RICE PRODUCTION IN KONKAN REGION- AN ECONOMIC ANALYSIS

By

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M.Sc. (Agri.)

DEPARTMENT OF AGRICULTURAL ECONOMICS,
FACULTY OF AGRICULTURE,
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JUNE, 2017

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A thesis submitted to the
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DR. BALASAHEB SAWANT KONKAN KRISHI VIDYAPEETH, DAPOLI
(Agricultural University)
Dist. Ratnagiri (Maharashtra State), India

In partial fulfillment of the requirements for the degree of

Doctor of Philosophy (Agriculture)

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CERTIFICATE

This is to certify that the thesis entitled, **"RICE PRODUCTION IN KONKAN REGION- AN ECONOMIC ANALYSIS"** submitted to the Faculty of Agriculture, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli, Dist. Ratnagiri, Maharashtra State, in the partial fulfillment of the requirements for the degree of ***Doctor of Philosophy (Agriculture)*** in **AGRICULTURAL ECONOMICS**, embodies the results of a piece of *bona-fide* research carried out by **MISS. SHINDE ARCHANA AMRUT** under my guidance and supervision and that no part of this thesis has been submitted for any other degree or diploma or published in other form. All the assistance and help received during the course of investigation and the sources of literature have been duly acknowledged by her.

Place: Dapoli
Dated: June, 2017

(V. A. Thorat)
Chairman, Advisory Committee
and Research Guide

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Now as I carry this thesis in my hand, I carry with me memories that will enrich my nostalgia.

Place: Dapoli

Date: June, 2017 **(Archana Amrut Shinde)**

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Thesis title	**:**	"Rice Production in Konkan Region – An Economic Analysis".
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THESIS ABSTRACT

The production of rice globally exhibited a fluctuating trend in the past few years. In 2014-15, the global production of rice was 479 million tonnes. India ranks second in terms of total rice production in the world, after China. India provides around 21 per cent of global rice production from its 28 per cent of the world's rice area. Uttar Pradesh ranks first in area under rice crop which is 5.87 million hectares during 2015-16. However, for the same period, West Bengal ranks first in production of rice crop i.e. 14.71 million tonnes and Punjab has the highest rice productivity of 3.84 t ha^{-1} in India. The total area under rice crop was 15.03 lakh hectares during 2015-16 which contributed 19.60 per cent of the total area under cereal crops (76.67 lakh hectares) in Maharashtra. The Konkan region occupies about 4.01 lakh hectares area under rice with production of about 11.28 lakh tonnes with productivity around 2.81 t ha^{-1}. The various methods are used by various scientists to predict the functional relationship between production and weather parameters. A research work in this aspect is needed for forecasting of the agricultural production in the heavy rainfall area like Konkan region. Thus, the present study entitled, "Rice Production in Konkan Region- an Economic Analysis" was undertaken to explore this particular aspect with the following specific objectives: i) To study the performance of rice with respect to area, production and productivity in Konkan region. ii) To examine the instability in the rice production. iii) To assess the impact of weather parameters on rice production. iv) To forecast the rice production in Konkan region.

Methodology:

The area under rice in Konkan region accounts for about 28 per cent of area in the state and production to 43.42 per cent. In view of this Konkan region was selected

purposively for the present study. The study is restricted to four districts of the Konkan region viz., Thane (Old), Raigad, Ratnagiri and Sindhudurg. The required data on area, production and productivity for the period 1989-90 to 2014-15 were obtained from the different published records of the State Government, Private institutions viz., Season and Crop Report, Statistical Abstract of Maharashtra State, District-wise Agricultural Data Base for Maharashtra, etc. The data on different weather parameters were obtained from the Indian Meteorological Department (IMD), Pune. Analysis of data was carried out with trend analysis and instability in area, production and productivity of rice crop; forecast models for rice production viz. regression analysis, aridity index method, ARIMA modeling and Artificial Neural Network (ANN) were employed to obtain forecast of the rice production and these models were compared by using different criteria.

Findings:

The trend analysis indicated that, over a period of time in Konkan region area under rice has declined. The decline in area under rice was more in Thane and Raigad districts. This could be attributed to fast urbanization, industrialization and shifting of agricultural land to non-agricultural uses in these districts. Thus, the hypothesis that “Area under rice in Konkan region is decreasing’ has been accepted. However, there has been increase in production and productivity of rice during the period under study. This significant increase in production and productivity could be attributed to development of different rice production technologies by Dr. B.S.K.K.V., Dapoli.

The analysis of instability revealed that, during the study period, area under rice was relatively stable whereas, there was great instability in production as well as productivity of rice in Konkan region. The instability in production and productivity of rice may be due to adoption of modern technologies by the rice farmers in Konkan region. In view of this the hypothesis that ‘production and productivity of rice in Konkan region is unstable’ is accepted.

It was observed that in Konkan region, among different weather parameters, maximum temperature of stage III, relative humidity of Stage I and sunshine hours in Stage I of crop growth had significant influence on production of rice.

Aridity index method was found inefficient for forecasting of rice production in Konkan region, as Konkan region falls under high rainfall area.

By ARIMA modeling, the models found best for Raigad, Ratnagiri, Sindhudurg and Thane district were ARIMA(0,0,3), ARIMA(0,0,2), ARIMA (0,0,1) and ARIMA

(0,0,2), respectively. The best fit model for Konkan region by ARIMA modeling was ARIMA (0,0,1) model.

Among the forecasting models studied, based on best model fit criteria, Artificial Neural Network (ANN) model was found to be most efficient for forecasting of rice production in Konkan region.

CHAPTER I

INTRODUCTION

The production of rice globally exhibited a fluctuating trend in the past few years. In 2014-15, the global production of rice was 479 million tonnes. This decreased to 473 million tonnes in the following year of 2015-16, registering a year on year decline of 1.2%. The 2016-17 global rice projection is seen at a new peak driven mainly by improved crops in Asia and particularly in India. In 2016-17, the global rice production was projected to increase to 486 million tonnes. This is an increase of 2.6 per cent when compared to the previous year of 2015-16 and 1.4 per cent increase when compared to 2014-15. Unlike fluctuating production during the period of three years from 2014-15 to 2016-17, the consumption of rice was however maintaining an increasing trend. In 2014-15, the total global consumption of rice was 481 million tonnes which increased marginally to 483 million tonnes in 2015-16. The total consumption of rice in the current year of 2016-17 is projected at 488 million tonnes. Based on current weather and planting indications as latest as July 2016, according to the FAO market indicator, forecast of world paddy production in 2016 was 746.8 million tonnes. This is an increase of 1.3 million tonnes as compared to the previous year. When translated in terms of milled basis, this is equivalent to 496.0 million tonnes. (**Source:** U.S. Department of Agriculture)

1.1 Scenario of rice production in India

India ranks second in terms of total rice production in the world, after China. The production scenario in the country has remained more or less same in the recent years. India provides around 21 per cent of global rice production from its 28 per cent of the world's rice area. Rice area in India has fluctuated fairly around 43.6 million hectares during the last two decades, with a maximum rice area of 45.5 million hectares in 2008-2009. Total rice production was maximum during the year 2013-14 (106.7 million tonnes) during the last two decades. Whereas, India's rice production decreased marginally to about 104.8 million tonnes during 2015-16. The total supply of rice in the country including imports was about 128 million tonnes and India exported about 12 million tonnes of rice in 2014-15. However, in 2015-16, the total supply of rice in the country decreased to 121 million tonnes and the total quantity of rice export from India was about 9 million tonnes. This year, the projection of total rice production in the country was about 107.5 million tonnes and the total supply was projected to be around 119.5 million tonnes in 2016-17. Total export of rice from India was projected to decrease to about 7.5 million tonnes in 2016-17. Rice productivity, which was at 1,740 kg ha^{-1} in 1990-1991, reached to 2,290 kg ha^{-1} in 2014-2015 with maximum of 2,461 kg ha^{-1} in 2012-2013. In India, rice is grown mostly in two major seasons, kharif (June – October) and rabi (October – February), while in some parts it is grown throughout the year. Rice in terms of area and production is highest during the kharif season, but rice productivity is higher in the rabi season. (**Source:** Rice in India: A Handbook of Statistics. Directorate of Rice Development, Patna).

The major rice growing states in India are West Bengal, Uttar Pradesh, Madhya Pradesh, Punjab, and Odisha. Uttar Pradesh ranks first in area under rice crop which is 5.87 million hectares accounts to 13.38 per cent of the total area under rice in India. However, West Bengal ranks first in production of rice crop i.e. 14.71 million tonnes which accounts to 14.04 per cent of the total production of rice in India. Punjab has the highest rice productivity of 3.84 t ha^{-1} in India.

1.2 Scenario of rice production in Maharashtra

Maharashtra is one of the important rice producing states in India which ranks 14^{th} in total production of rice. Rice is the second important crop after Sorghum in Maharashtra State. The total area under rice crop was 15.03 lakh hectares during 2015-16 which constituted 19.60 per cent of the total area under cereal crops (76.67 lakh hectares) in Maharashtra. Rice covered 37.60 per cent of total cereals production in Maharashtra, accounted to 25.93 lakh tonnes during the year 2015-16. The average productivity of the state was 1.73 t ha^{-1} for the year 2015-16. As regards to overall productivity, Uttar Pradesh ranks first with 5.98 million tonnes per hectare followed by West Bengal with 5.51 million tonnes per hectare and Andhra Pradesh with 4.36 million tonnes per hectare. The average productivity of the Maharashtra state is too low as compared to other major rice growing states viz. West Bengal, Uttar Pradesh, Madhya Pradesh, Punjab, Odisha etc.

In the Maharashtra state, rice is grown in various districts with varying extent. However, the major rice growing districts are Raigad, Palghar, Thane, Ratnagiri, Sindhudurg of Konkan region; Pune, Satara Sangli, Kolhapur districts of Pune division and Nashik, Nandurbar of Nashik division. Among these, Raigad district of Konkan region has highest area under rice (1.25 lakh hectare) along with highest production of 3.51 lakh tonnes.

1.3 Scenario of rice production in Konkan region

The Konkan region occupies an area of about 4.01 lakh hectares under rice with production of about 11.28 lakh tonnes with productivity around 2.81 t ha^{-1}. The Konkan region comprises five districts viz., Raigad, Palghar, Thane, Ratnagiri and Sindhudurg. The area under rice in Raigad districts is 1.25 lakh hectares with a production of 3.51 lakh tones of rice, which is the highest in Konkan region. Sindhudurg has highest productivity in Konkan region with 3.25 t ha^{-1}. Thane is supposed to be the lowest in area (0.58 lakh hectare), production (1.40 lakh tonnes) and productivity (2.42 t ha^{-1}) of rice in Konkan region. (**Source:** Socio-economic Review and District Statistical Abstracts of the Thane, Raigad, Ratnagiri and Sindhudurg districts 2014-15).

1.4 Weather forecasting for agriculture

Weather forecasting is defined as prediction of the state of the atmosphere for a given location applying the principles of physics, supplemented by a variety of statistical and empirical techniques and by technology. In addition to predictions of atmospheric phenomena themselves, weather forecasting includes predictions of changes on Earth's surface caused by atmospheric conditions (Cahir, 2013). Weather forecasts are important because they are issued to protect life and property, to save crops and to tell us what to expect in our atmospheric environment. Therefore, human beings have attempted to predict the weather informally for millennia and formally since the 19^{th} century for a variety of public and private uses, and some authors believed that an economic value resides behind weather forecasts and tried to estimate it through different methods (Craft, 2010).

Public uses can range from severe weather alerts and advisories to protect lives and minimize losses, to air and marine traffics both very sensitive to the weather. Utility companies (electricity, gas) rely on weather forecasts to anticipate demand which can be strongly affected by the weather. Furthermore, weather forecasting is essential in forests' management for preventing and controlling wildfires and for predicting conditions for the development of harmful insects. Weather forecasting has private uses as well. Increasingly, private companies pay for weather forecasts tailored to their needs so that they can increase their profits or avoid large losses. For example, supermarket chains may change the stocks on their shelves in different weather conditions.

Similar to the private sector, military weather forecaster's present weather conditions to the war fighter community. For example, a mobile unit in the UK Royal Air Force (RAF), working with the UK Meteorological Office (Met Office), forecasts the weather for regions in which British and allied servicemen and women are deployed.

However, systematic weather records became available during the 17^{th} century and were employed mainly in agriculture (Cahir, 2013) because farmers rely on weather forecasts to decide and plan farm activities. For instance, in the United States, national weather services provided by the Army Signal Corps beginning in 1870 were taken over by the Department of Agriculture in 1891 and by the early 1900s free mail service and telephone were providing forecasts daily to millions of American farmers, and by the 1920s radio broadcasts to agricultural interests were being made in most states.

1.5 Forecast models

In the past the human forecaster was responsible for generating the entire forecast based on available observations; today model based forecast is taking place and the human input is generally confined to choosing a model based on various parameters, such as model biases and performance. Using a consensus of forecast models, as well as ensemble members of the various models, can help reduce forecast error. However, forecasters are required to interpret the model data into weather forecasts and compare the model predictions against actual observations. If necessary, they modify a forecast if it is going wrong (Bengtsson, undated).

Many proposed prediction models of crop yield have been divided into two categories of mechanistic and empirical approaches (Poluektov and Topaj, 2001). The mechanistic models use mathematical functions to represent physical, biological, and chemical processes (Whisler *et. al.,* 1986). However, these models are suitable for areas outside the data range used for development. They tend to be complex and require many input parameters (Wang *et. al.*, 2002; Basso *et. al.*, 2001; Bolte, 1997). The empirical models are based on correlative factors between variables, which are relatively simple and require less data; but such models cannot be used in the areas outside data range that they have been created for. In early 1920s, simple descriptive approaches of the relationship between weather and crop growth were advented (Landau *et. al.*, 2000). Many such factors as changes in the weather conditions, soil moisture, topology, plant root water uptake, temperature-related stress, and the degree of nutrient consumption will affect crop yield. Predictive yield models needed many input data, the collecting of which is difficult. With increasing knowledge on plant growing processes and the way to express them by mathematical formulations, deterministic models have reached a high complexity. Simulations consider full crop developmental stages and/or durations between them as well as the plant reactions in different phenological stages to different environmental conditions by using empirical approximation functions. The underlying assumptions, viz. the response of plant growth to temperature and other environmental parameters during developmental stages are sometimes linear or even constant (Jame *et. al.*, 1999; Porter and

Jame, 1985). There are many studies on modeling crop environment relationships and developing operational yield-prediction systems. Furthermore, requirement for detailed meteorological, soil, and management inputs, not always available everywhere, has to be emphasized.

CropSyst (Cropping Systems Simulation Model) and MEDIWY (Model for Estimation of Dryland and Irrigated Wheat Yield) are two important simulation models (Sepaskhah *et. al.*, 2006; Claudio *et. al.*, 2003). CropSyst, a multi-year, multi-crop, and daily time step cropping system simulation model, was developed to serve as an analytical tool to study the effect of climate, soil and management on cropping system productivity as well as on environment. CropSyst simulates soil water, nitrogen budgets, crop growth and development, crop yield, residue production and decomposition, and soil erosion through water and salinity (Claudio *et al.*, 2003). Sepaskhah *et al.* (2006) evaluated MEDIWY model and modified it for simulation of Sabalan winter wheat under irrigated and rainfed conditions in Maragheh area (Eastern Azarbayejan Province, I. R. Iran) for three consecutive crop years. They compared the simulated and the obtained grain yields. It was found out that the simulated grain yield, under irrigated conditions was satisfactory, but they could not satisfactorily simulate grain yield under rainfed conditions. As a result, a large number of later approaches, models, algorithms, and statistical tools have been proposed and used for assessing yield prediction in agriculture.

Many authors have found linear correlation of yield with soil properties and environmental conditions (Sudduth *et. al.*, 1997; Khakural *et. al.*, 1999; Gemtos *et. al.*, 2004). Many other studies have used linear methods especially multiple linear regressions to predict yields using soil properties (Sudduth *et. al.*, 1997; Khakural *et. al.*, 1999; Wendroth *et. al.*, 1999). Many researchers used simple linear correlation of yield with soil properties, but the results are different from field to field and year to year (Gemtos *et. al.*, 2004; Khakural *et al.*, 1999; Drummond *et. al.*, 1995). Many studies have adopted complex linear methods such as multiple linear regressions, which consist of similar results (Kravchenko and Bullock, 2000; Khakural *et. al.*, 1999; Drummond *et. al.*, 1995). Some scientists proposed non linear statistical methods to investigate the yield response (Adams *et. al.*, 1999; Wendroth *et. al.*, 1999).

The functional relationship between weather factors (like rainfall and temperature) and the crop yield remains the most elusive and mysterious till today and a matter of intense debate, though research in this area dates back to 1900s (Tannura *et. al.*, 2008). Most of the researchers like Oury (1965), Stallings (1961) and Shaw (1964) have rejected the direct use of meteorological variables like rainfall and temperature primarily on the ground that the functional relationship between these variables and yield is not known. Some researchers have used aridity index in the econometric model to measure the impact of weather on crops. Oury (1965) has recommended the inclusion of aridity index into the econometric model of crop weather relation. He has argued that the term 'weather' includes many components and it is very difficult to limit only to one factor since they are interrelated. The aridity index approach is based on the works of Lang (1920), Köppen (1936), De Martonne (1926), Ängstrom (1936) and Thornthwaite (1948) as discussed in Oury (1965) in his study and others like Selyaninov (1928) and Ped (1975). These indexes were obtained by combining monthly data on precipitation and temperature.

Many researches on forecasting have been using the Box-Jenkins (1976) stochastic Autoregressive Integrated Moving Average (ARIMA) model. Badmus and Ariyo (2011) forecasted area of cultivation and production of maize in Nigeria using ARIMA model. Najeeb *et. al.*, (2005), employed Box-Jenkins model to forecast wheat area and production in Pakistan. Falak and Eatzaz (2008) analyzed future prospects of wheat production in Pakistan. They obtained the parameters of their forecasting model using Cobb-Douglas production function for wheat, while future values of various inputs are obtained as dynamic forecasts on the basis of separate ARIMA estimates for each input and for each Province. Rachana *et. al.*, (2010), used ARIMA model to forecast pigeon pea production in India. The Box- Jenkins methodology have been used by a number of researchers to forecast future demands in terms of internal consumption and export to adopt appropriate measures (Muhammad et al., 1992, Shabur and Hague, 1993, Sohail *et. al.*, 1994).

Some adaptive and non-parametric models have been recently introduced in environmental science for predictive purposes. Artificial neural network (ANN) models are a powerful empirical modeling approach and yet relatively simple compared with mechanistic models. The important dilemma in prediction models for crop yield is how the independent variables are coupled to each other. To alleviate this difficulty, ANN models have come to play a role. Expert systems and artificial intelligent algorithms are a relatively new subject of nonlinear techniques. Through ANN models one is able to solve highly nonlinear problems and to approximate virtually any smooth and measurable functions. In comparison to the state of the art of crop models, the requirements concerning the number of input parameters are less. It is felt that ANN models offer a more versatile empirical modeling approach in comparison to the linear regression methods used in rice yield since the rice yield is non-linear and autoregressive in nature.

Because ANN models allow an illustration of complex and non-linear relationships without rigorous assumptions regarding the distribution of samples (Bishop 1995; Breiman *et. al.*, 1984), the method is gaining popularity for research areas where there is little or incomplete understanding of the problem to be solved, but where training data are available. Artificial neural networks can be used to develop empirically based agronomic models. The ANN structure is based on the human brain's biological neural processes. Interrelationships of correlated variables that symbolically represent the interconnected processing neurons or nodes of the human brain are used to develop models. ANN models find relationships by observing a large number of input and output examples to develop a formula that can be used for predictions (Pachepsky *et. al.*, 1996). Nonlinear relationships overlooked by other methods can be determined with little a priori knowledge of the functional relationship (Elizondo *et. al.*, 1994).

Heinzow and Richard (2002) discussed the applicability of ANN models for predicting crop yield under climate change conditions. Input data were daily temperature and precipitation for different growth stages in four German zones. They developed a four layer ANN. Hosseini *et. al.* (2007) adopted ANN and multi-variable regression models for dry land wheat yield in a moderate climate in Ghorve of Kordestan Province, Iran. They showed that ANN model can estimate the crop yield with acceptable accuracy. Maximum and minimum air temperature, daily mean relative humidity, net radiation, precipitation, dew point temperature, and wind velocity were included as input data in their ANN models. Kaul *et. al.* (2005) developed ANN for corn and soybean yield predictions. They used the historical yield data at numerous locations in Maryland, USA. The results indicated ANN models as consistently producing more accurate results than others. Many of researchers have applied neural networks in the modeling of various scenarios to solve different problems, in which no explicit formulations were available (Fang *et. al.*, 2000). The main advantage of neural networks is that they are able to use prior information (historical underlying process data) to develop an accurate representation of the process or relationship of interest. In most studies, a feed-forward Multi- Layered Perception (MLP) paradigm consisting of one or more inputs, hidden layers, and output layer trained by back propagation (BP) is used. Due to its documented ability to model any function, MLP trained with BP is selected to develop apparatus, processes, and product prediction models (Hornik *et. al.*, 1989; Heinzow and Tol 2003; Jebaraj and Iniyan, 2006).

It is better to solve any problem with the minimum number of variables. When the number of variables is notably high, especially when there are limited number of samples, data reduction is useful. Also, when some input variables correlate with one another, another problem that is called multicollinearity, will appear. Correlation between inputs reduces the chance of having a unique solution (Samarasinghe, 2007). The best common method for data reduction and removal of multicollinearity is principal component analysis (PCA). PCA is a useful method to select the most important uncorrelated variables. PCA uses the mean and variance of each input variable and the covariance between variables to create a covariance matrix (COV) (Samarasinghe, 2007) and transforms the COV to obtain independent components that are linear summations of the original inputs. The results allow to either picking of individual original variables that are uncorrelated or use independent components that are independent as inputs to the model.

It is clear that the various methods are used by various scientists to predict the functional relationship between production and weather parameters. A research work in this aspect is needed for forecasting of the agricultural production in the heavy rainfall area like Konkan region. Thus, the present study entitled, "Rice Production in Konkan Region- an Economic Analysis" was undertaken with the following specific objectives:

1.6 Objectives of the study

1. To study the performance of rice with respect to area, production and productivity in Konkan region.
2. To examine the instability in the rice production.
3. To assess the impact of weather parameters on rice production.
4. To forecast the rice production in Konkan region.

1.7 Hypotheses of the study

1. Rice production and productivity in Konkan region is unstable.
2. Area under rice in Konkan region is decreasing.
3. The aridity index approach is superior to regression model by taking the individual meteorological factors.

1.8 Scope and Utility of Study

Konkan region is known as rice bowl of Maharashtra state. However, over the period of time area under rice is decreasing in Konkan region. The main reason may be urbanization and industrialization in the region. Approximate strategies needs to be taken to boost the agricultural development. Before deciding strategies for development, one must decide priorities in terms of development and food security. In food security, identify the existing trends of area, production and productivity that stand in the way of development. In the back drop of ‘doubling farm income’ the results of the study would be useful to the planners, policy makers for deciding future strategies.

1.9 Limitations of the study

The present study was based on the secondary data obtained from government published sources, as well as, from the records of the development agencies in the state. The analysis is limited to the available quantum of the data on the aspects of the study. An attempt is made to carry out analysis of the data by adopting suitable statistical techniques to arrive at the meaningful conclusions. Since the study is confined to Konkan region, results cannot be generalized.

CHAPTER II

REVIEW OF LITERATURE

Review of literature related to research topic is a necessary step in the conduct of any scientific research. It helps us in knowing the relevant research work carried out by other investigators. It provides needed information regarding our study and also helps in formulating the framework of the study, deciding objectives and methods of approach to the problem and analyzing the data collected. The knowledge of similar research work previously carried out relating to the problem under study is useful and provides guidance to the researchers in approaching the research problem and carrying out the research in proper direction. It also helps to compare the results of such other studies and the reasons for the variation. Some of the literature published related to research topic are reviewed in this chapter.

The literature reviewed in the present study was grouped objective-wise under following heads:

2.1 Trends in area, production and productivity of rice crop.

2.2 Growth and instability in area, production and productivity of rice crop.

2.3 Impact of weather parameters on rice production.

- 2.3.1 By Regression analysis.
- 2.3.2 By Aridity index method.
- 2.3.3 By ARIMA modeling.
- 2.3.4 By Artificial Neural network (ANN).

2.4 Forecast of the rice production.

2.1 Trends in area, production and productivity of rice crop.

Rao *et al.* (1981) analyzed the growth of state-wise area, production and productivity of rice in India during pre high yielding variety period (1955-56 and 1964-65) and high yielding variety period (1965-66 to 1977-79) with the help of compound growth rates. They observed that growth rate of area at country level was 0.88 per cent in HYV period as against 1.62 per cent in the pre HYV period. All the states showed low growth rates of area during HYV period, except West Bengal and Punjab, where the growth rate increased from 0.58 to 1.37 per cent and 6.46 to 7.41 per cent, respectively. The country had positive annual productivity growth rate of 2.56 per cent in HYV era, while it was 2.46 per cent in pre HYV era. All the states, barring Assam, experienced positive annual growth rates during both the periods. As regards production, the country experienced annual growth rates of 4.12 and 3.43 per cent in pre-HYV and HYV periods, respectively. This might be due to lower growth rates of area in almost all states.

Desai and Patel (1983) estimated growth rates of production, area and productivity of major foodgrain crops in the four states, viz. Gujarat, Madhya Pradesh, Maharashtra and Rajasthan of the Western region of India. The growth rate of wheat for the period of 1965-66 to 1981-82 was much higher than that of rice in all the four states in the western zone. The highest growth rate was in Rajasthan, followed by Maharashtra and Gujarat. Madhya Pradesh, however, lagged much behind.

Grewal and Rangi (1983) stated that the notable achievement in the production of food grain in the state of Punjab had reflected in the five-fold increase in the index of production of cereals during the period of 1960-61 to 1982-83. The result was that the Punjab state, with less than two per cent of the area in the country, accounted for as much as 60 per cent of the total food grain production for the central pool. The estimates showed that the production of wheat and paddy in the state could be increased by 27.6 per cent and 79.0 per cent, respectively at the end of 1991-92 compared to the level of 1981-82, provided vigorous extension efforts were made to ensure full adoption of known package of technology. This would give an annual increase of 2.76 per cent in wheat production and 7.9 per cent in paddy in the coming decade, compared to the compound growth rate of 5.40 and 17.9 per cent for wheat and paddy, respectively realized during the period 1966-67 to 1981-82.

George and Mukharjee (1986) observed that the annual growth rate of rice area in Kerala between 1960-61 and 1983-84 was only 0.15 per cent. The annual growth rate of area was positive i.e. 1.14 per cent during the first period (1960-61 to 1974-75). It turned out to be negative i.e. –1.50 per cent for the second period (1975-76 to 1983-84). The average annual growth rate of yield for the combined period was 1.01 per cent, while the growth rates of production were positive during both the periods. The growth rates during first period for area, production and yield were 1.14 per cent, 0.92 per cent and 2.06 per cent, respectively, while for the second period, they were 0.15 per cent, 1.01 per cent and 1.16 per cent, respectively.

Tomer (1989) studied the growth of area, production and productivity of important crops in Haryana for the period of sixteen years (1970-71 to 1985-86). Compound growth rates were calculated to examine the pattern of growth in the area, production and productivity of various crops. He observed that area under rice, wheat and cotton went up at the rate of

6.24, 3.42 and 4.28 per cent per annum, respectively. Whereas, the area under maize (5.87 per cent), bajra (3.28 per cent), gram (6.03 per cent) and barley (0.98 per cent) declined during period under study. The productivity of those crops increased for which area was increasing. The growth rates of production showed that rice (9.55 per cent) recorded higher growth, followed by rapeseed- mustard (7.80 per cent), wheat (6.21 per cent) and cotton (4.50 per cent). He concluded that rice, wheat, cotton and rapeseed-mustard were the only crops, which registered an increase in their production since 1970-73 in the state. While, crops like gram, jowar and sugarcane registered a significant decrease in their production. There was a non-significant decrease in production of bajra, maize and barley.

Arya and Rawat (1990) studied the district-wise agricultural growth in Haryana for the 15 years (1966-67 to 1980-81). They concluded that despite the inter state variation, long term trends of consistent increment in area, production and productivity growth were visible for wheat and rice among cereals and potato among commercial crops, barring Rohtak and Gurgaon districts, where productivity growth for rice recorded negative and statistically non significant growth rates. Area, production and productivity growth rates of commercial crops, including oilseeds, sugarcane and cotton, had registered increase in certain districts. The results demonstrated that crops like bajra, jowar, maize, barley and pulses had in general, registered declining trends in the districts. These findings indicated that increase in area under cereals at the cost of pulses and oilseeds had to be curbed.

Kalyankar and Ghulghule (1997) examined the growth in the productivity of major crops among different divisions in the state of Maharashtra for the period 1961 to 1994. They observed that per hectare productivity of paddy was comparatively higher in Konkan and Kolhapur division of Western Maharashtra. The growth rates for total cereals productivity were the highest in Amravati, followed by Kolhapur division. Similarly, higher growth rates were observed for total pulses productivity in Nasik division, while total oilseeds productivity increased with higher rate of growth in Nagpur division. Cotton productivity growth rates were higher than the state in Nagpur, Amravati, Aurangabad, Kolhapur and Pune divisions.

Barmah and Pandey (1998) studied growth trends and variabilities in area, production and productivity of rice crop grown in three seasons (Summer, autumn, winter) in Assam, India for the period 1968-96. The linear and compound growth rates indicated that the highest growth rates in terms of area and production were for summer rice, whereas the highest growth rates in productivity were for winter rice. Winter rice was found to be the most stable crop in terms of area, production and autumn rice in terms of productivity.

Ghosh (2002) studied trend random walks and structural breaks in Indian agriculture and reported that growth in productivity, rather than in area, had been the predominant source of growth in agricultural output. The growth of wheat and rice crop output increased 2.08 per cent and 1.64 per cent respective in first phase (1966-67 to 1970-7l) and 2.38 per cent and 1.80 percent in second phase (1971-72 to 1974-75).

Chethana and Singh (2005) worked out the compound growth rates and quinquennial changes in the area, production and productivity of cotton in Haryana state based on time series data for 1966-67 to 1996-97 compiled from the Statistical Abstract of Haryana. The analysis of data revealed that the area, production and productivity of American cotton had increased at the annual rate of 6.62, 7.70 and 1.02 per cent during 1966-67 to 1996-97. Both the area and production of desi cotton had a growth rate of 1.14 and 0.50 per cent, respectively during the same period. The total area, production and productivity of cotton (both desi and American) had shown a positive growth rate of 4.06, 5.36 and 0.70 per cent per annum during the study period.

Chaudhari and Pawar (2010) studied performance of major cereals in Marathwada region. The study was conducted in districts of Marathwada region to see the performance of major cereals in respect of area, production and productivity. Major cereal crops viz. Kharif sorghum, pearl millet, wheat and Rabi sorghum and total cereals were selected for study. Time series data for the period from 1985-86 to 2004-05, regarding area, production and productivity were collected from Epitome of Agriculture, published by Government of Maharashtra. The compound growth rate was worked out by fitting exponential trend equation and significance was tested with help of correlation coefficient by using ‘t’ test. The results of study revealed that majority of districts showed decline in area under Kharif sorghum and total cereals, whereas the area and production increased in case of pearl millet and wheat during the study period. Stagnation in productivity of Kharif sorghum was observed during the study period while productivity of pearl millet, wheat and total cereals rose in region and State.

Ashok and Sasikala (2011) studied the trends in production and comparison of cost of production and minimum support price of coarse cereal. This study estimates the Compound Growth Rate (CGR) of area, production and productivity of major coarse cereals and analyzes the trends in cost of production of coarse cereals and the Minimum Support Price (MSP) announced by the Government. The study is based on time series data on area, production and productivity of coarse cereals (bajra, maize, ragi, jowar) from 1970-71 to 2007 – 08 in Tamil Nadu. The 38 years data were classified at decadal intervals and the decadal trends in area, production and productivity were analyzed through CGR. The annual compound growth rate in maize crop was 6.32 percent in area, 9.47 per cent in production and 2.00 per cent in yield. In case of bajra, despite the increase in productivity by 1.91 percent, the production of bajra declined at the rate of 2.95 per cent.

Sharma (2013) worked on trends of area, production and productivity of food grain in the north eastern states of India. The study was based on secondary data from 1980-81 to 2011-12. The data were collected from several government publications and web site. To analyze the trend of area, production and productivity of food grains in northeastern states, the linear, quadratic and exponential functional forms were used. To fit the trend, linear functional form was used due to its higher R^2 value as compared to other two forms. Besides these, compound growth rate, coefficient of variation and instability index were also estimated. The effects of area, productivity and their interaction towards increasing production were also estimated in the present study. The growth of area, production and productivity of the total food grain was found to decrease in the state of Manipur, Meghalaya and Tripura during the period.

Borgohain (2013) studied the trend of area, production and productivity of rice crop in Assam and commented, though there was a remarkable shift in the state's economy from primary to secondary and tertiary sector in the recent years, Assam still continues to be predominantly an agrarian economy. Agricultural sector continues to support more than 75% population of the state directly or indirectly providing employment of more than 53% of the total workforce (Economic Survey, Assam, 2011-12). Rice is the main crop of Assam. So, the growth and development of rice cultivation is very important in Assam. The total rice production in the state stands at 1.141 million tonnes to 5.086 million tonnes with an average rice crop yield ranging from 855 kg/ha to 1983 kg/ha during 1950-51 to 2010-11 periods.

Mishra *et. al.* (2013) in their study on instability and forecasting using ARIMA model in area, production and productivity of onion in India, worked out trends in area, production and productivity of onion different parametric models like linear, logarithmic, quadratic, cubic, compound, growth and exponential models. Data related to area, production and yield of onion in India since 1978 to 2008 were collected from Agriculture at Glance, 2010. Since 1978, the area under onion has been increased from 0.21 million ha to 0.83 million ha till 2008, registering a growth of almost 295%. The production from mere 2.20 million tonnes reached to 13.97 million tonnes during 2008 and registering growth of almost 516%. The productivity of onion, which was 9091kg/ha, it has reached to 16260 kg/ha.

Biswas and Bhattachrya (2013) studied ARIMA modeling to forecast area and production of rice in West Bengal. According to them, crop area estimation and forecasting of crop yield are an essential procedure in supporting policy decision regarding land use allocation, food security and environmental issues. The study intended to give a comprehensive picture of rice production in West Bengal since independence. Separate data of area and production of rice in West Bengal were collected over the period of 1947-1948 to 2007-2008. The study reveals that the gross cultivated area from 1947-48 to 2007-08 both exhibits an increasing trend. After green revolution the area is increased only 22.98 per cent while the production is increased 168.73 per cent.

Tripathi *et. al.* (2013) studied past trends and forecasting in area, production and yield of Perl millet in India Using ARIMA model. They estimated trends in area, production and productivity of pearl millet in India. Time series data covering the period of 1950-2010 were used for the study. To work out trends in area, production and productivity of maize in Indian different parameter models like linear, logarithmic, quadratic, cubic, inverse, compound, growth and exponential model were attempted. In area of pearl millet, among all, compound model was found to be more efficient with maximum R^2 (0.377). In case of production of pearl millet, among all, power model was found to be more efficient with maximum R2 (0.618). The compound model was found best fit for explaining trends in productivity with maximum R^2 value of 0.794. The study reveals a spectacular simple growth rates for area, production and productivity of pearl millet. Parametric trend models can adequately delineate trends in area, production and productivity of pearl millet.

Dhekale *et. al.* (2014) studied parametric and non-parametric regression models for area, production and productivity trends of rice (*Oriza sativa*) crop. The present investigation was carried out to study the area, production and productivity trends and growth rates of rice crop grown in Gujarat, India for the period from 1949-50 to 2010-11. In parametric models different linear, non-linear and time-series models were employed. Appropriate time-series model was fitted after judging the time-series data for stationarity and best model was selected on the basis of various goodness of fit criteria viz., Akaike's Information Criterion (AIC), Bayesian Information Criterion (BIC), Root Mean Square Error (RMSE), etc. In nonparametric regression optimum bandwidth was computed by cross-validation method and Epanechnikov-kernel was used as the weight function. Relative growth rates of area, production and productivity were estimated based on the best fitted trend function. The nonparametric regression model emerged as the best fitted trend functions for the area, production of rice crop and for productivity. Gompertz model was best fitted trend function. The percent growth rate values are obtained for the successive years during the period under study for the area, production and productivity, when average showed that the production had increased at a rate of 3.26% per annum, which was due to combined effect of increase in area and productivity at a rate of 0.81 and 1.98% per annum, respectively.

Singh *et. al.* (2014) worked on instability in rice production in Gujarat through a decomposition analysis. The growth rates of rice area, production and productivity during 1982-83 to 2011-12 were 0.41, 1.25 and 0.83 per cent per annum respectively. The growth estimate from last 30 years data showed that negligible increase was recorded in area and production of rice. There was slight change in area under rice cultivation in Gujarat state. During the period 1982-83 to 2011-12, there was slight increase in area by 0.41 per cent per annum. Production and productivity of rice shown positive growth during the study period. Among the selected districts, growth in area was ranges between 0.01 to 1.88 % PA. The production growth was ranges between 0.91 to 2.76 %PA. Highest growth in production was observed in Ahmedabad district. Productivity growth was positive in the selected districts as well as in the state. Presently the yield level of rice in the state is comparatively low from national average need to be increased substantially.

2.2 Growth and instability in the rice production.

Ramesh Chand and Raju (2008) reported that in Andhra Pradesh instability in farm production is causing serious shocks to supply and farm income and there is a growing concern about increased volatility in farm production, prices and farm income. The study has estimated instability in three major crops before (1981-93) and after (1993-04) the initiation of economic reforms at the state and district levels in Andhra Pradesh. Instability index for area has shown an increase after 1992-93 for rice and cotton and decline in the case of groundnut. It increased from 11.5 to 13.4 in rice and from 17.5 to 18.8 in cotton. During both the periods, instability in area was lowest in groundnut. Rice, which is generally grown under irrigated conditions, showed somewhat higher instability in area as compared to groundnut. Area under cotton has shown more than double the fluctuations in area under groundnut. Instability has revealed that in a large state like Andhra Pradesh, and which is the case for most states of India, the instability status as perceived through the state level data may be vastly different from that experienced at the disaggregate level.

The study has concluded that the state level analysis does not reflect complete picture of shocks in agriculture production, and, further, shocks in production underestimates shocks in farm income. It has suggested the need for addressing risks in farm income by devising area-specific crop insurance or other suitable mechanisms.

Shende and Suryawanshi (2009) worked on the growth, instability and decomposition of cotton production in Maharashtra. The study was based on secondary time series data for 45 years. The simple coefficient of variability, Cuddy Della Valle index and Coppock's instability index were used to work out instability in area and productivity of cotton. The results indicated that compound growth rate of area under crop was over one percent for the entire district of all three regions and also the region as a whole during the overall period. The production and productivity instability in cotton crop was observed in almost the entire district in the state. It may be because of the crop largely depends on vagaries of nature and cotton production is subject to fluctuation from year to year and thus, causing heavy losses. A crop failure means not only the loss of farmer's income but also the loss of investment in the next crop season.

Awaghad *et. al.* (2010) assessed growth and instability of kharif sorghum in Western Vidarbh region. The performance of Kharif sorghum in different districts of Western Vidarbh region was studied by estimating the growth rates of area, production and productivity using "Exponential function". The study was based on secondary data collected for the period from 1975-76 to 2004-05. For comparison purpose the time period has divided into two periods i.e. period-I (1975-76 to 1989-90) and period-II (1990-91 to 2004-05). Coefficient of variation and Coppock's instability index has been computed to measure the degree of instability in area, production and productivity of kharif sorghum. The variability in area of kharif sorghum was highest in Buldana district. In case of production of kharif sorghum, the variability during period-II was higher as compared to period-I as well as overall period. Buldana records highest variability in production of kharif sorghum during period-II.

