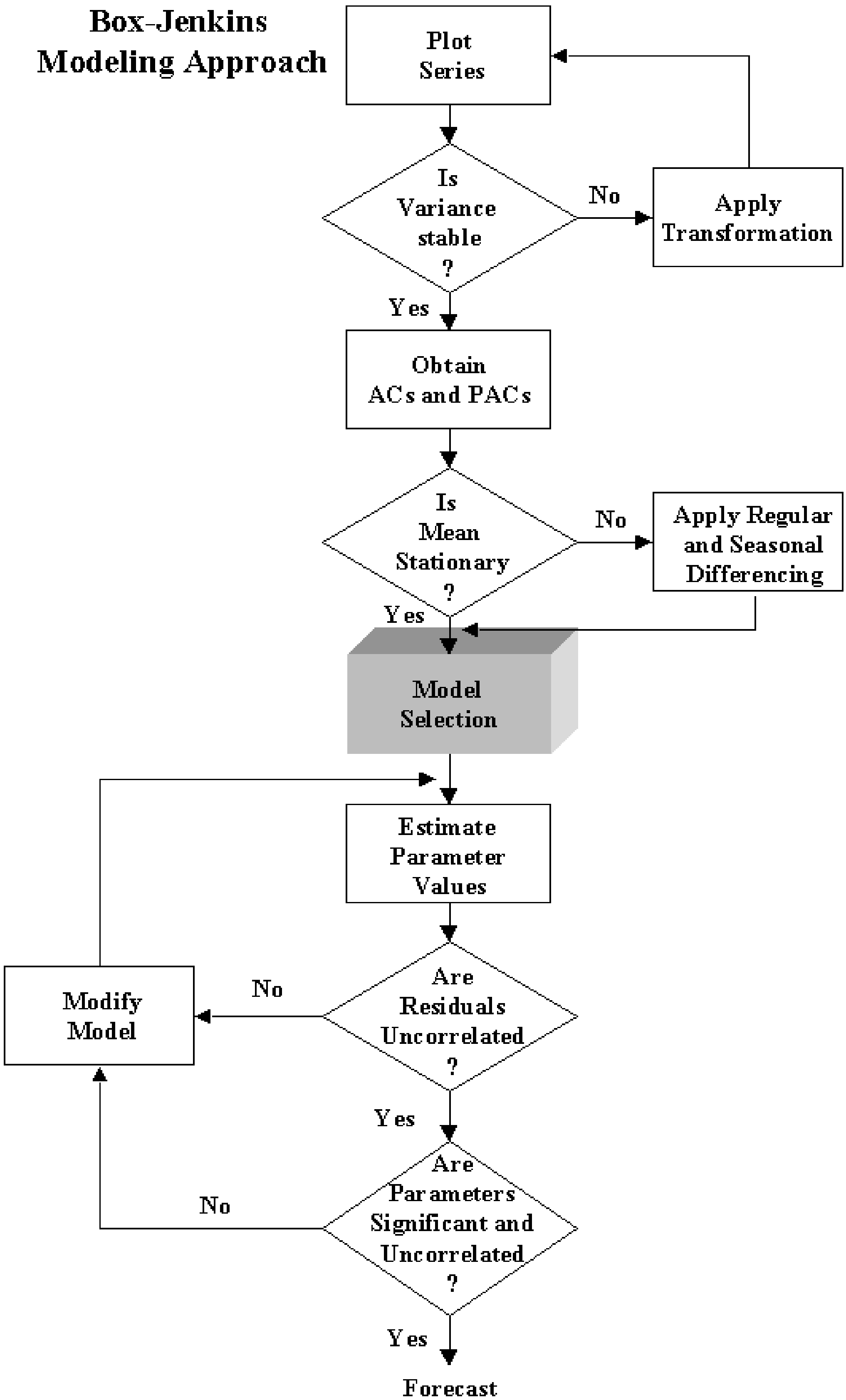
If U = 100 both models forecast with equal accuracy

U < 100 model forecast is best

Step 4: Forecasting

The forecast of the variable in the t^{th} year (Y_t) in ARIMA model is based on its past values. Due to this limitation, unlike multiple regression models, long range forecasting i.e., the values of the variable beyond $(n + 1)^{th}$ year cannot be forecasted. The forecasts can be obtained from the estimated ARIMA models.

Flow chart of Box-Jenkins Methodology



Chapter IV

RESULTS AND DISCUSSION

Keeping in view with the objectives formulated for the present study in the introduction chapter, this chapter deals with presentation and interpretation of the results obtained along with relevant discussions. For convenience and better focus, this chapter is divided into three sections:

4.1. To apply different linear, non linear and time series models to area, production and productivity of major coarse cereals in Andhra Pradesh.

4.2. To study the influence of weather parameters on Productivity of major coarse cereals in Andhra Pradesh.

4.3. To forecast the area, production and productivity of major coarse cereals in Andhra Pradesh by using best fitted model.

4.1. TO APPLY DIFFERENT LINEAR, NON LINEAR AND TIME SERIES MODELS OF MAJOR COARSE CEREALS IN ANDHRA PRADESH

In the present study, linear, non-linear models *viz.*, linear, logarithmic, inverse, quadratic, cubic, compound, S-curve, growth, power and exponential models have been fitted where as time series models include Auto Regressive (AR), Moving Average (MA), Auto Regressive Integrated Moving Average (ARIMA) and Exponential smoothing methods like Holt-Winter's Exponential smoothing, Exponential smoothing with damped trend, Log linear trend Exponential smoothing methods have been fitted to the data on area, production and productivity of the major coarse cereals viz., maize, sorghum, pearl millet and finger millet in Andhra Pradesh by considering 47 years data from 1966-67 to 2012-13. The results are presented crop wise as follows.

4.1.1. MAIZE

Maize is cultivated in nearly 150 Mha in about 160 countries having wider diversity of soil, climate, biodiversity and management practices that contributes 36 % (782 Mt.) in the global grain production.

In India, maize is the third most important cereal crop after rice and wheat with an area of 8672.6 thousand hectares and production of 22258.2 thousand tones.

4.1.1.1. Maize area

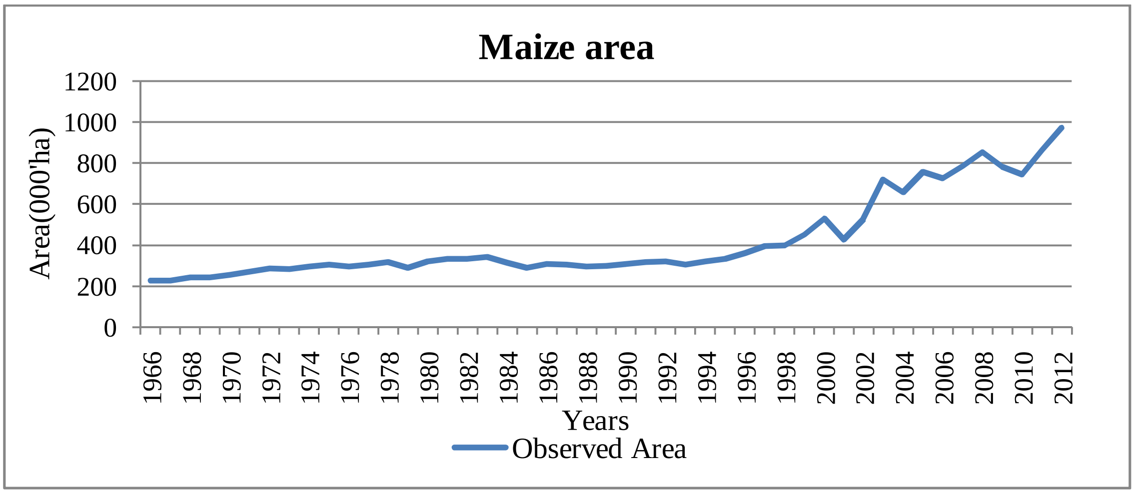


Figure 4.1 Observed Area of Maize in Andhra Pradesh

From the Figure 4.1 it was observed that the average area under Maize during the study period (1966-2012) was 422 thousand hectares in Andhra Pradesh. It was also observed that the area of maize crop has increased enormously from 227 thousand hectares in 1967 to 972 thousand hectares in the year 2012.

The results obtained for area of maize by fitting all the linear, non-linear and time series models were presented in Table 4.1.

Table 4.1. Linear, Non-linear and Time series models of Maize area in Andhra Pradesh

	Parameter				Criteria			
Model	**a**	**b**	**c**	**d**	**Theil's U-Statistic (%)**	**R^2**	**Adj R^2**	**MAPE**
Linear	118.582**	12.644**			88.33	0.717**	0.711**	23.81
Logarithmic	-18.579	151.380**			83.17	0.428**	0.415**	29.65
Inverse	464.949**	-454.399*			78.90	0.129*	0.110*	36.10
Quadratic	332.126**	-13.504**	0.545**		93.56	0.912**	0.910**	13.35
Cubic	219.750**	13.195*	-0.831**	0.019**	95.05	0.946**	0.945**	7.33
Compound	201.142**	1.027**			89.80	0.800**	0.788**	16.66
Power	141.343**	0.344**			83.31	0.541**	0.530**	22.50
S-curve	6.059**	-1.133**			77.95	0.196**	0.178**	29.62
Growth	5.304**	0.027**			89.80	0.800**	0.788**	16.66
Exponential	201.142**	0.027**			89.80	0.800**	0.788**	16.66
TIME SERIES MODELS								
ARIMA (0, 1, 0)					94.81	0.942	0.941	6.41
ARIMA (0, 1, 1)					**95.10**	**0.948**	**0.948**	**6.27**
ARIMA (1, 1, 0)					94.95	0.944	0.943	6.21
ARIMA (1, 1, 1)					95.15	0.949	0.948	6.78
Linear (Holt) Exponential Smoothing					94.84	0.944	0.943	5.78

1. *Source: Secondary data collected from Ministry of Agriculture, Govt of India,* www.Indiastat.com

2. The value of the criterion for a model with bold numerals shows that the model is better than the other models with respect to that criterion.

3. **,* indicate significant at 1% and 5% level of probability respectively.

From the above Table 4.1 It was found that all the models fitted well showing significant adjusted R^2 values. In comparison with all other models, ARIMA (0, 1, 1) was with high Theil's U-Statistic (95.10%), high R^2 (0.948) with significant adjusted R^2 (0.948) and the low MAPE (6.27) values. Hence, the

ARIMA (0, 1, 1) model was chosen for future forecasts of maize area. Sharma (2010) selected the same model for forecasting the food grain production of India, Sivaramane and Mathur (2010) used same model for forecasting of rice exports from India.

Among the linear, non-linear growth models cubic model identified as the best fitted model based on model selection criteria, but ARIMA (0, 1, 1) model was best as compared to cubic model.

4.1.1.2. Maize production

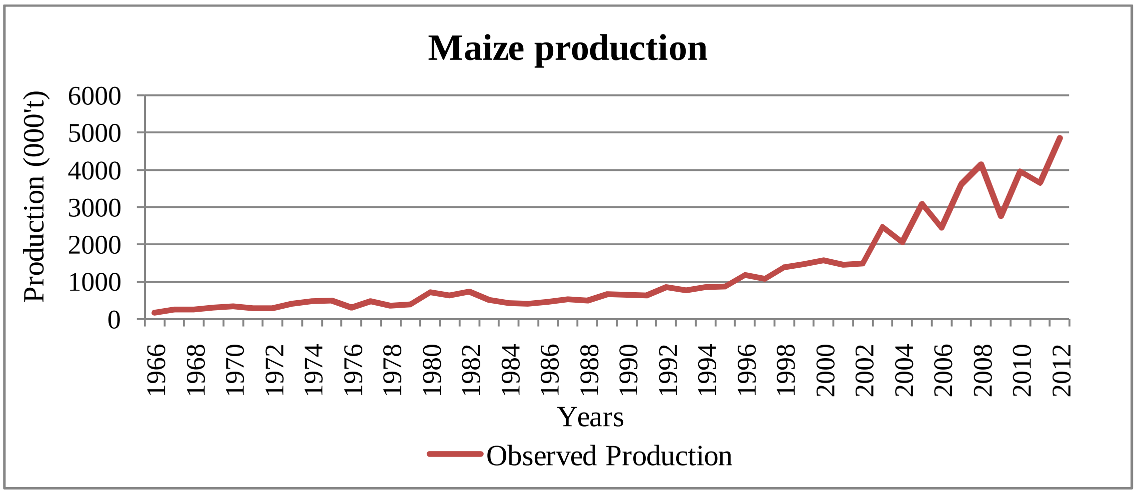


Figure 4.2. Observed Production of Maize in Andhra Pradesh

From the Figure 4.2 it was recorded that the average production of maize in Andhra Pradesh during the study period (1966-2012) was 1232 thousand tones. It was also observed that the production was tremendously increased from 302 thousand tonnes in the year 1976 to 4855 thousand tones in the year 2012.

The results obtained for production of maize during the study period by fitting all the models were presented in Table 4.2.

Table 4.2. Linear, Non-linear and Time series models of Maize production in Andhra Pradesh

Model	Parameter				Criteria			
	a	b	c	d	Theil's U-Statistics (%)	R^2	Adj R^2	MAPE
Linear	-554.538**	74.421**			80.47	0.709**	0.703**	76.00
Logarithmic	1316.812**	875.525**			70.92	0.409**	0.396**	106.00
Inverse	2521.230**	1469.641			62.56	0.113*	0.094*	123.00
Quadratic	750.342**	-85.360**	3.329**		89.89	0.918**	0.914**	36.00
Cubic	**100.827**	**68.955***	**-4.624****	**0.110****	**92.16**	**0.950****	**0.949****	**14.00**
Compound	189.946**	1.063**			85.99	0.863**	0.860**	23.00
Power	74.780**	0.825**			69.11	0.687**	0.680**	41.00
S-curve	6.991**	-2.917**			55.35	0.288**	0.272**	64.00
Growth	5.247**	0.061**			85.99	0.863**	0.860**	23.00
Exponential	189.946**	0.061**			85.99	0.863**	0.860**	23.00
Time Series Models								
ARIMA (0, 1, 0)					87.20	0.867	0.864	22.46
ARIMA (0, 1, 1)					90.73	0.930	0.928	19.39
ARIMA (1, 1, 0)					90.35	0.923	0.921	17.70
ARIMA (1, 1, 1)					90.96	0.933	0.932	19.01
Log Linear (Holt) Exponential Smoothing					89.98	0.921	0.919	17.96

1. *Source: Secondary data collected from Ministry of Agriculture, Govt of India,* www.Indiastat.com

2. The value of the criterion for a model with bold numerals shows that the model is better than the other models with respect to that criterion.