Mrutyunjay Swain (2010) analyzed the nature and sources of agricultural instability in the Bolangir district of Western Odisha, India. The nature of instability in agricultural production is examined by determining the agricultural instability index (AII) of variables such as area, production and yield of food grains and paddy, irrigation coverage, and annual rainfall. The period covered by the study (1984–2009), which is characterized by greater technology dissemination, is categorized into two sub- periods: (1984–1993) and (1994–2009). The effects of a change in major inputs on the variability of crop productivity were assessed using a double-log model. The yield decomposition analysis was used to examine the role of drought risk factors and the amount and productivity of inputs in crop yield growth. The extent of instability in agricultural production and productivity in the region was found to be quite high on account of the high level of rainfall variability and the low irrigation coverage. The value of the AII of production and productivity of food grains had increased from 26.8 per cent and 23.6 per cent, respectively, during Sub-period I to 82.5 per cent and 76.3 per cent, respectively, during Sub-period II. Moreover, the fluctuation in area, production, and yield of food grains and paddy is considerably larger during both periods in the district compared to that in the state. The AII of production and productivity of food grains was 65.2 per cent and 60.2 per cent, respectively, in the district compared to 26.8 per cent and 22.5 per cent, respectively, at the state level during the whole period (1984–2009). The level of instability in food grain production is much larger during the second sub-period.

Sharma (2013) worked on trends of area, production and productivity of food grain in the north eastern states of India. The study was based on secondary data from 1980-81 to 2011-12 collected from government publications and web site. The coefficients of variation (CV) of area, production and productivity of food grain crops were less than 0.551 per cent. The instability indices for area, production and productivity for food grain crops in the northeastern states were positive and thereby indicating less risk for growing food grain crops in the region. The increase in production is due to increase in area as well as interaction of area and productivity of food grain crops in the states.

Paltasingh and Goyari (2013) conducted a study on analyzing growth and instability in subsistence agriculture of Odisha. The study has analyzed the performance of agriculture in terms of growth and instability of yield, area and production of major crops in Odisha. The growth analysis has shown a gloomy picture in the post-reform era, as instability has augmented during this period, rendering the agricultural sector of Odisha as unsustainable. The various causes of low growth rate have been identified. The study has discarded the hypothesis of direct relation between high growth and high instability. Weather variability and price risk as prime source of instability have been analyzed and the study has shown that mainly weather variability plays a pivotal role than price fluctuations in augmenting risk.

Mishra *et. al.* (2013) in their study, instability and forecasting using ARIMA model in area, production and productivity of onion in India, revealed that, being second largest onion producing country, the study of production behavior and its future prediction is of utmost important. Data related to area, production and yield of onion in India since 1978 to 2008 were collected from Agriculture at Glance, 2010. The whole period was divided into two period's viz., period-I from 1978 to 1992 and period-II from 1993 to 2008to compare in area, production and yield between the two periods. Area of onion during the whole period shows highest degree of instability. As far as, the periods are concerned, the area, production and productivity of onion showed higher instability in period-II (1993-2008).

Shaikh and Joshi (2013) analyzed the instability and the growth in cotton area, production and Yield during the period 1977-2007 of three districts in Marathwada, for this purpose Co-efficient of variation, Coppock's Instability and Compound Growth Rate was worked out to find out instability associated. The area and production of Aurangabad is highly insufficient over the 30 year period where as the less variability in area was observed during the period II and the same pattern was observed in the period I. The Jalna has highly insignificant in terms of production and yield but the area has less significant only 26.32% variation was observed. Thus the district has better significant during the period I and period II in area, production and yield which was observed as 5.81% 29.35% and 25.34% respectively. The Beed district has similar pattern of insignificance as Aurangabad in terms of area and production as yield is less significant the district has better performance in significant during the period I and period III in terms of area, production and yield.

Bal Krishan and Amar Chanchal (2014) studied "Agricultural Growth and Instability in Western Himalayan Region: An Analysis of Himachal Pradesh, India". The study looks into the instability in area, production and yield of major crops in three agro climatic regions in the state and other dynamics associated with it. Instability in agricultural production, for any reason, results in unpredictable behavior and decision making from the population engaged in primary sector which is passed on to the economy as a whole.

Singh *et. al.* (2014) worked on the instability in rice production in Gujarat. The study concluded that the coefficient of variation for production of rice in Gujarat was 20.50 per cent for the period 1982-83 to 2011-12. For the selected districts, the coefficient of variation varied from 28 to 70 percent during the study period. The coefficient of variation in production was markedly high for Panchmahal district (70.90 percent) and Vadodara (64.12 percent). Instability was at moderate level in the districts of Ahmedabad (46.16 per cent), Surat (34.56 percent), Kheda (29.01 percent),) and Valsad (28.63 per cent). The coefficient of variation for rice production has been higher for the selected district compared to the state as a whole showing thereby that fluctuation in production was more in the selected districts compared to the state as a whole. Variability in production has been at a higher rate compared to area and productivity variability in this crop. The area-yield co-variance had a stabilizing effect on reduction of instability in rice production It can be inferred that the wide fluctuation in production of rice crop have been due to the high variability in its productivity. The future development programmes should envisage on increase of yield for bringing stabilization in production of the crop. The area instability also needs to be reduced. This could be reduced by more investment on research for rice production technology in the state.

Sihmar (2014) studied the growth and instability in agricultural production in Haryana. He reported that only a few crops such as rice and wheat are going to more stable but the coarse cereals and pulses are going to highest instable in area and production in Haryana. The trends rate of instability in the production of rice declining in Karnal, Kurukshetra, Ambala, Jind, Hisar, Sirsa and Faridabad throughout the study period. Ambala had medium instability during the first period and in the next period it had the lowest instability. Karnal and Kurukshetra, which showed the lowest instability during the first period, have recorded medium instability in second period. Gurgaon, which recorded medium instability during the first period, has recorded highest instability during third period of time. Rohtak has recorded high instability during first and second period, while it shows medium instability during 2000-01 to 2006-07. Because of rain fed area, the instability of rice in Gurgaon is increasing over the time period and registered as the highest instability district during 2000-01 to 2006-07.

Joshi and Singh (2015) performed "An Empirical Analysis of Growth and Instability in Major Spices in India". The study has examined trend in growth and instability of major spices in India for the last 39 years from 1974-75 to 2012-13, which were further divided into three sub-periods. The growth rates were worked out by fitting the exponential growth function and instability analysis was carried out by generating Cuddy Della instability index. The study has observed that almost all the spices have recorded a positive and significant growth rate in all the sub-periods. Sub-period II (1990-91 to 1999-00) is comparatively stable in terms of area, production and productivity in all the spices which also recorded a higher growth rates. Sub-period III (2000-01 to 2012-13) however witnessed fluctuations in growth rate in most of the spices. Variations in weather and price fluctuations were observed as the main factors affecting growth and instability in spices in

India. So, plans should be formulated to make spice sector more research oriented to prevent it from vagaries of weather and also plan should be oriented towards creation of efficient markets.

More *et. al.* (2015) conducted a study on performance of pulses crops in Gujarat state, for a period of fifty-two years from the year 1960-61 to 2010-11. Performance of crop was analyzed by decade wise i.e. period-I to period-V and overall period with the help of statistical techniques like Average, Growth Rate, Cuddy-Della Valle Instability Index and Decomposition Model. Results showed that, Pulse area in state was considerably increased. In recent years, area under Pigeon pea (*Cajanus cajan*) and other pulses was decreased and chickpea area was increased. Pigeon pea and other pulse crops i.e. green gram (*Vigna radiata*) and black gram (*Vigna mungo*) have recorded phenomenal growth during the year 1970-1980. Chickpea (*Cicer arietinum*) crop performed better during high growth period of Gujarat, compared to other pulse crops. Period – III i.e. 1981 to 1990 was recorded as anti-pulse decade in which productivity of all the major pluses was hampered. Pigeon pea crop was more stable as compared to other pulse crops in the state. Area expansion was a major reason for increase in production of pigeon pea and chickpea in the state. The Production of green gram and black gram was increased because of improvement in the yield and its interaction with area.

Pardhi *et. al.* (2015) performed decomposition analysis of cotton in Amravati division which was an attempt to study the growth and instability of cotton crop in Amravati division. The study revealed that compound growth rate of area under cotton was recorded high during period-I. The growth rate of yield under cotton was recorded high during period-III. The coefficient of variation and Coppock's instability index with regards to area (5.41and 6.35 %) was lowest in Akola district among cotton growing districts of Amravati division. However, coefficient of variation with regards to productivity (31.58%) was lowest in Yavatmal district and Coppock's instability index with regards to productivity (27.40%) was lowest in Amravati district. At overall period, the area effect was stronger factor for increasing production of cotton in all the districts and division as a whole.

2.3 Impact of weather parameters on rice production.

2.3.1 Impact of weather parameters on rice production by Regression analysis.

Khan *et.al.* (1988) worked on the relationship between rainfall, acreage and wheat production in the Northern Punjab to establish some empirical relationship between rainfall and wheat production in the three *barani* districts (Rawalpindi, Jhelum and Attock) of the northern Punjab. The data used for the study were for a period of 25 years (1960-61 to 1984-85) for which both rainfall and production statistics were available. To analyze the relationship between rainfall, wheat acreage and production, simple linear as well as multiple linear regression were employed. All the estimated regression coefficients expecting Rawalpindi and three districts (combined) and as much as 68 and 69% of variability in wheat production could be explained by rainfall and wheat acreage. The regression coefficient for Rawalpindi and Attok districts, indicated that for every additional 1mm rain would lead to an increase of 0.29 and 0.17 kg of wheat in these districts, respectively.

Menon *et.al.* (2002) studied yield prediction in Vanilla. Vanilla lacks synchronized flowering and fruiting and therefore selective harvest is warranted not only for realizing yield but also for formulating its marketing strategies. In view of this, a study was undertaken to develop a model for forecasting the yield in the vanilla plantations using biometric characters. A multiple regression equation was derived using yield as dependent variable and it exhibited a precision of about 95%. The regression coefficients of the independent variables were tested for significance and they were deleted on the basis of the significance of the partial regression coefficients and also considering the practical difficulties in recording a few growth parameters due to coiling nature of the vanilla vines. Therefore, the model was refined using the most significant attributes which are also easy to record in the plantations such as number of inflorescence, beans and bean length. The truncated model can be employed for forecasting the yield in vanilla plantations with a precision of about 93%. On comparison of the regression equations, the model incorporating three most important variables is more effective in forecasting the yield in vanilla without appreciable loss of accuracy.

K. Mohammadi *et.al.* (2005) conducted a study applying different methods for predicting spring inflow to the Amir Kabir reservoir in Karaj river watershed, located to the northwest of Tehran (Iran). Three different methods, artificial neural network (ANN), ARIMA time series and regression analysis between some hydroclimatological data and inflow, were used to predict the spring inflow to the reservoir. Twenty five years data were used for model fitting and training and five years were applied for testing. The coefficient for RA1, RA2 and RA3 model was 0.710, 0.665 and 0.485 respectively. The correlation coefficients for the models in verification period were 0.545, 0.844 and 0.711 respectively. The performances of models compared and the ANN model was found to model the flows better. Thus, ANN can be an effective tool for reservoir inflow forecasting in the Amir Kabir reservoir using snowmelt equivalent data.

Aneja *et.al.* (2008) worked on pre-harvest forecast models for cotton yield. The data for the four years were pooled and six stages were formed according growth stages of crop. A suitable statistical methodology for the pre-harvest estimates of cotton yield by taking biometrical characters as explanatory variables was proposed. The data were for four years i.e. from 2003-2006 collected through a pilot survey and the biometrical characters like height, girth, total number of balls etc. were observed at different stages of the crop growth. The multiple regression analysis of yield (Y) in various biometrical characteristics was studied using four models. The pooled analysis of all four years data showed that at stage-II, the value of R^2 was 0.395 and the contributing factors were height and diameter and both the partial regression coefficients were significant.

Md. Rezaul Karim *et.al.* (2010) studied the forecasting of wheat production in Bangladesh. The study was undertaken to find out appropriate model using seven contemporary model selection criteria that could best describe the growth pattern of wheat production in Bangladesh and its three major areas like Dmajpur, Rajshahi, and Rangpur districts during the time periods 1971-72 to 2004-05. It appeared from the study that the best fitted model for wheat production in Bangladesh, Dinajpur, Rajshahi, and Rangpur were quadratic, linear, and cubic model. It means that the assumption of constant annual rate of growth in per cent that lies behind the use of exponential/compound model which is very common in describing growth pattern was not true for the growth pattern of wheat production in Bangladesh. In Dinajpur District, linear model seemed to be appropriate. Five-year's forecasts of wheat production in Bangladesh, Dinajpur, Rajshahi, and Rangpur districts in the year 2005/06 were 1.55, 0.31, 0.24, and 0.37 million tons, respectively, with a 95 per cent confidence interval. The analysis found that if the present growth rates continue then the wheat production in Bangladesh, and Dinajpur, Rajshahi, and Rangpur districts would be 1.54, 0.35, 0.31, and 0.59 million tons, respectively, in the year 2009/10.

Mohammad Zaefizadeh *et.al.* (2011) studied comparison of multiple linear regressions (MLR) and artificial neural network (ANN) in predicting the yield using its components in the Hulless Barley. In this study 40 genotypes in a randomized complete block design with three replications for two years were planted in the region of Ardabil. The yield related data and its components over the years of the analysis of variance were combined. Results showed that there was a significant difference between genotypes and genotype interaction in the environment. MLR and ANN methods were used to predict yield in barley. The fitted model in a yield predicting linear regression method was as follows:

$Reg = 1.75 + 0.883 X_1 + 0.05017X_2 +1.984X_3$

Therefore, when the genotype environment interaction is significant, in the yield prediction, instead of the regression, a neural network approach is recommended.

Dildar Hussain Kazmi and Ghulam Rasul (2012) studied agrometeorological wheat yield prediction in rainfed Potohar region of Pakistan. This study represents a linear regression model making use of meteorological parameters at critical stages of crop's life cycle to predict the wheat yield about two months earlier than the harvesting. Decadal (ten days) agrometeorological data for Rabi season (for the period 1993-2011) being observed at Regional Agromet Centre, Rawalpindi have been utilized. The parameters studied for correlation were mainly rainfall (amount and days), air temperature (minimum, maximum, mean), heat units (on phonological basis), relative humidity, wind speed, sunshine duration, reference crop evapotranspiration etc. The regression coefficient obtained for rainfall, minimum temperature and sunshine was -18.41, 150.7 and 22.7 with R^2 value 0.56, 0.12 and 0.38 respectively. Finally, minimum temperature, sunshine duration and rainfall amount in January (tillering and stem extension phase) proved to be the reliable predictors for the final yield. The correlation coefficients for these parameters on individual basis resulted within the acceptable range where as in aggregate it remained 0.87, an optimistic value.

P. Rajendra Prasad *et. al.* (2012) performed a study on the growth trends of maize crop in Telangana region of Andhra Pradesh. In this study an attempt was made to assess the 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. The data of the study pertaining to area, production and productivity of Maize were collected from the website http://www.Indiastat.com (Statistical database). The trend equations were fitted 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. In case of Maize area, Compound function was found to be the best. The projected values for area and production were 515.12 thousand hectares and 1749.71 thousand tonnes in 2014 AD as per the best fit compound function.

Marzieh Mokarram and Ehsan Bijanzadeh (2016) worked on prediction of biological and grain yield of barley using multiple regression and artificial neural network models. In this study, an attempt has been made to analyze and compare multiple linear regression (MLR), and artificial neural network (ANN) including multi-layer perceptron (MLP) and radial basis function (RBF) models to predicting biological yield (BY) and yield (Y) of barely. Data were collected from the literatures on the subject of barley production that was existed in http://sid.ir website. Results of MLR model based on R^2 showed that Model 7, with 1000-kernel weight (gr), OC (%), grain/spike, soil pH, N applied (kg/ha), plant height (cm), and irrigation regime (according to FC) and Model 8 with 1000-kernel weight (gr), OC (%), soil pH, grain/spike, HI (%), plant height (cm), irrigation regime (according to FC), and plant density (plant/m^2), were the best models for prediction BY and Y of barley, respectively. The highest standardized coefficient (β) for prediction of BY was obtained in 1000-kernel weight (0.621), OC (0.396) and grain/spike (0.385). Also, for prediction of Y, 1000-kernel weight, OC, and grain/spike with 0.547, 0.403, and 0.347 had the highest β, respectively. Among the MLR, MLP and RBF models, MLP model had the highest R^2 values for prediction of BY (R^2=0.894) and Y (R^2=0.922). Overall, ANN models can be used to successfully estimate BY and Y from data.

2.3.2 Impact of weather parameters on rice production by Aridity Index method.

Habiballa Abdelhafiz Mohamed and Ali Abdalla Mohamed (2010) worked on classification of climates of Sudan using aridity indices. This study aims at determining a suitable climate classification system for Sudan through comparison of different aridity indices computed using long term (1971-2000) climatic data for 19 weather stations. Six aridity indices were used to assess the aridity in Sudan: (1) Emberger Aridity Index (2) De Martonne Aridity Index, (3) Thornthwaite Aridity Index, (4) UNEP Aridity Index (5) UNESCO Aridity Index and a newly devised Aridity Index (Eddebba Aridity Index). The results showed that Eddebba and Emberger aridity indices are more appropriate for classification of Sudan climates compared to other methods and that Sudan climate can be classified into hyper-arid, arid, semi-arid, sub-humid and humid zones.

Marius Lungu *et. al.* (2011) studied aridity, climatic risk phenomenon in Dobrudja. Aridity is a major permanent risk for the climate of Dobrudja territory. They reported that knowledge of aridity is necessary to explain the characteristics of the geographical landscape for the rational use of water resources. Definition and characterization of aridity as intensity were done by several methods and indicators, starting with Lang's rain factor (1920), continuing with De Martonne’s aridity index (1926), Thornthwaite’s aridity index (1948), moisture deficit and ending with the UNESCO aridity index (1979). De

Martonne's aridity index (1926) was recently amended by Murai and Hund (1991) to match the classification of vegetation in the world, but its use in the international literature has not been implemented so far. The spatial distribution of De Martonne's aridity index (Iar-DM) annually shows that Dobrudja has a high variability. In eastern Dobrudja, Iar-DM is below 20 (15-20), with small areas and lower values (below 15). Dobrudja's aridity is highlighted by all climatic aridity indices presented above; additional indicators can also be used. Increasing aridity in Dobrudja due to global warming is a real hazard, with the threat of desertification.

Attila Bussay *et.al.* (2012) performed the evaluation of aridity indices using SPOT normalized difference vegetation index values calculated over different time frames on Iberian rain-fed arable land. The objective of this study was to find the best-performing aridity index and time-frame in the Iberian Peninsula characterizing the effect of dryness on agricultural production. To achieve this goal time-series of 5 aridity indices for 1998 October–2009 December time-period were calculated on a 25X25 km grid, and the closest relationship with plant biomass was determined. Plant biomass was represented by the SPOT-VEGETATION Normalized Difference Vegetation Index (NDVI) satellite data masked out for rain-fed arable land for the period between 1998 and 2009, and also by official yield statistics of Spain and Portugal between 1999 and 2009. Aridity indices calculated for time frames matching the entire vegetative period resulted in the highest correlation coefficients with NDVI and with the crop yield. There was a difference between the two time frames covering twelve months. In contrast with the calendar year, using the hydrological year (1 October–30 September) ensured a very strong correlation between NDVI data and most aridity indices, with UNEP and Water Deficit aridity indices outperforming the others. Among the shorter time frames of April-October, January–October, and October–June, the latter provided very strong correlation between vegetation, UNEP and Water Deficit indices surpassing Budyko, De Martonne, and Thornthwaite aridity indices.

Bhandari (2012) carried a study on estimation of potential evapotranspiration and crop coefficient of wheat at Rupandehi district of Nepal. He estimated the potential evapotranspiration (PET) and crop coefficient (Kc) for Wheat, BL 3235 variety. A lysimeter is installed to estimate PET at the experimental farm of Agricultural Research Center of Bhairahawa, which is located in western part of Nepal. The Blaney-Criddle formula is used to estimate the Kc for wheat. The estimated values of PET and Kc for wheat at the four crop growth stages (initial, crop development, mid season/reproductive and late season/maturity) are 3.5 cm, 7.82 cm, 11.3 cm, 1.16 cm and 0.34, 0.67, 0.73, 0.06 respectively. The total value of PET and average value of Kc for Wheat is 23.78 cm and 0.45. Aridity index (AI), the ratio of precipitation to PET, is an important parameter to determine the dryness of a region. The average value of AI at the Wheat growing season (January to April, 2011) in Bhairahawa is 0.39, and is classified as a semiarid region.

Paltasingh *et. al.* (2012) incorporated 'Aridity index' variable in regression model to measure impact of weather on crop yield. This study has negated the method of direct use of meteorological factors (either monthly or seasonal), in multiple regression analysis to measure weather impact on crop yield where rainfall and temperature are incorporated in the model as increasing monotonic functions of yield. With evidences from Odisha, where agriculture is rainfed and weather-dependent, the study has advocated the incorporation of 'aridity index' variable in the regression model. The use of composite aridity index variable in econometric model has made the analysis more easy and logical. More importantly, the use of aridity index saves the 'degrees of freedom' which is very crucial in econometric analysis. In addition, the ambiguity of using the linear trend to proxy for technological progress is taken care of adequately by using cubic function of time. The testing of hypothesis of changing rainfall dependency has established the fact that the dependence of agriculture on rainfall in Odisha has declined slightly possibly because of the developments in irrigation and other facilities.

Rahman *et.al.* (2013) in their study on construction and study of aridity index based on temperature & rainfall data in Ishurdi, Pabna, Bangladesh reported that aridity index have important implications on agriculture of Bangladesh. Aridity can be equated with a deficiency of rainy days and ground moisture. In this study the Aridity Index in Ishurdi Pabna from time period (1996-2011) has been computed using De Martonne (1926). The index value is 26.26 i.e. the moist sub-humid class. Linear regression method is used to analysis the trend of Temperature & Rainfall and also has been used for projection. A study has been carried out to assess the increases of both temperature and rainfall in the Ishurdi Pabna. The monthly De Martonne (1926) aridity index is used to evaluate the monthly aridity index and it reveals the irrigation months in the study area. The rainfall characteristic is also analyzed which is used to compute the rainfall distribution within a year. An increasing trend of precipitation concentration is also observed in the study area. These results may be a first indication of the precipitation response to global warming.

Remus Prăvălie (2013) worked on climate issues on aridity trends of southern Oltenia in the last five decades. The study attempts to quantify the trend of climate aridisation of southern Oltenia in the last five decades (from 1961 to 2009) based on analysis of climate data on temperature, precipitations and potential evapotranspiration. These meteorological parameters were used to create specific climate indexes to assess the temporal trend of aridity (De Martonne Aridity Index, UNEP Aridity Index and Water Deficit Index), which are among the most representative of the analyzed phenomenon. The results showed that during the five decades analyzed, the aridity trend is pronounced, occurring especially after 1980 year. This threshold of growing aridity phenomenon is mainly due to the changes of climatic parameters such as: the lowering of the average annual rainfall, the rising of mean annual temperatures and the increasing of potential evapotranspiration as a result of the annual thermal regime change after 1980 year.

Fatima Fniguire *et. al.* (2014) studied some aspects of climate variability and increasing aridity in central Morocco over the last forty years. The study analyzed evolution of aridity through climate indexes, including precipitation, temperature and evapotranspiration over the last 40 years in the Tensift watershed (central Morocco). As preliminary results, in the Tensift basin, the temperature became higher during the last two decades. It diminishes paradoxally towards mountainous areas. A slight decrease of precipitation has been noticed in the foothill regions of the High Atlas and near the Haouz plain. The study of aridity evolutions by the aridity index of De Martonne and aridity index of UNEP takes into account respectively the ratio between the mean annual precipitation (P) and temperature (T) and the relationship between annual precipitation and evapotranspiration. Generally, the aridity is decreasing from downstream to upstream of the study area. But during the past two decades, the region of the Tensift knew a subtantial augmentation in arid land regime may be due to global warming and reduced precipitation measured. Typically, there is coherence between UNEP index and the index of the De Martonne from point of view of increasing aridity, which adds robustness to the result.

2.3.3 Impact of weather parameters on rice production by ARIMA modeling.

K. Mohammadi *et.al.* (2005). A study aims at applying different methods for predicting spring inflow to the Amir Kabir reservoir in Karaj river watershed, located to the northwest of Tehran (Iran). Three different methods, artificial neural network (ANN), ARIMA time series and regression analysis between some hydroclimatological data and inflow, were used to predict the spring inflow to the reservoir. Data from 1970 to 1994 were used for model calibration and training. Then, models were used to predict the spring inflow from 1995-1999. A number of models were applied to the series and finally a mixed ARIMA (1,0,1)(0,1,1,) model was selected. The coefficient for ARIMA model was 0.175. The ARIMA model produced a 30.78 percent error but ANN had significantly lower error compared with other methods.

Theptawan Wongsanao and Yaovarate Chaovanapoonphol (2010) worked on maize price forecasting in Northern region. The objective of this study was to study production situation and maize price in Northern Region of Thailand. It was based on monthly secondary data during January 1998-December 2009 covering 144 observations, and the application of ARIMA with exogenous variables (ARIMAX) models. Consequently, the most appropriate models for prediction were found to be ARIMA (12,1,1).

Awal and Siddique (2011) studied the rice production in Bangladesh employing ARIMA model to estimate growth pattern and also examine the best ARIMA model to efficiently forecasting Aus, Aman and Boro rice production in Bangladesh. It appeared that the time series data for Aus and Aman were 1st order homogenous stationary but Boro was 2nd order stationary. The study revealed that the best models were ARIMA (4,1,4), ARIMA (2,1,1), and ARIMA (2,2,3) for Aus, Aman, and Boro rice production, respectively. The analysis indicated that short-term forecasts were more efficient for ARIMA models compared to the deterministic models. The production uncertainty of rice could be minimized if production were forecasted well and necessary steps were taken against losses. The findings of this study would be more useful for policy makers, researchers as well as producers in order to forecast future national rice production more accurately in the short run.

Farhan Ahmed *et. al.* (2011) forecasted milk production in Pakistan using time series data from 1990 to 2010. ARIMA (p, d, q) model is considered for estimation where 'p' is the order of the autoregressive process, 'd' is the order of the homegeneity and 'q' the order of the moving average process. Presence of trend in data was checked through time series plots and stationarity through auto correlation and partial auto correlation functions. The projections were based on the assumption that agricultural price structure and policies will remain unchanged and consumer preference will remain the same. Using the ARIMA (1,1,1) forecasts from 2010 up to 2015 were made and production of milk in 2015 was estimated at 47492 t.

Juan Ruiz-Ramirez *et. al.* (2011) studied the time series analysis forecasting in sugar cane production to improve the profitability of the sugar cane refineries, time series data sets were used as they allow prediction of the expected returns and thus determine future demands on the inputs and inventories. In this research they used a time series model to forecast the Independencia sugar cane mill 2006-2007 production. The statistical software was used to analyze the volume of harvests from 1949 to 2006, the Box-Jenkins methodology to generate an auto-regressive integrated moving average (ARIMA) model. The 2006-2007 sugarcane production forecasted 11,974 tons, in contrast with the obtained production (12,736 tons). The results indicate that forecasting with the model is 94% accurate.

Nasiru Suleman and Solomon Sarpong (2012) reported that increasing demand for rice in Ghana has been a major concern to the government and other stakeholders. Recent concerns by the Coalition for African Rice Development (CARD) to double rice production within ten years in Sub-Saharan countries have triggered to implement strategies to boost rice production in the government. To fulfill this requirement, there is a need to monitor and forecast trends of rice production in the country. This study employs the Box-Jenkins approach to model milled rice production using time series data from 1960 to 2010. The analysis revealed that ARIMA (2, 1, 0) was the best model for forecasting milled rice production. Although, a ten years forecast with the model shows an increasing trend in production, the forecast value at 2015 (283.16 thousand metric tons) was not good enough to compare with the current production of Nigeria (2700 thousand metric tons), the leading producer of rice in West Africa.

Borkar (2012) in her study entitled "Forecasting cotton yield in Maharashtra using season time series model" described an empirical study of modeling and forecasting time series data of cotton yield in Maharashtra. Yearly cotton yield data for the period of 1964-65 to 2007-08 of Maharashtra were analyzed by time series methods. Autocorrelation and partial autocorrelation function were calculated for the data. The Box Jenkins ARIMA methodology has been used for forecasting. The diagnostic checking has shown that ARIMA (2,1,1,) is appropriate. The forecasts from 2008-09 to 2019-20 were calculated based on the selected model. The forecasting power of autoregressive integrated moving average model was used to forecast cotton yield for twelve leading years. The projections were based on assumptions of absence of random shocks in economy, agricultural price structure and policies will remain unchanged and consumers preference will be same.

Sivapathasundaram and Bogahawatte (2012) studied the past, present and future trends of paddy production in Sri Lanka and developed a time series model to detect the long term trend and prediction for future changes of paddy production for the three leading years. Autoregressive Integrated Moving Average (ARIMA) model was used to fit the data set which is complementary to the trend regression approach and forecasting of the concerned variable to the near future. Time series forecasting analysis utilized the secondary data of the Department of Census and Statistics of Sri Lanka for the period of 1952 to 2010. Non-stationarity in mean was corrected through differencing of the data of order 1. ARIMA (2, 1, 0) was the most suitable model used as this model has the 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. This model can be used by researchers for forecasting of paddy production in Sri Lanka. But, it should be updated continuously with incorporation of recent data.

Mishra *et. al.* (2013) in their study on instability and forecasting using ARIMA model in area, production and productivity of onion in India employed Box-Jenkins ARIMA modeling to forecast series under consideration. Data for the period 1978-2006 were used for the model building whereas; data for years 2007 and 2008 were taken for model validation. The study revealed that the ARIMA (1,1,5) model is best suited for modeling of onion area data. In case of production of onion the ARIMA (0,1,5) model is best fitted, it can be said that forecasted production will increases to 23.02 million tonnes during 2020. In case of the productivity of onion the ARIMA (1,1,4) model is best fitted and forecasted yield would be 17030 kg/ha in 2020.

Biswas and Bhattachrya (2013) attempted ARIMA modeling to forecast area and production of rice in West Bengal. According to them, crop area estimation and forecasting of crop yield are an essential procedure in supporting policy decision regarding land use allocation, food security and environmental issues. Separate data of area and production of rice in West Bengal were collected over the period of 1947-1948 to 2007-2008. The study reveals that, for the gross cultivated area ARIMA (2,1,3) model is found to be the best fitted model whereas, for the series of production ARIMA (2,1,1) is found to be the best fitted one. The model exhibits good accuracy level for future projection of area and production of rice in the state.

Tripathi *et. al.* (2013) the study focused on forecasting the cultivated area and production of pearl millet in India using Autoregressive Integrated Moving Average (ARIMA) model. Time series data covering the period of 1950-2010 was used for the study. The analyses forecast pearl millet production for the year 2020 to be about 9.15 million tons. Tentatively twelve models were selected for study purpose. Out of these models only three were selected on the basis of minimum values of AIC and BIC. The selected models were

ARIMA (0,1,0), ARIMA (0,1,1) and ARIMA (1,1,0). These models were compared according to minimum value of RMSE, MAE and MAPPE and maximum value of R^2 followed by autocorrelation function and partial autocorrelation function of residuals. The model also shows that the pearl millet area would be 8.67 million hectares in 2020. In The yield of pearl millet would be 1083.12 kg/ha in 2020. These projections will help information of good policies with respect to relative production, price structure as well as consumption of pearl millet in the country.

Verma *et. al.* (2013) in their study on forecasting sugarcane yield in Haryana expressed that forecasting of crop yield is one of the most important aspects of agricultural statistics system. ARIMA models are built for the data related to yield(s) of sugarcane crop in Karnal, Kurukshetra and Ambala districts of Haryana. Sugarcane yield data of the four/ five decades have been used for the model building and the forecast values are obtained for the 2009-10. After experimenting with different lags of the moving average and autoregressive process; ARIMA (0,1,1) for Ambala and Kaarnal, ARIMA (1,1,0) for Kurukshetra district/s have been fitted for the crop yield prediction. A perusal of the results indicates that the present deviations of the forecast yields form observed yield are within acceptable limits and favors the use of ARIMA models to get short-term forecast estimates.

M. Amin *et. al.* (2014) in their study on time series modeling for forecasting wheat production of Pakistan developed time series models and best model is identified for forecasting the wheat production of Pakistan. In this research large time periods i.e. 1902-2005 data were used. Various time series models were fitted on this data using two software's JMP and Statgraphics. On the basis of AIC they found that Model M i.e. ARIMA (1, 2, 2) has lowest AIC and they used this model to forecast wheat production. On the basis of this selected model, they have found that wheat production of Pakistan would become 26623.5 thousand tons in 2020, 30429.8 in 2030, 34236 in 2040, 38042.2 in 2050 and 41848.5 thousand tons in 2060. They also found that wheat production of Pakistan would become double in 2060 as compared in 2010.

Biswas *et. al.* (2014) studied forecasting wheat production using ARIMA model in Punjab. In the present study attempt was made to analyze, area, production and productivity of wheat for Punjab by time series method. Yearly wheat yield data for the period of 1950-51 to 2009-10 were used as input to forecast the yield upto the year 2020-21. The Box-Jenkins ARIMA method was put into use to forecast the yield. The validity of the model was tested by standard statistical techniques. The past 60 years data revealed that wheat yield was increased from 0.8 t/ha in 1950-51 to 4.3 t/ha in 2009-10. The model projected 15.3 per cent increase in wheat production in the years to come by 2020-21 in Punjab. Based on ARIMA output, wheat production of Punjab is likely to increase from 15844.7 thousand tons in 2010-11 to18271.7 thousand tons in 2020-21.

Chaudhari *et. al.* (2014) attempted to forecast cotton production in India. The study aimed at forecasting the cotton production in India by using the time series cotton production data for the period from 1950-51to 2010-11. To forecast the cotton production ARIMA models, introduced by Box and Jenkins were used. To test the reliability of model R^2, mean absolute percentage error (MAPE), and Bayesian Information Criterion (BIC) were used. Among the different class of ARIMA models, lowest BIC value worked out to be 254 for ARIMA (0,1,0,), which was the best fitted model. Based on model results the estimated cotton production in India would increase from 33.93 million bales during the year 2011-12 to 37.98 million bales during the year 2019-20.

Naveena *et. al.* (2014) studied forecasting of coconut production in India. The present study is an attempt to find an appropriate model to forecast the coconut production in India. Time series data for a period of 61 years from 1951-2012 were used. The best model has been selected based on the minimum root mean square error values. It has been found that ARIMA (1,1,1) model was found to be the best model. Forecast indicates that production of coconut in the year 2020 would be 1200 million nuts (8.51%) more than present production.

Brintha *et. al.* (2014) reported that the unobserved component model (UCM) is a promising alternative to ARIMA in overcoming problem of nonstationary data, as it does not make use of the stationary assumption. The study aimed at using UCM for annual national coconut production data from 1950 to 2012, which is nonstationary, and to forecast the coconut production in Sri Lanka. Results revealed that both the trend components, level and slope, have non-stochastic processes. Further, it revealed that the level was significant (p=0.0001) and slope was non-significant (p>0.1). The linear trend model zero variance slopes was found to be the best fit for the data with 11.3 years of estimated period of the cycle. The forecasted error for 2011 and 2012 were 1.08% and 1.69%, respectively. From the fitted model, predicted annual coconut production for 2013 was 2739.1 million nuts and the 95% CI is 2048.7 to 3429.5 million nuts. Thus, the use of UCM is recommended for annual data series, too.

Ramesh *et al.* (2014) conducted study on forecasting of maize production in Andhra Pradesh by ARIMA modeling. The paper attempted for forecasting of maize production in

Andhra Pradesh by Box-Jenkins Autoregressive Integrated Moving Average (ARIMA) method for the period of 1981-2010. They reported that ARIMA (1,1,0) was the best suitable to forecast maize production in Andhra Pradesh. The forecasting power of Autoregressive Integrated Moving Average model was used to forecast production for leading years. Production of maize in Andhra Pradesh was supposed to increase 78% from 1980 to 2010, which was projected to reach up to 85% in 2017 as prescribed by the model.

Verma *et. al.* (2014) conducted a study on yield trends of wheat crop in Haryana. ARIMA models were built for the data related to wheat yield in Ambala, Karnal, Kurukshetra, Sonipat, Jind and Gurgaon districts of eastern agro-climatic zone of Haryana. The crop yield data from 1960-61 to 2008-09 were used for the model building and the forecast value were obtained for the year 2008-09. After experimenting with different lags of the moving average and autoregressive process; ARIMA (0,1,1) for Ambala, Karnal, Kurukshetra, Sonipat and Jind districts, while ARIMA (1,1,0) for Gurgaon district were fitted for wheat yield forecasting purpose.

Ali *et al.* (2015) made an attempt to forecast production and yield of two main cash crops namely sugarcane and cotton of Pakistan by using Auto Regressive Moving Average (ARMA) and Auto Regressive Integrated Moving Average (ARIMA) models of forecasting. Using data for 1948 to 2012, productions and yields of both crops were forecasted for 18 years starting from 2013 to 2030. Appropriate models were selected based on certain selection criterion, for example, Schwarz-Bayesian Information Criteria (SBC) and Akaike Information Criteria (AIC). ARMA (1, 4), ARMA (1, 1) and ARMA (0, 1) were found appropriate for sugarcane production, sugarcane yield, and cotton production respectively, whereas ARIMA (2, 1, 1) was the suitable model for forecasting cotton yield. The forecasted values of sugarcane crop reveal that it will reach 71,414 thousand tonnes and its yield will attain 60,765 kg/ha by 2030. On the other hand, the forecast of cotton production is 15,479 thousand tonnes and its yield is 870 kg/ha for 2030.

Ljiljanić *et al.* (2015) studied wheat production analysis by using econometric models. The study analyzed time series data for the period 1994–2013 on areas sown with wheat, average yields, purchase price for wheat, subsidies and wheat used for seed in Serbia. They developed dynamic models, on which they forecasted that 89000 tons of wheat would be used in 2014 for an area of 507000 ha. This ARIMA model confirms that in wheat production economic factors have a dominant impact on sown areas and quantities of wheat used for seed.

Mishra *et al.* (2015) examined the performance of total food grains production in India and its major states during the period (1950-2009). The study also focuses on forecasting the area and production of total food grains in India using Autoregressive Integrated Moving Average (ARIMA) model. In an attempt to increase forecast accuracy, the study incorporated the factors of production in the ARIMA model as auxiliary variables. The study reveals that by and large estimated figures are closer to the observed figures when different factors are included in the model. Forecasting figures worked out using the best fitted ARIMA models with and or without the incorporation of factors of production indicate that Uttar Pradesh will be the leading state in India in total food grains production, with a production of 49455 thousand tonnes from an area of 19982 thousand hectare with 2718 kg/ha yield during year 2020.

Borkar (2015) described an empirical study of modeling and forecasting time series data of coconut production in India. Yearly coconut production data for the period of 1950-51 to 2012-13 of India were analyzed by time series methods. The Box-Jenkins Autoregressive Integrated Moving Average (ARIMA) methodology has been used for forecasting. The diagnostic checking has shown ARIMA (1,0,0,) is appropriate. The forecast from 2013-14 to 2019-20 were calculated based on the selected model. The forecasted production of coconut for the year 2019-20 would be 15705.86 nuts per hectare.

Dasyam *et al.* (2015) made an attempt to model and forecast the production of wheat in India by using annual time series data from 1961-2013. Parametric regression, exponential smoothing and Auto Regressive Integrated Moving Average (ARIMA) models were employed and compared. In this present work, possible ARIMA (p,d,q) models such as (1,1,1), (0,1,1) and (1,1,0) were compared to each other. Among all possible models, ARIMA (1,1,0) was selected as optimal and most appropriate model. The best fitted model was selected based on the performance of several goodness of fit criteria viz. Root Mean Squared Error (RMSE), Mean Absolute Percentage Error (MAPE), Mean Absolute Error (MAE), Mean Squared Error (MSE), Akaike Information Criterion (AIC), Schwarz's Bayesian Information Criterion (SBC) and R-squared values.. This study found ARIMA (1,1,0) as most appropriate to model the wheat production of India. The forecasted value by using this model was obtained as 100.271 million tons (MT) by 2017-18.

Singh *et al.* (2015) analyzed the data on area and production of paddy in Chhattisgarh for the period of 1974-75 to 2010-11 by time series methods. Appropriate Box-Jenkins Autoregressive Integrated Moving Average (ARIMA) model was fitted. Validity of the model was tested using standard statistical techniques. ARIMA (2,1,2) and ARIMA

(2,1,0) models were used to forecast paddy area and production in Baster Division of Chhattisgarh for four leading years. The results also showed paddy area forecast for the year 2015 to be about 598.22 thousand hectare with upper and lower limits 665.39 and 531.06 thousand hectares respectively. The model also showed paddy production forecast for the year 2015 to be about 1126.61 thousand tonnes with upper and lower limit 1430.16 and 823.05 thousand tonnes respectively.

2.3.4 Impact of weather parameters on rice production by Artificial Neural Network (ANN).

Safa *et.al.* (2000) estimated the crop production a few days or months before harvesting, using meteorological data. The study applied the ANNs to predict dry farming wheat yield. According to the available data and information from different areas in Iran, this research was accomplished using Sararood station data in Kermanshah Province which has the most complete homogeneous statistics. In this study, the results of climatology for the period (1990-99) for each of the eleven phenological stages of wheat including sowing, germination, emergence, third leaves, tillerng, stem formation, heading, flowering, milk maturity, wax maturity, full maturity and also eleven meteorological factors including: mean daily minimum temperature, extreme daily minimum temperature, mean daily maximum temperature, extreme daily maximum temperature, total daily rainfall, number of rainfall days, sum of sun hours, mean daily wind speed, extreme daily wind speed, mean daily relative humidity and sum of water requirement were collected separately for each farming year and arranged in two matrices:

- A matrix whose rows are repetitions of the statistical years (i) at each phenological stages of wheat (j) and the columns are meteorological factors (k).
- A matrix whose rows form each of the statistical years (i) and the columns are meteorological factors (k) at each phenological stage (j).

Finally, different networks were made for each stage and the optimum values of network parameters were obtained by trial and error. The model that obtained has the abilities of prediction of wheat yield with maximum errors of 45-60 kg/ha at least two months before full maturity stage and of determination of the priority order and importance of each meteorological factor effective in plant growth and crop yield.

K. Mohammadi *et.al.* (2005) applied different methods for predicting spring inflow to the Amir Kabir reservoir in Karaj river watershed, located to the northwest of Tehran (Iran). Three different methods, artificial neural network (ANN), ARIMA time series and regression analysis between some hydroclimatological data and inflow, were used to predict the spring inflow to the reservoir. Twenty five years of observed data were used to train or calibrate the models and five years were applied for testing. The performances of models compared and the ANN model was found to model the flows better. Thus, ANN can be an effective tool for reservoir inflow forecasting in the Amir Kabir reservoir using snowmelt equivalent data.

Pichaya Boonprasom and Gumpanart Bumroongitt (2005) applied an Artificial Neural Network (ANN) to forecast the tangerine yield, taking into account some influential factors, especially the weather conditions. Data and information relating to tangerine yield of Chiang Mai Province from 1992 to 2001 were collected. Weather data such as average monthly rainfall and average monthly temperature of relevant periods were also obtained. Five ANN models, with different input factors or different structures, were constructed for three sections of the experiment. The results indicated that the ANN had high potential and ability to forecast tangerine yield accurately despite small set of data available. The amount of rainfall was observed to have strong influence and contributed important information to the ANN in forecasting tangerine yield.

B. Ji *et.al.* (2007) studied artificial neural networks for rice yield prediction in mountainous regions and mentioned that decision-making processes in agriculture often require reliable crop response models. The Fujian province of China is a mountainous region where weather aberrations such as typhoons, floods and droughts threaten rice production. Agricultural management specialists need simple and accurate estimation techniques to predict rice yields in the planning process. The study compared effectiveness of multiple linear regression models with ANN models. Models were developed using historical yield data at multiple locations throughout Fujian. Field-specific rainfall data and the weather variables (daily sunshine hours, daily solar radiation, daily temperature sum and daily wind speed) were used for each location. Adjusting ANN parameters such as learning rate and number of hidden nodes affected the accuracy of rice yield predictions. Optimal learning rates were between 0.71 and 0.90. Smaller data sets required fewer hidden nodes and lower learning rates in model optimization. ANN models consistently produced more accurate yield predictions than regression models. ANN rice grain yield models for Fujian resulted in R^2 and RMSE of 0.67 and 891 whereas 0.52 and 1977 for linear regression. Although more time consuming to develop than multiple linear regression models, ANN models proved to be superior for accurately predicting rice yields under typical Fujian climatic conditions.

Singh and Prajneshu (2008) in their study entitled “Artificial Neural Network Methodology for Modeling and Forecasting Maize Crop Yield” highlighted that the potential of artificial neural network methodology for successfully tackling the realistic situation in which exact nonlinear functional relationship between response variable and a set of predictors is not known. The computer programs were written in MATLAB to train MLFANN using the two training. The MSEs for best trained MLFANN (11- 16-1) using CGDA and for traditionally used MLR were computed as 12.94 and 69.01, respectively; thereby clearly demonstrating superiority of MLFANN (11-16-1) over MLR for data under consideration. Finally, for the test data comprising 10 observations, predicted values of response variable using MLFANN (11-16-1) model along with actual values were obtained and have been reported. Evidently, predicted and actual values are quite close. They concluded that artificial neural network methodology is successful in describing the given data.

Abdolmohammad Mehnatkesh *et.al.* (2010) applied artificial neural networks and multiple linear regressions and sensitivity analysis to prediction of rainfed wheat grain yield and biomass. The study was conducted to evaluate the efficacy of artificial neural network (ANN) and multiple linear regression (MLR) tools to predict biomass and grain yield of winter wheat (cv. Sadri). A total of 404 sampling points were chosen at two sites with varying climatic conditions. Surface (0-30 cm) soil samples and data on wheat yield were collected at two sites in Koohrang and Ardal districts. Four parameter groups including terrain attributes, soil physical and chemical properties, precipitation, and weed biomass, including 57 factors were used as the inputs, and wheat grain and total biomass yield as the targets for ANN and MLR models. Predictor ANN and MLR models resulted in R^2 values of 0.84 and 0.53 for grain yield, respectively; and 0.69 and 0.26 for total biomass, respectively. These models resulted in RMSE values of 0.033 and 0.055 for grain yield, and 0.038 and 0.070 for total biomass, respectively. Moreover, the results showed that the ANN models were the best and could explain 84% and 69 % of the total variability in wheat grain and total biomass yield, respectively.

Keshavarzi and Sarmadian (2010) studied the comparison of artificial neural network and multivariate regression methods in prediction of soil cation exchange capacity. 70 soil samples were collected from different horizons of 15 soil profiles located in the Ziaran region, Qazvin province, Iran. Multivariate regression and neural network model (feed-forward back propagation network) were employed to develop a pedotransfer function for predicting soil parameter using easily measurable characteristics of clay and organic carbon. The performance of the multivariate regression and neural network model was evaluated using a test data set. In order to evaluate the models, root mean square error (RMSE) was used. The value of RMSE and R^2 derived by ANN model for CEC were 0.47 and 0.94 respectively, while these parameters for multivariate regression model were 0.65 and 0.88 respectively. Results showed that artificial neural network with seven neurons in hidden layer had better performance in predicting soil cation exchange capacity than multivariate regression.

Morteza Zangeneh *et.al.* (2010) worked on assessment of agricultural mechanization status of potato production by means of artificial neural network model. An artificial neural network (ANN) model was developed to assess mechanization status of potato farms in Iran. Mechanization index (MI) and level of mechanization (LOM) were used to characterize farming system of potato production in the region. To develop ANN model, data were obtained from farmers, government officials as well as from relevant databases. A wide range of explanatory parameters of farming activities were examined. Finally, 19 explanatory parameters were used as input variables to predict MI and LOM. Based on performance measures, single hidden layers with 8 and 3 neurons in the hidden layer were finally selected as the best configuration for predicting MI and LOM, respectively. For the optimal ANN models, the values of the model's outputs correlated well with actual outputs, with coefficient of determination (R^2) of 0.98 and 0.99 for MI and LOM, respectively. Sensitivity analyses were also conducted to investigate the effects of various explanatory parameters on the outputs. Since the ANN model can predict the two mechanization indicators, Mechanization Index (MI) and Level of Mechanization (LOM), for a target farming system with high accuracy, it could be a good alternative to regression for assessing agricultural mechanization of regional farms with similar conditions.

Khashei-Siuki *et.al.* (2011) reported that the prediction of crop yield with available data has important effects on socio-economic and political decisions at the regional scale. This study shows the ability of Artificial Neural Network (ANN) technology and Adaptive Neuro-Fuzzy Inference Systems (ANFIS) for the prediction of dryland wheat (*Triticum aestivum*) yield, based on the available daily weather and yearly agricultural data. Evapotranspiration, temperature (max, min, and dew temperature), precipitation, net radiation, and daily average relative humidity for twenty-two years at nine synoptic stations were the weather data used. The potential of ANN and Multi-Layered Preceptron (MLP) methods were examined to predict wheat yield. ANFIS and MLP models were compared by statistical test indices. Based on these results, ANFIS model consistently produced more accurate statistical indices (R^2= 0.67, RMSE= 151.9 kg ha-1, MAE= 130.7 kg ha-1), when temperature (max, min, and dew temperature) data were used as independent variables for prediction of dryland wheat yield.

Zangeneh *et.al.* (2011) performed a comparative study between parametric and artificial neural networks approaches for economical assessment of potato production in Iran. They compared the results of the application of two different approaches, parametric model (PM) and artificial neural networks (ANNs), for assessing economical productivity (EP), total costs of production (TCP) and benefit to cost ratio (BC) of potato crop. In this comparison, Cobb-Douglas function for PM and multilayer feed forward for implementing ANN models have been used. The ANN, having 8-6-12-1 topology with R^2 = 0.89, resulted in the best-suited model for estimating EP. Similarly, optimal topologies for TCP and BC were 8-13-15-1 (R^2 = 0.97) and 8-15-13-1 (R^2 = 0.94), respectively. In validating the PM and ANN models, mean absolute percentage error (MAPE) was used as performance indicator. The ANN approach allowed to reduce the MAPE from –184% for PM to less than 7% with a +30% to –95% variability range. Since ANN outperformed PM model, it should be preferred for estimating economical indices.

Mohammad Zaefizadeh *et.al.* (2011) studied comparison of multiple linear regressions (MLR) and artificial neural network (ANN) in predicting the yield using its components in the Hulless Barley. Yield prediction based on multi-layer neural network (ANN) using the Matlab Perceptron type software with (1-15-3) neural network structure that has three neurons in the input layer (number of fertile tillers, number of grains in the main (cluster) spike and one thousand grains weight), 15 neurons in the hidden layer and one neuron in output layer (yield). Stimulating function used was the hyperbolic tangent in hidden layer and linear activator function in output layer. Results showed that in the ANN technique the mean deviation index of estimation significantly was one-third (1 / 3) of its rate in the MLR, because there was a significant interaction between genotype and environment and its impact on estimation by MLR method. Therefore, when the genotype environment interaction is significant, in the yield prediction instead of the regression of a neural network approach is recommended due to high yield and more velocity in the estimation to be used.

Lida Eisazadeh *et.al.* (2013) studied modeling sediment yield using artificial neural network and multiple linear regression methods. The use of artificial neural networks modeling for prediction and forecasting variables in sedimentation are easier, cheaper and they begin to solve nonlinear problems. In this study, 25 sub basin of reservoir in West Azerbaijan province, Iran, were selected for estimating sediment yield by using multiple linear regression (MLR) and artificial neural network (ANN) methods. Therefore, 160 data sets of sediment yield have been used in selected sub basins of reservoirs. Some statistics including RMSE and R^2 were used to evaluate the performance of applied models. The results indicated the proposed ANN model could well predict the sediment yield with R^2 = 0. 86 and RMSE= 0.09 in comparison to the MLR model which it's R^2 and RMSE are 0.64 and 1.41 respectively. In particular, the ANN model had the capability of discovering non-linear relationships of sedimentation using geomorphologic parameters with reasonable precision.

Fátima Cibele Soares *et.al.* (2015) evaluated the performance of artificial neural networks to predict the corn grain yield in the city of Jaguari, Central region of Rio Grande do Sul, based on morphological characteristics of this culture. It used the data published by SOARES (2010) for training the neural networks. Several multilayer perceptron neural networks with backpropagation-optimized algorithm (Levenberg-Marquardt) were tested. The input layer variables used were leaf area index, total green matter, plant height and number of plants m-2 and the output layer: corn grain yield. Each architecture was trained 10 times, picking up at the end of training the one with lower mean relative error and less variance for data validation. Efficiency of the networks was analyzed by means of statistical indicators. Among many architectures trained, the network with 35 neurons in the hidden layer had the lowest error in training and validation processes. In this way, the neural network with architecture 4-35-1 presents a good performance, being efficient to estimate grain production, considering the region covered by the experiment.

Mohammad Ali HORMOZI *et.al.* (2015) in their study effect of various inputs on paddy production analyzed the effect of chemical fertilizer, seed, biocide, farm machinery and labor hours on production of paddy (paddy rice) in the Khuzestan province in the South Western part of Iran. The data used in this study were collected during a survey covering the crop year of 2009 in two climatic regions: (I) mountainous North Eastern Khuzestan and (II) the plains (the rest of Khuzestan). The data set consists of 93 observations. They test two methods (linear regression and neural network). They conclude that the results obtained by neural network with no hidden layer and linear regression are close to each other. They insist that for a data set of this type the regression analysis yields more reliable results as compared to a neural network. They suggested that machinery has a very clear positive effect on yield while fertilizer and labor doesn't affect. One can say that there is no necessity that increasing the amount of some "useful input" increase paddy production.

Safa *et.al.* (2015) used an artificial neural network (ANN) approach to model the wheat production in Canterbury, New Zealand. From an extensive data collection involving 40 farms, the average wheat production was estimated at 9.9 t ha-1. The final ANN model developed was capable of predicting wheat production under different conditions and farming systems using direct and indirect technical factors. The actual *RMSE* of the final NN model was estimated to be 0.37 t ha-1 on validation data. After examining more than 140 different factors, 6 factors were selected as influential input into the model. The final ANN model can predict wheat production based on farm conditions (wheat area and irrigation frequency), machinery condition (tractor hp ha-1 and number of passes of sprayer) and farm inputs (N and fungicides consumption) in Canterbury with an error margin of ±9% (±0.89 t ha-1).

Ghosh *et.al.* (2016) conducted a study on weed management through herbicide application in direct seeded rice and yield modeling by artificial neural network. The objective of the study was to predict the rice yield on the basis of weed control efficiency (WCE) and weed control index (WCI) of the selected herbicides at crop growing periods. WCE and WCI of the herbicides at different dates of observation were considered as inputs and yield as the output of the model. MLP network with various numbers of layers and neurons in each layer was constructed to predict the yield. The best model for predicting yield was one input layer having seventeen neurons, two hidden layers with nine neurons in the first one and four neurons in the second one, and an output layer (structure 17-9-4-1). The best model for yield prediction was selected on the basis of its lowest error values and highest R^2 value. About 88% of the predicted yield in our case can be explained from actual yield calculated from field experiment.

Marzieh Mokarram and Ehsan Bijanzadeh (2016) made an attempt to analyze and compare multiple linear regression (MLR), and artificial neural network (ANN) including multi-layer perceptron (MLP) and radial basis function (RBF) models to predicting biological yield (BY) and yield (Y) of barely. Data was collected from the literatures on the subject of barley production that was existed in http://sid.ir website. A total of 10563 data from 17 features were prepared in Excel software sheets. Then, the Matlab software was used to compare the models. Among the MLR, MLP and RBF models, MLP model had the highest R^2 values for prediction of BY (R^2=0.894) and Y (R^2=0.922). Also, using

RBF model, R^2 value was 0.82 and 0.75 for prediction of BY and Y, respectively. Overall, ANN models can be used to successfully estimate BY and Y from data.

2.4 Forecast of the rice production.

Md. Rezaul Karim *et.al.* (2010) studied forecasting of wheat production in Bangladesh. The study was undertaken to find out appropriate model using seven contemporary model selection criteria that could best describe the growth pattern of wheat production in Bangladesh and its three major areas like Dmajpur, Rajshahi, and Rangpur districts during the time periods 1971-72 to 2004-05. It appeared from the study that the best fitted model for wheat production in Bangladesh, Dinajpur, Rajshahi, and Rangpur were quadratic, linear, and cubic model. It means that the assumption of constant annual rate of growth in per cent that lies behind the use of exponential/compound model which is very common in describing growth pattern was not true for the growth pattern of wheat production in Bangladesh. In Dinajpur District, linear model seemed to be appropriate. Five-year's forecasts of wheat production in Bangladesh, Dinajpur, Rajshahi, and Rangpur districts in the year 2005/06 were 1.55, 0.31, 0.24, and 0.37 million tons, respectively, with a 95 per cent confidence interval. The analysis found that if the present growth rates continue then the wheat production in Bangladesh, and Dinajpur, Rajshahi, and Rangpur districts would be 1.54, 0.35, 0.31, and 0.59 million tons, respectively, in the year 2009/10.

Farhan Ahmed *et. al.* (2011) forecasted milk production in Pakistan using time series data from 1990 to 2010. ARIMA (p, d, q) model is considered for estimation where 'p' is the order of the autoregressive process, 'd' is the order of the homegeneity and 'q' the order of the moving average process. Presence of trend in data was checked through time series plots and stationarity through auto correlation and partial auto correlation functions. The projections were based on the assumption that agricultural price structure and policies would remain unchanged and consumer preference will remain the same. Using the ARIMA (1,1,1) forecasts from 2010 up to 2015 were made and production of milk in 2015 was estimated at 47492 t.

Juan Ruiz-Ramirez *et. al.* (2011) studied the time series analysis forecasting in sugar cane production to improve the profitability of the sugar cane refineries, time series data sets were used as they allow prediction of the expected returns and thus determine future demands on the inputs and inventories. In this research they used a time series model to forecast the Independencia sugar cane mill 2006-2007 production. The statistical software was used to analyze the volume of harvests from 1949 to 2006, the Box-Jenkins methodology to generate an auto-regressive integrated moving average (ARIMA) model. The 2006-2007 sugarcane production forecasted 11,974 tons, in contrast with the obtained production (12,736 tons). The results indicate that forecasting with the model is 94% accurate.

Nasiru Suleman and Solomon Sarpong (2012) reported that increasing demand for rice in Ghana has been a major concern to the government and other stakeholders. Recent concerns by the Coalition for African Rice Development (CARD) to double rice production within ten years in Sub-Saharan countries have triggered the to implement strategies to boost rice production in the government. To fulfill this requirement, there is a need to monitor and forecast trends of rice production in the country. This study employs the Box-Jenkins approach to model milled rice production using time series data from 1960 to 2010. The analysis revealed that ARIMA (2, 1, 0) was the best model for forecasting milled rice production. Although, a ten years forecast with the model shows an increasing trend in production, the forecast value at 2015 (283.16 thousand metric tons) was not good enough to compare with the current production of Nigeria (2700 thousand metric tons), the leading producer of rice in West Africa.

Borkar (2012) in her study forecasting cotton yield in Maharashtra using season time series model described an empirical study of modeling and forecasting time series data of cotton yield in Maharashtra. Yearly cotton yield data for the period of 1964-65 to 2007-08 of Maharashtra were analyzed by time series methods. Autocorrelation and partial autocorrelation function were calculated for the data. The Box Jenkins ARIMA methodology has been used for forecasting. The diagnostic checking has shown that ARIMA (2,1,1,) is appropriate. The forecasts from 2008-09 to 2019-20 were calculated based on the selected model. The forecasting power of autoregressive integrated moving average model was used to forecast cotton yield for twelve leading years. The projections were based on assumptions of absence of random shocks in economy, agricultural price structure and policies will remain unchanged and consumer's preference will be same.

Sivapathasundaram and Bogahawatte (2012) studied the past, present and future trends of paddy production in Sri Lanka and developed a time series model to detect the long term trend and prediction for future changes of paddy production for the three leading years. Autoregressive Integrated Moving Average (ARIMA) model was used to fit the data set which is complementary to the trend regression approach and forecasting of the concerned variable to the near future. Time series forecasting analysis utilized the secondary data of the Department of Census and Statistics of Sri Lanka for the period of 1952 to 2010. Non-stationarity in mean was corrected through differencing of the data of order 1. ARIMA (2, 1, 0) was the most suitable model used as this model has the 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. This model can be used by researchers for forecasting of paddy production in Sri Lanka. But, it should be updated continuously with incorporation of recent data.

Mishra *et. al.* (2013) in their study on instability and forecasting using ARIMA model in area, production and productivity of onion in India, employed Box-Jenkins ARIMA modeling to forecast series under consideration. Data for the period 1978-2006 were used for the model building whereas; data for years 2007 and 2008 were taken for model validation. The study revealed that the ARIMA (1,1,5) model is best suited for modeling of onion area data. In case of production of onion the ARIMA (0,1,5) model is best fitted, it can be said that forecasted production will increases to 23.02 million tonnes during 2020. In case of the productivity of onion the ARIMA (1,1,4) model is best fitted and forecasted yield would be 17030 kg/ha in 2020.

Tripathi *et. al.* (2013) the study focused on forecasting the cultivated area and production of pearl millet in India using Autoregressive Integrated Moving Average (ARIMA) model. Time series data covering the period of 1950-2010 was used for the study. The analyses forecast pearl millet production for the year 2020 to be about 9.15 million tons. Tentatively twelve models were selected for study purpose. Out of these models only three were selected on the basis of minimum values of AIC and BIC. The selected models were ARIMA (0,1,0), ARIMA (0,1,1) and ARIMA (1,1,0). These models were compared according to minimum value of RMSE, MAE and MAPPE and maximum value of R^2 followed by autocorrelation function and partial autocorrelation function of residuals. The model also shows that the pearl millet area would be 8.67 million hectares in 2020. In The yield of pearl millet would be 1083.12 kg/ha in 2020. These projections will help information of good policies with respect to relative production, price structure as well as consumption of pearl millet in the country.

M. Amin *et. al.* (2014) in their study on time series modeling for forecasting wheat production of Pakistan, developed time series models and best model is identified for forecasting the wheat production of Pakistan. In this research large time periods i.e. 1902-2005 data were used. Various time series models were fitted on this data using two software's JMP and Statgraphics. On the basis of AIC they found that Model M i.e. ARIMA (1, 2, 2) has lowest AIC and they used this model to forecast wheat production. On the basis of this selected model, they have found that wheat production of Pakistan would become 26623.5 thousand tons in 2020, 30429.8 in 2030, 34236 in 2040, 38042.2 in 2050 and 41848.5 thousand tons in 2060. They also found that wheat production of Pakistan would become double in 2060 as compared in 2010.

Biswas *et. al.* (2014) studied forecasting wheat production using ARIMA model in Punjab. In the present study attempt was made to analyze, area, production and productivity of wheat for Punjab by time series method. Yearly wheat yield data for the period of 1950-51 to 2009-10 were used as input to forecast the yield upto the year 2020-21. The Box-Jenkins ARIMA method was put into use to forecast the yield. The validity of the model was tested by standard statistical techniques. The past 60 years data revealed that wheat yield was increased from 0.8 t/ha in 1950-51 to 4.3 t/ha in 2009-10. The model projected 15.3 per cent increase in wheat production in the years to come by 2020-21 in Punjab. Based on ARIMA output, wheat production of Punjab is likely to increase from 15844.7 thousand tons in 2010-11 to18271.7 thousand tons in 2020-21.

Chaudhari *et. al.* (2014) attempt to forecast cotton production in India. The study aimed at forecasting the cotton production in India by using the time series cotton production data for the period from 1950-51to 2010-11. To forecast the cotton production ARIMA models, introduced by Box and Jenkins were used. To test the reliability of model R^2, mean absolute percentage error (MAPE), and Bayesian Information Criterion (BIC) were used. Among the different class of ARIMA models, lowest BIC value worked out to be 254 for ARIMA (0,1,0,), which was the best fitted model. Based on model results the estimated cotton production in India would increase from 33.93 million bales during the year 2011-12 to 37.98 million bales during the year 2019-20.

Naveena *et. al.* (2014) studied forecasting of coconut production in India. The present study is an attempt to find an appropriate model to forecast the coconut production in India. Time series data for a period of 61 years from 1951-2012 were used. The best model has been selected based on the minimum root mean square error values. It has been found that ARIMA (1,1,1) model was found to be the best model. Forecast indicates that production of coconut in the year 2020 would be 1200 million nuts (8.51%) more than present production.

Brintha *et. al.* (2014) reported that the unobserved component model (UCM) is a promising alternative to ARIMA in overcoming problem of nonstationary data, as it does not make use of the stationary assumption. The study aimed at using UCM for annual national coconut production data from 1950 to 2012, which is nonstationary, and to forecast the coconut production in Sri Lanka. Results revealed that both the trend components, level and slope, have non-stochastic processes. Further, it revealed that the level was significant (p=0.0001) and slope was non-significant (p>0.1). The linear trend model zero variance slopes was found to be the best fit for the data with 11.3 years of estimated period of the cycle. The forecasted error for 2011 and 2012 were 1.08% and 1.69%, respectively. From the fitted model, predicted annual coconut production for 2013 was 2739.1 million nuts and the 95% CI is 2048.7 to 3429.5 million nuts. Thus, the use of UCM is recommended for annual data series, too.

Ali *et al.* (2015) made an attempt to forecast production and yield of two main cash crops namely sugarcane and cotton of Pakistan by using Auto Regressive Moving Average (ARMA) and Auto Regressive Integrated Moving Average (ARIMA) models of forecasting. Using data for 1948 to 2012, productions and yields of both crops were forecasted for 18 years starting from 2013 to 2030. Appropriate models were selected based on certain selection criterion, for example, Schwarz-Bayesian Information Criteria (SBC) and Akaike Information Criteria (AIC). ARMA (1, 4), ARMA (1, 1) and ARMA (0, 1) were found appropriate for sugarcane production, sugarcane yield, and cotton production respectively, whereas ARIMA (2, 1, 1) was the suitable model for forecasting cotton yield. The forecasted values of sugarcane crop reveal that it will reach 71,414 thousand tonnes and its yield will attain 60,765 kg/ha by 2030. On the other hand, the forecast of cotton production is 15,479 thousand tonnes and its yield is 870 kg/ha for 2030.

Ljiljanić *et al.* (2015) studied wheat production analysis by using econometric models. The study analyzed time series data for the period 1994–2013 on areas sown with wheat, average yields, purchase price for wheat, subsidies and wheat used for seed in Serbia. They developed dynamic models, on which they forecasted that 89000 tons of wheat would be used in 2014 for an area of 507000 ha. This ARIMA model confirms that in wheat production economic factors have a dominant impact on sown areas and quantities of wheat used for seed.

Mishra *et al.* (2015) examined the performance of total food grains production in India and its major states during the period (1950-2009). The study also focuses on forecasting the area and production of total food grains in India using Autoregressive Integrated Moving Average (ARIMA) model. In an attempt to increase forecast accuracy, the study incorporated the factors of production in the ARIMA model as auxiliary variables. The study reveals that by and large estimated figures are closer to the observed figures when different factors are included in the model. Forecasting figures worked out using the best fitted ARIMA models with and or without the incorporation of factors of production indicate that Uttar Pradesh will be the leading state in India in total food grains production, with a production of 49455 thousand tonnes from an area of 19982 thousand hectare with 2718 kg/ha yield during year 2020.

Borkar (2015) described an empirical study of modeling and forecasting time series data of coconut production in India. Yearly coconut production data for the period of 1950-51 to 2012-13 of India were analyzed by time series methods. The Box-Jenkins Autoregressive Integrated Moving Average (ARIMA) methodology has been used for forecasting. The diagnostic checking has shown ARIMA (1,0,0,) is appropriate. The forecast from 2013-14 to 2019-20 were calculated based on the selected model. The forecasted production of coconut for the year 2019-20 would be 15705.86 nuts per hectare.

Dasyam *et al.* (2015) made an attempt to model and forecast the production of wheat in India by using annual time series data from 1961-2013. Parametric regression, exponential smoothing and Auto Regressive Integrated Moving Average (ARIMA) models were employed and compared. In this present work, possible ARIMA (p,d,q) models such as (1,1,1), (0,1,1) and (1,1,0) were compared to each other. Among all possible models, ARIMA (1,1,0) was selected as optimal and most appropriate model. The best fitted model was selected based on the performance of several goodness of fit criteria viz. Root Mean Squared Error (RMSE), Mean Absolute Percentage Error (MAPE), Mean Absolute Error (MAE), Mean Squared Error (MSE), Akaike Information Criterion (AIC), Schwarz's Bayesian Information Criterion (SBC) and R-squared values. This study found ARIMA (1,1,0) as most appropriate to model the wheat production of India. The forecasted value by using this model was obtained as 100.271 million tons (MT) by 2017-18.

Singh *et al.* (2015) analyzed the data on area and production of paddy in Chhattisgarh for the period of 1974-75 to 2010-11 by time series methods. Appropriate Box-Jenkins Autoregressive Integrated Moving Average (ARIMA) model was fitted. Validity of the model was tested using standard statistical techniques. ARIMA (2,1,2) and ARIMA (2,1,0) models were used to forecast paddy area and production in Baster Division of Chhattisgarh for four leading years. The results also showed paddy area forecast for the year 2015 to be about 598.22 thousand hectare with upper and lower limits 665.39 and 531.06 thousand hectares respectively. The model also showed paddy production forecast for the year 2015 to be about 1126.61 thousand tonnes with upper and lower limit 1430.16 and 823.05 thousand tonnes respectively.

CHAPTER III

SOCIO-ECONOMIC BACKGROUND OF KONKAN REGION

(Excluding Mumbai)

The socio-economic background of a study area has a direct influence on various agricultural activities carried out in that region. Various physical factors, like agro climatic conditions, soil type, irrigation facilities, transport and communication and other infrastructural facilities decide the suitability of a particular enterprise to that area. A brief account of geographical and socio-economic conditions prevailing in the selected area is given so as to have good understanding of the region and also to help in the interpretation of the results and drawing inferences.

3.1 Location

The Konkan region of Maharashtra falls under West Coast plains and Ghat region (Zone No. XII). It has a long narrow strip stretching from North to South along the West Coast of India. Its position on the world map is given by 150 37' to 180 04' north latitude and 730 19' to 740 13' east longitude. The region comprises Greater Mumbai, Thane, Palghar, Raigad, Ratnagiri and Sindhudurg districts of Maharashtra State. The total geographical area of Konkan region is 29.41 lakh hectares. The region has a hilly terrain and receives heavy rainfall ranging from 3000 to 4000 mm mainly during June to September. The climate is warm and humid almost throughout the year. The soils are mainly lateritic and medium black.

The Konkan region shows variation in agro-climatic features, soil types, crops and cropping pattern. Based on these variations, the region is broadly divided into two agro-climatic zones viz., South Konkan Coastal Zone (SKCZ) and North Konkan Coastal Zone (NKCZ). SKCZ includes Ratnagiri and Sindhudurg districts, whereas the NKCZ zone includes Raigad, Palghar and Thane districts.

3.2 Boundaries

All the five districts are surrounded by Sahyadri hills to the east, beyond which there are boundaries of six districts of Western Maharashtra region, Gujarat state towards north, Arabian Sea to the west and Goa to the south. The Konkan region has a coastal line of 640 km (excluding Mumbai).

3.3 Topography

The Konkan region can be divided in to three natural zones from the point of view of topography viz., (i) the coastal zone which is marked by rice cultivation on low lying areas and plantation of mango on hill slopes, coconut and arecanut along seacoast. (ii) The plateau surface, which is used for cereal crops like rice, nagli etc. and cashew nut on hill slopes and (iii) the hilly zone, which has good forests. The Sahyadri ranges on the eastern boundary have highly uneven natural surface and are agriculturally poor and natural vegetation is negligible.

3.4 Soil

Soils constitute the physical basis of an agriculture enterprise and play a vital role in the agricultural economy. Soils of Konkan region are found in several grades, depending on their location and admixture of different rocks. The predominant soils in south Konkan are lateritic which vary in colour from bright red to brownish. They are acidic and fairly well supplied with nitrogen and organic matter, while the soils of north Konkan are made up of 'Deccan Trap' which varies in colour from brownish to black.

On hill slopes, the soils are coarse, sandy in nature while in valleys they are clay loams. The soils of the hill slopes may be only 9 to 45 cm in depth while those of the flat lands and valleys are deeper than 60 cm. Their pH is slightly on the acidic side. Paddy is the main *Kharif* crop while in rabi season, crops like rabi jowar and pulses are taken on deeper soils.

The lateritic soils have three varieties of soils, viz., rice soils, *varkas* (light) soils and garden soils. The rice soils are generally found in low lying areas which receive the eroded soils from the upper reach and are usually rich in organic matter. The *varkas* soils which are on hill slopes are shallow and eroded soils, coarse in texture and yellowish red in colour. *Nagli (Eleusine coracana)* is the principal crop grown on these soils; it responds well to N and P fertilizers. The garden soils are light, easily workable, yellowish to brownish in colour and mostly support arecanut and coconut plantations.

3.5 Climate

The climatic conditions in the region are strongly influenced by its geographical conditions. It is distinctly different on coastal strip, where it is very humid and warm. On the other hand, the climate on the eastern slopes and plains at the foot of slopes is comparatively less humid. The per cent humidity ranges from 50-80 throughout the year. On an average, temperature ranges from 16 °C to 40 °C. The summer season from March to May is followed by the south-west monsoon season from June to September. The period from December to February is winter. Being the coastal area, the variation in temperature during the day and through the season is not large. Maximum temperature at the seacoast rarely goes beyond 38 °C and in the interior; it seldom crosses 40 °C, owing to the proximity of the sea.

3.6 Rainfall

Rainfall is the most dominant single weather parameter that influences plant growth and crop production because of its uncertainty and variable nature. Rainfall is not uniform in all parts of the Konkan region. The Konkan region gets assured rainfall ranging from 3000 to 4000 mm from the southwest monsoon during the months from June to September. Generally, the highest rainfall is in the month of July. It is less towards the north than south.

3.7 Area and population

The total geographical area of Konkan region is 30,125 sq km. According to 2011 census, total population of Konkan region is 161.51 lakhs, out of which, male population is 84.03 lakhs and female population is 77.47 lakhs. The density of population per sq. km. is 471 as against 365 for Maharashtra state. The proportion of urban population is higher than rural population. Rural population is 43.80 lakhs and urban population is 104.27 lakhs.

3.8 Land utilization

The land utilization information of Konkan region is presented in Table 3.1. It is observed from Table 3.1 that the net sown area in the region is only 35.63 per cent of the total geographical area. The area sown more than once is only 1.83 per cent. Barren and unculturable land constitutes 16.68 per cent. It shows that the topography of the region makes large part of its land unsuitable for cultivation. The proportion of culturable waste land in the Konkan region is 13.03 per cent. The current and other fallow land accounted to 10.85 per cent. This shows that there is good scope to bring the fallow land under plantation crops, particularly mango and cashew

This is being done by the government of Maharashtra through Employment Guarantee Scheme (EGS), which provides a good amount of subsidy to the farmers for undertaking plantation of horticultural crops. The area under forest is 18.66 per cent, which is also less than the recommended level of 30 per cent of the total geographical area. Efforts need to be made to increase area under forest and protect the available forest by following strict measures. The gross cropped area accounts for about 36.83 per cent of the total geographical area.

Table 3.1. Land utilization in Konkan region during 2014-15

Sl. No.	Land use category	Area (00 ha)	Percentage to total geographical area
1.	Total geographical area	29153	100.00
2.	Area under forest	5439	18.66
3.	Barren and unculturable land	4863	16.68
4.	Land put for non-agricultural uses	1424	4.88
5.	Culturable waste land	3800	13.03
6.	Current fallows	1316	4.51
7.	Other fallows	1847	6.34
8.	Net sown area	10388	35.63
9.	Area sown more than once	348	1.83
10.	Gross cropped area	10736	37.46

(**Source:** Socio-economic Review and District Statistical Abstracts of the Thane, Raigad, Ratnagiri and Sindhudurg districts 2014-15)

3.9 Cropping pattern

As the Konkan region is situated near the sea coast, there is heavy rainfall during monsoon. Paddy and Nagli are the major cereals grown in the region. Paddy cultivation is done on lowlands and the varkas lands are utilized for cultivation of hill millets like Nagli, Kodra, Vari etc. Varkas lands on hill slopes in heavy rainfall area provide good drainage and hence mango and cashew orchards thrive well on such lands. On coastal plains, coconut and arecanut gardens are well established.

It can be seen from the Table 3.2 that cereal crops dominate the cropping pattern of Konkan region. Paddy is a major cereal crop occupying 35.38 per cent of the gross cropped area. The area under foodgrain crops is 54.20 per cent, which includes the area under pulses accounting for about 3.59 per cent. Area under oilseed crops is less than one per cent. Fruit and vegetable crops are occupying about 38.52 percent of the gross cropped area having further scope of increasing area under these crops by bringing culturable wasteland under cultivation, which stands about 13.03 per cent of the total geographical area. The area under fodder crops is about 1.43 per cent. In fact, there is no much commercial cultivation of fodder crops in the region, except few patches in Thane and Raigad districts. The area shown in cropping pattern gives an idea about area under natural grass lands from where mostly dry grass is harvested.

Table 3.2 Cropping pattern of Konkan region

Sl. No.	Crops	Area in (00 ha)	Percentage to gross cropped area
1.	Cereals		
	a) Paddy	3250.78	35.38
	b) Other cereals	1399.01	25.23
	Total cereals	4649.79	50.60
2.	Pulses		

	a) Tur	34.61	0.38
	b) Gram	23.16	0.25
	c) Other pulses	272.52	2.97
	Total pulses	330.29	3.59
3.	Total foodgrains (cereals and pulses)	4980.08	54.20
4.	Total oilseeds	46.52	0.51
5.	Total fruits and vegetables	3539.41	38.52
6.	Fodder crops (natural grass lands)	131.39	1.43
7.	Total cropped area	9187.84	100

(**Source:** Socio-economic Review and District Statistical Abstracts of the Thane, Raigad, Ratnagiri and Sindhudurg districts 2014-15)

3.10 Fishery

The marine fishing is practiced all over the coastline of 640 km Konkan region (excluding Mumbai). Fishing is carried out with the traditional boats, as well as, mechanized trawlers. The fishery trade has flourished in Thane district, as there is always demand for fish in Mumbai market. Fishing trade is increasing gradually and still has vast potentialities. Total marine fish production during 2014-15 from four districts was 298775 MT.

Table 3.3 Marine fish production

District	Coastal length (km)	Production (MT)	Production MT/km length
Thane (including Palghar)	112	120924	1079.68
Raigad	240	41249	171.87
Ratnagiri	167	115042	688.87
Sindhudurg	121	21560	178.18
Konkan region	**640**	**298775**	**304.64**

(**Source:** Socio-economic Review and District Statistical Abstracts of the Thane, Raigad, Ratnagiri and Sindhudurg districts 2014-15)

There are 152 fisheries societies working in the region. The details about coastal length and fish production in each district during 2014-15 are given in Table 3.3. It is seen from Table 3.3 that the production per km length in Thane district was highest (1079.68MT), followed by Ratnagiri (688.87MT), Sindhudurg (178.18MT) and Raigad (171.87MT). In the Konkan region, per km length fish production is 304.64MT.