3. **,* indicate significant at 1% and 5% level of probability respectively.

Forecasted Cubic model is $\hat{Y}_{production} = \mathbf{100.827 + 68.955\,x - 4.624\,x^2 + 0.110\,x^3}$

In case of maize production from the above Table 4.2 the value of all fitted models showing significant adjusted R^2. But cubic model was with high Theil's U-Statistic (92.16%), highest R^2 (0.950) with significant adjusted R^2 (0.949) and the least MAPE (14.00) values. Hence, the cubic function was chosen for future forecasts of Maize production. Sandika *et al*. (2009) selected the same growth model for projecting Rice production and productivity.

Among the time series models ARIMA (1, 1, 1) identified as the best fitted model based on model selection criteria but cubic model was best as compared to ARIMA (1, 1, 1) model.

4.1.1.3. Maize productivity

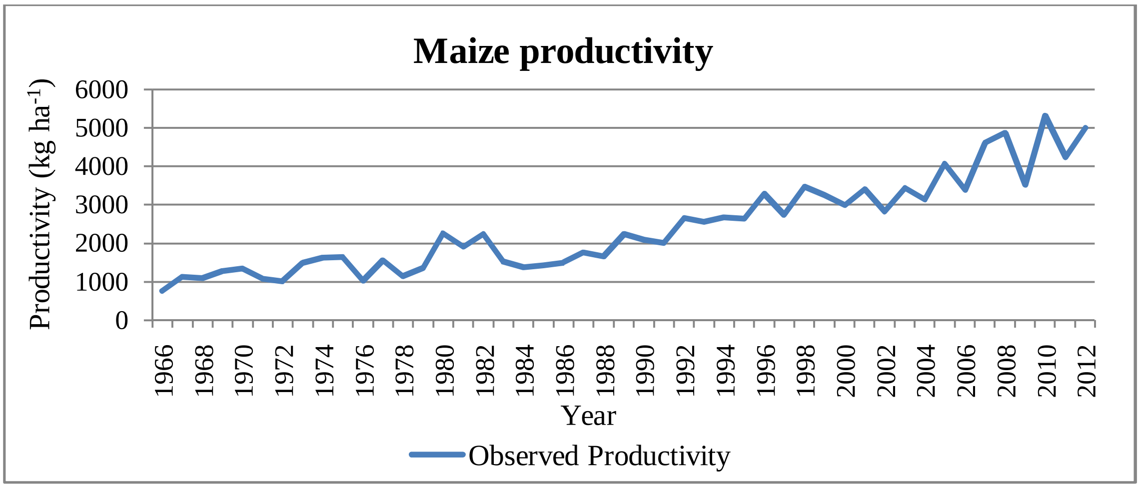


Figure 4.3. Observed Productivity of Maize in Andhra Pradesh

From the Figure 4.3 revealed that the average productivity of maize crop for the entire period was 2418 kg ha^{-1}. The data on productivity of maize in Andhra Pradesh during the study period of 1967 to 2012 showed an increasing trend. The maximum productivity was 5317 kg ha^{-1} in the year 2010 and minimum productivity was 1018 kg ha^{-1} in the year 1972.

The results obtained for productivity of maize during the study period by fitting all the models were presented in Table 4.3.

Table 4.3. Linear, Non-linear and Time series models of Maize productivity in Andhra Pradesh

	Parameter				Criteria			
Model	a	b	c	d	Theil's U-Statistic (%)	R^2	Adj R^2	MAPE
Linear	272.591	94.098**			91.38	0.847**	0.844**	19.13
Logarithmic	-891.606	1175.850**			65.93	0.414**	0.401**	53.01
Inverse	2881.591**	-3713.593*			60.18	0.138*	0.119*	44.43
Quadratic	1476.734**	-53.348**	3.072**		93.01	0.899**	0.896**	14.54
Cubic	**565.621****	**163.118****	**-8.085****	**0.155***	**93.05**	**0.900****	**0.897****	**14.46**
Compound	915.990**	1.037**			92.87	0.896*	0.894*	14.63
Power	508.664**	0.500**			57.74	0.683**	0.675**	28.00
S-curve	7.860**	-1.829**			47.43	0.306**	0.291**	51.00
Growth	6.820**	0.036**			92.87	0.896**	0.894**	14.63
Exponential	915.990**	0.036**			92.87	0.896**	0.894**	14.63
Time Series Models								
ARIMA (0, 1, 0)					89.09	0.747	0.741	18.72
ARIMA (0, 1, 1)					92.55	0.889	0.887	15.24
ARIMA (1, 1, 0)					91.77	0.862	0.859	14.89
ARIMA (1, 1, 1)					92.54	0.889	0.887	15.33
Log Linear Trend Exponential Smoothing					92.97	0.898	0.896	14.82

1. *Source: Secondary data collected from Ministry of Agriculture, Govt of India, www.Indiastat.com*

2. The value of the criterion for a model with bold numerals shows that the model is better than the other models with respect to that criterion.

3. **,* indicate significant at 1% and 5% level of probability respectively.

Forecasted Cubic model is $\hat{Y}_{productivity} = 565.621 + 163.118\,x - 8.085\,x^2 + 0.155\,x^3$

Based on model selection criteria among all the models cubic model was found to be best fit of its highest model accuracy having Theil's U-Statistic (93.05%), highest R^2 (0.900) with significant adjusted R^2 (0.897) and the least MAPE (14.46) values. Hence, the cubic function was chosen for future forecasts of Maize productivity. Sudha *et al.* (2012) selected the same growth model for projecting Rice area, production and productivity in Guntur district of Andhra Pradesh.

From time series models, log linear trend exponential smoothing has the highest R^2 and lowest MAPE values. But as compared to cubic model this model is less efficient.

4.1.2 Sorghum

Sorghum (*Sorghum bicolor* L.) is the fifth most important cereal crop grown in the world behind rice, corn, wheat and barley and the third leading cereal crop in the USA. It is cultivated for food, feed, beverage and fodder in Africa, Asia and Americas. In India sorghum grown in area of 6214 thousand hectares with annual production of 5282 thousand tonnes in 2012-13.

4.1.2.1. Sorghum area

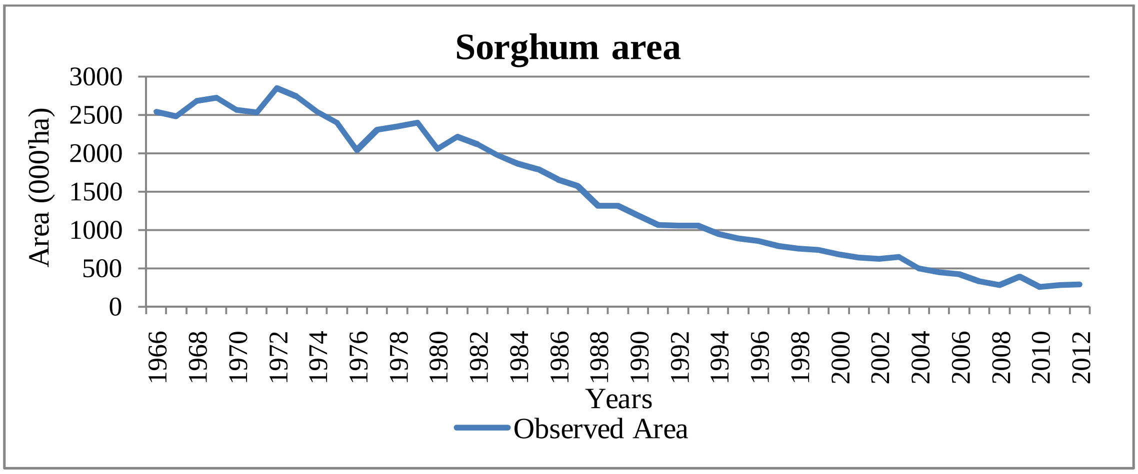


Figure 4.4. Observed Area of Sorghum in Andhra Pradesh

From the Figure 4.4 it was recorded that the average area of sorghum crop during the study period (1966-2012) was 1449 thousand hectares in Andhra Pradesh, maximum area was 2848 thousand hectares in the year 1972 and minimum was 254 thousand hectares in 2010. It was clearly observed that the area of the crop showed decreasing trend from 1981 onwards.

The time series data on area under sorghum for the study period of 1966 to 2012 was subjected to fitting of all the linear, non-linear growth models, time series models and the results were presented in the Table 4.4.

Table 4.4. Linear, Non-linear and Time series models of Sorghum area in Andhra Pradesh

Model	Parameter				Criteria			
	a	**b**	**c**	**d**	**Theil's U-Statistics (%)**	**R^2**	**Adj R^2**	**MAPE**
Linear	2938.199**	-62.053**			94.84	0.959**	0.958**	14.00
Logarithmic	3934.233**	-853.850**			87.21	0.756**	0.751**	37.51
Inverse	1191.209**	2729.44**			76.86	0.259**	0.242**	85.00
Quadratic	3002.612**	-69.940**	0.164		94.90	0.960**	0.959**	13.00
Cubic	**2623.101****	**20.226**	**-4.483****	**0.065****	**96.56**	**0.982****	**0.981****	**7.00**
Compound	4129.748**	0.948**			89.16	0.808**	0.804**	15.00
Power	8332.554**	-0.682**			71.02	0.637**	0.628**	42.00
S-curve	6.849**	2.040**			67.72	0.190**	0.172**	70.00
Growth	8.326**	-0.053**			89.16	0.808**	0.804**	15.00
Exponential	4129.748**	-0.053**			89.16	0.808**	0.804**	15.00
Time Series Models								
ARIMA (0, 1, 0)					96.24	0.978	0.977	7.62
ARIMA (0, 1, 1)					96.33	0.979	0.978	7.21
ARIMA (1, 1, 0)					96.29	0.979	0.979	7.31
ARIMA (1, 1, 1)					96.36	0.979	0.979	7.23
Damped Trend Exponential Smoothing					96.34	0.979	0.979	7.33

1. *Source: Secondary data collected from Ministry of Agriculture, Govt of India, www.Indiastat.com*

2. The value of the criterion for a model with bold numerals shows that the model is better than the other models with respect to that criterion.

3. **,* indicate significant at 1% and 5% level of probability respectively.

Forecasted Cubic model is $\hat{Y}_{Area}$ **= 2623.101 + 20.226 x - 4.483 x^2 + 0.065 x^3**

Under sorghum area all the linear and non-linear models showing highly significant adjusted R^2 but comparison with model selection criteria among all the models cubic model was with highest percentage of model accuracy Theil's U-Statistic (96.56%), R^2 (0.982) with significant adjusted R^2 (0.981) has least MAPE (7.00) values. Hence cubic model was chosen for forecasting purpose. Hasija *et al*. (2003) selected the same model for forecasting the area and production of Sugarcane for Haryana as a whole and also for zone 1, zone 2 and zone 4. Sudha *et al*. (2012) selected the same growth model for projecting Rice area, production and productivity in Guntur district of Andhra Pradesh. Similar results were reported by Mishra *et.al* (2013) for delineate trends in area, production and productivity of onion in Maharashtra**.**

Among time series models ARIMA (0, 1, 1) had the highest R^2 and lowest MAPE values. But as compared to cubic model this model is less efficient.

4.1.2.2. Sorghum production

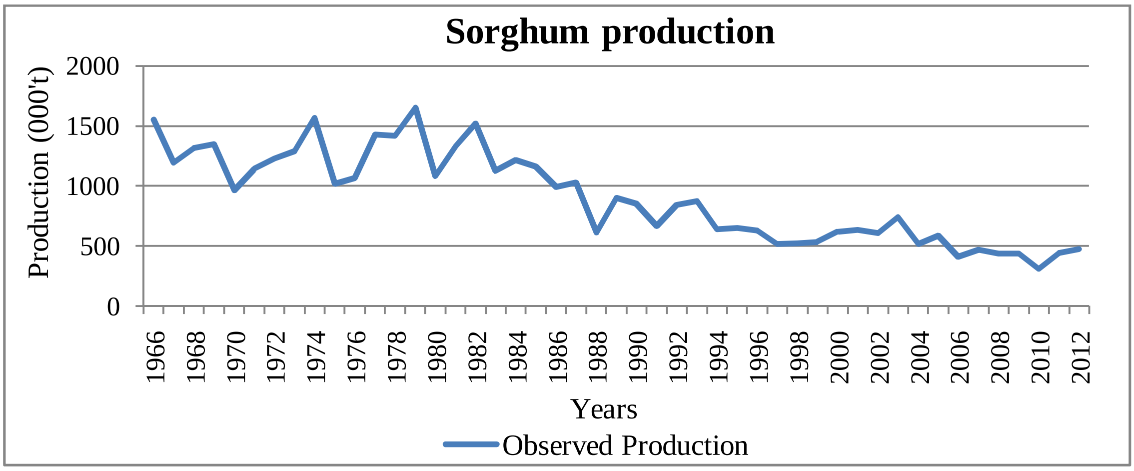


Figure 4.5. Observed Production of Sorghum

From the above Figure 4.5 it was recorded that the average production of the Sorghum crop for the entire period (1966-2012) was 906 thousand tonnes. The data on production of Sorghum in Andhra Pradesh during the study period of 1967 to 2012 showed there was an increasing and decreasing trend. Maximum production was 1656 thousand tones in the year 1979 and minimum production was 308 thousand tonnes in the year 2010.

The results obtained for production of Sorghum during the study period by fitting all the models were presented in Table 4.5.

Table 4.5. Linear, Non-linear and Time series models of Sorghum production in Andhra Pradesh

	Parameter				Criteria			
Model	**a**	**b**	**c**	**d**	**Theil's U-Statistic (%)**	**R^2**	**Adj R^2**	**MAPE**
Linear	1487.101**	-24.199**			90.83	0.966**	0.966**	15.07
Logarithmic	1850.627**	-324.427**			87.43	0.578**	0.569**	23.75
Inverse	801.514**	1109.931**			82.74	0.226**	0.209**	37.93
Quadratic	1433.334**	-17.616*	-0.137		90.90	0.967**	0.966**	15.60
Cubic	**1214.171****	**34.454**	**-2.821****	**0.037****	**91.72**	**0.972****	**0.972****	**13.75**
Compound	1666.036**	0.971**			89.75	0.958**	0.957**	15.87
Power	2184.459**	-0.378**			84.00	0.568**	0.558**	24.41
S-curve	6.603**	1.216**			80.51	0.197**	0.179**	35.90
Growth	7.418**	-.0.029**			89.75	0.958**	0.957**	15.87
Exponential	1666.036**	-0.029**			89.75	0.958**	0.957**	15.87
Time Series Models								
ARIMA (0, 1, 0)					89.15	0.668	0.661	18.24
ARIMA (0, 1, 1)					90.85	0.766	0.761	15.38
ARIMA (1, 1, 0)					90.14	0.727	0.721	16.43
ARIMA (1, 1, 1)					90.85	0.766	0.761	15.39
Damped Trend Exponential Smoothing					91.11	0.786	0.781	15.07

1. Source: Secondary data collected from Ministry of Agriculture, Govt of India, www.Indiastat.com

2. The value of the criterion for a model with bold numerals shows that the model is better than the other models with respect to that criterion.

3. **,* indicate significant at 1% and 5% level of probability respectively.

Forecasted Cubic model is $\hat{Y}_{production}$ **= 1214.171 + 34.454 x - 2.821 x^2 + 0.037 x^3**

It appears from the above Table 4.5 all the deterministic models showing highly significant adjusted R^2 but comparison with model selection criteria among all the models cubic model was with highest percentage of model accuracy Theil's U-Statistic (91.72%), R^2 (0.972) with significant adjusted R^2 (0.972) has least MAPE (13.75) values. Hence cubic model was chosen for forecasting purpose. Similar results were reported by Rahman and Imam (2008) forecasting area, production and productivity of pigeon pea, field pea, chick pea pulse production in Bangladesh.

Among all the time series models Damped Trend Exponential Smoothing was identified as the best fitted model based on model selection criteria. But cubic model was best as compared to Damped Trend Exponential Smoothing.

4.1.2.3. Sorghum productivity

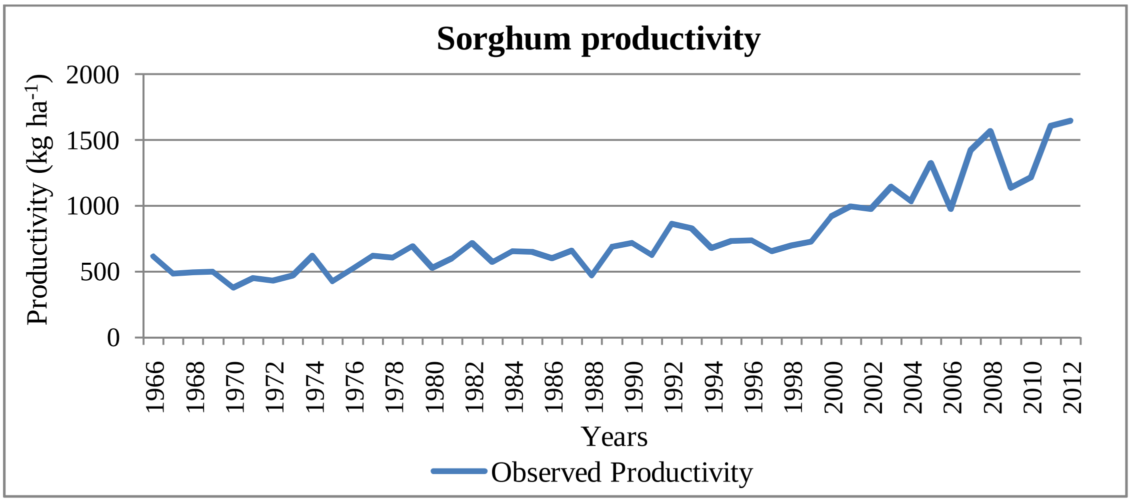


Figure 4.6. Observed Productivity of Sorghum in Andhra Pradesh

From the Figure 4.6 it was revealed that the average productivity of sorghum crop during the study period (1966-2012) was 779 kg ha^{-1}. The data on production of sorghum in Andhra Pradesh during the study period of 1967 to 2012 showed there was an increasing trend and highest productivity was observed in the year 2012 i.e. 1643 kg ha^{-1}.

The results obtained for production of sorghum during the study period by fitting all the models were presented in Table 4.6

Table 4.6. Linear, Non-linear and Time series models of Sorghum productivity in Andhra Pradesh

	Parameter				Criteria			
Model	**a**	**b**	**c**	**d**	**Theil's U-Statistics (%)**	**R^2**	**Adj R^2**	**MAPE**
Linear	295.298**	20.149**			89.90	0.724**	0.718**	16.89
Logarithmic	74.501	241.994**			85.37	0.435**	0.423**	24.68
Inverse	840.120**	-648.635*			81.34	0.104*	0.085*	32.55
Quadratic	574.684**	-14.062*	0.713**		92.77	0.858**	0.854**	13.50
Cubic	**438.603****	**18.269****	**-0.954****	**0.023***	**93.30**	**0.878****	**0.875****	**11.92**
Compound	403.932**	1.025**			91.02	0.788**	0.783**	13.42
Power	298.111**	0.305**			85.78	0.502**	0.481**	20.15
S-curve	6.663**	-0.827**			80.66	0.128*	0.108*	27.74
Growth	6.001**	0.024**			91.02	0.788**	0.783**	13.42
Exponential	403.932**	0.024**			91.02	0.788**	0.783**	13.42
Time Series Models								
ARIMA (0, 1, 0)					90.44	0.747	0.741	15.59
ARIMA (0, 1, 1)					92.76	0.857	0.854	13.22
ARIMA (1, 1, 0)					91.34	0.794	0.789	14.16
ARIMA (1, 1, 1)					92.77	0.858	0.855	13.20
Log Double (Brown) Exponential Smoothing					91.76	0.828	0.824	13.54

1. *Source: Secondary data collected from Ministry of Agriculture, Govt of India, www.Indiastat.com*

2. The value of the criterion for a model with bold numerals shows that the model is better than the other models with respect to that criterion.

3. **,* indicate significant at 1% and 5% level of probability respectively.

Forecasted Cubic model is $\hat{Y}_{productivity} = \mathbf{438.603 + 18.269\,x - 0.954\,x^2 + 0.023\,x^3}$

From the above Table it was observed that all the deterministic models showing highly significant adjusted R^2 at 1% level except Inverse and S-curve models are significant at 5% level. but comparison with model selection criteria among all the models Cubic model was with highest percentage of model accuracy Theil's U-Statistic (93.30%), R^2 (0.878) with significant adjusted R^2

(0.875) has least MAPE (11.92) values. Hence cubic model was chosen for forecasting purpose. Similar results were reported by Hassan *et al.* (2011) selected same model for forecasting of coarse rice prices in Bangladesh.

Among time series models ARIMA (1, 1, 1) has the highest R^2 and lowest MAPE values. But as compared to cubic model this model is less efficient.

4.1.3. PEARL MILLET

Pearl millet is the most widely cultivated cereal crop in India after rice and wheat. It is grown on more than 9.3 m ha with current grain production of 9.5 Mt and productivity of 1044 kg ha^{-1}. The major pearl millet growing states are Rajasthan, Maharashtra, Gujarat, Uttar Pradesh and Haryana which account for more than 90% of pearl millet acreage in country. The area under Pearl millet was 67 Mha, production was 111 Mt and productivity was 1657 kg ha^{-1} during 2012-13 in Andhra Pradesh.

4.1.3.1. Pearl millet area

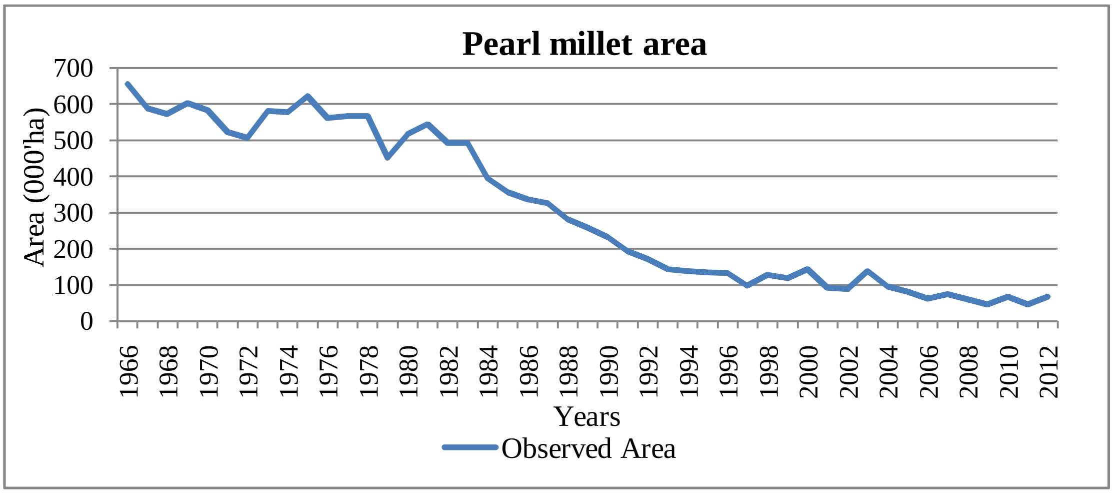


Figure 4.7. Observed Area of Pearl millet in Andhra Pradesh

From the Figure 4.7 it was observed that the average area of pearl millet in Andhra Pradesh during the study period (1966 to 2012) was 308 thousand hectares. Maximum area was 622 thousand hectares in the year 1975 and minimum was 45 thousand hectares in the years 2009 and 2011.

The results obtained for area of pearl millet during the study period by fitting all the models were presented in Table 4.7.

Table 4.7. Linear, Non-linear and Time series models of Pearl millet area in Andhra Pradesh

Model	Parameter				Criteria			
	a	**b**	**c**	**d**	**Theil's U-Statistics (%)**	**R^2**	**Adj R^2**	**MAPE**
Linear	667.860**	-14.980**			91.76	0.917**	0.915**	33
Logarithmic	992.412	-210.971			85.75	0.757**	0.752**	45
Inverse	240.283**	720.761**			74.68	0.296**	0.280**	107
Quadratic	712.451**	-20.440**	0.114*		92.16	0.924**	0.923**	24
Cubic	586.792**	9.415	-1.425**	0.021**	94.54	0.963**	0.962**	18
Compound	978.058**	0.940**			87.07	0.781**	0.776**	20
Power	2306.008**	-0.801**			65.40	0.660**	0.652**	47
S-curve	5.176**	2.491**			61.69	0.213**	0.196**	82
Growth	6.886**	-0.061**			87.07	0.781**	0.776**	20
Exponential	978.058**	-0.061**			87.07	0.781**	0.776**	20
Time Series Models								
ARIMA (0, 1, 0)					94.91	0.968	0.967	14
ARIMA (0, 1, 1)					95.02	0.969	0.968	13
ARIMA (1, 1, 0)					94.98	0.968	0.967	13
ARIMA (1, 1, 1)					95.01	0.969	0.968	14
Damped Trend Exponential Smoothing					**95.17**	**0.971**	**0.970**	**12**

1. *Source: Secondary data collected from Ministry of Agriculture, Govt of India, www.Indiastat.com*

2. The value of the criterion for a model with bold numerals shows that the model is better than the other models with respect to that criterion.

3. **,* indicate significant at 1% and 5% level of probability respectively.

Forecasted Cubic model is $586.792 + 9.415\,x - 1.425\,x^2 + 0.021\,x^3$

From the above Table 4.7 it was observed that all the traditional models showing highly significant adjusted R^2 at 1% level but comparison with model selection criteria among all the models damped trend exponential smoothing was with highest percentage of model accuracy Theil's U-Statistic (95.17%), R^2 (0.971) with highest adjusted R^2 (0.970) has least MAPE (12) values. Hence damped trend exponential smoothing was considered for forecasting purpose. Similar results reported by Masuda *et al*. (2009) forecasted world production of soybean.

Among the time series models ARIMA (0, 1, 1) was best fitted model based on model selection criteria but less as compared to cubic model.

4.1.3.2. Pearl millet production

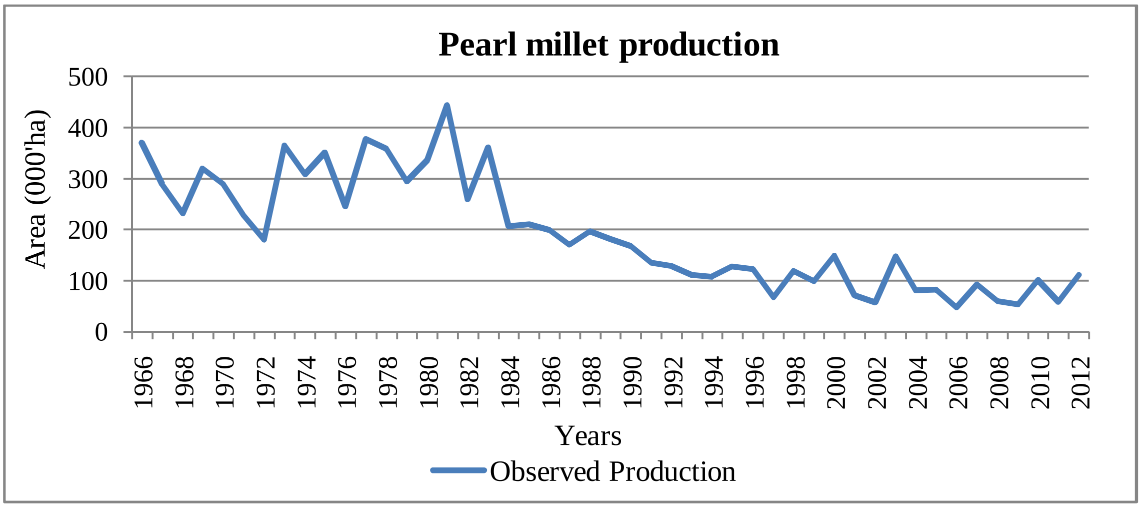


Figure 4.8 Observed Production of Pearl millet in Andhra Pradesh

It is evident from the Figure 4.8 that the average production for the study period (1966-2012) was 193 thousand tonnes in Andhra Pradesh. It was also observed that in decreasing trend from 1984 onwards. Maximum production was 444 thousand tonnes in the year 1981 and minimum was 47 thousand tones in the year 2006.