3.11 District wise milch animals in Konkan region

The information regarding district wise milch animals is presented in Table 3.4 It is observed from Table 3.4 that in Konkan region, there are 68,289 milch animals of which maximum (34.35 Per cent) in Ratnagiri district, followed by Sindhudurg (28.53 Per cent), Raigad (20.86 Per cent) and Thane district (16.26 Per cent). Among different types of milch animals, the proportion of crossbreed cows is maximum (41.69 Per cent) in Ratnagiri and it is minimum (8.88 Per cent) in Thane district.

Table 3.4 District-wise milch animals in Konkan region

(No.)

Sl. No.	District	Category			Total milch animals
		Cow		Buffalo	
		Crossbreed	Indigenous		
1.	Thane (including Palghar)	1749 (8.88)	3003 (13.15)	6351 (24.65)	11103 (16.26)
2.	Raigad	4788 (24.31)	5495 (24.07)	3962 (15.38)	14245 (20.86)
3.	Ratnagiri	8209 (41.69)	8693 (38.08)	6556 (25.44)	23458 (34.35)
4.	Sindhudurg	4946 (25.12)	5639 (24.70)	8898 (34.53)	19483 (28.53)
5.	**Konkan Region**	**19692 (100)**	**22830 (100)**	**25767 (100)**	**68289 (100)**

(Figures in parenthesis indicate percentage to Konkan)

(**Source:** Socio-economic Review and District Statistical Abstracts of the Thane, Raigad, Ratnagiri and Sindhudurg districts 2014-15)

As regards indigenous cows, the proportion is maximum (38.08 per cent) in Ratnagiri district and is minimum in Thane district (13.15 per cent). In respect of milch buffalo, maximum proportion is in Sindhudurg district (34.53 per cent), followed by Ratnagiri district (25.44 per cent), Thane district (24.65 per cent) and Raigad district (15.38 per cent). The analysis revealed that Thane and Raigad districts are having leading position in respect of number of milch animals. This is particularly true in respect of number of milch buffaloes.

3.12 Livestock

Livestock makes substantial contribution to the economy by providing subsidiary income to the farmers, food to human population and employment to labours. The livestock population in Konkan region as per 2012 census is presented in Table 3.5.

Table 3.5 indicated that as per livestock census 2012, total livestock population in Konkan region is 12.90 lakh heads, of which 82.54 per cent is bovine population. Cattle and buffalo population is 61.58 and 20.96 per cent, respectively.

Table 3.5 Livestock population in Konkan region

(No.)

Sl. No	Category	Thane	Raigad	Ratnagiri	Sindhudurg	Konkan region

1.	Cattle	103915 (39.01)	223926 (58.50)	319312 (80.47)	147410 (60.36)	794563 (61.58)
2.	Buffalo	90898 (34.12)	68720 (17.95)	43816 (11.04)	66935 (27.41)	270369 (20.96)
	Total bovine	194813 (73.13)	292646 (76.45)	363128 (91.51)	214345 (87.76)	1064932 (82.54)
3.	Sheep	2014 (0.76)	268 (0.07)	127 (0.03)	11 (0.005)	2420 (0.19)
4.	Goats	62461 (23.48)	87439 (22.84)	33071 (8.33)	28125 (11.52)	211096 (16.36)
5.	Horses	819 (0.31)	903 (0.24)	21 (0.01)	15 (0.01)	1758 (0.14)
	Donkeys	328 (0.12)	59 (0.02)	156 (0.04)	-	543 (0.04)
6.	Other livestock	5955 (2.24)	1472 (0.38)	296 (0.07)	1732 (0.71)	9455 (0.73)
7.	Total livestock	266390 (100)	382787 (100)	396799 (100)	244228 (100)	1290204 (100)
8.	Total poultry birds including other birds	2476190	3824751	824703	769151	7894795

(Figures in parenthesis indicate percentage to Total livestock)

(**Source:** Socio-economic Review and District Statistical Abstracts of the Thane, Raigad, Ratnagiri and Sindhudurg districts 2014-15)

3.13 Transport and communication

The total road length and length of railway route in the year 2014-15 was 39055 km. and 1141 km, respectively. The road length maintained by all authorities per 100 sq. km. of geographical area in the Konkan region in 2014-15 was 80.28 km. A major National highway viz., Mumbai-Goa highway runs lengthwise and serves as an important means of transportation. Most of the villages and towns are connected by small roads to highway. The Konkan railway is also becoming a major source of transport in the region. Telecommunication facilities are also well developed in the region, which helps in fast communication.

3.14 Co-operative societies

Co-operative sector covers various aspects of agricultural needs such as, extension to agriculture credits and provision of agricultural inputs through co-operative societies.

Table 3.6 District-wise co-operative societies in Konkan region

(No.)

Sl. No.	Item	Thane	Raigad	Ratnagiri	Sindhu-durg	Konkan Div.
1.	All types of co-operative societies	32266 (100)	5022 (100)	2890 (100)	1342 (100)	41520 (100)
2.	Co-operative Credit societies	413 (1.28)	131 (2.61)	381 (13.18)	228 (16.99)	1153 (2.78)
3.	Non-Agril. Credit societies	1159 (3.59)	486 (9.68)	331 (11.45)	178 (13.26)	2154 (5.19)
4.	Marketing societies	26 (0.08)	35 (0.70)	19 (0.66)	32 (2.38)	112 (0.27)
5.	Productive enterprises	1308 (4.05)	466 (9.28)	609 (21.07)	285 (21.24)	2668 (6.43)
6.	Social service & other co-operative society	29360 (90.99)	3904 (77.74)	1550 (53.63)	619 (46.13)	35433 (85.34)

(**Source:** Socio-economic Review and District Statistical Abstracts of the Thane, Raigad, Ratnagiri and Sindhudurg districts 2014-15)

At the end of 2014-15, there were 41520 numbers of all types of co-operative societies in Konkan region in which 1153 (2.78 per cent) were co-operative credit societies, 2154 (5.19 per cent) non-agricultural credit societies, 112 (0.27 per cent) marketing societies, 2668 (6.43 per cent) productive enterprises, 35433 (85.34 per cent) social service and other co-operative societies.

CHAPTER IV

METHODOLOGY

Methodology of any research is considered as heart of research, without which, one cannot proceed an inch further. It is the guiding path which leads us to achieve our decided objectives. In agriculture, many efforts were made to study the various aspects like production, marketing, finance, funding institutions, government policies, processing etc., but very less attempts have been made to assess the effect of weather parameters on the production capacity of crops, effect of climate change and forecast of crop yield.

With this view, the present study was conducted to investigate the functional relationship between various weather parameters and production of rice crop. There are many problems, especially in the agricultural sector, regarding the availability and accuracy of the data, aggregation of data over the period and over the area, reliability of data, etc. In spite of all these problems, this research was undertaken with the purpose to devise suitable forecasting model for rice production in Konkan region. The research methodology followed in the conduct of present study is described in this chapter under following heads:

4.1 Period of study

4.2 Sources of data

4.3 Selected parameters for model development

4.4 Analytical tools

4.5 Comparison of various forecast models

4.1 Period of study:

The data on the rice production and on different weather parameters for the four districts of Konkan region i.e. Ratnagiri, Raigad, Thane (Old) and Sindhudurg districts were collected from the secondary sources for the period from 1989-90 to 2014-15. The data for 26 years were used for analysis.

4.2 Sources of data:

The time series data on area, production and productivity of rice in Ratnagiri, Raigad, Thane and Sindhudurg district were required for the present study. Such data were collected from various secondary sources i.e. different published reports of the state government, for different time periods.

1. Season and Crop Reports, Department of Agriculture, Government of Maharashtra, Pune.

2. Statistical Abstract of Maharashtra State, Directorate of Economics and Statistics, Government of Maharashtra, Mumbai.
3. Socio-economic Review and District Statistical Abstracts of Thane, Raigad, Ratnagiri and Sindhudurg districts, Directorate of Economics and Statistics, Government of Maharashtra, Mumbai.

The historical weather data for Ratnagiri, Raigad, Thane and Sindhudurg district were required for the present study. Hence the data on all weather parameters were collected from the regional meteorological stations of respective districts. These data were supported by the data obtained from the Indian Meteorological Department (IMD), Pune.

4.3 Selection of parameters for model development:

Keeping in view the specific objectives of the study, historical weather data on various weather parameters were obtained from the different regional meteorological stations and IMD. Among different weather parameters, following weather parameters with time trend were selected to study the functional relationship between weather parameters and productivity of rice in Konkan region:

T : Time trend, to account for technological effect on rice production,

X_1 : Maximum temperature (^{0}C),

X_2 : Minimum temperature (^{0}C),

X_3 : Morning relative humidity (%),

X_4 : Afternoon relative humidity (%),

X_5 : Total rainfall (cms),

X_6 : Sunshine hours (hrs),

In this study, stage-wise average standardized weather parameters were used for analysis. According to various growth stages observed in life cycle of crop, the meteorological data were grouped into six crop growth stages. The details of the crop growth stages considered for the present study are given in Table 4.1.

Table 4.1 Crop growth stages according to standard meteorological weeks.

Week No.	Crop Week No.	Crop Growth Stage	Stage No.
23	1	Sowing	I
24	2	Seedling/ Transplanting	II
25	3		
26	4		III

27	5	Tillering	
28	6		
29	7		
30	8		
31	9		
32	10	Flag Leaf Stage	IV
33	11		
34	12	Flowering	V
35	13		
36	14		
37	15	Grain Filling and Maturity	VI
38	16		
39	17		
40	18		
41	19		

The data on weather parameters were collected from 23rd standard meteorological week (SMW) to 41st standard meteorological week.

Table 4.2 Details of variables used for modeling.

	Stage I	**Stage II**	**Stage III**	**Stage IV**	**Stage V**	**Stage VI**
Maximum temperature	T_MAX_STG_1	T_MAX_STG_2	T_MAX_STG_3	T_MAX_STG_4	T_MAX_STG_5	T_MAX_STG_6
Minimum temperature	T_MIN_STG_1	T_MIN_STG_2	T_MIN_STG_3	T_MIN_STG_4	T_MIN_STG_5	T_MIN_STG_6
Morning relative humidity (RH_1)	RH_M_STG_1	RH_M_STG_2	RH_M_STG_3	RH_M_STG_4	RH_M_STG_5	RH_M_STG_6
Evening relative humidity (RH_2)	RH_E_STG_1	RH_E_STG_2	RH_E_STG_3	RH_E_STG_4	RH_E_STG_5	RH_E_STG_6
Total rainfall	RN_FL_STG_1	RN_FL_STG_2	RN_FL_STG_3	RN_FL_STG_4	RN_FL_STG_5	RN_FL_STG_6
Sunshine hours	SSH_STG_1	SSH_STG_2	SSH_STG_3	SSH_STG_4	SSH_STG_5	SSH_STG_6

The details of variables used in modeling are as given in Table 4.2. The original daily data on various weather parameters were first arranged on weekly basis. Then, according to crop growth stages, the same data were arranged according crop growth stages.

4.4 Analytical tools

4.4.1 Estimation of trends in area, production and productivity.

The data for 36 years (1979-80 to 2014-15) were used to assess trends in area, production and productivity of rice. The period of study was sub-divided into four periods as shown below:

1. Period I :1979-1980 to 1988-1989
2. Period II :1989-1990 to 1998-1999
3. Period III :1999-2000 to 2008-2009
4. Period IV :2009-2010 to 2014-2015
5. Overall :1979-1980 to 2014-2015

Compound Growth Rates (CGR)

Compound growth rate was estimated by using exponential growth function as,

$Y = ab^t e^{ut}$

Where,

Y = Area / production/ productivity of the rice crop

a = Intercept

b = Regression or trend coefficient

t = Time

r = Compound growth rate

e = Error term

ut = Coefficient of error term

The compound growth rate was estimated as

C.G.R. (r) = [Antilog (log b) – 1] x 100

4.4.2 Estimation of the instability in the rice production.

The instability in area, production and productivity of rice for different time periods was estimated by using Cuddy-Della Valle instability index as under.

$$\text{Coefficient of Variation} = \frac{\text{Standard Deviation}}{\text{Mean}} \times 100$$

$$\text{Cuddy - Della Valle Instability Index} = \text{C. V.}\sqrt{1 - R^2}$$

Where,

C.V. = Coefficient of variation in %.

R^2 = The coefficient of determination from a time trend regression adjusted by the number of degrees of freedom.

4.4.3 Models for forecasting the rice production.

Four approaches were adopted for weather based forecasting of rice production: Regression analysis (between weather parameters and rice production), Aridity indices, ARIMA time series model and Artificial Neural Network (ANN) model.

4.4.3.1 Regression analysis:

Multiple regression analysis is the most commonly used method to explain relationship between a group of explanatory variables and dependent variable. In this study multiple regression analysis was performed to describe the functional relationship between production of rice and different weather parameters. Data collected were initially arranged week-wise and later on categorized according to crop growth stages. The original data were standardized for further analysis. Standardization was done in SAS software by using ‘proc standard’. The syntax used for the standardization was as follows:

```
/*Standardization of the data*/
        proc standard data= dataset mean=0 std=1 out= result;
        var inputs ;
        run;
```

Standardized variables obtained from the procedure were used as independent variables for further analysis. Regression analysis was performed in SAS software by using ‘proc reg’. The syntax used for the regression analysis was as follows:

```
/*Regression analysis*/
        proc reg data=dataset ;
        model output=inputs /
        selection=stepwise slentry=0.10 slstay=0.10 ;
        run;
```

After fitting the regression model, the next step was obtaining forecast values of the target output by fitted regression model for further few years. For this purpose ‘proc forecast’ procedure was used. The syntax for the procedure was as follows:

```
/*Forecast value*/
        proc forecast data=dataset lead=10 out=predicted;
        by inputs;
        var Y;
        run;
```

4.4.3.2 Aridity index:

The general idea behind the aridity index method is, instead of using original explanatory variables as an explanatory variable, the use of an index in regression analysis. Aridity index is an index which is developed by using those original explanatory variables. The use of composite aridity index variable in econometric model has made the analysis easier and logical [Paltasingh *et. al.* (2012)]. More importantly, the use of aridity index saves the 'degrees of freedom' which is very crucial in econometric analysis.

Most of the researchers like Oury (1965), Stallings (1961) and Shaw (1964) have rejected the direct use of meteorological variables like rainfall and temperature primarily on the ground that the functional relationship between these variables and yield was not known.

Oury (1965) has recommended the inclusion of aridity index into the econometric model of crop weather relation. The Aridity index i.e. the composite index which was initially used to distinguish dry climates from moist climates geographically at one point of time could be used to reflect weather variation over the years and it provided an operational tool for the production analysis. He had cited some indexes in his study as below:

- Index given by Thornthwaite (1948) which emphasized the importance of evaporation.
- Index given by Lang (1920) after recognizing temperature as the major factor for evaporation.

Lang (1920) had suggested one simple method. He used a coefficient of humidity which is defined as the ratio of precipitation or rainfall of a year to the sum of mean temperatures of the frost-free months divided by twelve. It is written as Equation (1):

$$I_L = \frac{P}{\frac{1}{12}\sum T > 0} \quad \dots (1)$$

where, P is the sum of the precipitation of a year and T is the annual mean temperature. The ratio is related directly to precipitation and inversely to temperature.

De Martonne (1926) modified the Lang's method and used it as a coefficient of humidity which is simply the ratio of precipitation to temperature by adding 10 in the denominator to avoid negative values of the ratio, i.e.

$$I_M = \frac{P}{T + 10} \quad \dots (2)$$

De Martonne applied a similar coefficient for characterizing various months, in which case the coefficient takes the form of Equation (3):

$$I_M^I = \frac{P.12}{T^I + 10} \quad \dots (3)$$

where, P is the precipitation and T^I is the mean temperature of the month. However, as Oury (1965) mentioned that the index could be for any number of cumulated months, it could be written as Equation (4):

$$I_M^{II} = \frac{\sum_{i=1}^{n} P_i .12}{n} \Bigg/ \frac{\sum_{i=1}^{n} T_i}{n} + 10 \quad \dots (4)$$

Here, P_i is monthly precipitation of the i^{th} month (in millimeters), T_i is the average monthly temperature (°C) for the i^{th} month and n stands for the number of months.

Angstrom (1936) suggested a modification in De Martonne's index of aridity. He found that the index of aridity was directly proportional to the amount of precipitation and inversely proportional to an exponential function of temperature. His humidity coefficient was written as Equation (5):

$$I_A = \frac{P}{1.07^T} \quad \dots (5)$$

Aridity Index and Econometric Modeling of Weather Impact on Crops:

The present study incorporated the aforementioned aridity indices into the econometric models. For establishing the relative strength of aridity index models empirically the linear model was included, where both weather factors were modeled in an increasing monotonic fashion. The final models over the time t were of following form:

$$Y = \alpha_0 + \alpha_1 P + \alpha_2 T + \alpha_3 t + \alpha_4 t^2 + \alpha_5 t^3 + \varepsilon \quad \dots (6)$$

$$Y = \beta_0 + \beta_1 \left(\frac{P}{T} \right) + \beta_2 t + \beta_3 t^2 + \beta_4 t^3 + \varepsilon^I \quad \dots (7)$$

$$Y = \mu_0 + \mu_1 \left(\frac{P}{T+10} \right) + \mu_2 t + \mu_3 t^2 + \mu_4 t^3 + \varepsilon^{II} \quad \dots (8)$$

$$Y = \theta_0 + \theta_1 \left(\frac{P}{1.07^T} \right) + \theta_2 t + \theta_3 t^2 + \theta_4 t^3 + \varepsilon^{III} \quad \dots (9)$$

$$Y = \pi_0 + \pi_1 \left(\frac{P}{0.1T} \right) + \pi_2 t + \pi_3 t^2 + \pi_4 t^3 + \varepsilon^{IV} \quad \dots (10)$$

Where, Y is the production of rice crop; P is the sum of precipitation during the crop growth period in mm; T is the mean temperature of the same period (°C); α_0, β_0, μ_0, π_0 and θ_0 are the constant intercept terms; β_1, μ_1, θ_1 and π_1 are the coefficients of different aridity indexes; other parameters are coefficients of trend variable; and ε^{I}, ε^{II}, ε^{III} and ε^{IV} are error-terms.

4.4.3.3 Forecasting (ARIMA) model:

In an Auto-Regressive Integrated Moving Average (ARIMA) model, time series variable is assumed to be a linear function of the previous actual values and random shocks. In general, an ARIMA model is characterized by the notation ARIMA (*p, d, q*), where *p, d* and *q* denote orders of Auto-Regression (AR), Integration (differencing) and Moving Average (MA), respectively. ARIMA is a parsimonious approach which can represent both stationary and non-stationary processes.

An ARIMA (*p, 0, q*) process is defined by Equation (1):

$$y_t = c + \emptyset_1 y_{t-1} + \emptyset_2 y_{t-2} + \cdots + \emptyset_p y_{t-p} + \varepsilon_t - \theta_1 \varepsilon_{t-1} - \theta_2 \varepsilon_{t-2} - \cdots - \theta_q \varepsilon_{t-q} \quad \ldots(1)$$

where, y_t and ε_t are the actual value and random error at time period t, respectively, Φ_i (i=1, 2,……,*p*) and θ_i (j=1, 2,……,*q*) are the model parameters. The random errors, ε_t are assumed to be independently and identically distributed with a mean of zero and a constant variance of σ^2.

The first step in the process of ARIMA modeling is to check for the stationarity of the series as the estimation procedure is available only for a stationary series. A series is regarded stationary if its statistical characteristics such as the mean and the autocorrelation structures are constant over time. The stochastic trend of the series is removed by differencing. After appropriate transformation and differencing, multiple ARIMA models were chosen on the basis of Auto-Correlation Function (ACF) and Partial Auto-Correlation Function (PACF) that closely fit the data. The parameters of the models were estimated through non-linear optimization procedure such that the overall measure of errors is minimized or the likelihood function is maximized. The most suitable ARIMA model was selected using the smallest Akaike Information Criterion (AIC) or Schwarz-Bayesian Criterion (SBC) value. In this study, all estimations and forecasting of ARIMA model was done using SAS 9.2.

ARIMA modeling was performed by using production as output and standardized variables, those were significant at 10 per cent level of probability in regression analysis, as inputs. To initialize the ARIMA procedure in SAS 9.2 ‘proc arima’ statement was used.

In order to run the 'proc arima' some differenced variables had to be created. Creating differenced variables and plotting those variables against time were the prior procedures. The syntax for the complete ARIMA procedure followed is as given below:

```
/* Creating a differenced variable*/
        data dataset;
        set dataset;
        dY=dif(Y);
        d2Y=dif (dY);
        d3Y=dif (d2Y);
        run;
/* Plotting the data*/
        proc gplot data=dataset;
        plot Y*t;
        plot dY*t;
        plot d2Y*t;
        plot d3Y*t;
        run;
/* ARIMA (1,1,1) */
        proc arima data=dataset;
        identify var=dY crosscorr =(inputs);
        estimate input=(inputs) p=1 q=1 plot;
        run;
```

The forecast of production was performed by selected ARIMA model with the help of following statement:

```
/* ARIMA (1,1,1) forecasting*/
        proc arima data=dataset;
        identify var=dY crosscorr=(inputs);
        estimate input=(inputs) p=1q=1 ;
        forecast lead=10;
        run;
```

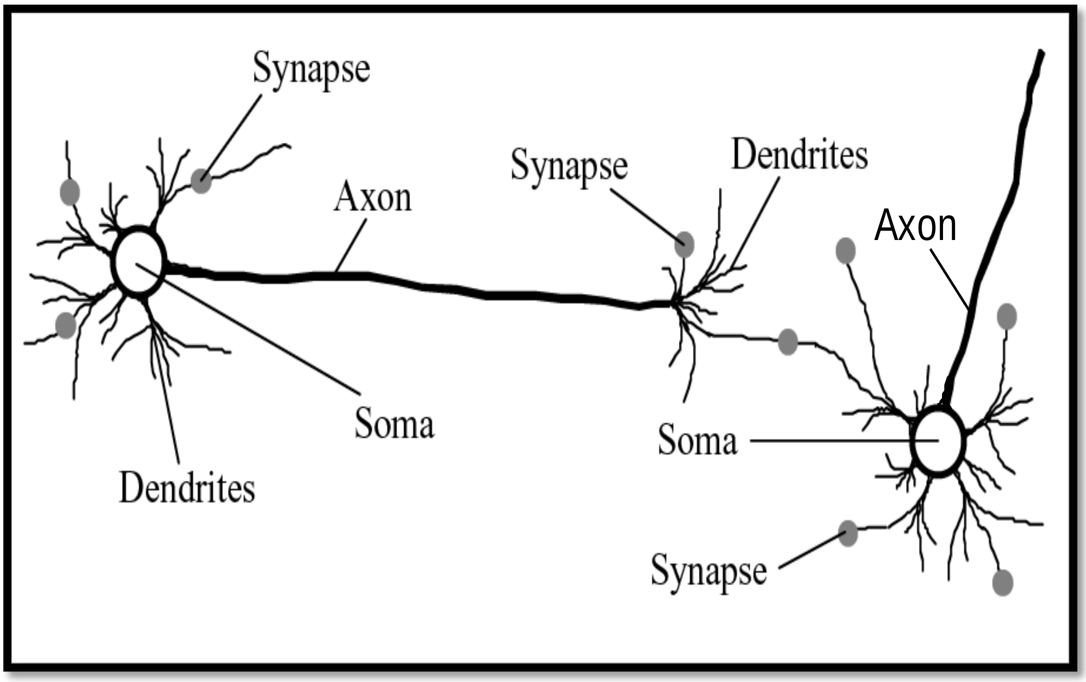
4.4.3.4 Artificial Neural Network (ANN):

An artificial neural network is a computer program that can recognize patterns in a given collection of data and produce a model for that data. The word network in the term 'artificial neural network' refers to the inter–connections between the neurons in the different layers of system. A typical system has three layers. The first layer is of input neurons which send data via synapses to the second layer of neurons (hidden layer), and then via more synapses to the third layer of output neurons. More complex systems will have more layers of neurons or some have increased numbers of input neurons and output neurons.

The synapses are the inter-connection strength between the neurons of different layers of system and they are called "weights" that manipulate the data in the calculations. Synapses vary in strength, strong strength allows a strong connections, weak strength allows a weak connections. Synapses can be either excitatory or inhibitory. If a input is positive, it acts as excitatory if the synaptic weight is positive. On the other hand, it acts as inhibitory if the synaptic weight is negative. It resembles the brain in two respects:

- Knowledge is acquired by the network through a learning process (trial and error).
- Inter-neuron connection strengths known as synaptic weights are used to store the knowledge.

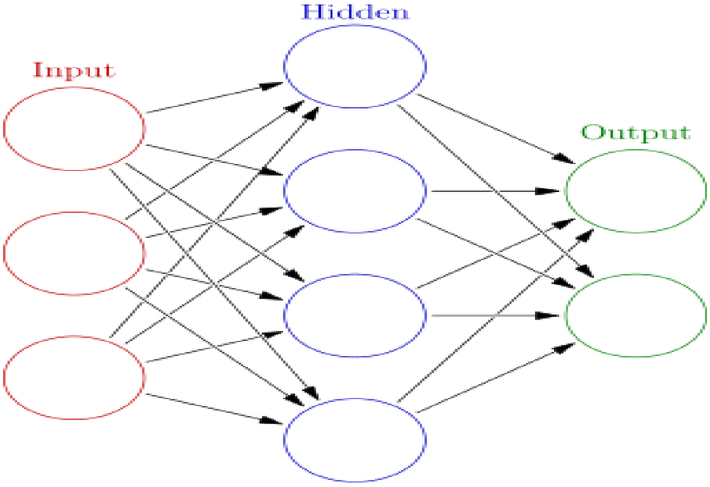
Biological neural network structure:



This is a structure of typical biological neuron and neural network. The main body of neuron is called ‘Soma’ which is present at the center. Soma acts as centre for processing of signal. The small and large numbers of connections are called as ‘Dendrites’. Dendrites provide inputs to the soma through ‘Synapses’ which determines its intensity. A long and bold single connection is called ‘Axon’. The processed signal passes to the other neuron through axon.

Artificial Neural Network Structure:

This is a typical ANN structure. The circles are indication of neurons and arrows indicates the connecting strength between them. The circles in the first layer are the input neuron who enters inputs into the system based on which the target output is determined. The circles in the last layer are the output neuron who receives the resulted output from the system. The central layer is hidden layer, neurons in this layer receives data from input neurons and after processing it, send resulted output to the output neurons.



Comparison between biological neural network and artificial neural network:

Biological Neural Network	*Artificial Neural Network*
Soma	Neuron
Dendrites	Inputs
Axon	Output
Synapse	Weight

There are some similarities between biological neural network and artificial neural network i.e. some of the parts of biological neural network can be compared with that of the artificial neural network as follows:

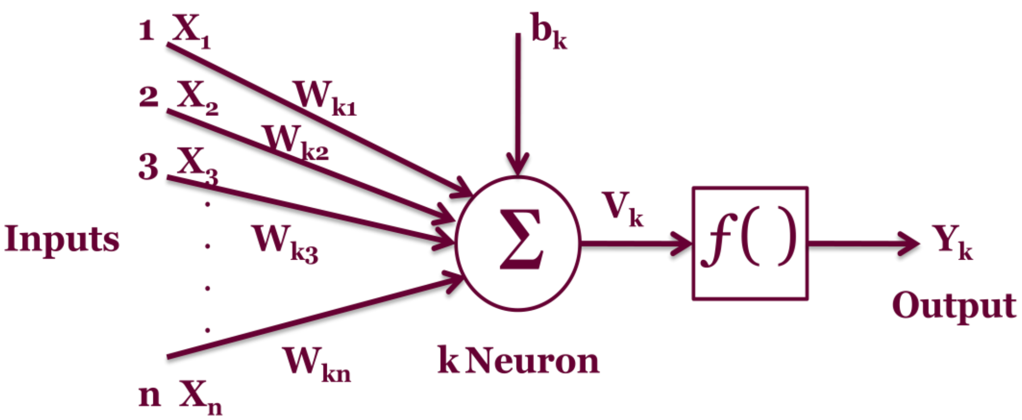
An ANN is typically defined by three types of parameters:

1. The interconnection pattern between the different layers of neurons.
2. The activation function that converts a neuron's weighted input to its output activation.
3. The learning process for updating the weights of the interconnections.

Characteristics of neural networks:

1. The NNs exhibit mapping capabilities, that is, they can map input patterns with their associated output patterns.
2. The NNs learn by examples. Thus, NN architectures can be 'trained' with known examples of a problem and they can be tested for their 'projection' capability on unknown instances of the problem.
3. The NNs possess the capability to generalize. Thus, they can predict new outcomes from past trends.
4. The NNs can process information in parallel, at high speed, and in a distributed manner.
5. The NNs are fault tolerant systems. They can, therefore, recall full patterns from incomplete or partial patterns.

ANN – Simple Neuron Structure:



This is a simple and single neuron structure or building block of artificial neural network. Suppose there is a artificial neuron (k) receiving inputs from some other source X_1, X_2,…, X_n. Every input has some connecting strength with the neuron i.e. some may connect strongly while some may weakly. Let us assume these synaptic weights are $W_{k1,}$ W_{k2},...,W_{kn} resp. W_{k1} indicates connecting strength from neuron 1 to neuron k. It is very important because it is uni-directional flow from neuron 1 to neuron k. It is not always necessary that W_{k1} is equal to W_{1k}. It may be or may not be equal to each other depending upon the situation.

Now, overall effect of these inputs could be obtained by a linear combination of all weighted inputs. i.e.

$$u_k = \sum_{j=1}^{n} x_j w_{kj}$$

b_k is called as bias. The bias is added to the network as an external input. Bias helps the neural network to learn even when the all other inputs are zero.

In order to know combined effect of all the inputs the bias b_k should be added to this sum. Therefore the combined input (V_k) can be given as:

$$v_k = u_k + b_k$$

This is a linear sum of all the weighted inputs. In order to arrive at some result or output value, one has to apply some kind of activation or transformation to it. This means applying some relationships (more specifically a function) which is commonly known as activation function or transformation function.

The bias is an external input to the system, let us called it as X_0 with connection strength or weight W_{k0}. Thus, we can redefine bias as:

$$b_k = x_0 w_{k0}$$

Thus, combined input will be

$$v_k = \sum_{j=1}^{n} x_j w_{kj} + x_0 w_{k0}$$

$$v_k = \sum_{j=0}^{n} x_j w_{kj}$$

Thus, output (Y_k) will be activation function of this combined input

$$y_k = f(v_k)$$

Activation Function:

An activation function controls the amplitude of the output of the neuron. There are various types of activation functions. They are as follows:

1. **Threshold Function:** It takes on a value of 0 if the summed input is less than a certain threshold value (v), and the value 1 if the summed input is greater than or equal to the threshold value.
2. **Step function**: It is a special case of Threshold function where threshold value is zero.

   If $V_k \geq 0$, then $Y_k = 1$

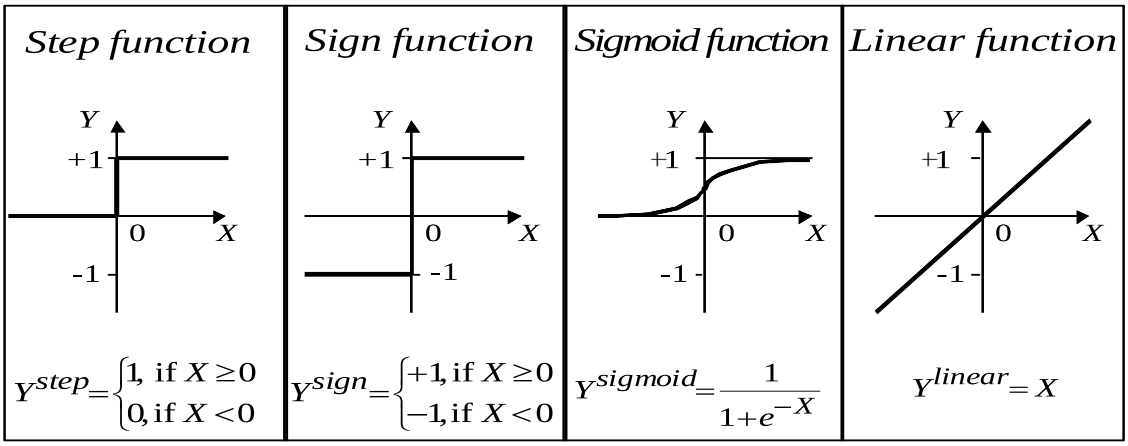
   If $V_k < 0$, then $Y_k = 0$
3. **Sign function:**

   If $V_k \geq 0$, then $Y_k = 1$

   If $V_k < 0$, then $Y_k = -1$
4. **Linear function:**

   $V_k = Y_k$

5. **Piecewise-Linear function:** This Y_k can take any value equal to V_k within a range i.e. hard limited. It is also called as Ramp function.
6. **Sigmoid function:** This function can range between 0 and 1 or -1 to 1 range. An example of the sigmoid function is the hyperbolic tangent function.
7. **Hyperbolic Tangent function:** It is also an example of the sigmoid function. The value of this function can ranges from -1 to 1.



Learning/Training Method:

The main property of all the artificial neural networks models (ANN) is the ability to learn from its surroundings, which is shown by the improvement of their performance through learning. Learning is the process by which, the free parameters from a neural network are adapted, through a stimulation process, by the environment in which a network is continued. The kind of learning is determined by the way in which the change of the parameters has taken place.

A neural network has to be configured such that the application of a set of inputs produces the desired set of output. One way of finding appropriate weight is to set the weights explicitly, using a priori knowledge. Another way is to 'train' the neural network by feeding teaching patterns and letting it change its weights according to some learning rule. Learning rules or methods in neural network can be broadly classified into three basic types:

1. Supervised learning
2. Unsupervised learning
3. Reinforced learning

1. Supervised learning:

A teacher is assumed to be present during the learning process, when a comparison is made between the network's computed output and the correct expected output, to determine the error. The error can then be used to change network parameters, which result in an improvement in performance.

- Learning algorithm will try to match known output.
- It requires known output.

2. Unsupervised learning:

In this learning method, the target output is not presented to the network. It is as if there is no teacher to present the desired patterns and hence, the system learns of its own by discovering and adapting to structural features in the input patterns.

- Learning algorithm will try to learn structure of data.
- It does not require known outputs.

3. Reinforced learning:

In this method, a teacher though available, does not present the expected answer but only indicates if the computed output is correct. The information provided helps the network in its learning process. A reward is given to correct answer and a penalty for a wrong answer computed.

Neural Network Architectures:

An ANN is defined as a data processing system consisting of a large number of simple highly inter connected processing elements (artificial neurons) in an architecture inspired by the structure of the brain. There are several types of architecture, some of them are:

1. Feed forward networks
2. Recurrent networks

1. Feed forward networks:

In a feed forward network, information flows in one direction along connecting pathways, from the input layer via the hidden layers to the final output layer. There is no feedback (loops) i.e., the output of any layer does not affect the output of same layer or preceding layer.

2. Recurrent networks:

These networks differ from feed forward network architectures in the sense that there is at least one feedback loop. Thus, in these networks, for example, there could exist one layer with feedback connections with the neurons of previous layer. There could also be neurons with self-feedback links, i.e. the output of a neuron is fed back into itself as input.

Artificial Neural Network Methodology Used in Present Study:

The analysis of artificial neural network carried out with production as dependent variable and standardized stage-wise weather parameters as explanatory variables. In order to run neural network procedure, it was necessary to run some other prior procedures. Thus, the complete syntax for neural network procedure was as follows:

```
/*Data mining database Procedure*/
        proc dmdb batch data=dataset
        out= out dmdbcat=data_cat;
        var Inputs ;
        target output;
        run;
/*Neural network procedure*/
        proc dmneurl data=dataset dmdbcat=data_cat
        outclass=oclass outest=estout out=dsout outfit=ofit
        ptable maxcomp=7 maxstage=7;
        var inputs ;
        target output ;
        run;
```

4.5 Comparison of various forecast models

Goodness of fit of the models was tested by Root Mean Square Error (RMSE), Mean Absolute Error (MAE) etc. (Montgomery *et al.,* 2003). These six criteria were worked out for data used for testing. The fitted models, which had lower values of these estimates, were considered to be better.

Root Mean Square Error (RMSE):

$$RMSE = \left[\frac{1}{n} \sum_{i=1}^{n} (Y_i - \hat{Y}_i)^2 \right]^{1/2}$$

Mean Error (ME):

$$ME = \frac{1}{n} \sum_{i=1}^{n} (Y_i - \hat{Y}_i)$$

Mean Square Error (MSE):

$$MSE = \frac{1}{n} \sum_{i=1}^{n} (Y_i - \hat{Y}_i)^2$$

Mean Absolute Error (MAE):

$$\mathrm{MAE} = \frac{1}{n}\sum_{i=1}^{n}\left|Y_i - \hat{Y}_i\right|$$

Mean Percentage Error (MPE):

$$\mathrm{MPE} = \frac{1}{n}\sum_{i=1}^{n}\left(\frac{Y_i - \hat{Y}_i}{Y_i}\right)\times 100$$

Mean Absolute Percentage Error (MAPE):

$$\mathrm{MAPE} = \frac{1}{n}\sum_{i=1}^{n}\left|\left(\frac{Y_i - \hat{Y}_i}{Y_i}\right)\times 100\right|$$

CHAPTER V

RESULTS AND DISCUSSION

To estimate the effect of weather variables on production of rice in Konkan region, 26 years production data from 1989-90 to 2014-15 were collected. For assessing joint influence of weather variables, different approaches were considered. Thus, the secondary data collected were analyzed as per methodology outlined and results of the analysis are presented and discussed as follows:

5.1 Trends in area, production and productivity of rice crop.

5.2 Growth and instability in area, production and productivity of rice crop.

5.3 Forecast models for rice production.

- 5.3.1 Regression analysis.
- 5.3.2 Aridity index method.
- 5.3.3 ARIMA modeling.
- 5.3.4 Artificial Neural Network (ANN).

5.4 Forecast of the rice production.

5.5 Comparison of various forecast models.

5.1 Trends in area, production and productivity of rice crop.

5.1.1 Trends in area under rice crop.

Rice is the staple food of Konkan region. This region falls under high rainfall zone. The copping pattern in the region is dominated by rice crop. In 1979-80 net sown area in Konkan region was 8023 hundred hectares out of which 55.34 per cent area was under rice crop. During 2014-15, the net sown area in Konkan region was 10388 hundred hectares. The proportion of area under rice was 42.74 per cent.

The temporal change and compound growth rates for area under rice crop are presented in Table 5.1. The Table 5.1 reveals that in 1979-80 the area under rice was 4.44 lakh hectares, which declined by 5.83 per cent during the study period. Area under rice in Konkan region decreased at the rate of 0.29 per cent per annum. The disaggregated analysis of area indicated that except Sindhudurg district, area under rice declined to the extent of 0.18 to 0.55 per cent per annum in different districts of Konkan region.

Table 5.1 Temporal change and compound growth rates of area under rice.