The results obtained for production of pearl millet during the study period by fitting all the models were presented in Table 4.8.

Table 4.8. Linear, Non-linear and Time series models of pearl millet production in Andhra Pradesh

	Parameter				Criteria			
Model	**a**	**b**	**c**	**d**	**Theil's U-Statistics (%)**	**R^2**	**Adj R^2**	**MAPE**
Linear	353.532**	-6.694**			86.28	0.699**	0.692**	28
Logarithmic	453.539**	-89.555**			82.50	0.521**	0.510**	38
Inverse	164.404**	301.489**			76.84	0.198**	0.180**	61
Quadratic	348.917**	-6.129*	-0.012**		86.28	0.699**	0.692**	28
Cubic	**256.770****	**15.764***	**-1.140****	**0.016****	**88.29**	**0.779****	**0.774****	**22**
Compound	420.400**	0.961**			84.56	0.624**	0.615**	25
Power	726.606**	-0.517**			76.24	0.530**	0.520**	37
S-curve	4.930**	1.636**			72.36	0.177**	0.159**	52
Growth	6.041**	-0.040**			84.56	0.624**	0.615**	25
Exponential	420.400**	-0.040**			84.56	0.624**	0.615**	25
Time Series Models								
ARIMA (0, 1, 0)					84.26	0.581	0.572	33.12
ARIMA (0, 1, 1)					86.92	0.718	0.712	26.99
ARIMA (1, 1, 0)					86.58	0.701	0.694	28.11
ARIMA (1, 1, 1)					87.12	0.726	0.720	26.37
Damped Trend Exponential Smoothing					87.34	0.739	0.733	25.41

1. *Source: Secondary data collected from Ministry of Agriculture, Govt of India, www.Indiastat.com*

2. The value of the criterion for a model with bold numerals shows that the model is better than the other models with respect to that criterion.

3. **,* indicate significant at 1% and 5% level of probability respectively.

Forecasted Cubic model is $\hat{Y}_{Production} = 256.770 + 15.764\,x - 1.140\,x^2 + 0.016\,x^3$

To select the best model, model selection criteria will be helpful. It is evident from Table 4.8 that the value of Theil's U-Statistic (88.29%), R^2 (0.779) with significant adjusted R^2 (0.774) are higher for cubic model compared to the other models. The value of MAPE (22) also lower for cubic model compared to other growth models. Thus the cubic model is seemed to be the best not only for describing the growth pattern of coarse cereals but also for making forecast with minimum forecast error. Similar results were reported by Sandika *et al*. (2009) selected the same growth model for projecting Rice production and productivity.

Among all time series models Damped Brown Exponential Smoothing (DBES) was identified as the best fitted model based on the model selection criteria but cubic model was best as compared to Damped Brown Exponential Smoothing (DBES).

4.1.3.3. Pearl millet productivity

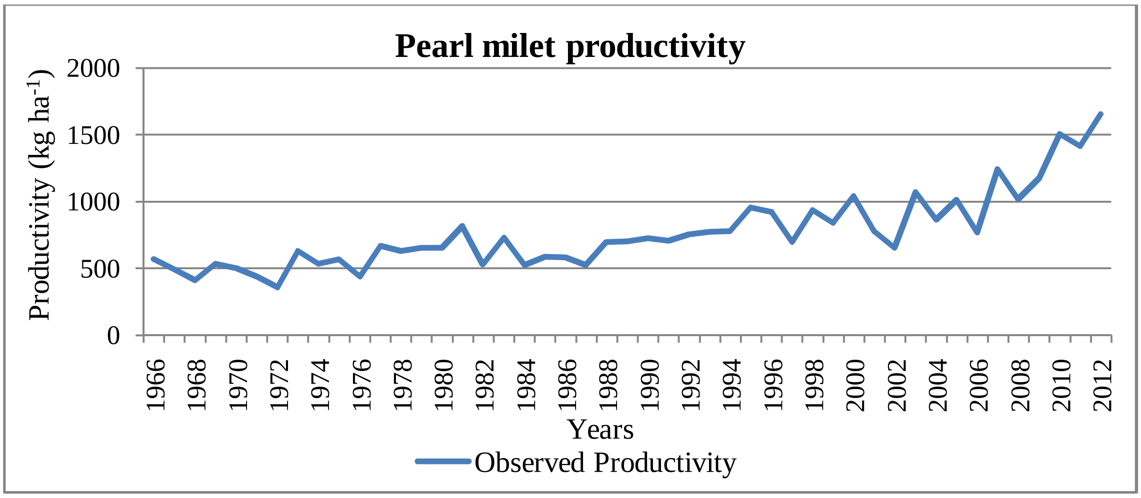


Figure 4.9. Observed productivity of pearl millet in Andhra Pradesh

From the Figure 4.9 it was recorded that the average productivity of sorghum crop for the entire period was 767kg ha^{-1}. Maximum productivity was 1657 kg ha^{-1} in the year 2012 and minimum productivity was 355 kg ha^{-1} in the year 1972. Though the area and production showed declining trend but productivity is on increasing trend. Similar results were reported by Karim *et al.* (2010) and Hassan *et al.* (2011) selected the same model for forecasting of coarse rice prices in Bangladesh.

The results obtained for productivity of pearl millet during the study period by fitting all the models were presented in Table 4.9.

Table 4.9. Linear, Non-linear and Time series models of Pearl millet productivity in Andhra Pradesh

	Parameter				Criteria			
Model	**a**	**b**	**c**	**d**	**Theil's U-Statistics (%)**	**R^2**	**Adj R^2**	**MAPE**
Linear	348.818**	17.406**			90.34	0.695**	0.688**	16
Logarithmic	132.266	217.916**			86.98	0.454**	0.442**	21
Inverse	826.609**	-636.015*			83.38	0.129**	0.110**	28
Quadratic	546.149**	-6.757	0.503**		91.83	0.780**	0.776**	14
Cubic	**384.995****	**31.531***	**-1.470***	**0.027****	**92.53**	**0.816****	**0.**812**	**14**
Compound	427.848**	1.022**			91.01	0.742**	0.736**	14
Power	313.376**	0.287**			87.40	0.492**	0.480**	18
S-curve	6.663**	-0.860**			82.98	0.134**	0.115**	24
Growth	6.059**	0.022**			91.01	0.742**	0.736**	14
Exponential	427.848**	0.022**			91.01	0.742**	0.736**	14
Time Series Models								
ARIMA (0, 1, 0)					89.25	0.612	0.603	18.88
ARIMA (0, 1, 1)					91.73	0.775	0.770	14.66
ARIMA (1, 1, 0)					91.67	0.769	0.764	14.49
ARIMA (1, 1, 1)					92.04	0.791	0.786	14.34
Damped Trend Exponential Smoothing					91.45	0.766	0.761	14.08

1. *Source: Secondary data collected from Ministry of Agriculture, Govt of India,* www.Indiastat.com

2. The value of the criterion for a model with bold numerals shows that the model is better than the other models with respect to that criterion.

3. **,* indicate significant at 1% and 5% level of probability respectively.

Forecasted Cubic model is $\hat{Y}_{\Pr oductivity}$ **= 384.995 + 31.531 x - 1.470 x^2 + 0.027 x^3**

It is evident from the above Table 4.9 that the value of Theil's U-Statistic (92.53%), R^2 (0.816) with significant adjusted R^2 (0.812) are higher for cubic model compared to the other linear and non-linear growth models. The value of MAPE (14) also lower for cubic model compared to other growth models. Hence cubic model was chosen for forecasting of area, production and productivity.

Same model was selected by Hossain and Hassan (2013) describes the growth pattern of milk, meat and egg production in Bangladesh. They selected cubic model for forecasting of milk and meat production and Rahman *et al.* (2013) was used cubic model for forecasting of pigeon pea, chickpea and field pea pulse production.

Among the time series models ARIMA (1, 1, 1) was identified as best model based on model selection criteria but as compared to ARIMA (1, 1, 1) cubic model was best fitted.

4.1.4. Finger millet

Finger millet is extensively cultivated in India, Africa, Ceylon, Malaysia, China and Japan. In India it is cultivated over an area of 2.65 Mha with total production of about 2.9 Mt. It is widely grown in Karnataka, Tamil Nadu, Andhra Pradesh, Orissa, Bihar, Gujarat and Maharashtra and in the hilly regions of Uttar Pradesh and Himachal Pradesh.

4.1.4.1. Finger millet area

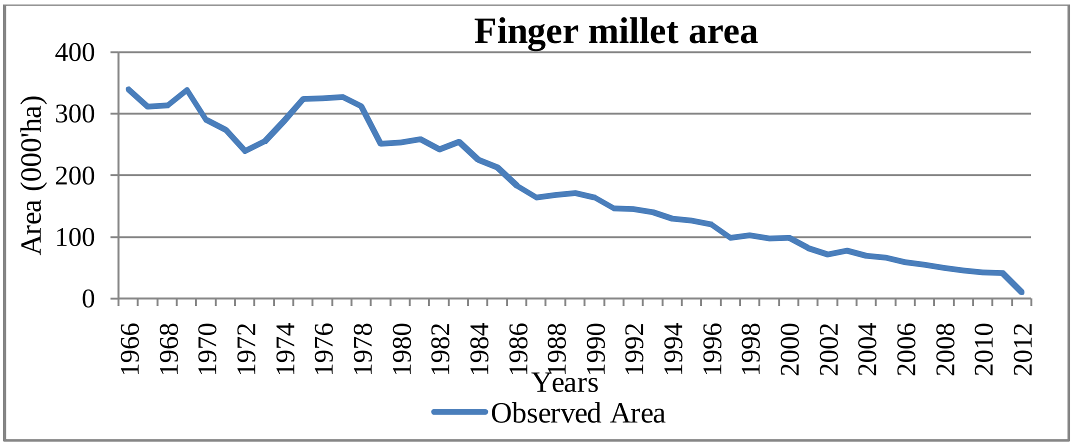


Figure 4.10. Observed area of Finger millet in Andhra Pradesh

From the above graph 4.10 it was observed that the average area under finger millet in Andhra Pradesh during the study period (1966-2012) was 178 thousand hectares. Area of finger millet in Andhra Pradesh state showed a decreasing growth during the study period of 1966 to 2012. Maximum area was observed as 328 thousand hectares in the year 1977 and minimum was 10 thousand hectares in the year 2012. The results obtained for area of finger millet during the study period by fitting all the models were presented in Table 4.10.

Table 4.10. Linear, Non-linear and Time series models of Finger millet area in Andhra Pradesh.

	Parameter				Criteria			
Model	**a**	**b**	**c**	**d**	**Theil's U-Statistics (%)**	**R^2**	**Adj R^2**	**MAPE**
Linear	349.411**	-7.145**			94.16	0.943**	0.942**	13.45
Logarithmic	465.820**	-98.906**			87.66	0.752**	0.747**	44.26
Inverse	146.048**	337.710**			78.49	0.290**	0.277**	91.93
Quadratic	348.572**	-7.042**	-0.002		94.16	0.943**	0.942**	11.46
Cubic	316.322**	0.620	-0.397**	0.005**	94.80	0.954**	0.953**	13.42
Compound	492.124**	0.950**			88.52	0.765**	0.760**	22.48
Power	951.875**	-0.652**			73.29	0.575**	0.565**	48.74
S-curve	4.771**	2.005**			69.83	0.182**	0.163**	78.30
Growth	6.199**	-0.052**			88.52	0.765**	0.760**	22.48
Exponential	492.124**	-0.052**			88.52	0.765**	0.760**	22.48
Time Series Models								
ARIMA (0, 1, 0)					95.50	0.966	0.965	12.21
ARIMA (0, 1, 1)					95.49	0.966	0.965	12.20
ARIMA (1, 1, 0)					95.49	0.966	0.965	12.20
ARIMA (1, 1, 1)					**95.69**	**0.968**	**0.967**	**11.38**
Linear (Holt) Exponential Smoothing					95.60	0.968	0.967	11.94

1. *Source: Secondary data collected from Ministry of Agriculture, Govt of India, www.Indiastat.com*

2. The value of the criterion for a model with bold numerals shows that the model is better than the other models with respect to that criterion.

3. **,* indicate significant at 1% and 5% level of probability respectively.

From the above Table 4.10 it was reported that adjusted R^2 values for all the models were significant. In case of finger millet area ARIMA (1, 1, 1)had the least Mean Absolute Percent Error (11.38) value with highest Theil's-U Statistic (Model accuracy) (95.69%), R^2 (0.968) and adjusted R^2 (0.967). Hence, ARIMA (1, 1, 1) model is used for future forecasts. Iqbal *et al*. (2005) selected same model for forecasting of wheat area in Pakistan.

Among all growth models cubic model was best fitted based on highest R^2 and least MAPE values but less as compared to ARIMA (1, 1, 1).

4.1.4.2. Finger millet production

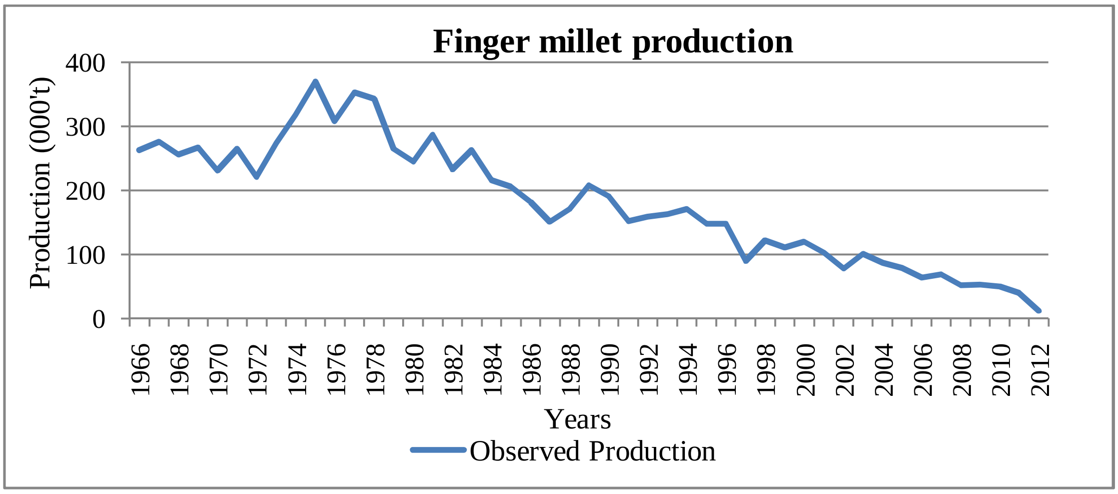


Figure 4.11. Observed Production of Finger millet in Andhra Pradesh

From the Figure 4.11 it was found that the average production of Finger millet in Andhra Pradesh during the study period (1966-2012) was 182 thousand hectares. Production of finger millet in Andhra Pradesh during the study period of 1967 to 2012 had shown an increasing and decreasing trend.

The results obtained for production of finger millet during the study period by fitting all the models were presented in Table 4.11.

Table 4.11. Linear, Non-linear and Time series models of Finger millet production in Andhra Pradesh.

	Parameter							
Model	**a**	**b**	**c**	**d**	**Theil's U-Statistics (%)**	**R^2**	**Adj R^2**	**MAPE**
Linear	331.221**	-6.234**			90.72	0.835**	0.831**	17.15
Logarithmic	409.974**	-78.462**			84.42	0.550**	0.540**	50.76
Inverse	160.592**	222.436**			78.04	0.147**	0.128**	82.78
Quadratic	297.160**	-2.064	-0.087**		91.44	0.859**	0.856**	14.99
Cubic	246.175**	10.050**	-0.711**	0.009**	92.76	0.893**	0.891**	18.26
Compound	444.508**	0.956**			85.78	0.595**	0.586**	28.32
Power	723.577**	-0.538**			75.21	0.466**	0.455**	50.56
S-curve	4.878**	1.490*			73.12	0.120**	0.100*	76.86
Growth	6.097**	-0.045**			85.78	0.595**	0.586**	28.32
Exponential	444.508**	-0.045**			85.78	0.595**	0.586**	28.32
Time Series Models								
ARIMA (0, 1, 0)					92.39	0.889	0.887	17.49
ARIMA (0, 1, 1)					92.81	0.901	0.899	15.80
ARIMA (1, 1, 0)					92.80	0.901	0.899	16.38
ARIMA (1, 1, 1)					**92.97**	**0.907**	**0.905**	**15.12**
Damped Trend Exponential Smoothing					92.75	0.899	0.897	16.25

1. *Source: Secondary data collected from Ministry of Agriculture, Govt of India, www.Indiastat.com*

2. The value of the criterion for a model with bold numerals shows that the model is better than the other models with respect to that criterion.

3. **,* indicate significant at 1% and 5% level of probability respectively.

From the above Table 4.11 all the linear and non-linear models fitted well showing significant adjusted R^2 values except Inverse and S-curve models. Among all these models ARIMA (1, 1, 1) was selected because of its highest model accuracy (92.97), R^2 (0.907) with highly significant adjusted R^2 (0.905) and least MAPE (15.12) values. Hence ARIMA (1, 1, 1) model was chosen for future forecasts. Similar results were reported by Pal *et al*. (2007) forecasting milk production in India.

Among all growth models cubic model was best fitted based on highest R^2 and least MAPE values but less as compared to ARIMA (1, 1, 1).

4.1.4.3. Finger millet productivity

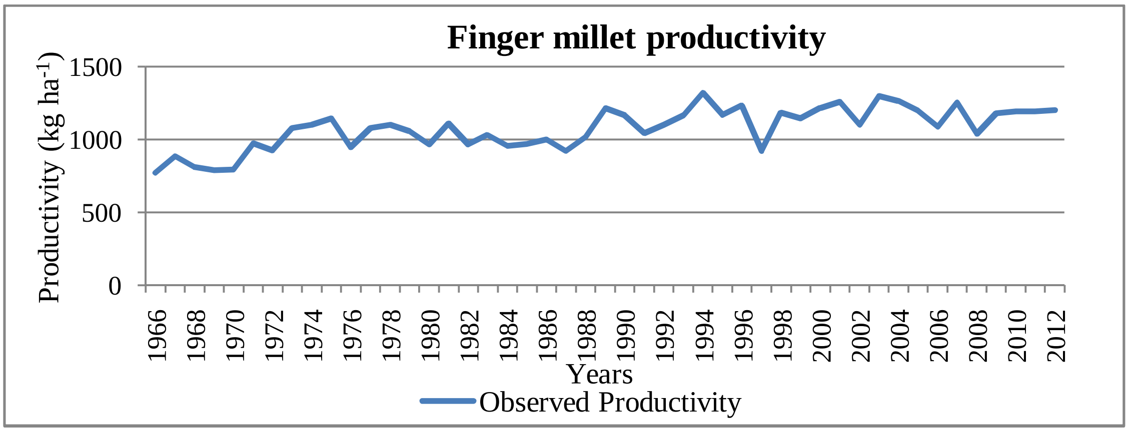


Figure 4.12. Observed Productivity of Finger millet in Andhra Pradesh

From the Figure 4.12 it was found that the average productivity of Finger millet in Andhra Pradesh during the study period (1967 to 2012) was 1074 kg ha^{-1}. Maximum productivity was 1319 kg ha^{-1} in the year 1994 and minimum was 788 kg ha^{-1} in the year 1969. The results obtained by fitting all the models were presented in Table 4.12.

Table 4.12. Linear, Non-linear and Time series models of Finger millet productivity in Andhra Pradesh

	Parameter				Criteria			
Model	**a**	**b**	**c**	**d**	**Theil's U-Statistics (%)**	**R^2**	**Adj R^2**	**MAPE**
Linear	896.910**	7.393**			95.55	0.520**	0.510**	7.77
Logarithmic	724.376**	120.234**			95.80	0.573**	0.563**	7.32
Inverse	1123.123**	-516.631**			94.83	0.350**	0.330**	9.22
Quadratic	827.420**	15.902**	-0.177*		95.76	0.564**	0.554**	7.28
Cubic	807.572**	20.617	-0.420	0.003	95.77	0.567**	0.560**	7.26
Compound	896.221**	1.007**			95.46	0.503**	0.492**	7.83
Power	**751.614****	**0.120****			**95.82**	**0.577****	**0.568****	**7.18**

S-curve	7.021**	-0.530**			94.94	0.383**	0.370**	8.99
Growth	6.798**	0.007**			95.46	0.503**	0.492**	7.83
Exponential	896.221**	0.007**			95.46	0.503**	0.492**	7.83
Time Series Models								
ARIMA (0, 1, 0)					94.44	0.169	0.151	9.09
ARIMA (0, 1, 1)					95.49	0.457	0.445	7.55
ARIMA (1, 1, 0)					95.24	0.393	0.380	7.92
ARIMA (1, 1, 1)					95.61	0.486	0.475	7.46
Linear Trend					95.55	0.520	0.509	7.77

1. *Source: Secondary data collected from Ministry of Agriculture, Govt of India,* www.Indiastat.com

2. The value of the criterion for a model with bold numerals shows that the model is better than the other models with respect to that criterion.

3. **,* indicate significant at 1% and 5% level of probability respectively.

Forecasted Power model is $\hat{Y}_{productivity} = (751.614)^*(t)^{0.120}$

All the linear and non-linear models have showing significant adjusted R^2 values. Among all linear, non-linear and time series models the Power function was found to be best fitted with higher significant adjusted R^2 (0.568), R^2 (0.577) had highest model accuracy Theil's U-Statistic (95.82%) and least MAPE (7.18) values. Hence power function was chosen for forecasting purpose.

Among all the time series models Linear Trend was best fitted model based on model selection criteria like highest theil's U-Statistic, R^2 with highest adjusted R^2 has least MAPE values. But power model was best as compared to Linear Trend.

4.2. INFLUENCE OF WEATHER PARAMETERS ON PRODUCTIVITY OF COARSE CEREALS

Major Coarse Cereals like Maize, Sorghum, Pearl millet and Finger millet Productivity recorded during 1983-84 to 2012-13 in Andhra Pradesh can be considered as the combined influence of weather parameters. The objective was made to find out the influence of weather parameters on Productivity

(Productivity). The weather parameters considered for the present study were Rainfall (mm), Maximum temperature (^{0}C), Minimum temperature (^{0}C), Morning Relative Humidity (RH1) (%) and Evening Relative Humidity (RH2) (%). Crop wise results obtained as follows.

4.2.1. Correlation analysis and Multiple Linear Regression analysis of Maize

Table 4.13. Correlation between productivity (Productivity) of Maize and weather parameters

Weather Parameters	Productivity	Test of significance (t) for Productivity
Max temp (^{0}C)	-0.20	1.135
Min temp (^{0}C)	-0.27	1.485
Rainfall (mm)	0.31	1.775
RH1 (%)	0.73	5.708*
RH2 (%)	0.51	3.197*

* significant at 5% level, t tab value = 2.048

Source: Weather data collected from Post harvest technology, Agricultural college, Bapatla

4.2.1.1 Correlation Analysis

From the above Table 4.13 it was revealed that the association between weather parameters on productivity (Productivity) was measured using Karl-Pearson's correlation coefficient.

Considerable association between weather parameters and maize Productivity was observed that Rainfall (0.31), RH1 (0.73) and RH2 (0.51) showed positive correlation and Maximum temperature (-0.20), Minimum temperature (-0.27) showed negative correlation and test of significance was carried out where RH1 and RH2 were found to be positively significant and all other parameters were found to be non-significant at 5 percent level of significance.

4.2.1.2. Multiple Linear Regression Analysis

In case of multiple linear regression analysis maize Productivity was considered as dependent variable and independent variables were Maximum temperature, Minimum temperature, Rainfall, RH1 and RH2. The model was found to be significant at 5% level of significance with R^2 = 0.582. The forecasted model was showed in following Table 4.14.

Table 4.14. Forecasted models for Productivity of Maize on weather parameters

Dependent Variable	Model	R^2
Productivity	$\hat{Y}$ = - 37898.3 - 16.65 (Max temp) + 10.29 (Min temp) -5.97 (Rainfall) + 442.20^{**} (RH1) + 91.40 (RH2)	0.582^{*}

**,*significant at 1% and 5% level respectively

From the above Table 4.14 it was found that among all the weather parameters Morning relative humidity (RH1) was positively significant at 1% level on Productivity. But with lowest coefficient of determination (58.2%), other than weather parameters many factors are influencing at 41.8% on Productivity of maize.

4.2.2. Correlation analysis and Multiple Linear Regression analysis of Sorghum

Table 4.15. Correlation between productivity (Productivity) of Sorghum and weather parameters

Weather Parameters	Productivity	Test of significance (t) for Productivity
Max temp (^{0}C)	-0.22	1.222
Min temp (^{0}C)	-0.22	1.234
Rainfall (mm)	0.04	0.238
RH1 (%)	0.65	4.547*
RH2 (%)	0.34	1.967

* significant at 5% level, t tab value = 2.048

Source: Weather data collected from Post harvest technology, Agricultural college, Bapatla

4.2.2.1 Correlation Analysis

The association between weather parameters on productivity (Productivity) was measured using Karl- Pearson's correlation coefficient, shown that where Rainfall (0.04), RH1 (0.65) and RH2 (0.34) showed positive correlation and Maximum temperature (-0.225), Minimum temperature (-0.227) showed negative correlation. And test of significance analysis was carried out where RH1was found to be positively significant and all other parameters were found to be non-significant at 5 percent level of significance.

4.2.2.2. Multiple Linear Regression Analysis

In case of multiple linear regression analysis sorghum Productivity was considered as dependent variable and independent variables were Maximum temperature, Minimum temperature, Rainfall, RH1 and RH2. The model was found to be significant at 5% level of significance with R^2 = 0.578. The forecasted model was showed in the Table 4.16.

Table 4.16. Forecasted models for Productivity of Sorghum on weather parameters

Dependent Variable	Model	R^2
Productivity	$\hat{Y}$ = -12243.12 - 9.74 (Max temp) + 12.18 (Min temp) - 5.73*(Rainfall) + 162.05**(RH1) + 9.86 (RH2)	0.578*

**,*significant at 1% and 5% level respectively

From the above Table 4.16 it was found that among all the weather parameters for Productivity rainfall and morning relative humidity (RH1) was negatively and positively significant at 5% and 1% level respectively. But with lowest coefficient of determination (57.8%) other than weather parameters many factors are influencing at 42.2% Productivity of sorghum.

4.2.3. Correlation analysis and Multiple Linear Regression analysis of Pearl millet

Table 4.17. Correlation between productivity of Pearl millet and weather parameters

Weather Parameters	Productivity	Test of significance (t) for Productivity
Max temp (^{0}C)	-0.14	0.760
Min temp (^{0}C)	-0.14	0.802
Rainfall (mm)	0.24	1.355
RH1 (%)	0.66	4.707*
RH2 (%)	0.49	2.990*

* significant at 5% level, t tab value = 2.048

Source: Weather data collected from Post harvest technology, Agricultural college, Bapatla

4.2.3.1 Correlation Analysis

From the Table 4.17 it was Shown that the association between weather parameters on pearl millet productivity (Productivity) was measured using Karl-Pearson's correlation coefficient, in pearl millet Productivity observed that where Rainfall (0.24), RH1 (0.66) and RH2 (0.49) showed positive correlation and Maximum temperature (-0.142), minimum temperature (-0.149) showed negative correlation. And test of significance analysis was carried out where RH1 and RH2 was found to be positively significant and all other parameters were found to be non-significant at 5 percent level of significance.

4.2.3.2 Multiple Linear Regression Analysis

In case of multiple linear regression analysis pearl millet Productivity was considered as dependent variable and independent variables were Maximum temperature, Minimum temperature, Rainfall, RH1 and RH2. The model was found to be significant at 5% level of significance with R^2 = 0.514. The forecasted model was showed in the Table 4.18.