(Area in "00" ha)

	Raigad	Ratnagiri	Sindhudurg	Thane	Konkan
Period I (1979-80 to 1988-89)					
1979-80	1457	780	733	1903	4440

1988-89	1501	811	790	1504	4606
% change	3.02	3.97	7.78	-20.97	3.74
CGR	0.36*** (0.0018)	0.26 NS (0.0042)	1.51* (0.0030)	-1.42*** (0.0072)	0.34** (0.0013)
Period II (1989-90 to 1998-99)					
1989-90	1496	820	794	1513	4623
1998-99	1354	788	801	1421	4364
% change	-9.49	-3.90	0.88	-6.08	-5.60
CGR	-1.29* (0.0035)	-0.07 NS (0.0029)	0.004 NS (0.0012)	-0.26 NS (0.0024)	-0.51* (0.0011)
Period III (1999-2000 to 2008-09)					
1999-2000	1357	799	799	1418	4373
2008-09	1323	775	785	1406	4289
% change	-2.51	-3.00	-1.75	-0.85	-1.92
CGR	-0.27** (0.0011)	-0.34* (0.0009)	-0.13** (0.0005)	-0.10** (0.0004)	-0.20* (0.00058)
Period IV (2009-10 to 2014-15)					
2009-10	1304	774	785	1386	4249
2014-15	1241	728	705	1507	4181
% change	-4.83	-5.94	-10.19	8.73	-1.60
CGR	-0.77 NS (0.0087)	-1.77*** (0.0072)	-0.97 NS (0.0118)	1.48*** (0.0057)	-0.22 NS (0.0048)
Overall (1979-80 to 2014-15)					
1979-80	1457	780	733	1903	4440
2014-15	1241	728	705	1507	4181
% change	-14.82	-6.67	-3.82	-20.81	-5.83
CGR	-0.55* (0.0005)	-0.18* (0.0005)	0.04 NS (0.0006)	-0.37* (0.0007)	-0.29* (0.0003)

(*, ** and *** - Significant at 1, 5 and 10 per cent level of probability, respectively. NS- Non-significant.) (Figures in parentheses are Standard Errors)

Area under rice, during study period marginally increased 0.04 per cent per annum in Sindhudurg district. The decline in area was sharp in Raigad (0.55 per cent) and Thane (0.37 per cent) districts. The sharp decline in the area under rice could be attributed to fast urbanization, industrialization and shift of agricultural land to non-agricultural use in these districts.

During period I, the area under rice in Konkan region, grew at the rate of 0.34 per cent per annum. However, it registered a negative growth in remaining periods. During period I, area showed increasing trend in Konkan region except Thane district where, area under rice decreased by 1.42 per cent per annum. The reverse trend was observed in period II. The area under rice in Konkan region declined at the rate of 0.51 per cent per annum. Among the districts the decline in area was maximum in Raigad (1.29 per cent) followed by Thane (0.26 per cent) and Ratnagiri (0.07per cent). In period II area under rice in

Konkan region showed negative change of 1.92 per cent over base year. The compound growth rates of area under rice in different districts revealed that in all the districts area under rice registered a negative growth. Similar trends were observed in period IV.

The forgoing analysis indicated that, over a period of time in Konkan region area under rice has declined. The decline in area under rice was more in Thane and Raigad district. This could be attributed to fast urbanization or industrialization and shifting of agricultural land to non-agricultural uses, in these districts. Thus, the hypothesis that "Area under rice in Konkan region is decreasing' has been accepted.

Similar results were also observed by Perke D.S. (2014). The change in the area under rice in Konkan region was -7.55 per cent.

5.1.2 Trends in production of rice crop.

The temporal change and the compound growth rate of production of rice in the Konkan region are presented in Table 5.2. Production of rice in Konkan region increased from 788.0 MT in 1979-80 to 1120.2 MT in 2014-15. This indicated that during the period under study production of rice in Konkan region increased to the tune of 42.16 per cent over base year. The trends in production of rice indicated a positive growth. In Konkan region, production of rice registered a growth of 0.81 per cent per annum during the period under study. Among the districts, in Sindhudurg district, production of rice significantly increased by 1.80 per cent per annum followed by Ratnagiri (1.23 per cent) and Raigad (0.42 per cent) per annum.

The period-wise trends in rice production revealed that during period II per annum growth in rice production was maximum (2.27 per cent) followed by period IV (1.86 per cent). In period I, Ratnagiri and Sindhudurg district registered a significant growth of 0.11 and 2.02 per cent per annum, respectively.

Table 5.2 Temporal change and compound growth rates of production of rice.

(Production in "00" Tonnes)

	Raigad	Ratnagiri	Sindhudurg	Thane	Konkan
Period I (1979-80 to 1988-89)					
1979-80	2755	1479	1279	2919	7880
1988-89	3440	1708	1466	3004	9618
% change	24.86	15.48	14.62	2.91	22.06
CGR	1.47 ^{NS} (0.0091)	0.11*** (0.0212)	2.02** (0.0076)	-2.07 ^{NS} (0.0200)	0.58 ^{NS} (0.0121)
Period II (1989-90 to 1998-99)					
1989-90	2975	1871	1844	2823	9513
1998-99	3417	2202	2183	2728	10590
% change	14.86	17.69	18.83	-3.37	11.32
CGR	2.07**	1.61**	3.33**	2.08 ^{NS}	2.27*

	(0.0084)	(0.0066)	(0.0105)	(0.0124)	(0.005)
Period III (1999-2000 to 2008-09)					
1999-2000	3285	1928	1813	3020	10046
2008-09	3598	2013	2158	3034	10803
% change	9.53	4.41	19.03	0.46	7.54
CGR	0.70^{NS} (0.0118)	1.29^{NS} (0.0145)	2.17*** (0.0102)	2.68^{NS} (0.0329)	1.58^{NS} (0.0158)
Period IV (2009-10 to 2014-15)					
2009-10	3294	2030	2046	2908	10277
2014-15	3425	2115	2141	3521	11202
% change	3.98	4.19	4.64	21.08	9.00
CGR	1.36^{NS} (0.0168)	-0.24^{NS} (0.0121)	0.82^{NS} (0.0070)	4.56** (0.0123)	1.86*** (0.0077)
Overall (1979-80 to 2014-15)					
1979-80	2755	1479	1279	2919	7880
2014-15	3425	2115	2141	3521	11202
% change	24.32	43.00	67.40	20.62	42.16
CGR	0.42* (0.0014)	1.23* (0.0021)	1.80* (0.0017)	0.32^{NS} (0.0032)	0.81* (0.0016)

(*, ** and *** - Significant at 1, 5 and 10 per cent level of probability, respectively.)
NS- Non-significant.) (Figures in parentheses are Standard Errors)

During period II, production of rice increased significantly by 3.33 per cent per annum in Sindhudurg district followed by Raigad (2.07 per cent) and Ratnagiri (1.81 per cent). In period III, significant growth (2.17 per cent) in rice production was observed only in Sindhudurg district. While, rice production in Thane district during period IV grew at the rate of 4.56 per cent per annum. Whereas, for other districts growth in rice production was positive but non-significant except for Ratnagiri district.

Similar results were also observed by Perke D.S. (2014). In his study he observed that the per cent change over base year has shown increase in rice production in Raigad, Ratnagiri and Sindhudurg district by 7.55, 59.35 and 57.6 per cent, respectively. In Konkan region it was increased by 19.08 per cent.

5.1.3 Trends in productivity of rice crop.

The trends in productivity of rice in Konkan region are presented in Table 5.3. It is seen from the Table 5.3 that in 1979-80 productivity of rice in Konkan was 1796 kg/ha which increased to 2679 kg/ha in 2014-15. The per cent change in productivity during this period was to the tune of 49.16 per cent. The compound growth rate revealed that productivity of rice grew at the rate of 1.09 per cent per annum during the same period. Among the districts, productivity of rice registered impressive growth of 1.89 per cent per annum in Sindhudurg district followed by Ratnagiri (1.57 per cent) and Raigad (1.07 per cent).

During period I, except in Thane productivity of rice was positive but not significant in all the districts. However, in period II, productivity of rice registered a positive and significant growth in all districts of Konkan region. The highest growth in productivity was recorded in Raigad (3.50 per cent) followed by Sindhudurg (3.29 per cent) and Thane (2.30 per cent). In period III, only Sindhudurg district registered a significant growth of 2.31 per cent per annum. The compound growth rate of productivity of rice during period IV indicated that barring Raigad district for other districts the growth in productivity of rice was significant. The highest per annum growth was observed in Thane (5.46 per cent) followed by Sindhudurg (3.83 per cent) and Ratnagiri (1.55 per cent).

The results are supported by the observations made by Perke D.S. (2014). Over study period the increase in rice productivity in Thane, Raigad, Ratnagiri and Sindhudurg district was 3.74, 28.79, 95.48 and 55.00 per cent, respectively, and in Konkan region it was 28.82 per cent.

Table 5.3 Temporal change and compound growth rates of productivity of rice.

(Productivity kg/ha)

	Raigad	**Ratnagiri**	**Sindhudurg**	**Thane**	**Konkan**
Period I (1979-80 to 1988-89)					
1979-80	1829	1690	1682	1903	1796
1988-89	2292	2106	1856	1997	2088
% change	25.31	24.62	10.34	4.94	16.26
CGR	1.42 (0.0095)	1.53 (0.0202)	0.9 (0.0062)	-1.82 (0.0189)	0.18 (0.0117)
Period II (1989-90 to 1998-99)					
1989-90	1989	2282	2322	1866	2058
1998-99	2568	2794	2725	1920	2427
% change	29.11	22.44	17.36	2.89	17.93
CGR	3.50* (0.0087)	1.69*** (0.0074)	3.29** (0.0097)	2.30*** (0.0109)	3.17* (0.0083)
Period III (1999-2000 to 2008-09)					
1999-2000	2421	2413	2269	2130	2295
2008-09	2720	2597	2749	2158	2519
% change	12.35	7.63	21.15	1.31	9.76
CGR	0.97 (0.0114)	1.64 (0.0144)	2.31*** (0.0102)	2.79 (0.0329)	1.79 (0.0157)
Period IV (2009-10 to 2014-15)					
2009-10	2526	2623	2606	2098	2419

2014-15	2793	2904	3037	2612	2679
% change	10.57	10.71	16.54	24.50	10.75
CGR	2.4 (0.0156)	1.55*** (0.0069)	3.83** (0.0102)	5.46*** (0.0209)	2.08 (0.0098)
Overall (1979-80 to 2014-15)					
1979-80	1829	1690	1682	1903	1796
2014-15	2793	2904	3037	2612	2679
% change	52.71	71.83	80.56	37.26	49.16
CGR	1.07* (0.0015)	1.57* (0.0020)	1.89* (0.0014)	0.66* (0.003)	1.09* (0.0017)

(*, ** and *** - Significant at 1, 5 and 10 per cent level of probability, respectively.) NS- Non-significant.) (Figures in parentheses are Standard Errors)

The temporal changes and compound growth rates of area, production and productivity of rice revealed that there has been continuous decline in area under rice in Konkan region. However, there has been increase in production and productivity of rice during the period under study. This significant increase in production and productivity could be attributed to development of different rice production technologies by Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli. The university has developed and released 25 high yielding and 5 hybrid rice varieties along with other production technologies.

5.2 Growth and instability in area, production and productivity of rice crop.

5.2.1 Instability in area, production and productivity of rice crop in Raigad district.

The coefficient of variation and Instability Index of the area, production and productivity of rice crop in Raigad district are depicted in Table 5.4.

Table 5.4 Period-wise instability in area, production and productivity of rice in Raigad district.

	Period I	Period II	Period III	Period IV	Overall
Area					
Coefficient of variation (%)	1.84	4.99	1.23	3.57	6.52
Cuddy-Della Instability Index	1.48	3.04	0.91	3.28	2.91
Production					
Coefficient of variation (%)	9.31	9.00	10.36	6.81	9.80
Cuddy-Della Instability Index	8.01	6.75	10.16	6.31	8.81
Productivity					
Coefficient of variation (%)	9.49	12.05	10.27	7.46	14.03
Cuddy-Della Instability Index	8.29	6.58	9.87	5.88	8.83

It could be observed from Table 5.4 that, among the different time periods, variation in area of rice in Raigad district was the highest during period II (4.99 per cent) followed by period III (3.57 per cent). During overall period, variation in area under rice in Raigad district was 6.52 per cent. The area under rice was found relatively stable during the period I (1.48 per cent) and period III (0.91 per cent), whereas, it was relatively unstable during period IV (3.28 per cent). The instability index for area was estimated to 2.91 which indicated that area under rice in Raigad district was unstable.

The period-wise comparison of variability in production showed that, there was high degree of variation (10.36 per cent) in period III followed by period I (9.31 per cent), period II (9.00 per cent) and period IV (6.81 per cent) with overall variation to the tune of 9.80 per cent. As far as the instability is concerned, the instability index of rice production varied between 6.81 in period IV to 10.36 in period III, with overall instability index of 8.81.

During the period under study variation in productivity of rice in Raigad district was 14.03 per cent. Among the different time periods, variation in productivity was more in period II (12.05 per cent) followed by period III (10.27 per cent), period I (9.49 per cent) and period IV (7.46 per cent). Instability index showed that, the productivity of rice in Raigad district was highly instable during the period III (9.87) followed by period I (8.29), period II (6.58) and period IV (5.88) with overall instability of 8.83.

5.2.2 Instability in area, production and productivity of rice crop in Ratnagiri district.

The coefficient of variation and instability indices for the area, production and productivity of rice crop in Ratnagiri district are presented in Table 5.5.

It could be seen from the Table 5.5 that, variation in area was more pronounced (4.21 per cent) during period IV. At overall level variability in area was 3.52 per cent. The instability index showed that area under rice in Ratnagiri district was relatively unstable (3.60) during period I. The instability index ranged between 0.80 in period III to 3.60 in period I with overall instability index of 2.98.

Table 5.5 Period-wise instability in area, production and productivity of rice in Ratnagiri district.

	Period I	**Period II**	**Period III**	**Period IV**	**Overall**
Area					
Coefficient of variation (%)	3.68	2.46	1.30	4.21	3.52

Cuddy-Della Instability Index	3.60	2.45	0.80	2.61	2.98
Production					
Coefficient of variation (%)	15.82	7.65	12.60	4.51	16.40
Cuddy-Della Instability Index	15.75	5.80	12.09	4.49	10.89
Productivity					
Coefficient of variation (%)	16.36	8.31	12.62	3.74	18.79
Cuddy-Della Instability Index	15.49	6.43	11.77	2.47	10.45

Among the different time periods, coefficient of variation for production was highest (15.82 per cent) during period I, followed by period III (12.60 per cent) and period II (7.65 per cent) with overall level 16.40 per cent. Similar trends were noticed in case of instability indices. Production was highly instable during period I (15.75), followed by period III (12.09) and Period II (5.80). At overall level instability index turned out to be 10.89.

The variation in productivity was more (16.36 per cent) during period I, followed by period III (12.62 per cent) and period II (8.31 per cent). For overall period coefficient of variation for productivity was 18.79 per cent. The productivity of rice in Ratnagiri district was most instable (15.49) during period I and it was comparatively stable (2.47) during period IV. The instability index (10.45) for overall period revealed that the productivity of rice in Ratnagiri district was instable during the study period.

5.2.3 Instability in area, production and productivity of rice crop in Sindhudurg district.

The variability in area, production and productivity of rice in Sindhudurg district was assessed by coefficient of variation and instability index presented in Table 5.6.

Table 5.6 Period-wise instability in area, production and productivity of rice in Sindhudurg district.

	Period I	Period II	Period III	Period IV	Overall
Area					
Coefficient of variation (%)	5.22	1.00	0.60	4.67	3.54
Cuddy-Della Instability Index	2.59	1.00	0.45	4.33	3.52
Production					
Coefficient of variation (%)	8.87	13.24	10.69	3.09	20.47
Cuddy-Della Instability	6.34	8.64	8.67	2.66	10.43

Index					
Productivity					
Coefficient of variation (%)	5.89	12.63	10.93	8.19	20.91
Cuddy-Della Instability Index	5.20	7.90	8.69	4.06	8.52

The Table 5.6 revealed that, variation in area under rice in Sindhudurg district was found least (0.60 per cent) during period III and it was highest (5.22 per cent) during period I. At overall level, the variation in area was 3.54 per cent. It was also seen that, area under rice was comparatively more instable (4.33) during period IV followed by period I (2.59). Area was found stable during period II and period III. Whereas, for overall period instability index was 3.52, indicated instability in area under rice.

It is evident from coefficient of variation for production of rice varied from 3.09 per cent in period IV to 13.24 per cent in period II, with overall variation to the tune of 20.47 per cent. Similar trend was observed in instability index, which ranged between 2.66 to 8.67 for IV and III period, respectively. For the overall period instability index worked out to 10.43.

Over the different time period, the variation in productivity was highest (12.63 per cent) in period II followed by period III (10.93 per cent) and period IV (8.19 per cent). For the overall study period, variation in productivity was to the tune of 20.91 per cent. At overall level, the productivity of rice was found more instable (8.52) whereas; decadal comparison showed that the productivity was highly instable in period III (8.69).

5.2.4 Instability in area, production and productivity of rice in Thane district.

The coefficient of variation and Instability Index of the area, production and productivity of rice crop in Thane district is depicted in Table 5.7.

It is observed from the Table No. 5.7 that, variation in area was more (8.30 per cent) during period I followed by period IV (3.56 per cent) and period II (2.20). At overall level variability in area was 6.21 per cent. The instability index showed that area under rice in Thane district was more instable (6.84) during period I. For the period under study, instability index turned out to be 4.68 indicating instability in area under rice.

Over the different time periods, coefficient of variation for production of rice was highest (25.47 per cent) during period III, followed by period I (15.27 per cent) and period II (13.13 per cent) with overall level 17.31. Similar trends were noticed in case of instability index. Productivity was found highly unstable during period III (24.82) and relatively stable during period IV (8.00). At overall level, instability index turned out to be 16.95.

Table 5.7 Period-wise instability in area, production and productivity of rice in Thane district.

	Period I	Period II	Period III	Period IV	Overall
Area					
Coefficient of variation (%)	8.30	2.20	0.48	3.56	6.21
Cuddy-Della Instability Index	6.84	2.06	0.36	2.20	4.68
Production					
Coefficient of variation (%)	15.27	13.13	25.47	9.74	17.31
Cuddy-Della Instability Index	14.28	11.33	24.82	4.69	16.95
Productivity					
Coefficient of variation (%)	14.47	12.29	25.47	13.09	18.29
Cuddy-Della Instability Index	13.67	10.00	24.75	8.00	16.81

The variation in productivity was more (25.47 per cent) during period III, followed by period I (14.47 per cent) and period VI (13.09 per cent). For overall period coefficient of variation for productivity was 18.29 per cent. The productivity of rice in Thane district was most instable (24.75) during period III as revealed by instability index followed by period I (13.67), period II (10.00) and period IV (8.00). The instability index (16.81) for overall period revealed the productivity of rice in Ratnagiri district was instable.

5.2.5 Instability in area, production and productivity of rice crop in Konkan region.

The coefficient of variation and instability index of the area, production and productivity of rice in Konkan region are depicted in Table 5.8.

The coefficient of variation and instability index for area under rice ranged between 0.79 to 1.85 per cent and 0.50 to 1.81, respectively. At overall level, coefficient of variation and instability index was 3.42 per cent and 1.63, respectively this revealed that the area under rice is relatively stable in Konkan region.

Table 5.8 Period-wise instability in area, production and productivity of rice in Konkan region.

	Period I	Period II	Period III	Period IV	Overall

Area					
Coefficient of variation (%)	1.52	1.80	0.79	1.85	3.42
Cuddy-Della Instability Index	1.12	0.94	0.50	1.81	1.63
Production					
Coefficient of variation (%)	10.00	8.08	13.66	4.57	12.74
Cuddy-Della Instability Index	9.76	4.35	12.99	2.92	9.66
Productivity					
Coefficient of variation (%)	9.46	12.10	13.77	5.41	15.27
Cuddy-Della Instability Index	9.41	7.62	12.89	3.69	10.47

The period-wise comparison of variability in production showed that, there was more variation (13.66 per cent) during period III followed by period I (10.00 per cent), period II (8.08 per cent) and period IV (4.57per cent) with overall variation to the tune of 12.47 per cent. As far as the instability is concerned, the production of rice in Konkan region was more instable during period III (12.99) and least instable during period IV (2.92). Overall instability in production of rice was 9.66.

The variation in productivity of rice in Konkan region was 15.27 per cent over the study period, whereas, over the different time periods, it varied between 5.41 to 13.77 per cent. Instability index showed that, productivity of rice in Konkan region was highly instable during the period III (12.89) followed by period I (9.41), period II (7.62) and period IV (3.69) with overall instability of 10.47.

The foregoing analysis revealed that during the study period area under rice was relatively stable whereas, there was great instability in production as well as productivity of rice in Konkan region. The instability in production and productivity of rice may be due to adoption of modern technologies by the rice farmers in Konkan region. In view of this the hypothesis that ‘production and productivity of rice in Konkan region is instable’ is accepted.

5.3 Forecast models for rice production.

5.3.1 Forecast models for rice production by Regression analysis.

The empirical regression approach is extensively used to study the cause and effect relationship among the dependent variable as a result of set of explanatory variables. The regression analysis was performed between dependent variable production (Y) and explanatory variables (36 variables) i.e. crop growth stage-wise weather parameters for the period from 1989-90 to 2010-11 (as given in table 4.2). To assess the effect of weather parameters on rice production the weather parameters of different crop growth stages were considered. For the estimation of model, 22 years data were used and 4 years data were used for testing forecasting efficiency of estimated model. The crop stage-wise weather data were standardized and significant variables were determined by step-wise method.

5.3.1.1 Parameter estimates of regression model for Raigad district.

The results obtained from the regression analysis for Raigad district are presented in Table 5.9.

It is evident from Table 5.9 that, among the variables included in the model only two variables viz. T_MIN_STG_2 and RN_FL_STG_1 were retained in the model after step down regression. The variables retained in the model accounted for 41 per cent variation in the production of rice in Raigad district. The coefficients of the variables revealed that with one unit increase in the minimum temperature during stage II, production of rice increased by 113.78 units and one unit increase in rainfall during stage I decreases the rice production by 188.06 units.

Table 5.9 Parameter estimates of regression model for Raigad district.

Variable	Parameter Estimate	Standard Error
Intercept	3178.55*	50.8668
T_MIN_STG_2	113.782**	54.2135
RN_FL_STG_1	-188.06*	54.2136
R^2 = 0.41		

(*, ** and *** - Significant at 1, 5 and 10 per cent level of probability respectively.)

The rainfall has negative effect on rice production may be because rice is sown by 'Rohu' method in Raigad district, wherein the sprouted seed of rice is directly broadcasted in the field. Due to heavy rainfall the sprouted seeds may get washed out which adversely affects the plant population and ultimately production of rice.

5.3.1.2 Parameter estimates of regression model for Ratnagiri district.

It could be observed from the Table 5.10 that, out of total variables included in the model only two variables viz. T_MIN_STG_1 and RN_FL_STG_2 were found significant at 5 per cent and 1 per cent level of significance in Ratnagiri district, respectively. About 42 per cent of variation in production was explained by the two significant variables in the model.

Table 5.10 Parameter estimates of regression model for Ratnagiri district.

Variable	Parameter Estimate	Standard Error
Intercept	1942.32*	24.4514

T_MIN_STG_1	-122.83**	32.7816
RN_FL_STG_2	224.098*	41.0729
R^2 = 0.42		

(*, ** and *** - Significant at 1, 5 and 10 per cent level of probability respectively.)

The regression coefficient of minimum temperature in stage I indicated that one unit increase in minimum temperature during stage I decreased the production of rice by 122.83 units whereas, that of rainfall in stage II indicated that one unit increase in rainfall during stage II increased the production of rice by 224.098 units.

5.3.1.3 Parameter estimates of regression model for Sindhudurg district.

The results of the regression analysis for Sindhudurg district were presented in Table 5.11.

Table 5.11 Parameter estimates of regression model Sindhudurg for district.

Variable	Parameter Estimate	Standard Error
Intercept	1949.68*	33.8475
T_MAX_STG_2	-78.501***	39.2524
T_MAX_STG_5	171.249*	37.1371
RH_M_STG_6	144.792*	35.79
RN_FL_STG_3	107.903**	38.2459
R^2 = 0.70		

(*, ** and *** - Significant at 1, 5 and 10 per cent level of probability respectively.)

It is observed from the Table 5.11 that, out of total variables included in the model four variables viz. T_MAX_STG_2, T_MAX_STG_5, RH_M_STG_6 and RN_FL_STG_3 were retained in the model. These four variables retained in the model accounted for 70 per cent of variation in production. The coefficient of variables revealed that one unit increase in the maximum temperature at stage V, morning relative humidity at stage VI and rainfall at stage III production of rice increases by 171.25, 144.79 and 107.90 units, respectively. Whereas, one unit increase in maximum temperature at stage II production of rice decreased by 78.50 units.

5.3.1.4 Parameter estimates of regression model for Thane district.

The results of the regression analysis for Thane district are given in Table 5.12. Among the variables included in the model only two variables viz. RH_E_STG_5 and RN_FL_STG_5 were turned out to be significant. The variables retained in the model accounted for 19 per cent variation in production of rice in Thane district. The regression coefficient of evening relative humidity at stage V revealed that one unit increase in evening relative humidity during stage V production of rice decreased by 190.5 units.

Whereas, that of rainfall at stage V indicated that one unit increase in rainfall during stage V increased the production of rice by 226.86 units.

Table 5.12 Parameter estimates of regression model for Thane district.

Variable	Parameter Estimate	Standard Error
Intercept	2967.86*	112.419
RH_E_STG_5	-190.5**	121.201
RN_FL_STG_5	226.859***	121.201
R^2 = 0.19		

(*, ** and *** - Significant at 1, 5 and 10 per cent level of probability respectively.)

5.3.1.5 Parameter estimates of regression model for Konkan region.

The parameters estimated for regression model for Konkan region are presented in Table 5.13.

Table 5.13 Parameter estimates of regression model for Konkan region.

Variable	Parameter Estimate	Standard Error
Intercept	10041.00*	200.797
T_MAX_STG_3	605.510**	238.251
RH_M_STG_1	977.463**	422.120
SSH_STG_1	695.609***	392.477
R^2 = 0.33		

(*, ** and *** - Significant at 1, 5 and 10 per cent level of probability respectively.)

The results of multiple regression analysis revealed that three variables viz. maximum temperature at stage II, morning relative humidity at stage I and sunshine hours at stage I turn out to be significant. The variables retained in the model accounted for 33 per cent of variation in rice production. The coefficient of variables revealed that one unit increase in maximum temperature at stage III (tillering stage), morning relative humidity at stage I (sowing stage) and sunshine hours at stage I (sowing stage) results in increasing the production by 605.51, 977.46 and 695.61 units, respectively.

5.3.2 Forecast models for rice production by Aridity index model.

Aridity indices are used for climate classification particularly in arid areas. Aridity results from presence of dry descending air. Aridity therefore, usually expressed as rainfall and temperature. Aridity is defined as a deficiency of moisture especially when resulting from absence of rainfall or it is long term lack of rainfall or moisture.

To estimate the variation in production due to weather, many rely on econometric models where crop production is considered as function of aridity index for the measure of weather. The study intended to examine the impact of weather on rice production in Konkan region. The inclusion of aridity index in the model strengthens the yield response of precipitation is not constant rather a function of temperature and vice-versa. The same amount of precipitation will have different effects if accompanied by varying levels of temperature and vice-versa. Thus, the response function of two factors is inter-related. In view of this the aridity indices were incorporated into the econometric models.

Aridity index method was used to estimate the relationship between weather parameters and the production of rice. In aridity index method, an index has to be developed first by using various weather parameters and then functional relationship was derived by using that aridity index. The weather parameters used to develop aridity index were 'P' is the sum of precipitation and 'T' is mean temperature. The advantage of use of aridity index is it reduces the problem of degree of freedom in the analysis.

5.3.2.1 Parameter estimates of Aridity index model for Raigad district.

Aridity indices were developed for defining functional relationship between production of rice and weather parameters. The results of all the aridity indices for Raigad district are presented in Table 5.14. The Table 5.14 revealed that the coefficient of indices was non-significant at 10 per cent level of significance. R^2 values of all the indices were at par. Among these indices, for Raigad district, the linear regression model with precipitation (P) and temperature (T) has highest R^2 value of 0.25 which indicated that 25 per cent variation in production of rice was explained by variables precipitation and temperature.

Table 5.14 Parameter estimates of Aridity index model for Raigad district.

Sr. No.	Index	Coefficient	P value	R^2
1.	P	-0.11	0.23	0.25
	T	2.11	0.92	
2.	(P/T)	-1.94	0.23	0.23
3.	[P/(T+10)]	-3.32	0.18	0.24
4.	$(P/1.07^T)$	-0.33	0.28	0.22
5.	(P/0.1T)	-0.19	0.23	0.23

5.3.2.2 Parameter estimates of Aridity index model for Ratnagiri district.

The results of various aridity indices for Ratnagiri district are given in Table 5.15. It was observed that none of the coefficient was significant at 10 per cent level of significance. Among the various indices the linear regression model has highest R^2 value of 0.23 which indicates that 23 per cent variation in production of rice was explained by precipitation and temperature.

Table 5.15 Parameter estimates of Aridity index model for Ratnagiri district.

Sr. No.	Index	Coefficient	P value	R^2

1.	P	0.08	0.43	0.23
	T	10.07	0.73	
2.	(P/T)	0.75	0.70	0.20
3.	[P/(T+10)]	1.63	0.59	0.21
4.	$(P/1.07^T)$	0.07	0.84	0.20
5.	(P/0.1T)	0.07	0.70	0.20

5.3.2.3 Parameter estimates of Aridity index model for Sindhudurg district.

The Table 5.16 elicits the results of various aridity indices used for fitting models for Sindhudurg district. It was observed that the linear regression model with precipitation (P) and temperature (T) has highest R^2 value of 0.64 which indicates that 64 per cent variation in production of rice were explained by precipitation and temperature. However, coefficients of the various indices were also found insignificant at 10 per cent level of significance.

Table 5.16 Parameter estimates of Aridity index model for Sindhudurg district.

Sr. No.	Index	Coefficient	P value	R^2
1.	P	0.09	0.41	0.64
	T	5.87	0.79	
2.	(P/T)	0.68	0.70	0.62
3.	[P/(T+10)]	1.53	0.60	0.63
4.	$(P/1.07^T)$	0.07	0.82	0.62
5.	(P/0.1T)	0.07	0.70	0.62

5.3.2.4 Parameter estimates of Aridity index model for Thane district.

The results of aridity index models for Thane district are presented in Table 5.17. It could be seen from the Table 5.17 that the coefficients of indices are non-significant at 10 per cent level of significance. R^2 values of all the indices are close to each other. Among the various indices, for Thane district, the linear regression model has highest R^2 value (0.07) which indicated that only 7 per cent variation in production of rice was explained by precipitation and temperature.

Table 5.17 Parameter estimates of Aridity index model for Thane district.

Sr. No.	Index	Coefficient	P value	R^2
1.	P	-0.24	0.42	0.07
	T	-28.84	0.77	
2.	(P/T)	-2.48	0.56	0.04
3.	[P/(T+10)]	-4.40	0.51	0.05
4.	$(P/1.07^T)$	-0.38	0.62	0.04
5.	(P/0.1T)	-0.25	0.56	0.04

5.3.2.5 Parameter estimates of Aridity index model for Konkan region.

Table 5.18 Parameter estimates of Aridity index model for Konkan region.

Sr. No.	Index	Coefficient	P value	R^2
1.	P	0.72	0.33	0.20
	T	687.40	0.51	
2.	(P/T)	14.59	0.43	0.17
3.	[P/(T+10)]	20.53	0.42	0.17
4.	$(P/1.07^T)$	3.08	0.46	0.16
5.	(P/0.1T)	1.46	0.43	0.17

The results of aridity index modeling for Konkan region are presented in Table 5.18. It could be observed from the Table 5.18 that similar trend was also found in Konkan region. None of aridity index model found 'best fit' based on R^2 value and statistical significance of coefficients.

The results indicated that index based models did not render satisfactory results as the coefficients were not statistically significant. Aridity index method was found inefficient for forecasting of rice production in Konkan region. It could be because; Konkan region falls under high rainfall area and aridity indices are worked out for water scarcity area. Thus, the hypothesis that "The aridity index approach is superior to regression model by taking the individual meteorological factors" is rejected.

5.3.3 Forecast models for rice production by ARIMA modeling.

Autocorrelation function is very constructive tool to find out whether a time-series is stationary or not. Both Autocorrelation Function (ACF) and Partial Autocorrelation Function (PACF) are used to determine moving average and autoregressive orders of the model, respectively. The diagnostic checks are done using L-jung and Box chi-square test. In addition, model selection criteria AIC, SBC and R^2 are used to select best model.

5.3.3.1 Results of some selected ARIMA models for Raigad district.

The stationarity of the data for Raigad district was tested with the help of ACF, PACF and trend of production as presented in Fig.1. There was no slow decay on ACF and data of production showed horizontal trend which indicated that the data were stationary. The residual plot technique was also applied to selected model as shown in Fig.2. All the ACF and PACF of residuals lie between 95 per cent confidence limits. This indicated the good fit of model. Stationarity was also checked by using ADF test, the results of which showed that the coefficient of lag value (-1.266) with standard error (0.22) and t-statistics (-5.7) was significant indicated that the data were stationary (Annexure-I). So the tentative specifications of the model would be ARIMA (0,0,3),

ARIMA (1,0,3), ARIMA (1,0,4), ARIMA (0,0,4) and ARIMA (0,0,1). All these models were estimated and their diagnostic checks were done using L-jung and Box chi-square test. In addition, model selection criteria R^2, AIC and SBC were used to select best model. The value of chi-square with p-value and the values of model selection criterions for Raigad district are presented in Table 5.19

Table 5.19 Results of some selected ARIMA models for Raigad district.

	ARIMA (0,0,3)	**ARIMA (1,0,3)**	**ARIMA (1,0,4)**	**ARIMA (0,0,4)**	**ARIMA (0,0,1)**
Constant	3174.0* (13.35)	3175.4* (11.15)	3182.6* (17.38)	3174.5* (15.41)	3173.8* (6.65)
MA1,1	0.35 (0.29)	0.27 (0.39)	0.40 (31.48)	0.36 (0.31)	1.00* (0.20)
MA1,2	-0.09 (0.24)	-0.08 (0.24)	-0.30 (3.45)	-0.11 (0.28)	-
MA1,3	0.74* (0.27)	0.81* (0.25)	0.99 (8.26)	0.68** (0.29)	-
MA1,4	-	-	-0.27 (28.57)	0.08 (0.32)	-
AR1,1	-	-0.13 (0.39)	0.29 (31.52)	-	-
(T_MIN_ STG_2)	85.7*** (42.67)	96.9** (43.13)	141.5* (40.65)	90.71*** (44.69)	57.24 (34.42)
(RN_FL_ STG_1)	-183.6* (39.14)	-194.3* (39.60)	-169.7* (36.40)	-183.73* (41.42)	-219.1* (21.48)
AIC	299	300	301	301	302
SBC	306	308	309	309	306
R^2	0.40	0.37	0.29	0.40	0.39
Chi-Square	12.49	12.31	14.33	13.06	25.29
P-value	0.64	0.58	0.35	0.52	0.09

The Table 5.19 showed the coefficients of autoregressive and moving average components for each selected model. It was almost clear from the comparison of AIC values that ARIMA (0,0,3) model was the most suited model for the forecast of production for Raigad district. For ARIMA (0,0,3) model, the MA3 component was found significant at 1 per cent level of significance. The AIC and SBC values for the same were 299.05 and 305.60 respectively. The R^2 value for the ARIMA (0,0,3) model was 0.40 which revealed that 40 per cent variability in the dependent variable was explained by the variables included in the model. The chi-square value (12.49) was found insignificant which meant that the residuals of the respective time series were white noise implied that the model fitness is acceptable.

5.3.3.2 Results of some selected ARIMA models for Ratnagiri district.

The Fig.3 elaborated the stationarity of the data of rice production for Ratnagiri. There was no slow decay on ACF and data of production showing horizontal trend which indicated that the data were stationary. The residual plots for the same are shown in Fig.4. All the ACF and PACF of residuals lie between 95 per cent confidence limits indicated stationarity of data. Stationarity of the data was also checked by using ADF test. The results showed that the coefficient of lag value (-1.397) with standard error (0.22) and t-statistics (-6.25) was significant indicated that the data were stationary (Annexure-I).

The Details of some best fitted ARIMA models, on the basis of AIC, SBC, chi-square and p-value criteria, for Ratnagiri district are depicted in Table 5.20.

Table 5.20 Results of some selected ARIMA models for Ratnagiri district

	ARIMA (0,0,2)	ARIMA (2,0,0)	ARIMA (1,0,2)	ARIMA (0,0,3)	ARIMA (1,0,0)
Constant	1934.2* (39.16)	1935.1* (39.96)	1933.2* (42.75)	1933.5* (42.03)	1942.1* (27.69)
MA1,1	0.26 (0.22)	-	0.36 (0.45)	0.24 (0.26)	-
MA1,2	-0.52** (0.24)	-	-0.55** (0.23)	-0.52*** (0.26)	-
MA1,3	-	-	-	-0.05 (0.29)	-
AR1,1	-	-0.18 (0.23)	0.12 (0.53)	-	-0.25 (0.24)
AR1,2	-	0.38 (0.28)	-	-	-
(T_MIN_ STG_1)	-62.89*** (34.12)	-65.52 (42.19)	-63.74*** (34.17)	-63.77*** (34.61)	-88.52** (40.24)
(RN_FL_ STG_2)	110.89* (36.83)	120.87* (35.05)	114.08* (38.93)	113.41* (38.99)	127.70* (40.87)
AIC	287	289	289	289	290
SBC	293	294	296	296	294
R^2	0.47	0.30	0.23	0.36	0.32
Chi-Square	15.01	16.75	14.75	14.72	23.96
P-value	0.52	0.40	0.40	0.47	0.12

It was almost clear from the comparison of AIC and SBC values that ARIMA (0,0,2) model was the most suited model for the forecast of rice production in Ratnagiri district. For ARIMA (0,0,2) model, the MA2 component were found significant at 5 per cent level of significance. The AIC and SBC values for the same was 287 and 293 respectively. The R^2 value for the ARIMA (0,0,2) model was 0.47 which showed that 47 per cent variation in the dependent variable was explained by the variables included in the model. The chi-square value (15.01) was found insignificant which meant that the residuals of the respective time series were white noise implied that the model fitness is acceptable.

5.3.3.3 Results of some selected ARIMA models for Sindhudurg district.

The Details of some best fitted ARIMA models, on the basis of AIC, SBC, chi-square and p-value criteria, for Sindhudurg district are given in Table 5.21.

Table 5.21 Results of some selected ARIMA models for Sindhudurg district

	ARIMA (0,0,1)	ARIMA (0,0,2)	ARIMA (1,0,2)	ARIMA (3,0,2)	ARIMA (4,0,0)
Constant	1948.4* (5.49)	1948.3* (6.77)	1861.2* (98.94)	1765.4* (106.42)	1739.2* (111.83)
MA1,1	1.00** (0.39)	0.88** (0.40)	0.67*** (0.32)	0.28 (0.62)	-
MA1,2	-	0.11 (0.42)	-1.00** (0.3)	-1.00 (0.66)	-
AR1,1	-	-	0.75* (0.27)	0.34 (0.65)	0.19 (0.27)
AR1,2	-	-	-	0.13 (0.48)	1.03* (0.24)
AR1,3	-	-	-	0.31 (0.59)	0.34 (0.28)
AR1,4	-	-	-	-	-0.57*** (0.29)
(T_MAX_ STG_2)	-102.70* (31.26)	-95.38** (36.20)	-73.72*** (36.53)	-59.45*** (32.36)	-77.55* (26.06)
(T_MAX_ STG_5)	222.45* (26.28)	216.65* (32.21)	93.93** (35.79)	115.34** (42.09)	122.73* (30.31)
(RH_M_ STG_6)	180.50* (25.54)	181.94* (35.82)	40.23 (58.02)	17.81 (60.50)	-17.64 (33.12)
(RN_FL_ STG_3)	132.90* (43.97)	129.14** (51.76)	83.24* (25.36)	71.48** (26.77)	64.91** (24.54)
AIC	281	284	285	289	289
SBC	288	293	295	301	300
R^2	0.53	0.58	0.46	0.12	0.10
Chi-Square	9.96	9.89	4.69	10.72	6.61
P-value	0.91	0.87	0.99	0.63	0.95

The stationarity of the data for Sindhudurg district were tested with the help of ACF, PACF and trend of production presented in Fig.5. There was no slow decay on ACF and data of production showing horizontal trend which indicated that the data were stationary. The residual plot technique was also applied to selected model as shown in Fig.6. All the ACF and PACF of residuals lie between 95 per cent confidence limits which indicated the stationarity of time-series. Stationarity was also checked by using ADF test, the results of which showed that the coefficient of lag value (-0.398) with standard error (0.18) and t-statistics (-2.19) was significant indicated that the data were stationary (Annexure-I).

It was clear from the comparison of AIC and SBC values that ARIMA (0,0,1) model was the most suited model for the forecast of production for Sindhudurg district. For ARIMA (0,0,1) model, the MA1 component was found significant at 5 per cent level of significance. The AIC and SBC values for the same was 281 and 288 respectively. The R^2 value for the ARIMA (0,0,1) model was 0.53 which showed that 53 per cent variability in the dependent variable was explained by the variables included in the model. The chi-square value (9.96) was found insignificant which meant that the residuals of the respective time series were white noise implied that the model fitness is acceptable.

5.3.3.4 Results of some selected ARIMA models for Thane district.

The stationarity of the data was tested as mentioned earlier with the help of graphs of ACF, PACF and trend of production as presented in Fig.7. There were no significant spikes in both the functions which indicated that the data were stationary. The residual plot technique was also applied to see stationarity of time-series as shown in Fig.8. All the ACF and PACF of residuals lie between 95 per cent confidence limits. This indicated stationarity of time-series. Stationarity was also checked by using ADF test, the results of which showed that the coefficient of lag value (-1.246) with standard error (0.22) and t-statistics (-5.59) was significant indicated that the data were stationary (Annexure-I).

The Details of best fitted ARIMA models, on the basis of AIC, SBC, chi-square and p-value criteria, for Thane district are depicted in Table 5.22.

It was clear from the comparison of AIC and SBC values that ARIMA (0,0,2) model was the most acceptable model for the forecast of rice production in Thane district. For ARIMA (0,0,2) model, the MA2 component was found significant at 5 per cent level of significance. The AIC and SBC values for the same were 334 and 344 respectively which are lowest as compared to other ARIMA models. The R^2 value for the ARIMA (0,0,2) model was 0.52 which showed that 52 per cent variation in the dependent variable was explained by the variables included in the model. The chi-square value (8.89) was found insignificant which meant that the residuals of the respective time series were white noise implied that the model fitness is acceptable.

Table 5.22 Results of some selected ARIMA models for Thane district

	ARIMA (0,0,2)	**ARIMA (2,0,0)**	**ARIMA (1,0,2)**	**ARIMA (0,0,3)**	**ARIMA (1,0,0)**

Constant	2946.8* (171.88)	2951.2* (145.24)	3028.1* (168.14)	3009.6* (21.46)	2971.3* (99.92)
MA1,1	-0.12 (0.24)	-	-0.81* (0.15)	0.27 (0.29)	-
MA1,2	-0.53** (0.26)	-	-1.00* (0.26)	0.003 (0.31)	-
MA1,3	-	-	-	0.73** (0.33)	-
AR1,1	-	-0.08 (0.25)	-0.52** (0.24)	-	-0.15 (0.25)
AR1,2	-	0.32 (0.25)	-	-	-
(RH_E_ STG_5)	-321.84** (133.24)	-235.25 (152.64)	-413.54* (131.95)	-257.32*** (126.96)	-179.77 (140.14)
(RN_FL_ STG_5)	293.14*** (141.98)	208.41 (128.15)	360.55** (171.95)	211.17*** (114.92)	193.04 (116.99)
AIC	334	335	336	337	338
SBC	344	342	343	346	347
R^2	0.52	0.39	0.20	0.53	0.28
Chi-Square	8.89	14.84	9.28	16.48	20.64
P-value	0.92	0.54	0.86	0.35	0.24

5.3.3.5 Results of some selected ARIMA models for Konkan region.

The stationarity of the data was tested with the help of ACF, PACF and trend of production as shown in Fig.9. There were no significant spikes which indicated that the time-series were stationary. The residual plot technique was also applied to selected model as shown in Fig.10. All the ACF and PACF of residuals lie between 95 per cent confidence limits. Stationarity was also checked by using ADF test, the results of which showed that the coefficient of lag value (-1.218) with standard error (0.22) and t-statistics (-5.47) was significant indicated that the data were stationary (Annexure-I).

The Details of some best fitted ARIMA models, on the basis of AIC, SBC, chi-square and p-value criteria, for Konkan region are depicted in Table 5.23.

Table 5.23 Results of some selected ARIMA models for Konkan region.

	ARIMA (0,0,1)	**ARIMA (1,0,1)**	**ARIMA (0,0,2)**	**ARIMA (1,0,2)**	**ARIMA (1,0,0)**
Constant	10038.5* (21.42)	10038.3* (21.71)	10039.8* (22.43)	10035.8* (128.08)	10035.5* (117.71)
MA1,1	1.00* (0.28)	1.00** (0.46)	0.95* (0.30)	-0.47 (7.31)	-
MA1,2	-	-	0.05 (0.42)	-	-
AR1,1	-	-0.03 (0.43)	-	-1.06 (7.40)	-0.61* (0.21)

AR1,2	-	-	-	-0.26 (4.58)	-
(T_MAX_ STG_3)	657.31* (186.72)	656.00** (257.68)	674.80* (249.70)	334.58 (212.23)	333.82 (196.42)
(RH_M_ STG_1)	1173.70* (290.38)	1209.90* (309.81)	1161.00* (310.18)	999.34* (347.88)	1006.10* (301.56)
(SSH_ STG_1)	1356.00* (352.73)	1427.90* (367.64)	1333.60* (382.56)	1167.90* (395.02)	1183.80* (340.49)
AIC	361	362	363	364	365
SBC	366	369	369	372	370
R^2	0.30	0.39	0.36	0.30	0.29
Chi-Square	7.27	8.02	7.35	8.41	7.53
P-value	0.98	0.95	0.97	0.91	0.98

The comparison of AIC and SBC values revealed that for ARIMA (0,0,1) model these values were lowest, which indicated that ARIMA (0,0,1) model was the most suited model for the forecast of production for Konkan region. For ARIMA (0,0,1) model, the MA1 component was found significant at 1 per cent level of significance. The AIC and SBC values for the same was 361 and 366 respectively. The R^2 value for the ARIMA (0,0,1) model was 0.30 which showed that 30 per cent variability in the dependent variable was explained by the variables included in the model. The chi-square value (7.27) was found insignificant which meant that the residuals of the respective time series were white noise implied that the model fitness is acceptable.

5.3.4 Forecast models for rice production by Artificial Neural Network (ANN).

The productivity of rice is influenced by several major factors such as weather, soil, fertilization etc. In the present study only weather data were selected to study the factors affecting production of rice using weather variables. Second order variables were generated and arranged according to crop growth stages as per original scale. Out of various architectures of neural network, the best architecture was selected, which was made up of three layered feed forward network. Different seven activation functions were tried. TANH network function was found most efficient activation function for hidden and output layer. The performance of proposed network was assessed by its Root Mean Squared Error (RMSE) value along with accuracy.

5.3.4.1 Summary across stages for Raigad district.

It is evident from the Table 5.24 that the iteration stopped when the error increases or remain constant. It was observed that, the validation performance for Raigad district was obtained at RMSE value 23.57 with 100.00 per cent accuracy.

Table 5.24 Summary across stages for Raigad district.

Stage	Activation	Link	SSE	RMSE	Accuracy
0	LOGIST	IDENT	512211	270.505	76.10
1	EXP	IDENT	323418	568.698	83.43
2	SQUARE	IDENT	37631.4	193.988	95.81
3	LOGIST	IDENT	12245.3	110.658	94.15
4	TANH	IDENT	2285.6	47.8077	98.07
5	TANH	IDENT	1270.6	35.645	100.00
6	TANH	IDENT	555.5	23.569	100.00

5.3.4.2 Summary across stages for Ratnagiri district.

Table 5.25 Summary across stages for Ratnagiri district.

Stage	Activation	Link	SSE	RMSE	Accuracy
0	LOGIST	IDENT	222137	210.778	69.54
1	EXP	IDENT	61361.5	247.713	91.13
2	SIN	IDENT	22797.3	150.988	97.99
3	LOGIST	IDENT	20750	144.049	98.00
4	SIN	IDENT	11207.9	105.867	100.00
5	ARCTAN	IDENT	1485.9	38.547	99.02
6	LOGIST	IDENT	371.665	19.2786	100.00
7	SIN	IDENT	209.059	14.4589	100.00

The model fit results obtained by performing neural network procedure for Ratnagiri district are presented in the Table 5.25. It was observed that, the best model fit results for Ratnagiri district were obtained for Stage 8, for which RMSE (14.46) was the lowest. The accuracy of model to fit for the data was 100.00 per cent.

5.3.4.3 Summary across stages for Sindhudurg district.

The Table 5.26 explained the stage-wise results obtained by performing neural network procedure for Sindhudurg district.

Table 5.26 Summary across stages for Sindhudurg district.

Stage	Activation	Link	SSE	RMSE	Accuracy
0	SIN	IDENT	245856	187.409	81.00
1	TANH	IDENT	46594	215.856	94.97
2	EXP	IDENT	13519.9	116.275	99.01
3	SQUARE	IDENT	1324.2	36.3898	100.00
4	TANH	IDENT	163.681	12.7938	99.06
5	ARCTAN	IDENT	55.6129	7.45741	100.00
6	SIN	IDENT	33.3889	5.77832	99.04

It is observed from the Table 5.26 that, the best fit results for Sindhudurg district were obtained at Stage 7, where RMSE (5.78) was found lowest. The accuracy of model to fit for the data was 99.04 per cent. The SIN activation function was found most suitable.

5.3.4.4 Summary across stages for Thane district.

The Table 5.27 depicts stage-wise results obtained for neural network procedure for Thane district.

Table 5.27 Summary across stages for Thane district.

Stage	Activation	Link	SSE	RMSE	Accuracy
0	EXP	IDENT	1675173	578.822	74.87
1	LOGIST	IDENT	568438	753.948	95.79
2	EXP	IDENT	403859	635.499	91.04
3	TANH	IDENT	75123.3	274.086	100.00
4	SQUARE	IDENT	25813.7	160.667	96.10
5	LOGIST	IDENT	5056.6	71.1099	99.03
6	ARCTAN	IDENT	1895.5	43.537	100.00
7	LOGIST	IDENT	713.397	26.7095	100.00

The Table 5.27 explained that, the best fit results for Thane district were obtained at Stage 8, where RMSE (26.71) was found lowest. The LOGIST activation function was used at this stage which gave accuracy of 100.00 per cent.

5.3.4.5 Summary across stages for Konkan region district.

The results of neural network procedure for Konkan region are presented in the Table 5.28.

Table 5.28 Summary across stages for Konkan region.

Stage	Activation	Link	SSE	RMSE	Accuracy
0	SIN	IDENT	5375664	876.329	70.71
1	TANH	IDENT	2835383	1683.86	86.00
2	SIN	IDENT	662115	813.705	94.00
3	TANH	IDENT	202980	450.533	97.04
4	LOGIST	IDENT	69412.9	263.463	99.03
5	ARCTAN	IDENT	35597.5	188.673	100.00
6	SQUARE	IDENT	3245.2	56.9671	100.00

The stage-wise results obtained by performing neural network procedure for Konkan region showed that, the best fit results for Konkan region were obtained at Stage 7, RMSE (56.97) was found lowest. The activation function found most suitable for last stage was SIN function. The accuracy of model to fit for the data was 100.00 per cent.

5.3.4.6 Model fit statistics by Artificial Neural Network.

The model fit statistics obtained by artificial neural network for all the districts and Konkan region is explained in Table 5.29.

Table 5.29 Model fit statistics of Artificial Neural Network.

	Stage	RMSE	Accuracy (%)	AIC	SBC
Raigad	7	23.569	100.00	281	396
Ratnagiri	8	14.459	100.00	322	470

Sindhudurg	7	5.778	99.04	219	334
Thane	8	26.709	100.00	349	497
Konkan	7	56.970	100.00	320	434

It was observed that, the best model fit results for Raigad, Sindhudurg district and Konkan region were obtained at stage 7, whereas for Ratnagiri and Thane district it was found at stage 8. Among the four districts, for Sindhudurg district, the RMSE (5.78) for the model was found lowest. The accuracy of all models was almost 100.00 per cent. The model fit was also judged by AIC and SBC values. It was observed that for selected trained models AIC and SBC values were lowest, indicating best fit of the model.

5.3.4.7 Predicted rice production for Raigad District by Artificial Neural Network.

The Table 5.30 shows the actual values and the values predicted by neural network for the training data for Raigad district.

Table 5.30 Predicted rice production for Raigad District by Artificial Neural Network.

(Production in "00" Tonnes)

Year	Actual production	Predicted production	Error
1990	2975	2973.58	1.4237
1991	2503	2495.29	7.7119
1992	3356	3358.62	-2.6151
1993	2945	2942.93	2.0694
1994	3284	3275.26	8.7434
1995	2985	2983.20	1.7959
1996	3215	3229.01	-14.0095
1997	3315	3313.36	1.6367
1998	3343	3336.75	6.2535
1999	3417	3411.92	5.0838
2000	3285	3290.65	-5.6509
2001	2917	2915.64	1.3554
2002	3568	3563.21	4.7946
2003	2778	2776.54	1.4575
2004	3763	3766.10	-3.0956
2005	2972	2967.73	4.2742
2006	2950	2947.37	2.6337
2007	3145	3147.82	-2.8184
2008	3372	3377.41	-5.4127
2009	3598	3600.38	-2.3838
2010	3294	3295.53	-1.5317
2011	2948	2947.39	0.6086
RMSE		5.0240	
R^2		0.9997	

It was observed that, the actual values and predicted values are at par. The error obtained showed that there was very less difference in actual and predicted value. The lowest error was obtained for the year 2011 (0.61) when the actual and predicted values were 2948 and 2947.39 hundred tonnes, respectively. The Root Mean Square Error (RMSE) for the Raigad district was 5.0240 whereas the total variation explained by the variables included was 99.97 per cent. The predicted training data obtained from this model is plotted against the observed training data and the coefficient of determination was determined (Fig.11). The developed artificial neural network model explained about 100 per cent of the variability in rice production in Raigad district.

5.3.4.8 Predicted rice production for Ratnagiri District by Artificial Neural Network.

The artificial neural network for rice production in Ratnagiri district resulted in R^2 value of 99.98 and RMSE 3.08, which indicated the 'best fit' of model.

Table 5.31 Predicted rice production for Ratnagiri District by Artificial Neural Network.

(Production in "00" Tonnes)

Year	Actual production	Predicted production	Error
1990	1871	1876.86	-5.86496
1991	1713	1718.06	-5.05519
1992	1881	1883.36	-2.3637
1993	1739	1746.43	-7.43451
1994	1934	1935.82	-1.82024
1995	1804	1804.83	-0.82818
1996	1943	1942.59	0.40947
1997	2043	2047.35	-4.34945
1998	1840	1837.98	2.01683
1999	2202	2204.11	-2.11306
2000	1928	1926.83	1.17065
2001	1671	1670.29	0.7122
2002	2102	2099.73	2.27369
2003	1491	1494.11	-3.11154
2004	2391	2392.2	-1.19983
2005	1872	1875.92	-3.91505
2006	1952	1953.22	-1.21956
2007	2112	2111.28	0.71975
2008	1968	1969.87	-1.86975
2009	2013	2015.11	-2.1084
2010	2030	2033.27	-3.27433
2011	2231	2232.57	-1.57042
RMSE		3.0819	
R^2		0.9998	

The plot of predicted testing data against observed testing data is shown in Fig.12. The developed artificial neural network model explained 99.98 per cent variation in rice production in Ratnagiri district.

5.3.4.9 Predicted rice production for Sindhudurg District by Artificial Neural Network.

The results for training data by the artificial neural network procedure for Sindhudurg district are presented in the Table 5.32.

Table 5.32 Predicted rice production for Sindhudurg District by Artificial Neural Network.

(Production in "00" Tonnes)

Year	Actual production	Predicted production	Error
1990	1844	1846.83	-2.82561
1991	1588	1586.62	1.38261
1992	1413	1412.03	0.97446
1993	1593	1592.52	0.4765
1994	1616	1615.02	0.9817
1995	1887	1886.41	0.59425
1996	1811	1810.20	0.79705
1997	1929	1927.73	1.2744
1998	2051	2050.02	0.97508
1999	2183	2184.40	-1.39602
2000	1813	1814.64	-1.63583
2001	1975	1973.87	1.13049
2002	1974	1974.63	-0.62695
2003	1723	1722.66	0.34068
2004	2454	2455.07	-1.06861
2005	2193	2193.81	-0.81175
2006	2242	2241.95	0.05494
2007	2292	2293.77	-1.76681
2008	2138	2138.00	0.00412
2009	2158	2159.00	-1.00327
2010	2046	2046.04	-0.0441
2011	1970	1967.67	2.33317
RMSE		1.2324	
R^2		0.9999	

It could be demonstrated from Table 5.32 that the model was trained well as the predicted values by neural network and actual values were matched well for the training data for Sindhudurg district. The error was found least in the year 2008 (0.004) when the actual and predicted value was 2138 and 2137.996 hundred tonnes, respectively. The R^2 value for the data was 99.99 per cent which showed that the model explained almost all the variation in rice production. The Root Mean Square Error (RMSE) was 1.2324 which also indicates the 'best fit' of the model for forecasting of rice production in Sindhudurg district.

5.3.4.10 Predicted rice production for Thane District by Artificial Neural Network.

It was clearly observed from the Table 5.33 that, the actual values and predicted values were at par. The error obtained showed that there was very less difference in actual and predicted value of rice production. The lowest error was obtained in the year 1992 (0.68) when the actual and predicted value was 2694 and 2693.32 hundred tonnes, respectively. The Root Mean Square Error (RMSE) value for the Thane district was 5.6939 along with R^2 value 99.99 per cent. This revealed that the model was 'best fit' for the data which explained 99.99 per cent variability in rice production.

Table 5.33 Predicted rice production for Thane District by Artificial Neural Network.

(Production in "00" Tonnes)

Year	Actual production	Predicted production	Error
1990	2823	2825.52	-2.5224
1991	2879	2879.95	-0.9509
1992	2694	2693.32	0.6777
1993	2850	2844.00	5.9972
1994	3034	3031.17	2.8288
1995	2927	2932.77	-5.7673
1996	3258	3262.35	-4.3498
1997	3963	3959.66	3.3398
1998	3519	3531.52	-12.5237
1999	2728	2737.48	-9.4791
2000	3020	3027.13	-7.1283
2001	1753	1746.72	6.2836
2002	3451	3447.23	3.7665
2003	1598	1593.54	4.4597
2004	3975	3973.56	1.4426
2005	3354	3357.09	-3.0899
2006	3106	3103.68	2.3161
2007	2574	2578.17	-4.1719
2008	3092	3086.43	5.5748
2009	3034	3027.18	6.8208
2010	2908	2918.46	-10.4633
2011	2753	2755.41	-2.4117
RMSE		5.6939	
R^2		0.9999	

5.3.4.11 Predicted rice production for Konkan region by Artificial Neural Network.

The results for training data by the artificial neural network procedure for Konkan region are presented in the Table 5.34.

Table 5.34 Predicted rice production for Konkan region by Artificial Neural Network.

(Production in "00" Tonnes)

Year	Actual production	Predicted production	Error
1990	9513	9511.43	1.5683

1991	8683	8687.67	-4.6668
1992	9344	9327.12	16.8846
1993	9127	9129.69	-2.6871
1994	9868	9876.95	-8.9496
1995	9603	9601.86	1.1393
1996	10227	10208.14	18.8567
1997	11250	11226.2	23.7996
1998	10753	10744.74	8.2603
1999	10590	10589.60	0.403
2000	10046	10046.18	-0.1754
2001	8316	8335.84	-19.8439
2002	11095	11096.44	-1.4429
2003	7590	7572.10	17.8951
2004	12583	12606.96	-23.9621
2005	10391	10402.42	-11.424
2006	10250	10240.68	9.3157
2007	10123	10123.51	-0.5142
2008	10570	10568.38	1.6249
2009	10803	10808.34	-5.3382
2010	10277	10259.95	17.0451
2011	9901	9906.23	-5.2315
RMSE		12.1456	
R^2		0.9999	

It could be seen that there was minimum deviation in the actual values and the values predicted by neural network for the training data. The scatter plot of predicted training data against actual training data is shown in fig. 15. The developed artificial neural network model explained 99.99 per cent variability. The RMSE value was 12.15 which indicated ‘best fit’ of the model.

5.4 Forecast of the rice production.

5.4.1 Forecast of rice production by selected regression models.

The forecast values of the rice production for next five years are presented in Table 5.35. The forecast value for the Konkan region, with the best fitted regression model, for 2019-20 would be 11033.01 hundred tonnes whereas for Raigad, Ratnagiri, Sindhudurg and Thane district, it would be 3409.75, 2190.87, 2499.00 and 2931.80 hundred tonnes, respectively for the same period.

Table 5.35 Forecast of rice production by selected regression models.

(Production in "00" Tonnes)

Year	Raigad	Ratnagiri	Sindhudurg	Thane	Konkan

2015-16	3362.32	2129.78	2386.32	2939.20	10829.53
2016-17	3374.18	2160.43	2414.49	2937.35	10880.40
2017-18	3386.04	2162.69	2442.66	2935.50	10931.27
2018-19	3397.89	2181.76	2470.83	2933.65	10982.14
2019-20	3409.75	2190.87	2499.00	2931.80	11033.01

5.4.2 Forecast of rice production by Aridity index models.

It was observed that, as none of the aridity indices were found significant at 10 per cent level of significance, the aridity index approach did not give the best fit model for forecasting of rice production. It could be attributed to the fact that Konkan region falls under high rainfall area and aridity indices are worked out for water scarcity area. Hence, it could be concluded that the forecasting of the rice production by using aridity index approach is inefficient. Therefore, this approach could not be used for forecasting purpose in Konkan region.

5.4.3 Forecast of rice production by ARIMA method.

The forecast of rice production in different districts and Konkan region as a whole were obtained by using respective ARIMA models discussed earlier. The results of the same are depicted in Table 5.36. For Konkan region as a whole in the year 2019-20 rice production would be 10043.89 hundred tonnes. Among the different districts forecast of rice production, for 2019-20, varied between 1943.83 hundred tonnes in Ratnagiri district to 3177.14 hundred tonnes in Raigad district.

Table 5.36 Forecast of rice production by ARIMA method.

(Production in "00" Tonnes)

Year	Lead	Raigad	Ratnagiri	Sindhudurg	Thane	Konkan
2015-16	1	3182.40	1920.96	1940.57	2953.86	10050.51
2016-17	2	3173.81	1953.66	1942.35	2980.54	10035.59
2017-18	3	3178.24	1931.79	1943.22	2949.18	10046.08
2018-19	4	3176.00	1945.93	1943.63	2985.29	10038.70
2019-20	5	3177.14	1936.62	1943.83	2945.76	10043.89

5.4.3 Forecast of rice production by Artificial Neural Network.

The forecasted production of rice for all the districts and Konkan region are depicted in Table 5.37. The forecast of rice production for the Konkan region, with the artificial neural network model, for 2019-20 would be 11095 hundred tonnes. Whereas, for

Raigad, Ratnagiri, Sindhudurg and Thane district it would be 3568, 2391, 2242 and 3975 hundred tonnes, respectively.

Table 5.37 Forecast of rice production by Artificial Neural Network.

(Production in "00" Tonnes)

Year	Raigad	Ratnagiri	Sindhudurg	Thane	Konkan
2015-16	3284	1968	1974	3034	10227
2016-17	3294	2030	2046	3106	10277
2017-18	3343	2102	2138	3354	10570
2018-19	3372	2202	2183	3519	10753
2019-20	3568	2391	2242	3975	11095

5.5 Comparison of various forecast models.

The models for prediction of rice production were compared by using criterion like Root Mean Square Error (RMSC), Mean Square Error (MSE), Mean Absolute Error (MAE), Mean Error (ME), Mean Percentage Error (MPE) and Mean Absolute Percentage Error (MAPE). The criterions were developed by using the predicted and observed values of rice production and error values for the respective model.

It could be concluded from Table 5.38 that after due comparison of all the criterions, the Artificial Neural Network (ANN) model was found efficient model for forecasting of rice production in Konkan region. The entire evaluation criterion revealed that the artificial neural network had superiority to regression analysis, aridity index approach and ARIMA modeling approach.

Table 5.38 Comparison of various forecast models.

	Regression	Aridity index	ARIMA	ANN
Raigad				
RMSE	274.90	240.06	166.26	13.37
MAE	233.95	222.81	144.53	11.70
MSE	75570.47	57631.08	27641.72	178.70
ME	-196.68	-47.85	-21.53	-1.41
MPE	-6.69	-2.01	-1.01	-0.04
MAPE	7.78	7.18	4.60	0.37
Ratnagiri				
RMSE	118.54	324.06	203.36	9.13
MAE	93.11	316.92	181.74	8.32
MSE	14051.86	105012.17	41353.98	83.28
ME	47.38	316.92	181.74	0.93
MPE	2.06	14.68	8.39	0.06
MAPE	4.28	14.68	8.39	0.39
Sindhudurg				
RMSE	285.08	238.28	120.40	16.33
MAE	282.15	233.06	103.27	13.87

MSE	81271.16	56779.07	14496.75	266.62
ME	-282.15	233.06	103.27	2.00
MPE	-13.94	11.40	4.99	0.10
MAPE	13.94	11.40	4.99	0.69
Thane				
RMSE	359.84	469.73	343.54	9.25
MAE	253.18	367.41	246.23	7.67
MSE	129481.76	220647.05	118019.19	85.56
ME	253.18	367.41	233.12	-4.47
MPE	7.34	10.84	6.71	-0.15
MAPE	7.34	10.84	7.16	0.25
Konkan				
RMSE	442.35	1416.73	653.40	39.24
MAE	403.53	1343.26	464.78	27.49
MSE	195670.96	2007126.29	426929.10	1539.85
ME	-191.86	-1343.26	464.78	15.46
MPE	-1.99	-12.98	4.25	0.14
MAPE	3.88	12.98	4.25	0.26

CHAPTER VI

SUMMARY AND CONCLUSIONS

Weather plays an important role in agricultural production. It has a profound influence on the growth, development and yields of a crop. There is no aspect of crop culture that is devoid of the impact of weather. Weather parameters have direct and distinct effect the agricultural production. This dependency of crop production necessitates the defining relationship between crop production and weather parameters. Various methods are used by various scientists to predict the functional relationship between production and weather parameters. A research work in this aspect is needed for forecasting of the agricultural production in the heavy rainfall area like Konkan region. Thus, the present study entitled, "Rice Production in Konkan Region- an Economic Analysis" was undertaken to explore this particular aspect with the following specific objectives:

5. To study the performance of rice with respect to area, production and productivity in Konkan region.
6. To examine the instability in the rice production.
7. To assess the impact of weather parameters on rice production.
8. To forecast the rice production in Konkan region.

Methodology

The data on the rice production and on different weather parameters for the four districts of Konkan region i.e. Ratnagiri, Raigad, Thane and Sindhudurg district were collected from the secondary sources for the period from 1989-90 to 2014-15. The data for 26 years were used for analysis. The time series data on area, production and productivity of rice in Raigad, Ratnagiri, Sindhudurg and Thane district were collected from various secondary sources i.e. different published reports of the state government, for different time periods. The data on the all weather parameters were collected from the regional meteorological stations of respective districts. These data were supported by the data obtained from the Indian Meteorological Department, Pune. In this study, stage-wise average standardized weather parameters were used for analysis.

Estimation of trends in area, production and productivity:

The data for 36 (1979-80 to 2014-15) were used to assess trends in area, production and productivity of rice. The period of study was sub-divided into decades for further analysis.

Compound Growth Rates (CGR):

Compound growth rate was estimated by using exponential growth function as,

$Y = ab^t$

The compound growth rate was estimated as C.G.R. (r) = [Antilog (log b) – 1] x 100

Estimation of the instability in the rice production:

The instability in area, production and productivity of rice for different time periods was estimated by using Cuddy-Della Valle instability index.

Models for forecasting the rice production:

1. Regression analysis:

Multiple regression analysis is the most commonly used method to explain relationship between a group of explanatory variables and dependent variable. The original data were standardized for further analysis. Standardization is done in SAS software by using ‘proc standard’.

2. Aridity Index:

The general idea behind the aridity index method is the use of an index, instead of using original explanatory variables, as an explanatory variable in regression analysis. Aridity index is an index which is developed by using those original explanatory variables. The study incorporates the aforementioned aridity indices into the econometric models.

3. Forecasting (ARIMA) model:

ARIMA modeling was performed by using production as output and standardized variables. To initialize the ARIMA procedure in SAS 9.2 ‘proc arima’ statement was used. In order to run the ‘proc arima’ some differenced variables had to be created. Creating differenced variables and plotting those variables against time were the prior procedures.

4. Artificial Neural Network (ANN):

The analysis of artificial neural network carried out with production as dependent variable and standardized stage-wise weather parameters as explanatory variables. In order to run neural network procedure in SAS 9.2 ‘proc dmneurl’ statement was used.

Comparison of various forecast models:

The models for prediction of rice production were compared by using criterion like Root Mean Square Error (RMSC), Mean Square Error (MSE), Mean Absolute Error (MAE), Mean Error (ME), Mean Percentage Error (MPE) and Mean Absolute Percentage Error (MAPE).

Findings

6.1 Trends in area, production and productivity of rice crop.

6.1.1 Trends in area under rice crop.

It reveals that in 1979-80 the area under rice was 4.44 lakh hectares, which decline by 5.83 per cent during the study period. Area under rice in Konkan region decreased at the rate of 0.29 per cent per annum. The disaggregated analysis of area indicated that except Sindhudurg district, area under rice declined to the extent of 0.18 to 0.55 per cent per annum in different districts of Konkan region.

The forgoing analysis indicated that, over a period of time in Konkan region area under rice has declined. The decline in area under rice was more in Thane and Raigad district. This could be attributed to fast urbanization or industrialization and shifting of agricultural land to non-agricultural uses, in these districts. Thus, the hypothesis that "Area under rice in Konkan region is decreasing' has been accepted.

6.1.2 Trends in production of rice crop.

Production of rice in Konkan region increased from 788.0 MT in 1979-80 to 1120.2 MT in 2014-15. This indicated that during the period under study production of rice in Konkan region increased to the tune of 42.16 per cent over base year. The trends in production of rice indicated a positive growth. In Konkan region, production of rice registered a growth of 0.81 per cent per annum during the period under study. Among the districts, in Sindhudurg district, production of rice significantly increased by 1.80 per cent per annum followed by Ratnagiri (1.23 per cent per annum).

In period I, Ratnagiri and Sindhudurg district registered a significant growth of 0.11 2.02 per cent per annum, respectively. During period II, production of rice increased significantly by 3.33 per cent per annum in Sindhudurg district followed by Raigad (2.07 per cent) and Ratnagiri (1.81 per cent). In period III, significant growth (2.17 per cent) in rice production was observed only in Sindhudurg district. While, rice production in Thane district during period IV grew at the rate of 4.56 per cent per annum. Whereas, for other districts growth in rice production was positive but non-significant except for Ratnagiri district.

6.1.3 Trends in productivity of rice crop.

. It is seen that in 1979-80 productivity of rice in Konkan was 1796 kg/ha which increased to 2679 kg/ha in 2014-15. The per cent change in productivity during this period was to the tune of 49.16 per cent. The compound growth rate revealed that productivity of rice grew at the rate of 1.09 per cent per annum during the same period. Among the districts, productivity of rice registered impressive growth of 1.89 per cent per annum in Sindhudurg district followed by Ratnagiri (1.57 per cent) and Raigad (1.07 per cent).

The temporal changes and compound growth rates of area, production and productivity of rice revealed that there has been continuous decline in area under rice in Konkan region. However, there has been increase in production and productivity of rice during the period under study. This significant increase in production and productivity could be attributed to development of different rice production technologies by Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli. The university has developed and released 25 high yielding and 5 hybrids of rice varieties along with other production technologies.

6.2 Growth and instability in area, production and productivity of rice crop.

6.2.1 Instability in area, production and productivity of rice crop in Raigad district.

During overall period, variation in area under rice in Raigad district was 6.52 per cent. The instability index for area was estimated to 2.91 which indicated that area under rice in Raigad district was unstable. The period-wise comparison of variability in production showed that, there was high degree of variation (10.36 per cent) in period III with overall variation to the tune of 9.80 per cent. The instability index of rice production varied between 6.81 in period IV to 10.36 in period III, with overall instability index of 8.81. During the period under study variation in productivity of rice in Raigad district was 14.03 per cent. Instability index showed that, the productivity of rice in Raigad district was highly instable during the period III (9.87) with overall instability of 8.83.

6.2.2 Instability in area, production and productivity of rice crop in Ratnagiri district.

At overall level variability in area was 3.52 per cent. The instability index ranged between 0.80 in period III to 3.60 in period I with overall instability index of 2.98. Among the different time period, coefficient of variation for production was highest (15.82 per cent) during period I with overall level 16.40 per cent. Production was highly instable during period I (15.75). At overall level instability index turned out to be 10.89. For overall period coefficient of variation for productivity was 18.79 per cent. The instability index (10.45) for overall period revealed that the productivity of rice in Ratnagiri district was instable during the study period.

6.2.3 Instability in area, production and productivity of rice crop in Sindhudurg district.

At overall level, the variation in area was 3.54 per cent. It can also be seen that, area under rice was comparatively more instable (4.33) during period IV. For overall period instability index was 3.52, indicated instability in area under rice. It is evident from coefficient of variation for production of rice varied from 3.09 per cent in period IV to 13.24 per cent in period II, with overall variation to the tune of 20.47 per cent. For the overall period instability index for area under rice worked out to 10.43. For the overall study period, variation in productivity was to the tune of 20.91 per cent. At overall level, the productivity of rice was found more instable (8.52).

6.2.4 Instability in area, production and productivity of rice in Thane district.

At overall level variability in area was 6.21 per cent. For the period under study, instability index turned out to be 4.68 indicating instability in area under rice. Over the different time periods, coefficient of variation for production of rice was highest (25.47 per cent) during period III with overall level 17.31. Productivity was found highly unstable during period III (24.82) and relatively stable during period IV (8.00). At overall level instability index turned out to be 16.95. For overall period coefficient of variation for productivity was 18.29 per cent. The instability index (16.81) for overall period revealed the productivity of rice in Ratnagiri district was instable.

6.2.5 Instability in area, production and productivity of rice crop in Konkan region.

At overall level coefficient of variation and instability index was 3.42 and 1.63 per cent, respectively this revealed that the area under rice is relatively stable in Konkan region. The period-wise comparison of variability in production showed that, there was more variation (13.66 per cent) during period III with overall variation to the tune of 12.47 per cent. Overall instability in production of rice was 9.66. The variation in productivity of rice in Konkan region was 15.27 per cent over the study period. Instability index showed that, productivity of rice in Konkan region was highly instable during the period III (12.89) with overall instability of 10.47.

The foregoing analysis revealed that during the study period area under rice was relatively stable whereas, there was great instability in production as well as productivity of rice in Konkan region. The instability in production and productivity of rice may be due to adoption of modern technologies by the rice farmers in Konkan region. In view of this the hypothesis that ‘production and productivity of rice in Konkan region is instable’ is accepted.

6.3 Forecast models for rice production.

6.3.1 Forecast models for rice production by Regression analysis.

The regression analysis was performed between dependent variable production (Y) and explanatory variables (36 variables) i.e. crop growth stage-wise weather parameters for the period from 1989-90 to 2010-11. The crop stage-wise weather data were standardized and significant variables were determined by step-wise method.

6.3.1.1 Parameter estimates of regression model for Raigad district.

It is evident that, among the variables included in the model only two variables viz. T_MIN_STG_2 and RN_FL_STG_1 were retained in the model after step down regression. The variables retained in the model accounted for 41 per cent variation in the production of rice in Raigad district. The coefficients of the variables revealed that with one unit increase in the minimum temperature during stage II, production of rice increase by 113.78 units and one unit increase in rainfall during stage I decreases the rice production by 188.06 units.

6.3.1.2 Parameter estimates of regression model for Ratnagiri district.

It could be observed that, out of total variables included in the model only two variables viz. T_MIN_STG_1 and RN_FL_STG_2 were found significant at 10 per cent level of significance in Ratnagiri district. About 42 per cent of variation in production was explained by the two significant variables in the model. The regression coefficient of minimum temperature in stage I indicated that one unit increase in minimum temperature during stage I decreases the production of rice by 122.83 units whereas, that of rainfall in stage II indicated that one unit increase in rainfall during stage II increases the production of rice by 224.098 units.

6.3.1.3 Parameter estimates of regression model for Sindhudurg district.

It is observed that, out of total variables included in the model four variables viz. T_MAX_STG_2, T_MAX_STG_5, RH_M_STG_6 and RN_FL_STG_3 were retained in the model. These four variables retained in the model accounted for 70 per cent of variation in production. The coefficient of variables revealed that one unit increase in the maximum temperature at stage V, morning relative humidity at stage VI and rainfall at stage III production of rice increases by 171.25, 144.79 and 107.90 units, respectively.

Whereas, one unit increases in maximum temperature at stage II production of rice decreases by 78.50 units.

6.3.1.4 Parameter estimates of regression model for Thane district.

Among the variables included in the model only two variables viz. RH_E_STG_5 and RN_FL_STG_5 were turned out to be significant. The variables retained in the model accounted for 19 per cent variation in production of rice in Thane district. The regression coefficient of evening relative humidity at stage V revealed that one unit increase in evening relative humidity during stage V production of rice decreases by 190.5 units. Whereas, that of rainfall at stage V indicated that one unit increase in rainfall during stage V increases the production of rice by 226.86 units.

6.3.1.5 Parameter estimates of regression model for Konkan region.

The results of multiple regression analysis revealed that three variables viz. maximum temperature at stage II, morning relative humidity at stage I and sunshine hours at stage I turn out to be significant. The variables retained in the model accounted for 33 per cent of variation in rice production. The coefficient of variables revealed that one unit increase in maximum temperature at stage III (tillering stage), morning relative humidity at stage I (sowing stage) and sunshine hours at stage I (sowing stage) results in increasing the production by 605.51, 977.46 and 695.61 units, respectively.

6.3.2 Forecast models for rice production by Aridity index model.

Aridity index method was used to estimate the relationship between weather parameters and the production of rice. In aridity index method, an index has to be developed first by using various weather parameters and then functional relationship was derived by using that aridity index. The weather parameters used to develop aridity index were ‘P’ is the sum of precipitation and ‘T’ is mean temperature. The advantage of use of aridity index is it reduces the problem of degree of freedom in the analysis.

6.3.2.1 Parameter estimates of Aridity index model for Raigad district.

Aridity indices were developed for defining functional relationship between production of rice and weather parameters. It revealed that the coefficient of indices was non-significant at 10 per cent level of significance. R^2 values of all the indices were at par. Among these indices, for Raigad district, the linear regression model with precipitation (P) and temperature (T) has highest R^2 value of 0.25 which indicated that 25 per cent variation in production of rice is explained by variables precipitation and temperature.

6.3.2.2 Parameter estimates of Aridity index model for Ratnagiri district.

It was observed that none of the coefficient was significant at 10 per cent level of significance. Among the various indices the linear regression model has highest R^2 value of 0.23 which indicates that 23 per cent variation in production of rice is explained by precipitation and temperature.

6.3.2.3 Parameter estimates of Aridity index model for Sindhudurg district.

It was observed that the linear regression model with precipitation (P) and temperature (T) has highest R^2 value of 0.64 which indicates that 64 per cent variation in production of rice were explained by precipitation and temperature. However, coefficients of the various indices are also found insignificant at 10 per cent level of significance.

6.3.2.4 Parameter estimates of Aridity index model for Thane district.

It could be seen that the coefficients of indices are non-significant at 10 per cent level of significance. R^2 values of all the indices are close to each other. Among the various indices, for Thane district, the linear regression model has highest R^2 value (0.07) which indicated that only 7 per cent variation in production of rice were explained by precipitation and temperature.

6.3.2.5 Parameter estimates of Aridity index model for Konkan region.

It could be observed that similar trend was also found in Konkan region. None of aridity index model found 'best fit' based on R^2 value and statistical significance of coefficients.