Table 4.18. Forecasted models for Productivity of Pearl millet on weather parameters

Dependent Variable	Model	R^2
Productivity	$\hat{Y}$ = -10272.0 - 1.82 (Max temp) + 10.86 (Min temp) - 2.67 (Rainfall) + 111.23** (RH1) + 33.29 (RH2)	0.514*

**,*significant at 1% and 5% level respectively

From the above Table 4.18 it was observed that among all the weather parameters only morning relative humidity (RH1) was positively significant at 1% level. But with lowest coefficient of determination (51.4%), other than weather parameters many factors are influencing at 48.6% on Productivity of Pearl millet.

4.2.4. Correlation analysis and Multiple Linear Regression analysis of Finger millet

Table 4.19. Correlation between productivity (Productivity) of Finger millet and weather parameters

Weather Parameters	Productivity	Test of significance (t) for Productivity
Max temp (^{0}C)	-0.03	0.203
Min temp (^{0}C)	-0.05	0.279
Rainfall (mm)	0.23	1.254
RH1 (%)	0.47	2.895*
RH2 (%)	0.24	1.316

* significant at 5% level, t tab value = 2.048

Source: Weather data collected from Post harvest technology, Agricultural college, Bapatla

4.2.4.1 Correlation Analysis

The association between weather parameters on finger millet Productivity was analysed by using Karl- Pearson correlation coefficient, where Rainfall (0.23), RH1 (0.47) and RH2 (0.24) showed positive correlation and Maximum temperature (-0.03), minimum temperature (-0.05) showed negative correlation. And test of significance analysis was carried out where RH1 was found to be positively significant and all other parameters were found to be non-significant at 5 percent level of significance.

4.2.4.2 Multiple Linear Regression Analysis

In multiple linear regression analysis finger millet Productivity was considered as dependent variable and independent variables were Maximum temperature, Minimum temperature, Rainfall, RH1 and RH2. The model was found to be significant at 5% level with lowest R^2 = 0.246. The forecasted model was showed in below Table 4.20.

Table 4.20. Forecasted Models for Productivity of Finger millet on weather parameters

Dependent Variable	Model	R^2
Productivity	$\hat{Y}$ = -1699.6 - 0.95 (Max temp) + 4.19 (Min temp) -0.21 (Rainfall) + 35.28* (RH1) - 0.80 (RH2)	0.246*

**,*significant at 1% and 5% level respectively

From the above Table 4.20. It was found that among all the weather parameters in productivity RH1 was found to be positively significant at 5% level. But with lowest coefficient of determination (24.6%), other than weather parameters many factors are influencing at 75.4% on Productivity of Finger millet.

4.3. FORECASTING OF AREA, PRODUCTION AND PRODUCTIVITY OF MAJOR COARSE CEREALS IN ANDHRA PRADESH BY USING BEST FITTED MODEL

In this section, future forecasts of area, production and productivity of major coarse cereals in Andhra Pradesh were presented up to 2020 AD based upon the best fitted model. The forecasts were presented crop wise as follows.

4.3.1. Maize

The future forecasts of area, production and productivity of maize crop by 2020 AD were calculated in Andhra Pradesh state and based on the best identified fitted model in Linear, Non-Linear models and time series models the maize area was forecasted and tabulated in the Table 4.21.

Among all the models ARIMA (0, 1, 1) was found to be best fitted model for area under maize in Andhra Pradesh as it has exhibited highest Theil's U-Statistic (model accuracy), highest R^2 and Adjusted R^2 having least MAPE values. The forecasted area of maize by 2020 AD is expected to be 1347.47 thousand hectares. The forecasts showed an increasing trend by 2020 AD from the Average of study period. Based on the best identified fitted ARIMA model the maize area was forecasted and tabulated in the Table 4.21.

Table 4.21. Forecasted values of Maize area by ARIMA

YEAR	Forecasted Area ('000 hectares)
2013	989.35
2014	1037.32
2015	1087.51
2016	1139.99
2017	1194.85
2018	1252.16
2019	1312.01
2020	1374.47

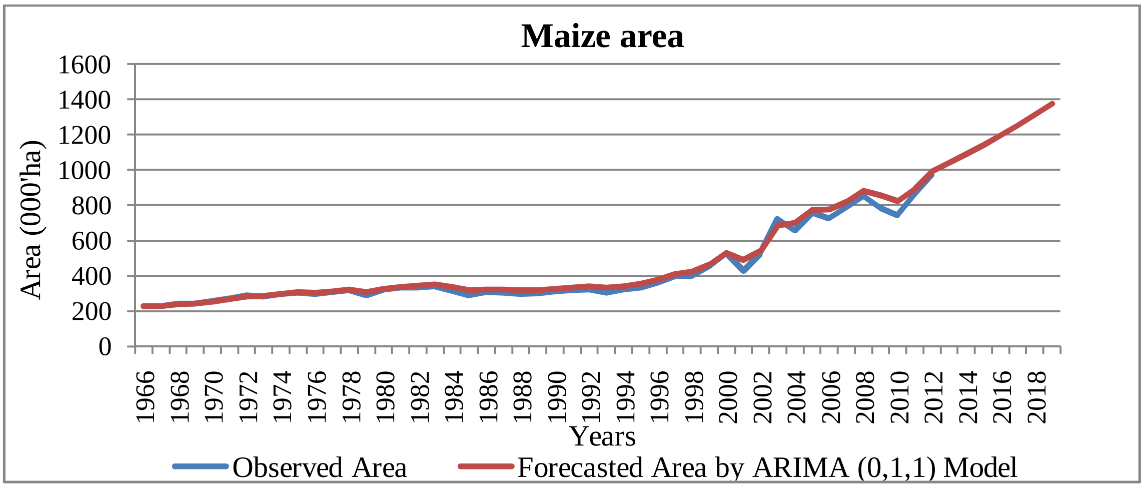


Fig. 4.13. Observed and forecasted trends of Maize area in Andhra Pradesh

Regarding the production of maize cubic model was selected as the best for future forecasts by 2020 AD as it had the highest Theil's U-Statistic (model accuracy), highest R^2 and Adjusted R^2 having least MAPE values. By using this model the forecasted production would be 8282.41 thousand tonnes in 2020 AD. The forecasts showed an increasing trend by 2020 AD is above from the Average of study period. Based on the best identified fitted (cubic) model the Maize productivity was forecasted and tabulated in the Table 4.22. Similar results were reported by Hasija *et al*. (2003)

4.22. Forecasted values of Maize production by cubic model

Year	Forecasted Production ('000 tonnes)
2013	4972.08
2014	5371.99
2015	5795.12
2016	6242.15
2017	6713.73
2018	7210.52
2019	7733.19
2020	8282.41

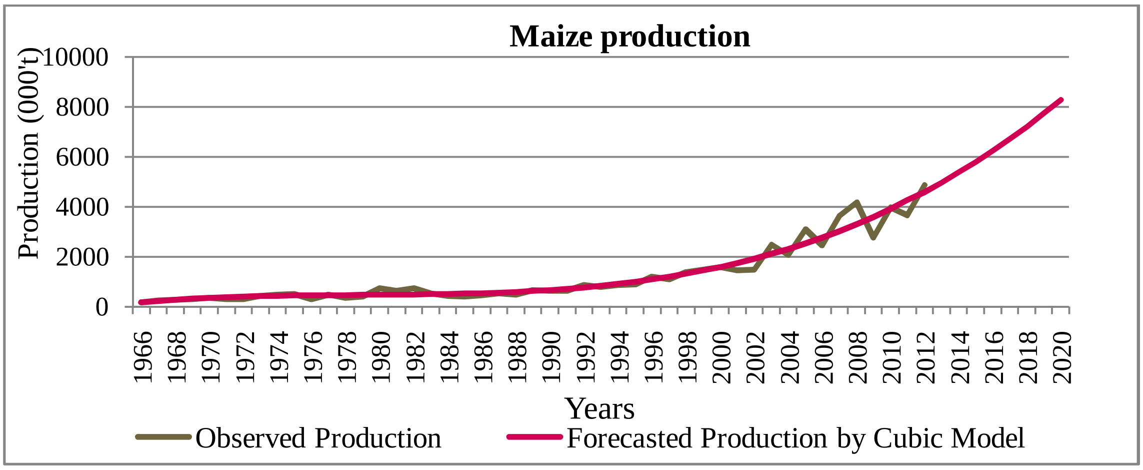


Fig: 4.14. Observed and forecasted trends of Maize production in Andhra Pradesh

Productivity of maize was forecasted by using cubic model which has exhibited highest Theil's U-Statistic (model accuracy), highest coefficient of determination (R^2) and Adjusted R^2 having least MAPE values. By using this model the forecasted productivity would be 10860.94 kg ha^{-1} in 2020 AD. The forecasts showed an increasing trend by 2020 AD from the Average of study period. Based on the best identified fitted (cubic) model the sorghum productivity was forecasted and tabulated in the Table 4.23. Similar results were obtained by Sudha *et al*. (2012), Hassan *et al*. (2011)

Table 4.23. Forecasted values of Maize productivity by cubic model

Year	Forecasted Productivity (kg ha^{-1})
2013	6904.53
2014	7376.93
2015	7878.71
2016	8410.80
2017	8974.14
2018	9569.66
2019	10198.28
2020	10860.94

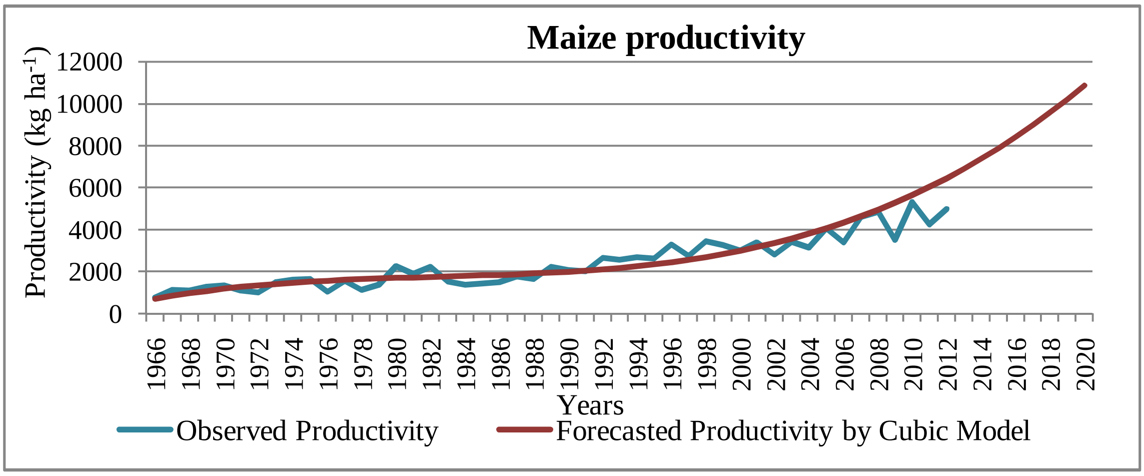


Figure 4.15. Observed and forecasted trends of Maize productivity in Andhra Pradesh

4.3.2. Sorghum

The future forecasts of area, production and productivity of sorghum by 2020 AD were calculated and the results were presented as follows.

area under sorghum in Andhra Pradesh was forecasted by cubic model which was found to be best fit as it had highest Theil's U-Statistic (model accuracy), highest R^2 and Adjusted R^2 having least MAPE, MAE values for predicting the area for future years. The forecasted area of sorghum by 2020 AD would be 913.49 thousand hectares. The forecasts showed an increasing trend by 2020 AD from the Average of study period. Based on the best identified fitted (cubic) model the sorghum productivity was forecasted and tabulated in the Table 4.24. Similar results were observed by Sandika *et al.* (2009).

Table 4.24. Forecasted values of Sorghum area by cubic model

Year	Forecasted Area ('000 hectares)
2013	403.59
2014	444.47
2015	495.35
2016	556.64
2017	628.71
2018	711.95
2019	806.75
2020	913.49

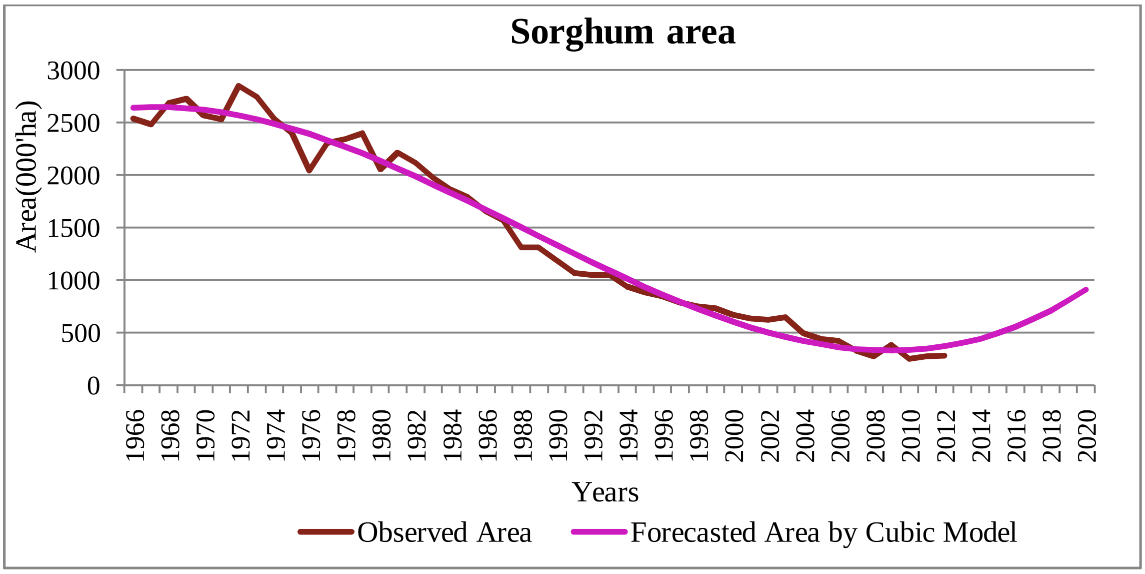


Fig. 4.16.Observed and forecasted trends of Sorghum area in Andhra Pradesh

Regarding the production also cubic model was selected as the best fitted model for future forecasts by 2020 AD as it had the highest Theil's U-Statistic (model accuracy), highest R^2 and Adjusted R^2 having least MAPE values. By using this model the forecasted production would be 775.50 thousand tonnes. The forecasted values of sorghum production showed an increasing trend by 2020 AD. Based on the best identified fitted (cubic) model the sorghum production was forecasted and tabulated in the Table 4.25.