The results indicated that index based models did not render satisfactory results as the coefficients were not statistically significant. Aridity index method was found inefficient for forecasting of rice production in Konkan region. It could be because; Konkan region falls under high rainfall area and aridity indices are worked out for water scarcity area. Thus, the hypothesis that "The aridity index approach is superior to regression model by taking the individual meteorological factors" is rejected.

6.3.3 Forecast models for rice production by ARIMA modeling.

Autocorrelation function is very constructive tool to find out whether a time-series is stationary or not. Both Autocorrelation Function (ACF) and Partial Autocorrelation Function (PACF) are used to determined moving average and autoregressive orders of the model, respectively. The diagnostic checks are done using L-jung and Box chi-square test. In addition model selection criteria AIC, SBC and R^2 are used to select best model.

6.3.3.1 Results of some selected ARIMA models for Raigad district.

Stationarity was checked by using ADF test, the results of which showed that the coefficient of lag value (-1.266) with standard error (0.22) and t-statistics (-5.7) was significant indicated that the data is stationary. It was almost clear from the comparison of AIC values that ARIMA (0,0,3) model was the most suited model for the forecast of production for Raigad district. The R^2 value for the ARIMA (0,0,3) model was 0.40 which revealed that 40 per cent variability in the dependent variable was explained by the variables included in the model. The chi-square value (12.49) was found insignificant which means that the residuals of the respective time series are white noise implied that the model fitness is acceptable.

6.3.3.2 Results of some selected ARIMA models for Ratnagiri district.

Stationarity of the data was checked by using ADF test. The results showed that the coefficient of lag value (-1.397) with standard error (0.22) and t-statistics (-6.25) was significant indicated that the data is stationary. It was almost clear from the comparison of AIC and SBC values that ARIMA (0,0,2) model was the most suited model for the forecast of rice production in Ratnagiri district. The R^2 value for the ARIMA (0,0,2) model was 0.47 which showed that 47 per cent variation in the dependent variable was explained by the variables included in the model. The chi-square value (15.01) was found insignificant which means that the residuals of the respective time series are white noise implied that the model fitness is acceptable.

6.3.3.3 Results of some selected ARIMA models for Sindhudurg district.

Stationarity was checked by using ADF test, the results of which showed that the coefficient of lag value (-0.398) with standard error (0.18) and t-statistics (-2.19) was significant indicated that the data is stationary. It was clear from the comparison of AIC and SBC values that ARIMA (0,0,1) model was the most suited model for the forecast of production for Sindhudurg district. The R^2 value for the ARIMA (0,0,1) model was 0.53 which showed that 53 per cent variability in the dependent variable was explained by the variables included in the model. The chi-square value (9.96) was found insignificant which means that the residuals of the respective time series are white noise implied that the model fitness is acceptable.

6.3.3.4 Results of some selected ARIMA models for Thane district.

Stationarity was checked by using ADF test, the results of which showed that the coefficient of lag value (-1.246) with standard error (0.22) and t-statistics (-5.59) was significant indicated that the data is stationary. It was clear from the comparison of AIC and SBC values that ARIMA (0,0,2) model was the most acceptable model for the forecast of rice production in Thane district. The R^2 value for the ARIMA (0,0,2) model was 0.52 which showed that 52 per cent variation in the dependent variable was explained by the variables included in the model. The chi-square value (8.89) was found insignificant which means that the residuals of the respective time series are white noise implied that the model fitness is acceptable.

6.3.3.5 Results of some selected ARIMA models for Konkan region.

Stationarity was checked by using ADF test, the results of which showed that the coefficient of lag value (-1.218) with standard error (0.22) and t-statistics (-5.47) was significant indicated that the data is stationary. The comparison of AIC and SBC values revealed that for ARIMA (0,0,1) model these values are lowest, which indicated that ARIMA (0,0,1) model was the most suited model for the forecast of production for Konkan region. The R^2 value for the ARIMA (0,0,1) model was 0.30 which showed that 30 per cent variability in the dependent variable was explained by the variables included in the model. The chi-square value (7.27) was found insignificant which means that the residuals of the respective time series are white noise implied that the model fitness is acceptable.

6.3.4 Forecast models for rice production by Artificial Neural Network (ANN).

Out of various architectures of neural network, the best architecture was selected, which was made up of three layered feed forward network. The performance of proposed network was assessed by its Root Mean Squared Error (RMSE) value along with accuracy.

6.3.4.1 Summary across stages for Raigad district.

It is evident that the iteration stopped when the error increases or remain constant. It was observed that, the validation performance for Raigad district was obtained at RMSE value 23.57 with 100.00 per cent accuracy. Different seven activation functions were tried. TANH network function was found most efficient activation function for hidden and output layer.

6.3.4.2 Summary across stages for Ratnagiri district.

The model fit results obtained by performing neural network procedure for Ratnagiri district showed that, the best model fit results for Ratnagiri district were obtained for Stage 8, for which RMSE (14.46) was the lowest. The accuracy of model to fit for the data was 100.00 per cent.

6.3.4.3 Summary across stages for Sindhudurg district.

The explained the stage-wise results obtained by performing neural network procedure for Sindhudurg district. It is observed that, the best fit results for Sindhudurg district were obtained at Stage 7, where RMSE (5.78) was found lowest. The accuracy of model to fit for the data was 99.04 per cent. The SIN activation function was found most suitable.

6.3.4.4 Summary across stages for Thane district.

It explained that, the best fit results for Thane district were obtained at Stage 8, where RMSE (26.71) was found lowest. The LOGIST activation function was used at this stage which gave accuracy of 100.00 per cent.

6.3.4.5 Summary across stages for Konkan region district.

The stage-wise results obtained by performing neural network procedure for Konkan region showed that, the best fit results for Konkan region were obtained at Stage 7, RMSE (56.97) was found lowest. The activation function found most suitable for last stage was SIN function. The accuracy of model to fit for the data was 100.00 per cent.

6.3.4.6 Model fit statistics by Artificial Neural Network.

It was observed that, the best model fit results for Raigad, Sindhudurg district and Konkan region were obtained at stage 7, whereas for Ratnagiri and Thane district it was found at stage 8. Among the four districts, for Sindhudurg district, the RMSE (5.78) for the model was found lowest. The accuracy of all models was almost 100.00 per cent. The model fit was also judged by AIC and SBC values. It was observed that for selected trained models AIC and SBC values were lowest, indicating best fit of the model.

6.3.4.7 Predicted rice production for Raigad District by Artificial Neural Network.

It was observed that, the actual values and predicted values are at par. The error obtained showed that there was very less difference in actual and predicted value. The lowest error was obtained for the year 2011 (0.61) when the actual and predicted values were 2948 and 2947.39 hundred tonnes, respectively. The Root Mean Square Error (RMSE) for the Raigad district was 5.0240 whereas the total variation explained by the variables included was 99.97 per cent.

6.3.4.8 Predicted rice production for Ratnagiri District by Artificial Neural Network.

The artificial neural network for rice production in Ratnagiri district resulted in R^2 value of 99.98 and RMSE 3.08, which indicated the 'best fit' of model. The developed artificial neural network model explained 99.98 per cent variation in rice production in Ratnagiri district.

6.3.4.9 Predicted rice production for Sindhudurg District by Artificial Neural Network.

It could be demonstrated the model is trained well as the predicted values by neural network and actual values were matched well for the training data for Sindhudurg district. The error was found least in the year 2008 (0.004) when the actual and predicted value was 2138 and 2137.996 hundred tonnes, respectively. The R^2 value for the data was 99.99 per cent which showed that the model explained almost all the variation in rice production. The Root Mean Square Error (RMSE) was 1.2324 which also indicates the 'best fit' of the model for forecasting of rice production in Sindhudurg district.

6.3.4.10 Predicted rice production for Thane District by Artificial Neural Network.

It was clearly observed that, the actual values and predicted values were at par. The error obtained showed that there was very less difference in actual and predicted value of rice production. The lowest error was obtained in the year 1992 (0.68) when the actual and predicted value was 2694 and 2693.32 hundred tonnes, respectively. The Root Mean Square Error (RMSE) value for the Thane district was 5.6939 along with R^2 value 99.99 per cent. This revealed that the model was 'best fit' for the data which explained 99.99 per cent variability in rice production.

6.3.4.11 Predicted rice production for Konkan region by Artificial Neural Network.

It could be seen that there was minimum deviation in the actual values and the values predicted by neural network for the training data. The developed artificial neural network model explained 99.99 per cent variability. The RMSE value was 12.15 which indicated 'best fit' of the model.

6.4 Forecast of the rice production.

6.4.1 Forecast of rice production by selected regression models.

The forecast value for the Konkan region, with the best fitted regression model, for 2019-20 would be 11033.01 hundred tonnes whereas for Raigad, Ratnagiri, Sindhudurg and Thane district, it would be 3409.75, 2190.87, 2499.00 and 2931.80 hundred tonnes, respectively for the same period.

6.4.2 Forecast of rice production by Aridity index models.

It was observed that, as none of the aridity indices were found significant at 10 per cent level of significance, the aridity index approach did not give the best fit model for forecasting of rice production. It could be attributed to the fact that Konkan region falls under high rainfall area and aridity indices are worked out for water scarcity area. Hence, it could be concluded that the forecasting of the rice production by using aridity index approach is inefficient. Therefore, this approach could not be used for forecasting purpose in Konkan region.

6.4.3 Forecast of rice production by ARIMA method.

The forecast of rice production in different districts and Konkan region as a whole were obtained by using respective ARIMA models discussed earlier. For Konkan region as a whole in the year 2019-20 rice production would be 10043.89 hundred tonnes. Among the different districts forecast of rice production, for 2019-20, varied between 1943.83 hundred tonnes in Ratnagiri district to 3177.14 hundred tonnes in Raigad district.

6.4.3 Forecast of rice production by Artificial Neural Network.

The forecasted production of rice for all the districts and Konkan region showed the forecast of rice production for the Konkan region, with the artificial neural network model, for 2019-20 would be 11095 hundred tonnes. Whereas, for Raigad, Ratnagiri, Sindhudurg and Thane district it would be 3568, 2391, 2242 and 3975 hundred tonnes, respectively.

6.5 Comparison of various forecast models.

The models for prediction of rice production were compared by using criterion like RMSC, MSE, MAE, ME, MPE and MAPE. It could be concluded that after due comparison of all the criterions, the Artificial Neural Network (ANN) model was found efficient model for forecasting of rice production in Konkan region. The entire evaluation criterion revealed that the artificial neural network had superiority to regression analysis, aridity index approach and ARIMA modeling approach.

Conclusions:

Based on the results of the present study, following broad conclusions are drawn:

1. The area under rice cultivation decreased during study period in Konkan region.
2. Decline in area under rice in Raigad district was about 0.55 per cent per annum whereas in Thane district it declined at the rate of 0.37 per cent per annum.
3. The production and productivity of rice increased over the study period in Konkan region.
4. In Konkan region the production increased at the rate of 0.81 per cent per annum.
5. The production and productivity of Sindhudurg district increased at the rate of 1.80 and 1.89 per cent per annum respectively followed by Ratnagiri district.
6. The variability in area, production and productivity of Konkan region for overall study period was 3.42, 12.74 and 15.27 per cent, respectively.

7. In Konkan region, the area under rice cultivation was more unstable in period IV whereas, production and productivity were more unstable during period III.
8. It was observed that in Konkan region, among different weather parameters maximum temperature of stage III, relative humidity of Stage I and sunshine hours in Stage I of crop growth had influence on production of rice.
9. Aridity index method was found inefficient for forecasting of rice production in Konkan region. It could be because of Konkan region falls under high rainfall area and aridity indices were worked out for water scarcity area.
10. By ARIMA modeling, the models found best for Raigad, Ratnagiri, Sindhudurg and Thane district were ARIMA(0,0,3), ARIMA(0,0,2), ARIMA (0,0,1) and ARIMA (0,0,2), respectively.
11. The best fit model for Konkan region by ARIMA modeling was ARIMA (0,0,1) model.
12. Among the forecasting models studied, based on best model fit criteria, Artificial Neural Network (ANN) model was found to be most efficient for forecasting of rice production in Konkan region.

Policy Implications:

Government of Maharashtra has to device policy regarding shift in land under cultivation to non-agricultural uses to mitigate further decline in area under rice cultivation in general and in particular in Thane and Raigad districts.

In forecasting, the use of Artificial Neural Network model for forecasting is suggested for efficient forecasting.

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Appendix-I

The results of ADF test for stationarity check of data.

Parameter Estimates					
Variable	**Lag**	**Parameter Estimate**	**Standard Error**	**t Value**	**Pr > |t|**
Raigad	**1**	-1.2656	0.22199	-5.7	<.0001
Ratnagiri	**1**	-1.3971	0.22367	-6.25	<.0001
Sindhudurg	**1**	-0.3983	0.1821	-2.19	0.0414
Thane	**1**	-1.2455	0.22287	-5.59	<.0001
Konkan	**1**	-1.2176	0.22256	-5.47	<.0001

Appendix-II (A)

Test results obtained by regression model.

(Production in "00" Tonnes)

Year	Actual Production	Predicted Production	Error
Raigad			
2011-12	2943	3314.90	-371.90
2012-13	2943	3326.75	-383.75
2013-14	3233	3338.61	-105.61
2014-15	3425	3350.47	74.53
Average	3136.00	3332.68	-196.68
Ratnagiri			
2011-12	2217	1998.48	218.52
2012-13	2219	2156.54	62.46
2013-14	2024	2083.37	-59.37
2014-15	2115	2147.10	-32.1
Average	2143.75	2096.37	47.38
Sindhudurg			
2011-12	1982	2273.64	-291.64
2012-13	2012	2301.81	-289.81
2013-14	2000	2329.98	-329.98
2014-15	2141	2358.15	-217.15
Average	2033.75	2315.90	-282.15
Thane			
2011-12	2949	2946.60	2.4
2012-13	2949	2944.75	4.25
2013-14	3369	2942.90	426.1
2014-15	3521	2941.05	579.95
Average	3197.00	2943.83	253.18
Konkan			
2011-12	10091	10626.05	-535.05
2012-13	10123	10676.92	-553.92
2013-14	10626	10727.79	-101.79
2014-15	11202	10778.66	423.34
Average	10510.50	10702.36	-191.86

Appendix-II (B)

Test results obtained by Aridity index model.

(Production in "00" Tonnes)

Year	Actual Production	Predicted Production	Error
Raigad			
2011-12	2943	3224.00	-281.00
2012-13	2943	3203.33	-260.33
2013-14	3233	3164.27	68.73
2014-15	3425	3143.81	281.19
Average	3136.00	3183.85	-47.85
Ratnagiri			
2011-12	2217	1835.82	381.18
2012-13	2219	1839.82	379.18
2013-14	2024	1804.15	219.85
2014-15	2115	1827.53	287.47
Average	2143.75	1826.83	316.92
Sindhudurg			
2011-12	1982	1787.63	194.37
2012-13	2012	1793.76	218.24
2013-14	2000	1798.12	201.88
2014-15	2141	1823.27	317.73
Average	2033.75	1800.70	233.06
Thane			
2011-12	2949	2867.22	81.78
2012-13	2949	2868.90	80.10
2013-14	3369	2799.96	569.04
2014-15	3521	2782.30	738.70
Average	3197.00	2829.60	367.41
Konkan			
2011-12	10091	11860.86	-1769.86
2012-13	10123	11833.46	-1710.46
2013-14	10626	11871.72	-1245.72
2014-15	11202	11849.00	-647.00
Average	10510.50	11853.76	-1343.26

Appendix-II (C)

Test results obtained by ARIMA method.

(Production in "00" Tonnes)

Year	Actual Production	Predicted Production	Error

Raigad [ARIMA (0,0,3)]			
2011-12	2943	3103.95	-160.95
2012-13	2943	3097.51	-154.51
2013-14	3233	3249.66	-16.66
2014-15	3425	3179.01	245.99
Average	3136.00	3157.53	-21.53
Ratnagiri [ARIMA (0,0,2)]			
2011-12	2217	1887.40	329.60
2012-13	2219	2088.80	130.20
2013-14	2024	1935.92	88.08
2014-15	2115	1935.92	179.08
Average	2143.75	1962.01	181.74
Sindhudurg [ARIMA (0,0,1)]			
2011-12	1982	1942.62	39.38
2012-13	2012	1913.27	98.73
2013-14	2000	1929.18	70.82
2014-15	2141	1936.86	204.14
Average	2033.75	1930.48	103.27
Thane [ARIMA (0,0,2)]			
2011-12	2949	2968.94	-19.94
2012-13	2949	2955.27	-6.27
2013-14	3369	2967.39	401.61
2014-15	3521	2963.91	557.09
Average	3197.00	2963.88	233.12
Konkan [ARIMA (0,0,1)]			
2011-12	10091	10077.59	13.41
2012-13	10123	10016.55	106.45
2013-14	10626	10059.47	566.53
2014-15	11202	10029.29	1172.71
Average	10510.50	10045.70	464.78

Appendix-II (D)

Test results obtained by Artificial Neural Network.

(Production in "00" Tonnes)

Year	Actual Production	Predicted Production	Error
Raigad			
2011-12	2943	2947.23	-4.2255
2012-13	2943	2931.77	11.2282

2013-14	3233	3254.99	-21.9873
2014-15	3425	3415.66	9.3416
Average	3136.00	3137.41	-1.41
Ratnagiri			
2011-12	2217	2220.74	-3.7436
2012-13	2219	2230.03	-11.0252
2013-14	2024	2011.12	12.8846
2014-15	2115	2109.38	5.6182
Average	2143.75	2142.82	0.93
Sindhudurg			
2011-12	1982	1961.25	20.7492
2012-13	2012	2008.90	3.0978
2013-14	2000	2023.75	-23.7533
2014-15	2141	2133.11	7.8942
Average	2033.75	2031.75	2.00
Thane			
2011-12	2949	2952.47	-3.4681
2012-13	2949	2965.44	-16.4403
2013-14	3369	3362.61	6.3871
2014-15	3521	3525.37	4.3751
Average	3197.00	3201.47	-2.29
Konkan			
2011-12	10091	10093.58	-2.5804
2012-13	10123	10144.48	-21.4831
2013-14	10626	10551.41	74.5885
2014-15	11202	11190.70	11.2973
Average	10510.50	10495.04	15.46

Fig. 1 Trend and Correlation Analysis for Production of Rice in Raigad district.

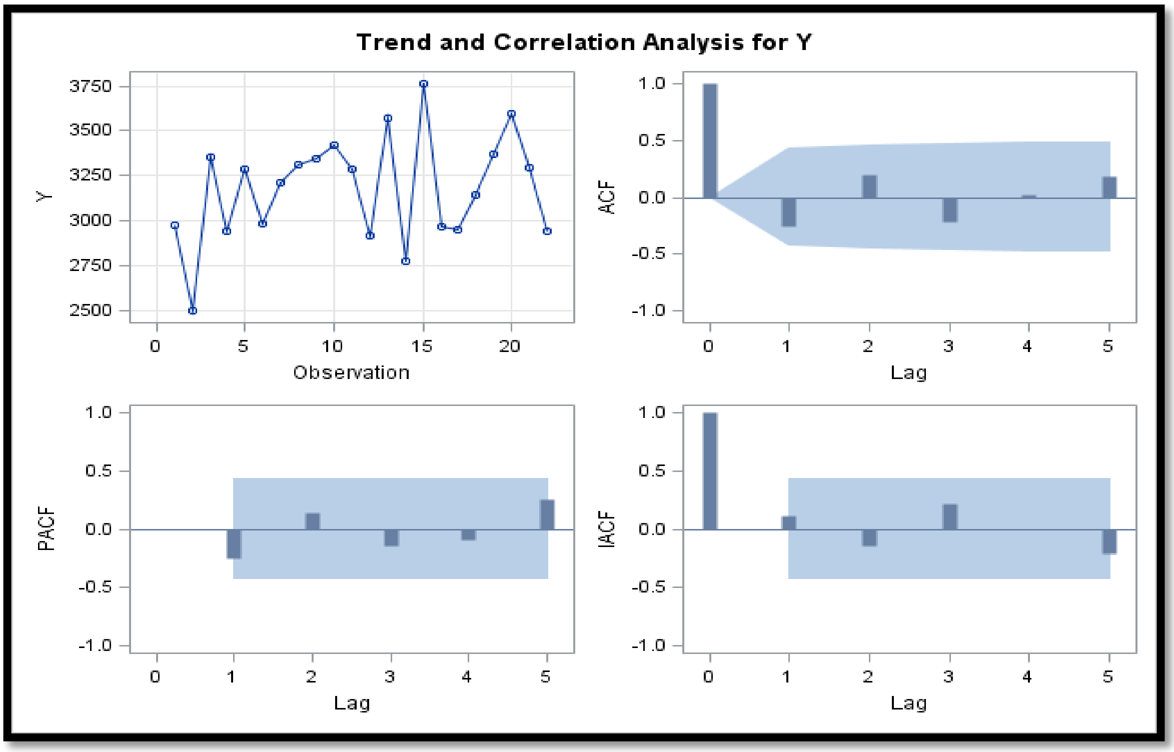


Fig. 2 Residual Correlation Diagnostics for Production of Rice in Raigad district.

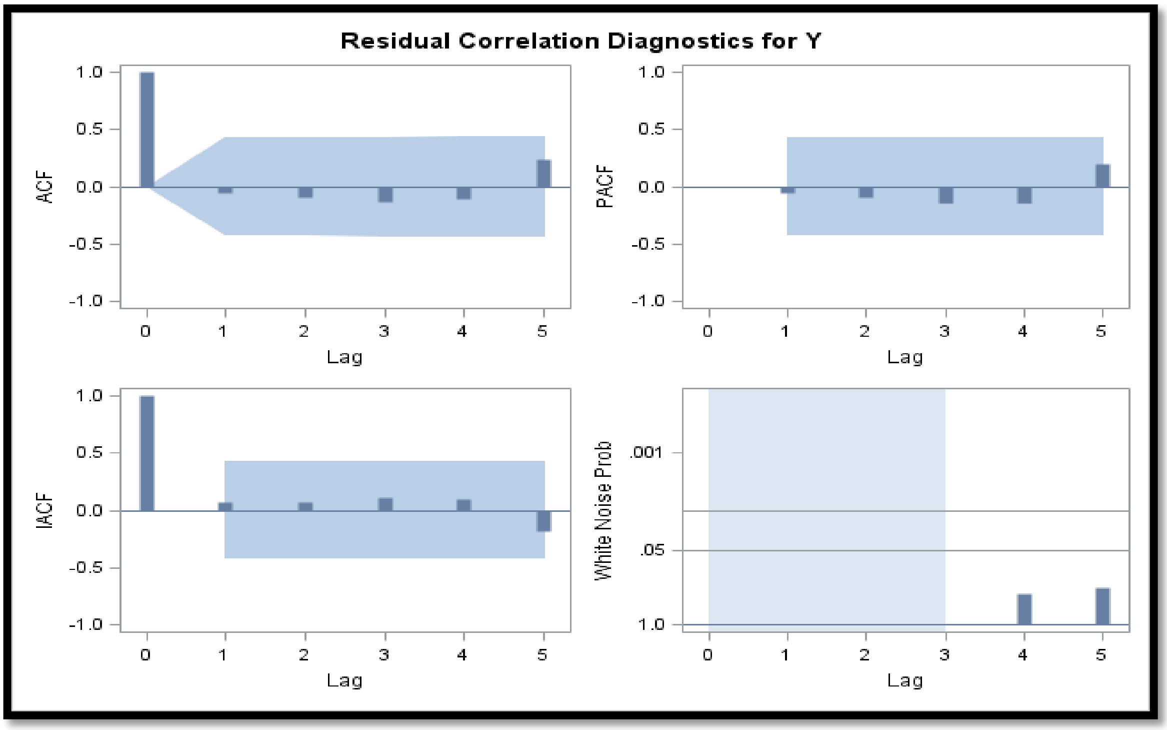


Fig. 3 Trend and Correlation Analysis for Production of Rice in Ratnagiri district.

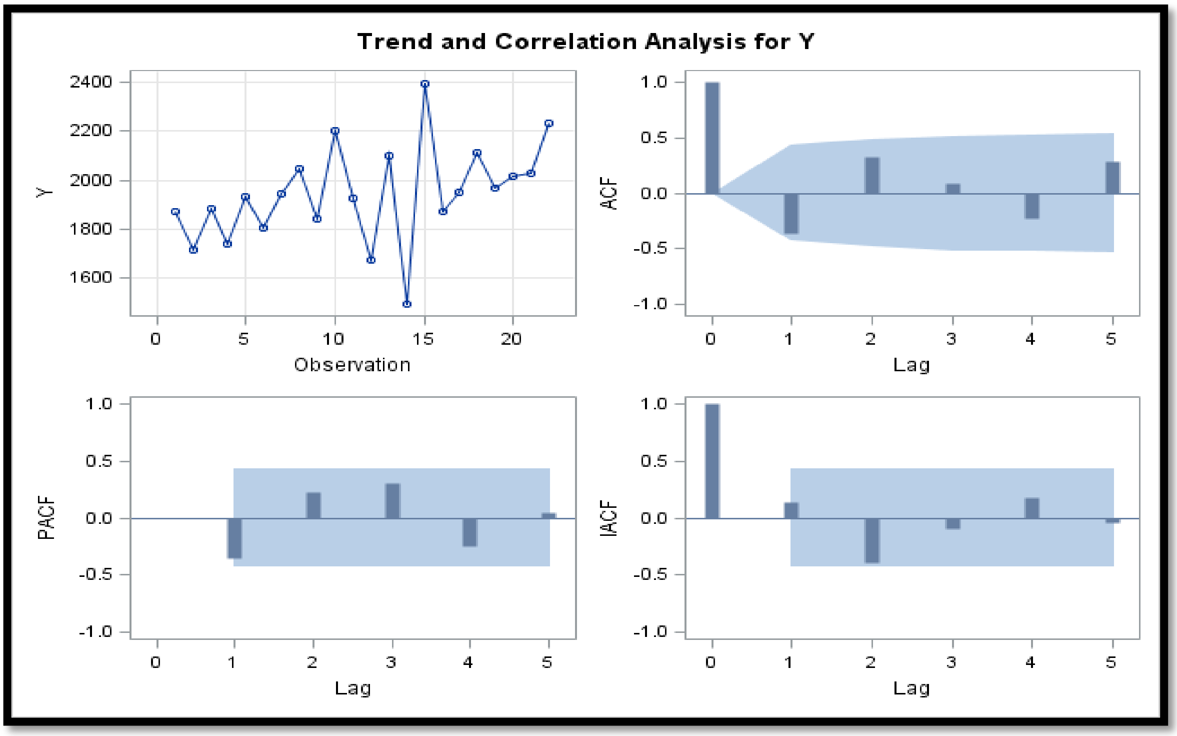


Fig. 4 Residual Correlation Diagnostics for Production of Rice in Ratnagiri district.

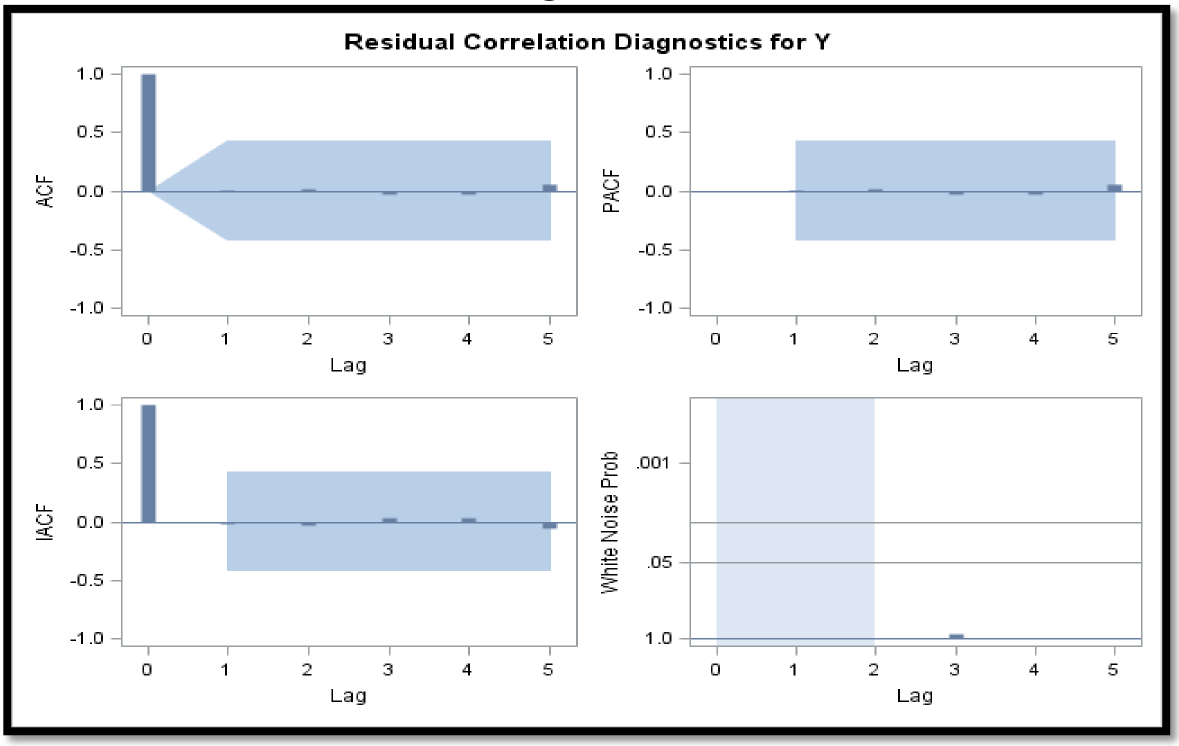


Fig. 5 Trend and Correlation Analysis for Production of Rice in Sindhudurg district.

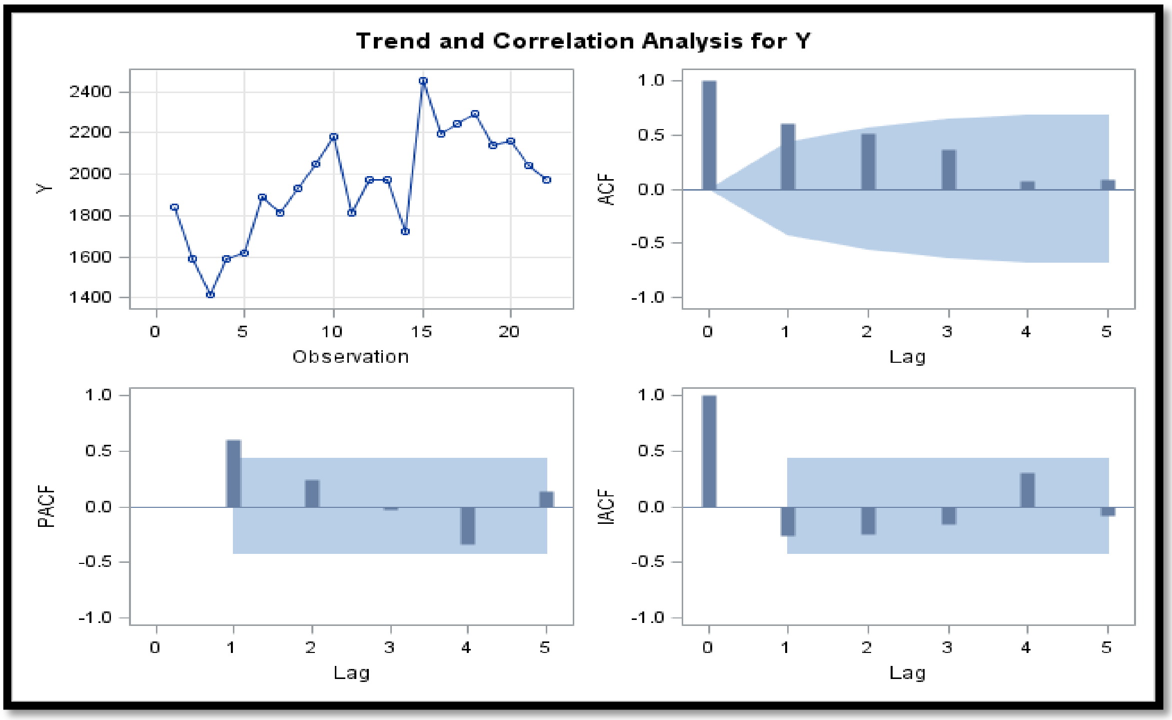


Fig. 6 Residual Correlation Diagnostics for Production of Rice in Sindhudurg district.

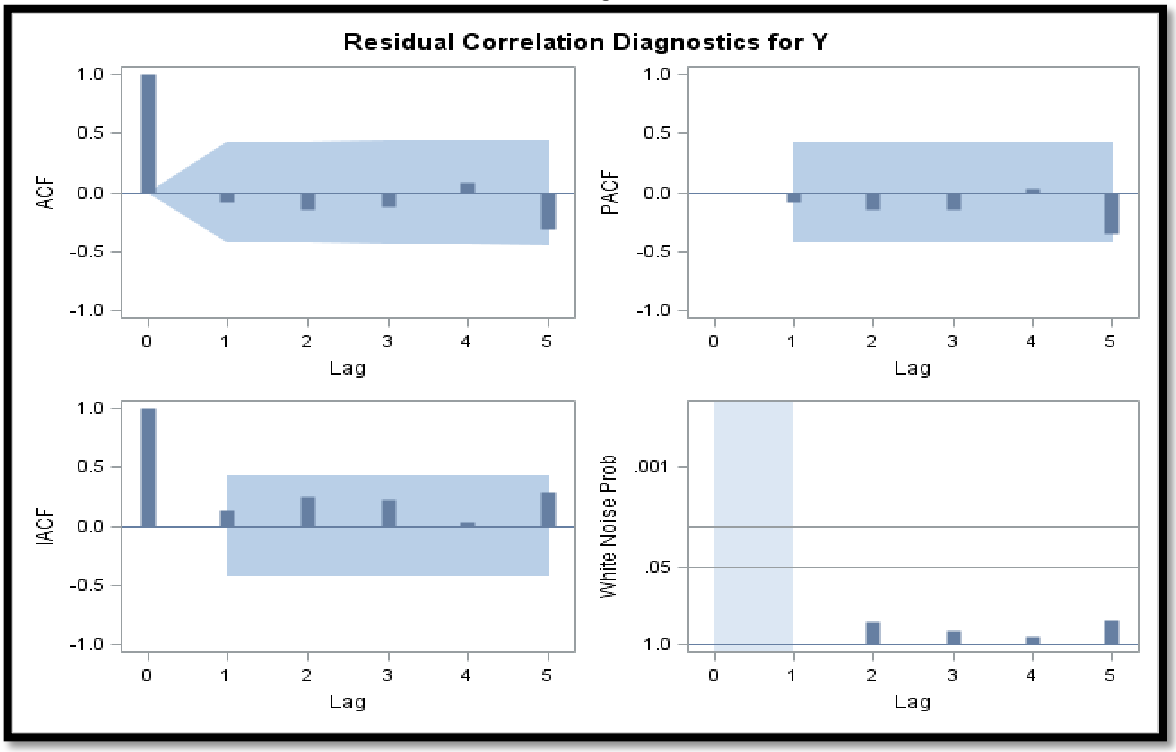


Fig. 7 Trend and Correlation Analysis for Production of Rice in Thane district.

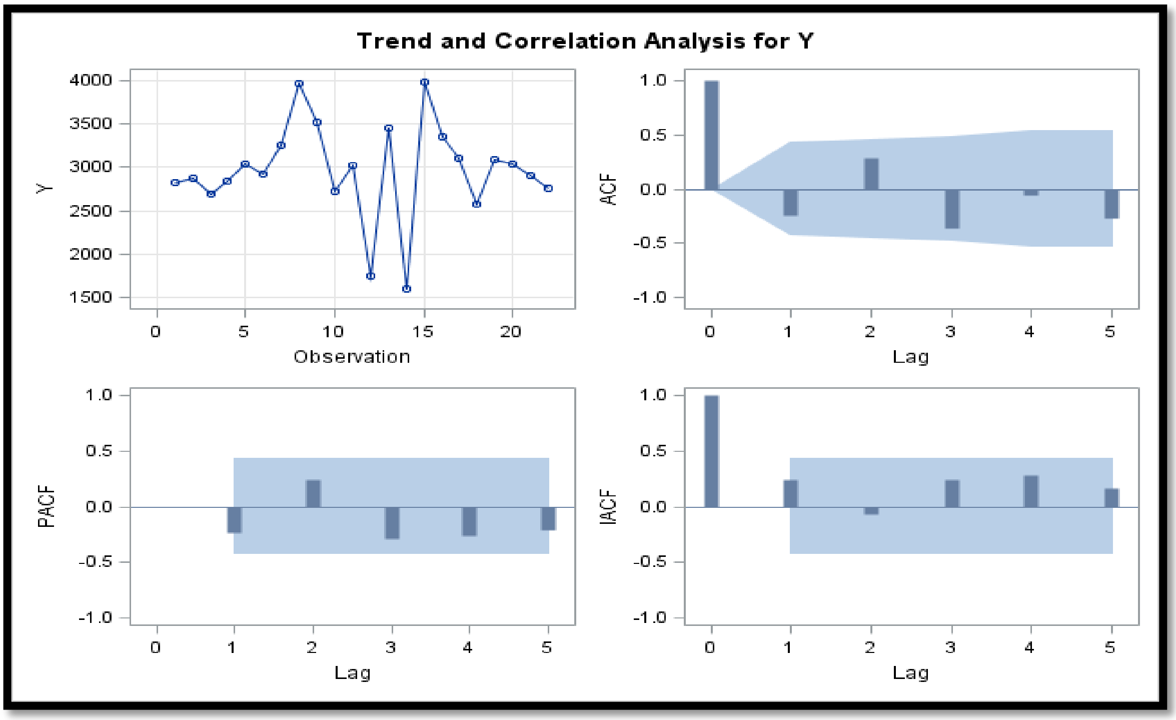


Fig. 8 Residual Correlation Diagnostics for Production of Rice in Thane district.

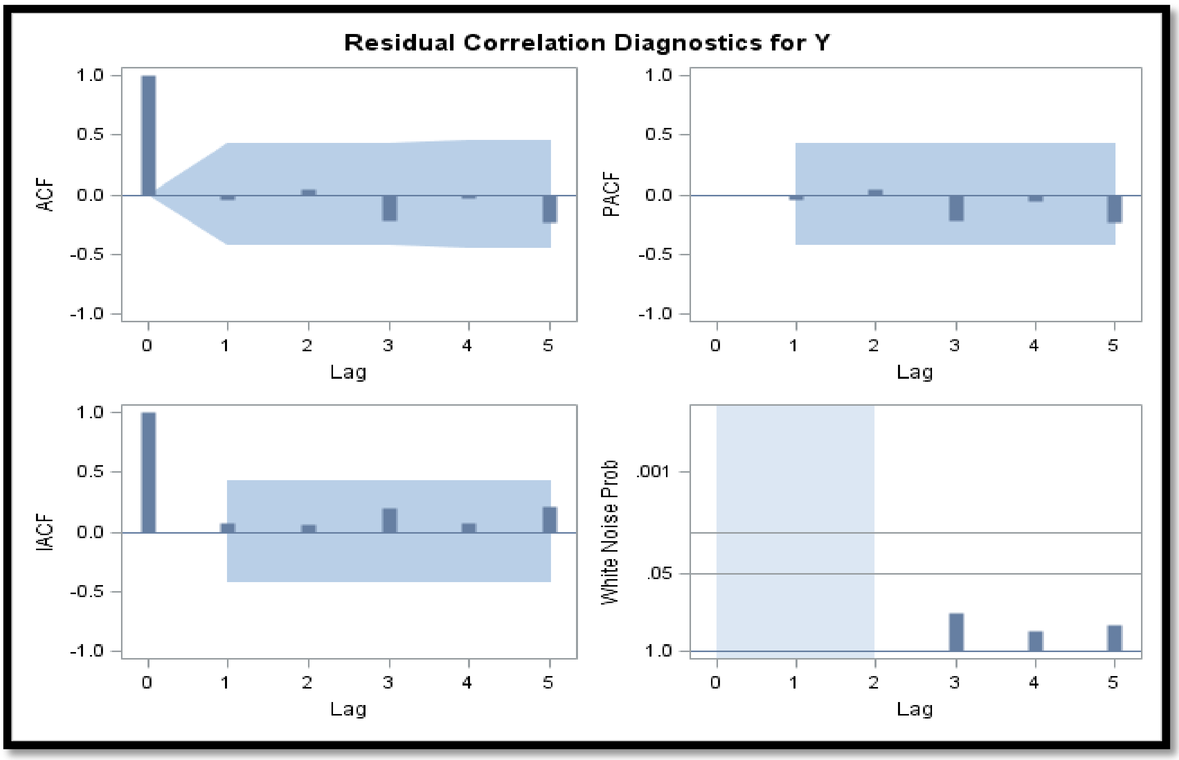


Fig. 9 Trend and Correlation Analysis for Production of Rice in Konkan region.