Table 4.25. Forecasted values of Sorghum production by cubic model

Year	Forecasted Production ('000 tonnes)
2013	490.93
2014	514.80
2015	543.99
2016	578.71
2017	619.21
2018	665.68
2019	718.37
2020	775.50

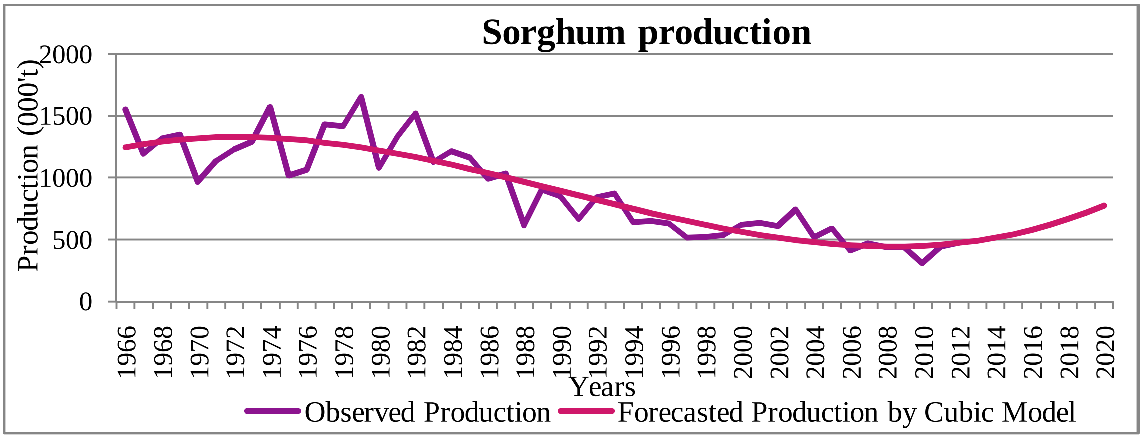


Figure 4.17. Observed and forecasted trends of Sorghum production in Andhra Pradesh

Among all linear, non-linear and Time series models productivity of sorghum was forecasted by using cubic model which had exhibited highest Theil's U-Statistic (model accuracy), highest R^2 and Adjusted R^2 having least MAPE values. By using this model the forecasted productivity would be 2409.25 kg ha^{-1}. The forecasts showed an increasing trend by 2020 AD from the Average of study period. Based on the best identified fitted (cubic) model the sorghum productivity was forecasted and tabulated in the Table 4.26. Similar results were observed by Rahman and Imam (2008)

4.26. Forecasted values of Sorghum productivity by cubic model

Year	Forecasted Productivity (kg ha^{-1})
2013	1677.91
2014	1767.00
2015	1860.99
2016	1960.01
2017	2064.21
2018	2173.73
2019	2288.69
2020	2409.25

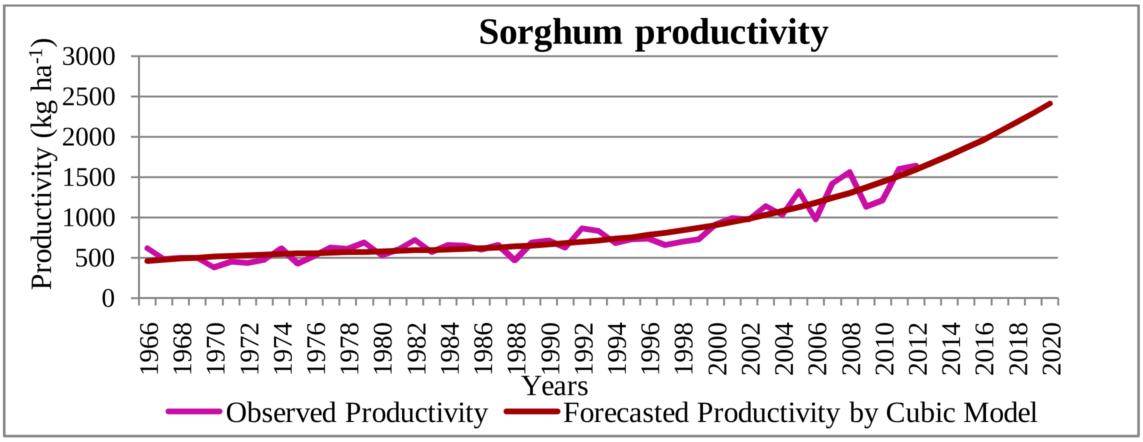


Fig. 4.18. Observed and forecasted trends of Sorghum productivity in Andhra Pradesh

4.3.3. Pearl millet

The future forecasts of area, production and productivity of pearl millet by 2020 AD were calculated and the results were presented as follows.

Area of pearl millet in Andhra Pradesh was forecasted by ARIMA (0,1,1) model because Fig. 4.19. shows that the forecasted values of damped trend exponential smoothing values recorded negative so next preference was given to ARIMA (0,1,1) model which was found to be the best fit as it had highest Theil's U-Statistic (model accuracy), highest R^2 and Adjusted R^2 having least MAPE values for predicting the area for future years. The forecasted values of area showed decreasing trend by 2020 AD from the average of study period. Based on the best identified fitted model ARIMA (0,1,1) the pearl millet area was forecasted and presented in the Table 4.27.

Table 4.27. Forecasted values of Pearl millet area by ARIMA

Year	Forecasted Area ('000 hectares)
2013	54
2014	49
2015	45
2016	41
2017	37
2018	33
2019	30
2020	27

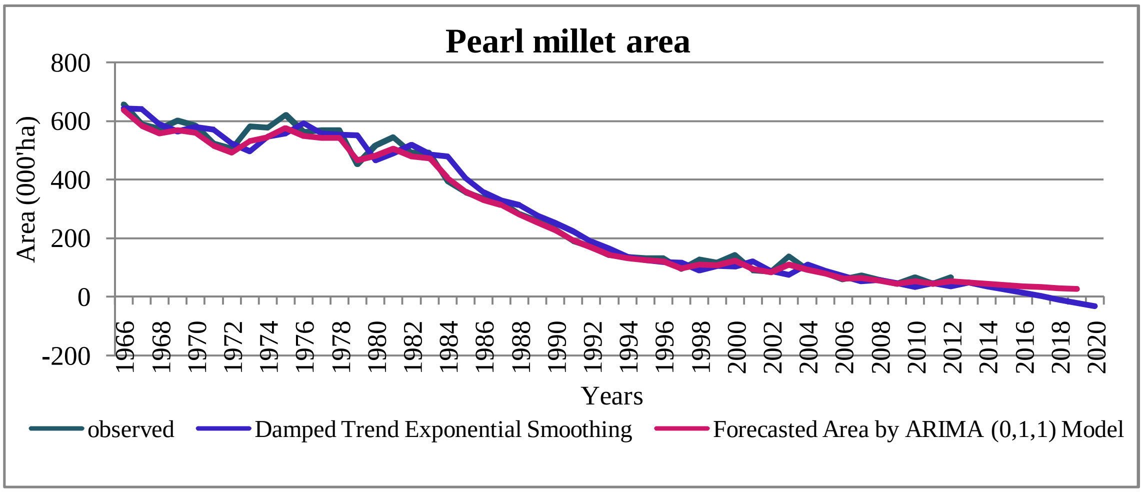


Figure 4.19. Observed and forecasted trends of Pearl millet area in Andhra Pradesh

Regarding the production of pearl millet crop also cubic model was selected as the best for future forecasts by 2020 AD as it had the highest Theil's U-Statistic (model accuracy), highest R^2 and Adjusted R^2 having least MAPE values. By using this model the forecasted production would be 282.26 thousand tonnes. The forecasted values of pearl millet production showed an increasing trend by 2020 AD from the average of study period. Based on the best identified model (cubic) the Pearl millet production was forecasted and tabulated in the Table 4.28.

Table 4.28. Forecasted values of Pearl millet production by cubic model

Year	Forecasted Production ('000 tonnes)
2013	119.74
2014	135.51
2015	153.60
2016	174.11
2017	197.14
2018	222.78
2019	251.12
2020	282.26

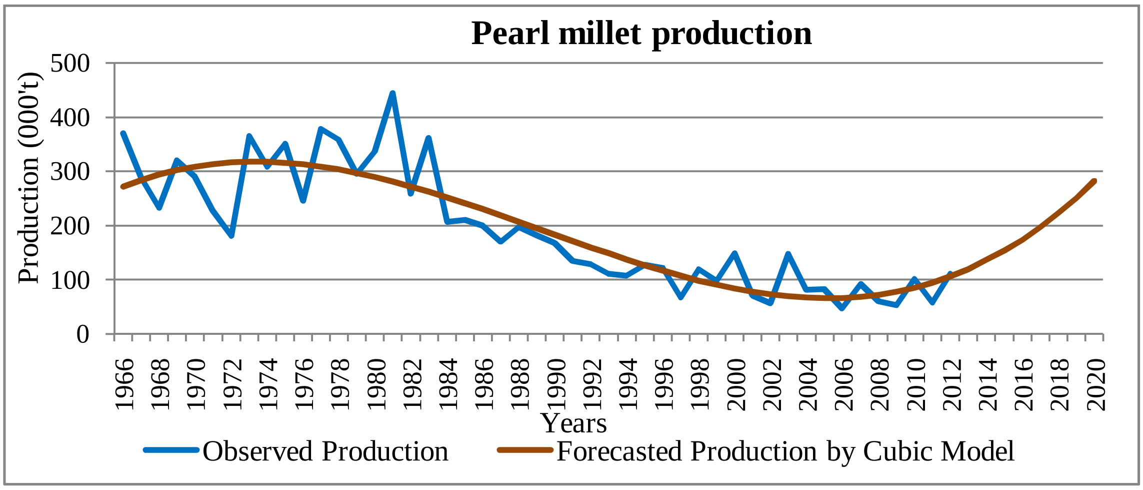


Figure 4.20. Observed and forecasted trends of Pearl millet production in Andhra Pradesh

Productivity of pearl millet crop also forecasted by using cubic model which had exhibited highest Theil's U-Statistic (model accuracy), highest R^2 and Adjusted R^2 having least MAPE values. By using this model the forecasted productivity would be 2232 kg ha^{-1}. The forecasts showed an increasing trend by 2020 AD and it was presented in Table 4.29. The results were in confirmation with those obtained by Hassan *et al.* (2011) and Hossain and Hassan (2013).

Table 4.29 Forecasted values of Pearl millet productivity by Cubic model

Year	Forecasted Productivity (kg ha^{-1})
2013	1542.77
2014	1625.13
2015	1712.61
2016	1805.37
2017	1903.58
2018	2007.40
2019	2116.99
2020	2232.53

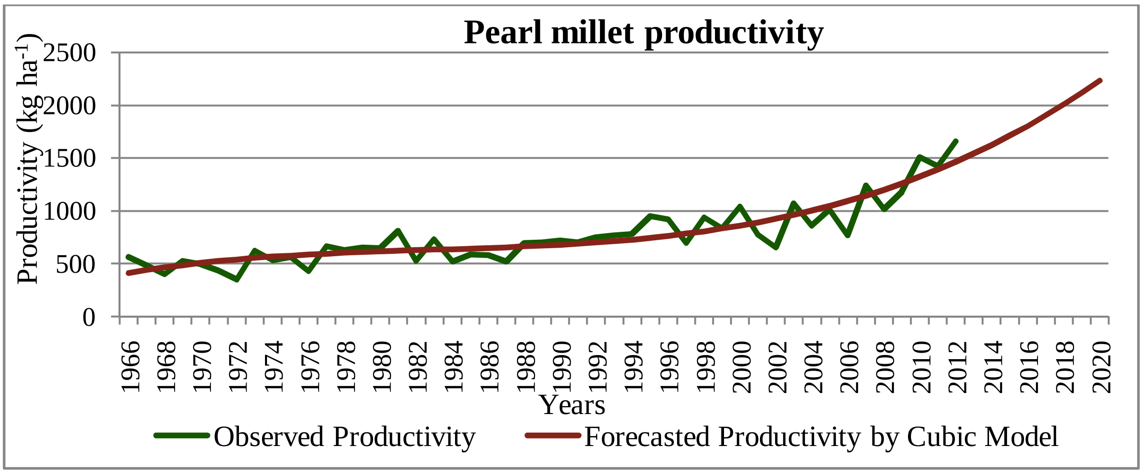


Figure 4.21. Observed and forecasted trends of Pearl millet productivity in Andhra Pradesh

4.3.4. Finger millet

The future forecasts of area, production and productivity of Finger millet by 2020 AD were calculated and the results were presented as follows.

ARIMA (1, 1, 1) model was found to be best fitted model for forecasts of finger millet area in Andhra Pradesh as it had highest Theil's U-Statistic (model accuracy), highest R^2 and Adjusted R^2 having least MAPE values. So the forecasted area of Finger millet by 2020 AD would be 0.91 thousand hectares. The forecasted values of area showed a decreasing trend by 2020 AD from the Average of study period. Based on the best identified model (ARIMA) the area of Finger millet was forecasted and tabulated in the Table 4.30. Similar results were obtained in the same situation by Chandran and Pandey (2007).

Table 4.30. Forecasted values of Finger millet area by ARIMA Model

Year	Forecasted Area ('000 hectares)
2013	9.44
2014	8.03
2015	6.27
2016	4.49
2017	2.93
2018	1.74
2019	1.04
2020	0.91

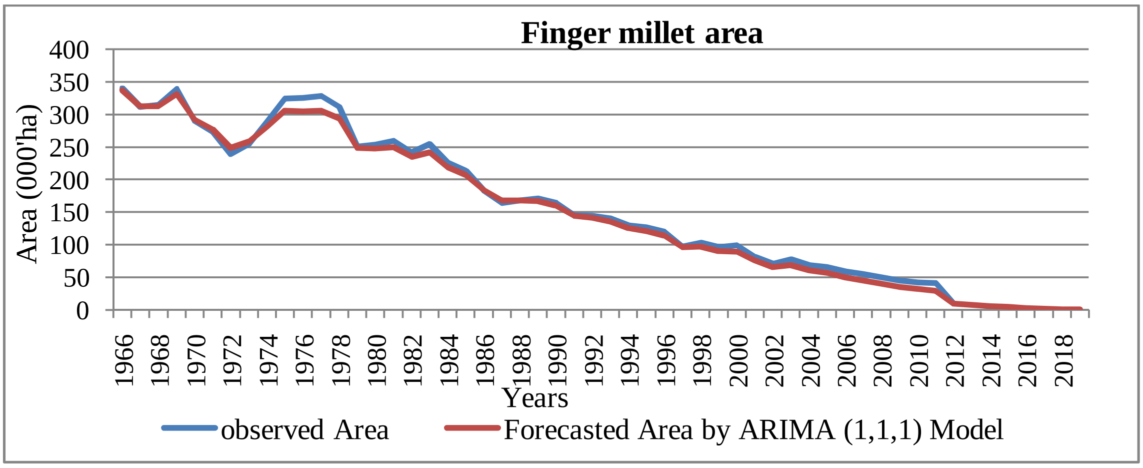


Figure. 4.22. Observed and forecasted trends of Finger millet area in Andhra Pradesh

Regarding the production of finger millet ARIMA (1, 1, 1) was selected as the best fitted model for future forecasts by 2020 AD as it had exhibited highest Theil's U-Statistic (model accuracy), highest R^2 and Adjusted R^2 having least MAPE values. By using this model the forecasted production would be 90.16 thousand tonnes. The forecasted values of finger millet production showed a decreasing trend by 2020 AD from the average of study period. Based on the best identified fitted (ARIMA) model the finger millet production was forecasted and tabulated in the Table 4.31. Similar results were reported by Iqbal *et al*. (2005) and Pal *et al*. (2007).

Table 4.31. Forecasted values of Finger millet production by ARIMA model

Year	Forecasted Production ('000 tonnes)
2013	12.96
2014	11.40
2015	8.93
2016	6.37
2017	4.16
2018	2.55
2019	1.67
2020	1.62

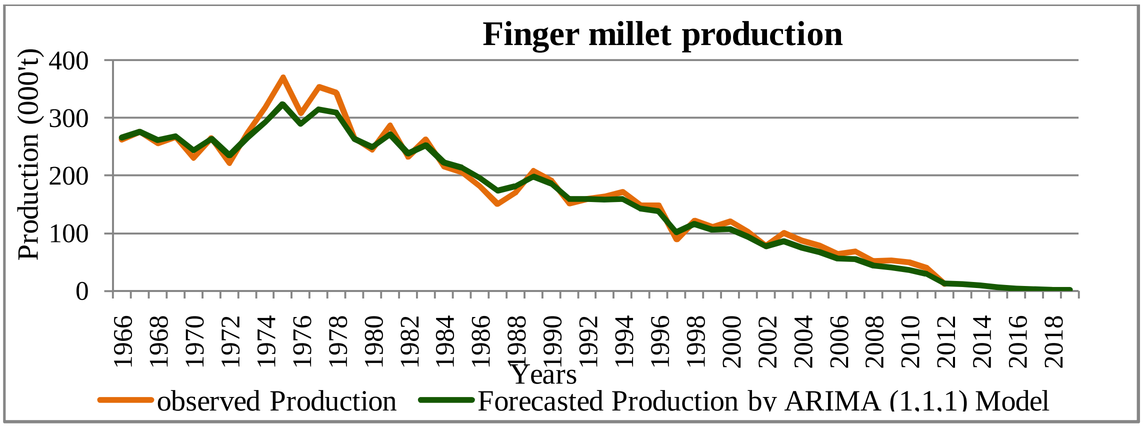


Figure 4.23.Observed and forecasted trends of Finger millet production in Andhra Pradesh

Productivity of finger millet was forecasted by using Power model which had exhibited highest Theil's U-Statistic (model accuracy), highest R^2 and Adjusted R^2 having least MAPE values. By using this model the forecasted productivity would be 1214.21 kg ha^{-1}. The forecasts showed an increasing trend by 2020 AD from the Average of study period and results were presented in the Table 4.32.

Table 4.32. Forecasted values of Finger millet productivity by power model

Year	Forecasted Productivity (kg ha^{-1})
2013	1194.59
2014	1197.54
2015	1200.44
2016	1203.29
2017	1206.09
2018	1208.84
2019	1211.55
2020	1214.21

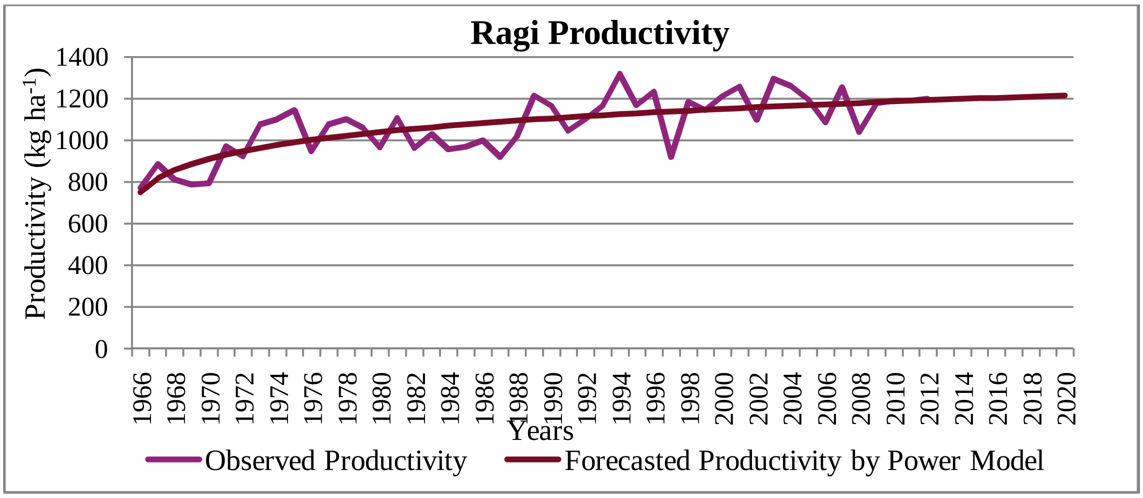


Figure 4.24. Observed and forecasted trends of Finger millet productivity in Andhra Pradesh

Chapter V

SUMMARY AND CONCLUSIONS

This chapter presents the summary and conclusions of the study and suggestions for future work.

INTRODUCTION

The present investigation has been undertaken to identify the best Linear and Non-Linear growth models, time series models like ARIMA, Exponential Smoothing models etc., to predict the future forecasts (up to 2020 A.D) in area, production and productivity of major coarse cereals like Maize, Sorghum, Pearl millet and Finger millet crops during the study period from 1966-67 to 2012-13. The best fitted model was chosen based on model selection criteria like highest Theil's U-Statistic, highest coefficient of determination (R^2), Adjusted R^2 and with least MAPE values for the purpose of future forecasts up to 2020 A.D. The analysis has been taken in Andhra Pradesh.

Some statistical analyses like correlation analysis, multiple linear regression analysis were used to know the influence of weather parameters on productivity of Maize, Sorghum, Pearl millet and Finger millet crops.

This study aimed to make a long-term forecast analysis on crop production and thus provide the public, researchers, and decision-makers with basal data on crop production in the future. The results will help people to understand possible changes in crop production, make decisions for agricultural management and food commerce, etc.

The time series data pertaining to area, production and productivity of major coarse cereals in Andhra Pradesh were collected from Statistical abstracts of Andhra Pradesh and Ministry of Agriculture, Govt of India, www.indiastat.com for the period of 47 years i.e., from 1966 to 2012.

The purpose of research was to develop suitable models for describing future forecasts by employing different linear, non-linear models like linear, logarithmic, inverse, quadratic, cubic, compound, S-curve, growth, power and exponential and time series models like ARIMA, Exponential Smoothing methods which include Linear (Holt) Exponential Smoothing, Damped (Brown) Exponetial Smoothinmg, Linear Trend, Log Linear Trend Exponential Smoothing etc., The model which showed relatively the highest model accuracy (Theil's U-Statistic), coefficient of determination (R2) with significant adjusted R2 having least MAPE was chosen for the purpose of forecasting of area, production and productivity of different crops up to 2020 A.D.

The analysis of area, production and productivity of major coarse cereals in Andhra Pradesh revealed the following features over a period of time. The highlights of the results are enumerated below:

It is observed that the average area, production and productivity under maize in Andhra Pradesh during the study period were 422 thousand hectares, 1232 thousand tonnes, and 2418 kg ha-1 respectively. The future forecasts of area by ARIMA indicated that there would be substantial increasing trend and the future forecasts by cubic model was indicated that there would be substantial increasing in production and productivity in the future. It was observed that the forecasted area by 2020 AD would be 1374.47 thousand hectares. The forecasted production and productivity would be 8282.41 thousand tonnes and 10860.94 kg ha-1 respectively by 2020 AD.

The average area, production and productivity under sorghum in Andhra Pradesh during the study period were 1449 thousand hectares, 906 thousand tonnes and 779 kg ha-1 respectively. The future forecasts were worked out by cubic model revealed that there would be substantial increase in area, production and productivity of sorghum crop. The forecasted area, production and productivity by 2020 AD would be 913.49 thousand hectares, 775.50 thousand tonnes and 2409.25 kg ha-1 respectively.

The average area, production and productivity under Pearl millet in Andhra Pradesh during the study period were 308 thousand hectares, 193 thousand tonnes and 767 kg ha-1 respectively. Among all linear, non-linear, time series models and exponential smoothing models the future forecasts were calculated by cubic model revealed that there would be gradual increase in area, production and productivity of Pearl millet. The forecasted area under Pearl millet by 2020 AD would be 349.71 thousand hectares, forecasted production under Pearl millet would be 282.26 thousand tonnes and forecasted productivity is expected to be 2232.53 kg ha-1 by 2020 AD.

The average area, production and productivity of finger millet in Andhra Pradesh during the study period were 178 thousand hectares, 182 thousand tonnes and 1074 kg ha-1 respectively. The future forecasts of area and production were worked out by ARIMA (0,1,1) model. The forecasts indicated that there would be considerable decrease in area and production of finger millet. But regarding productivity of finger millet, it was found that power model was best fitted for future forecasts and it revealed that there would be an increasing trend. It was observed that the forecasted area of Finger millet by 2020 AD would be 0.91 thousand hectares in Andhra Pradesh, the forecasted production and productivity would be 1.62 thousand tonnes and 1214.21 kg ha^{-1} respectively by 2020 AD.

In turn productivity of major coarse cereals like Maize, Sorghum, Pearl millet and Finger millet were affected by weather parameters like Maximum temperature (^{0}C), Minimum temperature (^{0}C), Rainfall (mm), Morning Relative Humidity (RH1) (%) and Evening Relative Humidity (RH2) (%) etc., Hence, influence of weather parameters on Productivity was also analyzed by using Karl Pearson's correlation and Multiple Linear Regression Analysis. It is observed that there was non-significant correlation with rainfall, maximum temperature and minimum temperatures. RH1 and RH2 were positively significant in productivity of maize.

In case of sorghum productivity RH1was found to be positively significant and all other parameters were found to be non-significant.

In Pearl millet, where RH1and RH2 was found to be positively significant and all other parameters were found to be non-significant in productivity

In Finger millet productivity RH1 was found to be positively significant and all other parameters were found to be non-significant.

Multiple Linear Regression technique was applied to estimate the productivity of major coarse cereals like maize, sorghum, pearl millet and Finger millet based on weather parameters. The results revealed that predicted model was found to be significant at 5% level in the entire selected crops productivity on the weather parameters. Morning relative humidity (RH1) was positively significant at 1% level on productivity. But with lowest coefficient of determination it can be concluded that other than weather parameters many factors are influencing the productivity of Maize.

In sorghum, for productivity rainfall was negatively significant at 5 percent level, RH1 was positively significant at 1% level. But with lowest coefficient of determination other than weather parameters many factors are influencing the productivity of Sorghum.

In case of pearl millet productivity among all weather parameters RH1 was found to be positively significant at 5% level. But with lowest coefficient of determination other than weather parameters many factors are influencing the productivity.

For finger millet crop also among all the weather parameters RH1 was positively significant at 5% level. But with lowest coefficient of determination other than weather parameters many factors are influencing the productivity of Finger millet.

CONCLUSIONS

- The study reveals that cubic model was identified as the best model in maize production and productivity, sorghum area, production and productivity, pearl millet production and productivity.
- ARIMA (0, 1, 1) model was best fitted in maize area and pearl millet area.
- ARIMA (1, 1, 1) model was best fitted in finger millet area and production. But regarding productivity of finger millet, it was found that power model was best fitted.
- It was observed that maize, Sorghum crops showed increasing trend by 2020 AD in area, production and productivity. In pearl millet area showed decreasing trend, production and productivity showed increasing trend and for finger millet crop area and production showed decreasing trend but productivity showed an increasing trend.
- The association of weather parameters on productivity was measured using Karl Pearson's correlation where RH1 and RH2 showed significant correlation with productivity of Maize crop.
- In Sorghum crop RH1 showed significant correlation with productivity.
- In Pearl millet, RH1and RH2 showed significant correlation with productivity.
- In case of Finger millet for productivity only RH1 showed significant correlation.
- The Multiple Linear Regression Analysis revealed that the predicted models for all the crops were significant in RH1. It was also identified that other than weather parameters many factors like soil, chemicals, fertilizers etc., are influencing productivity of these crops.

IMPLICATIONS

1. Third degree polynomial was found to be best fitted in predicting the future forecasts in area, production and productivity of coarse cereals. This model is easy to use, based on the information obtained. Hence this model can be used to found the trend in future which will be useful for policy makers.

2. Forecasting the production of crops is very useful for international marketing, exports and imports of these commodities.

3. Price fluctuations, demand can also be estimated with these forecasts. This could be used as a guideline for policy makers in order to bring about the development of the country.

FUTURE LINE OF WORK

The present study was limited to coarse cereals only with few models. Therefore it is suggested

1. Different crops data can be used to fit models and also for the forecasting.

2. Other non-linear regression models like Morgan Mercer Flodin (MMF), Richards, Weibull and Sinusoidal can also be used.

3. Other advanced forecasting models like Artificial Neural Networks (ANN) can also be used for forecasting.

4. The Andhra Pradesh data on coarse cereals was taken, hence different states and countries data can be used to fit models and to forecast different crops.

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*** Originals not seen**

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