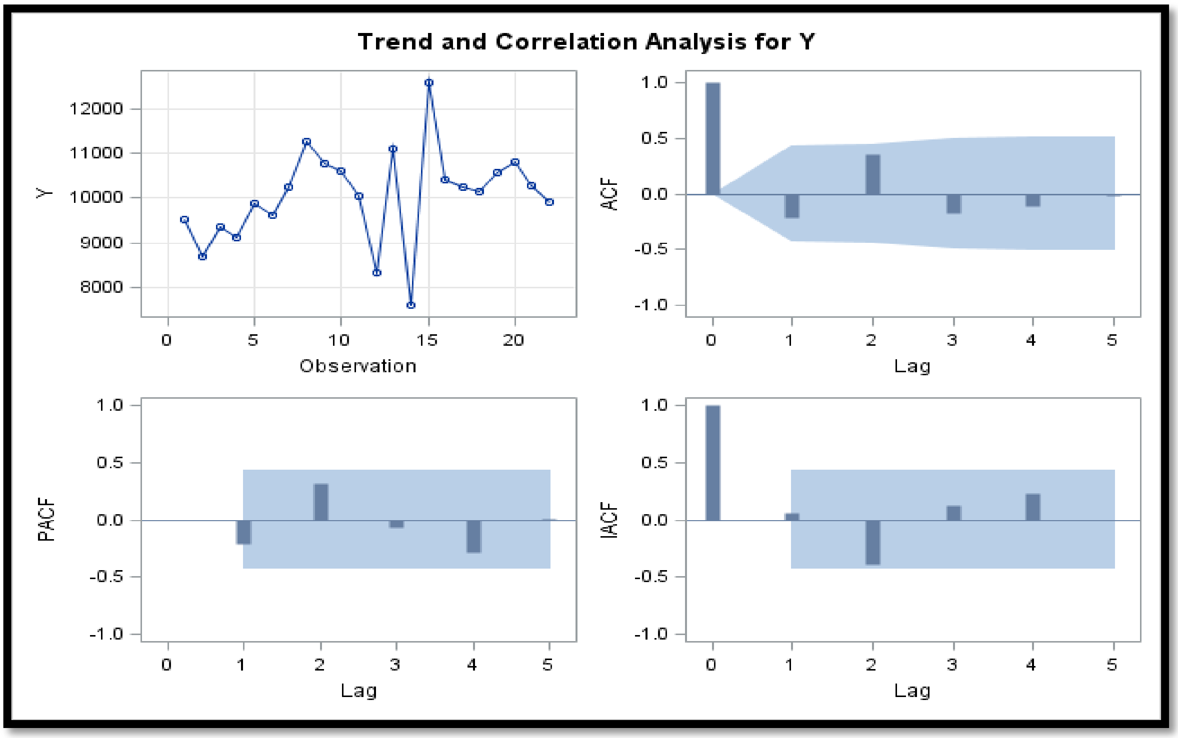


Fig. 10 Residual Correlation Diagnostics for Production of Rice in Konkan region.

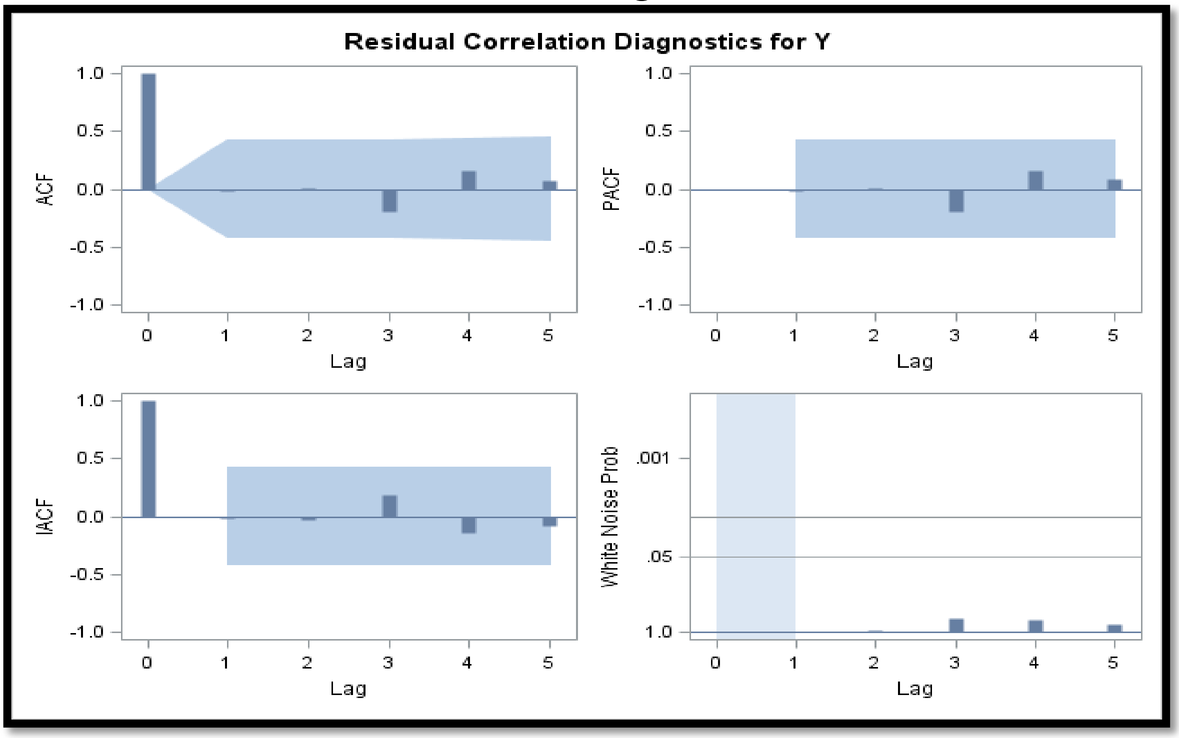


Fig.11 Scatter plot between observed and predicted rice production in Raigad district.

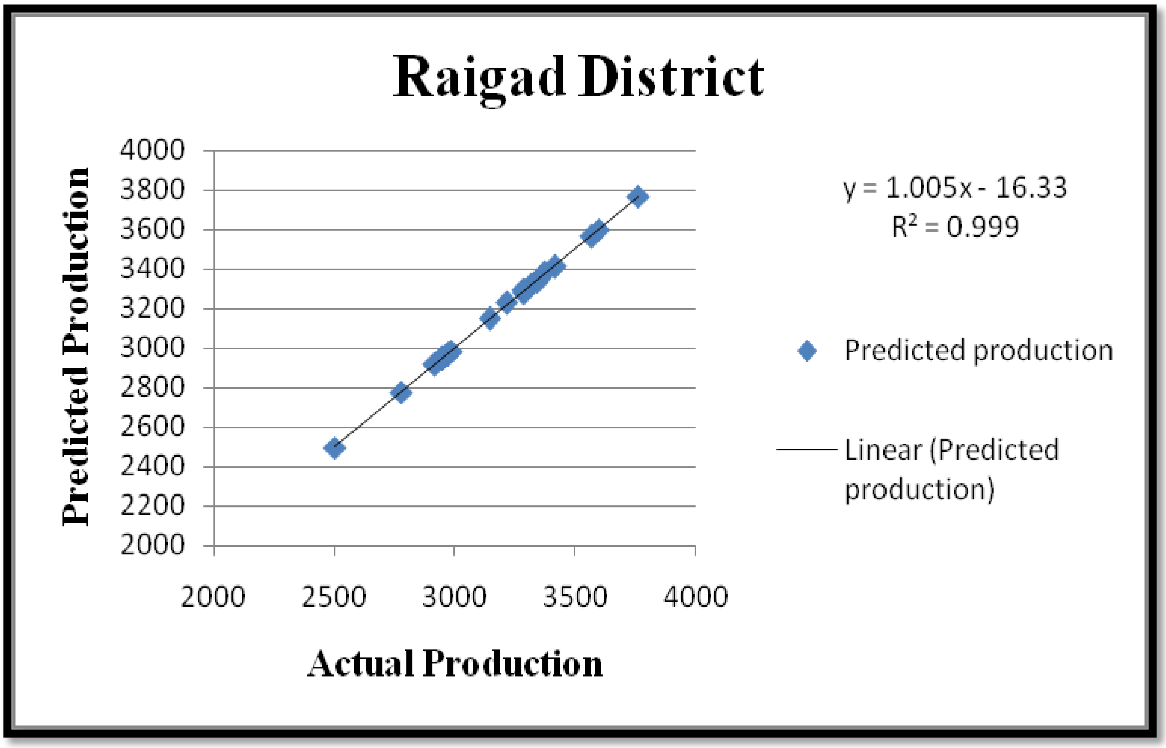


Fig.12 Scatter plot between observed and predicted rice production in Ratnagiri district.

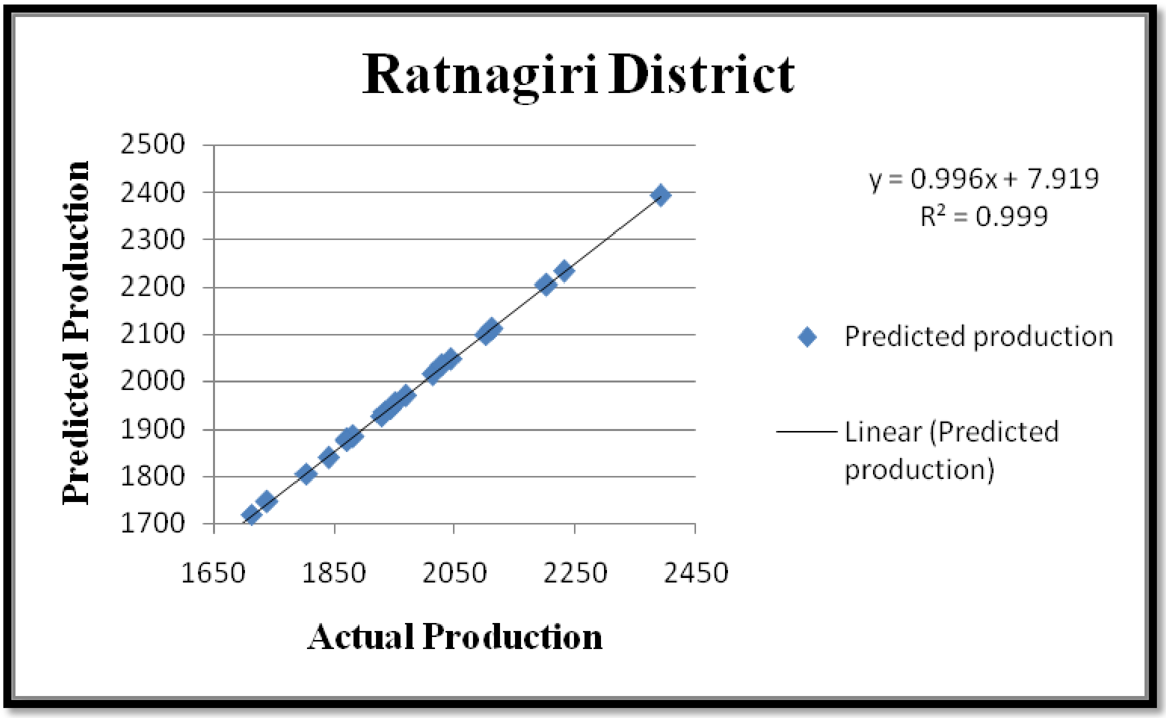


Fig.13 Scatter plot between observed and predicted rice production in Sindhudurg district.

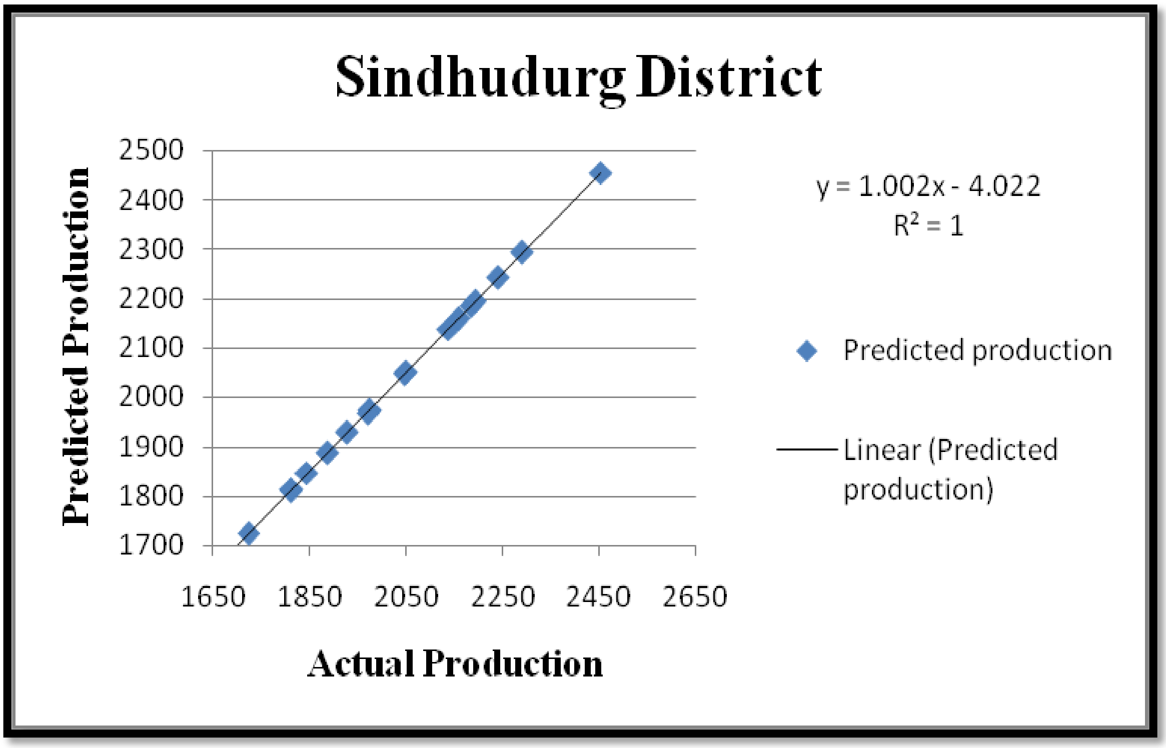


Fig.14 Scatter plot between observed and predicted rice production in Thane district.

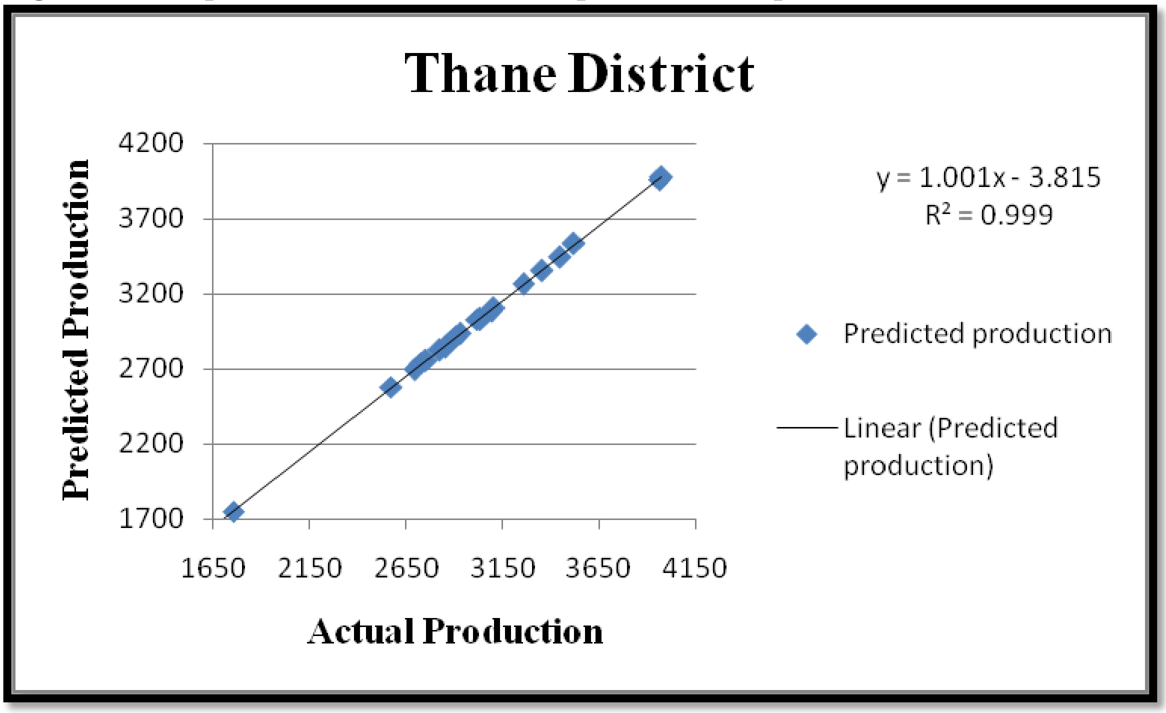
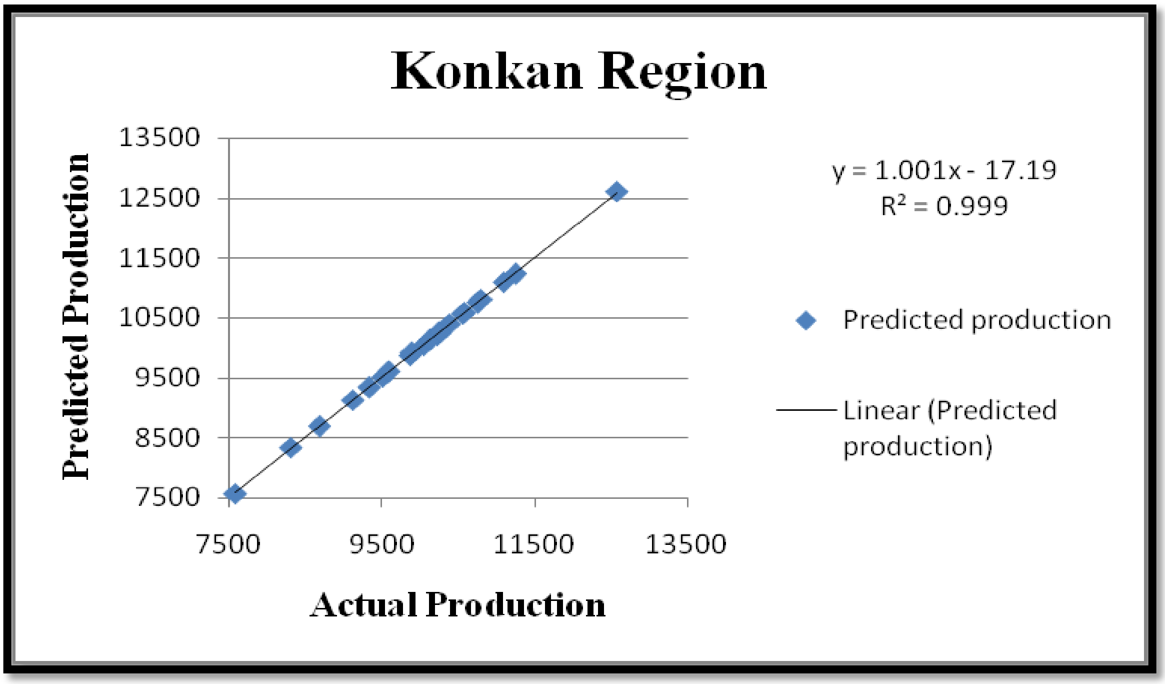


Fig.15 Scatter plot between observed and predicted rice production in Konkan region.


Konkan Region
Predicted Production
13500
12500
11500
10500
9500
8500
7500
7500
9500
11500
13500
Actual Production
y = 1.001x - 17.19
R² = 0.999
Predicted production
Linear (Predicted production)

INTRODUCTION

REVIEW OF LITERATURE

SOCIO-ECONOMIC BACKGROUND OF KONKAN REGION

METHODOLOGY

RESULTS AND DISCUSSION

SUMMARY AND CONCLUSIONS

LITERATURE CITED

APPENDICES

DEPARTMENT OF AGRICULTURAL ECONOMICS
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Discipline : Agricultural Economics **Research guide** : Dr. V. A. Thorat
Research title : Rice Production in Konkan Region – An Economic Analysis.

ABSTRACT

Introduction:

Rice is a staple crop all over the world. Rice is one of the most important food crops of India in term of area and production. India is the second largest producer and consumer of rice in the world. Rice production in India crossed the mark of 100 million MT in 2011-12 accounting for 22.81% of global production in that year. The productivity of rice has increased from 1984 kg per hectare in 2004-05 to 2372 kg per hectare in 2011-12.

Rice is the second important crop after Jowar in Maharashtra State. The total area under rice crop remained stable around 15 lakh ha and production around 24 lakh tones with 1.7 to 1.9 t/ha productivity during last 15 years in the state. In Konkan region the area under rice cultivation was 4.136 lakh ha while production was10.42 lakh tons with productivity of 2.56 t/ha during 2011-12.

Objectives:

1. To study the performance of rice with respect to area, production and productivity in Konkan region.
2. To examine the instability in the rice production.
3. To assess the impact of weather parameters on rice production.
4. To forecast the rice production in Konkan region.

Hypothesis:

1. Rice production and productivity in Konkan region is increasing.
2. Area under rice in Konkan region is decreasing.
3. The aridity index approach is superior to regression model by taking the individual meteorological factors.

Methodology:

Selection of area:

The area under rice in Konkan region accounts for about 28 per cent of area in the state and production to 43.42 per cent. In view of this Konkan region will be selected purposively for the present study. The study is restricted to four districts of the Konkan region viz., Thane (Old), Raigad, Ratnagiri and Sindhudurg.

The data:

The required data on area, production and productivity for the period 1989-90 to 2014-15 will be obtained from the different published records of the State Government, Private institutions viz., Season and Crop Report, Statistical Abstract of Maharashtra State, District-wise Agricultural Data Base for Maharashtra, etc. The data on different weather parameters will be obtained from the Indian Meteorological Department (IMD), Pune.

Analysis of data:

1 Trends in area, production and productivity of rice crop.

2 Growth and instability in area, production and productivity of rice crop.

3 Forecast models for rice production.

   3.1 Regression analysis.

   3.2 Aridity index method.

   3.3 ARIMA modeling.

   3.4 Artificial Neural Network (ANN).

4 Forecast of the rice production.

5 Comparison of various forecast models.

Conclusions:

1. The area under rice cultivation decreased during study period in Konkan region.
2. Decline in area under rice in Raigad district was about 0.55 per cent per annum whereas in Thane district it declined at the rate of 0.37 per cent per annum.
3. The production and productivity of rice increased over the study period in Konkan region.
4. In Konkan region the production increased at the rate of 0.81 per cent per annum.
5. The production and productivity of Sindhudurg district increased at the rate of 1.80 and 1.89 per cent per annum respectively followed by Ratnagiri district.
6. The variability in area, production and productivity of Konkan region for overall study period was 3.42, 12.74 and 15.27 per cent, respectively.
7. In Konkan region, the area under rice cultivation was more unstable in period IV whereas, production and productivity was more unstable during period III.
8. It was observed that in Konkan region, among different weather parameters maximum temperature of stage III, relative humidity of Stage I and sunshine hours in Stage I of crop growth had influence on production of rice.
9. Aridity index method was found inefficient for forecasting of rice production in Konkan region. It could be because of Konkan region falls under high rainfall area and aridity indices were worked out for water scarcity area.
10. By ARIMA modeling, the models found best for Raigad, Ratnagiri, Sindhudurg and Thane district were ARIMA(0,0,3), ARIMA(0,0,2), ARIMA (0,0,1) and ARIMA (0,0,2), respectively.
11. The best fit model for Konkan region by ARIMA modeling was ARIMA (0,0,1) model.
12. Among the forecasting models studied, based on best model fit criteria, Artificial Neural Network (ANN) model was found to be most efficient for forecasting of rice production in Konkan region.

Welcome

SYNOPSIS OF RESEARCH WORK

Presented by:

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Chairman and Research Guide:

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Title of Research Work

Rice Production In Konkan Region- An Economic Analysis

Advisory Committee

Sr. No.	Designation	Name
1.	Chairman and Research Guide	Dr. V. A. Thorat
2.	Member I	Dr. J. M. Talathi
3.	Member II	Dr. V. G. Patil
4.	Member III	Dr. J. S. Dhekale
5.	Member IV	Dr. A.C. Deorukhakar

Objectives

1) To study the performance of rice with respect to area, production and productivity.
2) To examine the instability in the rice production.
3) To assess the impact of weather parameters on rice production in Konkan region.
4) To forecast the rice production in Konkan region.

Hypothesis

1. Rice production and productivity in Konkan region is increasing.
2. Area under rice in Konkan region is decreasing.
3. The aridity index approach is superior to regression model by taking the individual meteorological factors.

Key points

Part I - Trends in area, production and productivity of rice crop.

Part II - Growth and instability in area, production and productivity of rice crop.

Part III - Forecast models for rice production by Regression analysis.

Part IV - Forecast models for rice production by Aridity index method.

Part V - Forecast models for rice production by ARIMA modeling.

Part VI - Forecast models for rice production by Artificial Neural Network (ANN).

Part VII- Forecast of the rice production.

Part VIII - Comparison of various forecast models.

Part I - Trends in area, production and productivity of rice crop

Methodology

Compound growth rates of area, production and productivity:- Compound growth rates of area, production and productivity of rice will be estimated by using non- linear equation.

$$Y = ab^t$$

Where, Y = area, production and productivity

t = time period

b = regression coefficient

a = intercept

$$CGR = (\text{Antilog } b - 1) \times 100$$

Table No. 1 Temporal change and compound growth rates of area under rice in Konkan region.

(Area in "00" ha)

	Raigad	Ratnagiri	Sindhudurg	Thane	Konkan
Period I (1979-80 to 1988-89)					
1979-80	1457	780	733	1903	4440
1988-89	1501	811	790	1504	4606
% change	3.02	3.97	7.78	-20.97	3.74
CGR	0.36*** (0.0018)	0.26^{NS} (0.0042)	1.51* (0.0030)	-1.42*** (0.0072)	0.34** (0.0013)
Period II (1989-90 to 1998-99)					
1989-90	1496	820	794	1513	4623
1998-99	1354	788	801	1421	4364
% change	-9.49	-3.90	0.88	-6.08	**-5.60**
CGR	-1.29* (0.0035)	-0.07^{NS} (0.0029)	0.004^{NS} (0.0012)	-0.26^{NS} (0.0024)	**-0.51* (0.0011)**
Period III (1999-2000 to 2008-09)					
1999-2000	1357	799	799	1418	4373
2008-09	1323	775	785	1406	4289
% change	-2.51	-3.00	-1.75	-0.85	-1.92
CGR	-0.27** (0.0011)	-0.34* (0.0009)	-0.13** (0.0005)	-0.10** (0.0004)	-0.20* (0.00058)

Continued…

Table No. 1 Temporal change and compound growth rates of area under rice in Konkan region.

Period IV (2009-10 to 2014-15)					
2009-10	1304	774	785	1386	4249
2014-15	1241	728	705	1507	4181
% change	-4.83	-5.94	-10.19	8.73	-1.60
CGR	-0.77^{NS} (0.0087)	-1.77*** (0.0072)	-0.97^{NS} (0.0118)	1.48*** (0.0057)	-0.22^{NS} (0.0048)
Overall (1979-80 to 2014-15)					
1979-80	1457	780	733	1903	4440
2014-15	1241	728	705	1507	4181
% change	-14.82	-6.67	-3.82	**-20.81**	-5.83
CGR	**-0.55* (0.0005)**	-0.18* (0.0005)	0.04^{NS} (0.0006)	-0.37* (0.0007)	-0.29* (0.0003)

(*, ** and *** - Significant at 1, 5 and 10 per cent level of profitability respectively. NS-Non-significant.) (Figures in parentheses indicate Standard Error)

Table No. 2 Temporal change and compound growth rates of production of rice in Konkan region.

(Production in "00" Tonnes)

	Raigad	Ratnagiri	Sindhudurg	Thane	Konkan
Period I (1979-80 to 1988-89)					
1979-80	2755	1479	1279	2919	7880
1988-89	3440	1708	1466	3004	9618
% change	24.86	15.48	14.62	2.91	**22.06**
CGR	1.47^{NS} (0.0091)	0.11*** (0.0212)	2.02** (0.0076)	-2.07^{NS} (0.0200)	0.58^{NS} (0.0121)
Period II (1989-90 to 1998-99)					
1989-90	2975	1871	1844	2823	9513
1998-99	3417	2202	2183	2728	10590
% change	14.86	17.69	18.83	-3.37	11.32
CGR	2.07** (0.0084)	1.61** (0.0066)	3.33** (0.0105)	2.08^{NS} (0.0124)	**2.27* (0.005)**
Period III (1999-2000 to 2008-09)					
1999-2000	3285	1928	1813	3020	10046
2008-09	3598	2013	2158	3034	10803
% change	9.53	4.41	19.03	0.46	7.54
CGR	0.7^{NS} (0.0118)	1.29^{NS} (0.0145)	2.17*** (0.0102)	2.68^{NS} (0.0329)	1.58^{NS} (0.0158)

Continued…

Table No. 2 Temporal change and compound growth rates of production of rice in Konkan region.

Period IV (2009-10 to 2014-15)					
2009-10	3294	2030	2046	2908	10277
2014-15	3425	2115	2141	3521	11202
% change	3.98	4.19	4.64	21.08	9.00
CGR	1.36NS (0.0168)	-0.24NS (0.0121)	0.82NS (0.0070)	4.56** (0.0123)	1.86*** (0.0077)
Overall (1979-80 to 2014-15)					
1979-80	2755	1479	1279	2919	7880
2014-15	3425	2115	2141	3521	11202
% change	24.32	43.00	**67.40**	20.62	42.16
CGR	0.42* (0.0014)	1.23* (0.0021)	**1.80* (0.0017)**	0.32NS (0.0032)	0.81* (0.0016)

(*, ** and *** - Significant at 1, 5 and 10 per cent level of probability respectively. NS- Non-significant.) (Figures in parentheses indicate Standard Error)

Table No. 3 Temporal change and compound growth rates of productivity of rice in Konkan region.

(Productivity kg/ha)

	Raigad	**Ratnagiri**	**Sindhudurg**	**Thane**	**Konkan**
Period I (1979-80 to 1988-89)					
1979-80	1829	1690	1682	1903	1796
1988-89	2292	2106	1856	1997	2088
% change	25.31	24.62	10.34	4.94	16.26
CGR	1.42NS (0.0095)	1.53NS (0.0202)	0.9NS (0.0062)	-1.82NS (0.0189)	0.18NS (0.0117)
Period II (1989-90 to 1998-99)					
1989-90	1989	2282	2322	1866	2058
1998-99	2568	2794	2725	1920	2427
% change	29.11	22.44	17.36	2.89	**17.93**
CGR	3.50* (0.0087)	1.69*** (0.0074)	3.29** (0.0097)	2.30*** (0.0109)	**3.17* (0.0083)**
Period III (1999-2000 to 2008-09)					
1999-2000	2421	2413	2269	2130	2295
2008-09	2720	2597	2749	2158	2519
% change	12.35	7.63	21.15	1.31	9.76
CGR	0.97NS (0.0114)	1.64NS (0.0144)	2.31*** (0.0102)	2.79NS (0.0329)	1.79NS (0.0157)

Continued…

Table No. 3 Temporal change and compound growth rates of productivity of rice crop in Konkan region.

Period IV (2009-10 to 2014-15)					
2009-10	2526	2623	2606	2098	2419
2014-15	2793	2904	3037	2612	2679
% change	10.57	10.71	16.54	24.50	10.75
CGR	2.4^{NS} (0.0156)	1.55*** (0.0069)	3.83** (0.0102)	5.46*** (0.0209)	2.08^{NS} (0.0098)
Overall (1979-80 to 2014-15)					
1979-80	1829	1690	1682	1903	1796
2014-15	2793	2904	3037	2612	2679
% change	52.71	71.83	**80.56**	37.26	49.16
CGR	1.07* (0.0015)	1.57* (0.0020)	**1.89* (0.0014)**	0.66* (0.003)	1.09* (0.0017)

(*, ** and *** - Significant at 1, 5 and 10 per cent level of profitability respectively. NS- Non-significant.) (Figures in parentheses indicate Standard Error)

Part II -
Growth and instability in area, production and productivity of rice crop

Methodology

Instability index -

$$\text{Coefficient of Variation (C. V.)} = \frac{\text{Standard Deviation}}{\text{Mean}}$$

Cuddy Della Instability Index = C.V. $\sqrt{1-R^2}$

Where, C.V. = The simple estimate of coefficient of variation in %, and
R^2 = The coefficient of determination from a time trend regression adjusted by the number of degrees of freedom

Table No. 4 Instability in area, production and productivity of rice in Raigad district.

	Period I	Period II	Period III	Period IV	Overall
Area					
Coefficient of variation (%)	1.84	**4.99**	1.23	3.57	**6.52**
Cuddy-Della Instability Index	1.48	3.04	0.91	**3.28**	2.91
Production					
Coefficient of variation (%)	9.31	9.00	**10.36**	6.81	9.80
Cuddy-Della Instability Index	8.01	6.75	**10.16**	6.31	8.81
Productivity					
Coefficient of variation (%)	9.49	**12.05**	10.27	7.46	14.03
Cuddy-Della Instability Index	8.29	6.58	**9.87**	5.88	8.83

Table No. 5 Instability in area, production and productivity of rice in Ratnagiri district.

	Period I	**Period II**	**Period III**	**Period IV**	**Overall**
Area					
Coefficient of variation (%)	3.68	2.46	1.30	**4.21**	3.52
Cuddy-Della Instability Index	**3.60**	2.45	0.80	2.61	2.98
Production					
Coefficient of variation (%)	**15.82**	7.65	12.60	4.51	16.40
Cuddy-Della Instability Index	**15.75**	5.80	12.09	4.49	10.89
Productivity					
Coefficient of variation (%)	**16.36**	8.31	12.62	3.74	18.79
Cuddy-Della Instability Index	**15.49**	6.43	11.77	2.47	10.45

Table No. 6 Instability in area, production and productivity of rice in Sindhudurg district.

	Period I	**Period II**	**Period III**	**Period IV**	**Overall**
Area					
Coefficient of variation (%)	**5.22**	1.00	0.60	4.67	3.54
Cuddy-Della Instability Index	2.59	1.00	0.45	**4.33**	3.52
Production					
Coefficient of variation (%)	8.87	**13.24**	10.69	3.09	**20.47**
Cuddy-Della Instability Index	6.34	8.64	**8.67**	2.66	10.43
Productivity					
Coefficient of variation (%)	5.89	**12.63**	10.93	8.19	**20.91**
Cuddy-Della Instability Index	5.20	7.90	**8.69**	4.06	8.52

Table No. 7 Instability in area, production and productivity of rice in Thane district.

	Period I	**Period II**	**Period III**	**Period IV**	**Overall**
Area					
Coefficient of variation (%)	**8.30**	2.20	0.48	3.56	6.21
Cuddy-Della Instability Index	**6.84**	2.06	0.36	2.20	**4.68**
Production					
Coefficient of variation (%)	15.27	13.13	**25.47**	9.74	17.31
Cuddy-Della Instability Index	14.28	11.33	**24.82**	4.69	**16.95**
Productivity					
Coefficient of variation (%)	14.47	12.29	**25.47**	13.09	18.29
Cuddy-Della Instability Index	13.67	10.00	**24.75**	8.00	**16.81**

Table No. 8 Instability in area, production and productivity of rice in Konkan region.

	Period I	**Period II**	**Period III**	**Period IV**	**Overall**
Area					
Coefficient of variation (%)	1.52	1.80	0.79	**1.85**	3.42
Cuddy-Della Instability Index	1.12	0.94	0.50	**1.81**	1.63
Production					
Coefficient of variation (%)	10.00	8.08	**13.66**	4.57	12.74
Cuddy-Della Instability Index	9.76	4.35	**12.99**	2.92	9.66
Productivity					
Coefficient of variation (%)	9.46	12.10	**13.77**	5.41	15.27
Cuddy-Della Instability Index	9.41	7.62	**12.89**	3.69	10.47

Table No. 9 Instability in area, production and productivity of rice among districts and Konkan region.

	Raigad	Ratnagiri	Sindhudurg	Thane	Konkan
Area					
Coefficient of variation (%)	**6.52**	3.52	3.54	6.21	3.42
Cuddy-Della Instability Index	2.91	2.98	3.52	**4.68**	1.63
Production					
Coefficient of variation (%)	9.8	16.4	**20.47**	17.31	12.74
Cuddy-Della Instability Index	8.81	10.89	10.43	**16.95**	9.66
Productivity					
Coefficient of variation (%)	14.03	18.79	**20.91**	18.29	15.27
Cuddy-Della Instability Index	8.83	10.45	8.52	**16.81**	10.47

Part III -
Forecast models for rice production by Regression analysis

Methodology

```
/*Standardization of the data*/
    proc standard data= dataset mean=0 std=1 out= result;
    var inputs ;
    run;
/*Regression analysis*/
    proc reg data=dataset ;
    model output=inputs /
    selection=stepwise slentry=0.10 slstay=0.10 ;
    run;
/*Forecast value*/
    proc forecast data=dataset lead=10 out=predicted;
    by inputs;
    var Y;
    run;
```

Table No. 10 Parameter estimates of regression model for Raigad district.

Variable	Parameter Estimate	Standard Error
Intercept	3178.55*	50.8668
T_MIN_STG_2	113.782**	54.2135
RN_FL_STG_1	-188.06*	54.2136
R^2 = 0.41		

(*, ** and *** - Significant at 1, 5 and 10 per cent level of profitability respectively.)

Table No. 11 Parameter estimates of regression model for Ratnagiri district.

Variable	Parameter Estimate	Standard Error
Intercept	1942.32*	24.4514
T_MIN_STG_1	-122.83**	32.7816
RN_FL_STG_2	224.098*	41.0729
R^2 = 0.42		

(*, ** and *** - Significant at 1, 5 and 10 per cent level of profitability respectively.)

Table No. 12 Parameter estimates of regression model for Sindhudurg district.

Variable	Parameter Estimate	Standard Error
Intercept	1949.68*	33.8475
T_MAX_STG_2	-78.501***	39.2524
T_MAX_STG_5	171.249*	37.1371
RH_M_STG_6	144.792*	35.79
RN_FL_STG_3	107.903**	38.2459
R^2 = 0.70		

(*, ** and *** - Significant at 1, 5 and 10 per cent level of profitability respectively.)

Table No. 13 Parameter estimates of regression model for Thane district.

Variable	Parameter Estimate	Standard Error
Intercept	2967.86*	112.419
RH_E_STG_5	-190.5**	121.201
RN_FL_STG_5	226.859***	121.201
R^2 = 0.19		

(*, ** and *** - Significant at 1, 5 and 10 per cent level of profitability respectively.)

Table No. 14 Parameter estimates of regression model for Konkan region.

Variable	Parameter Estimate	Standard Error
Intercept	10041.00*	200.797
T_MAX_STG_3	605.510**	238.251
RH_M_STG_1	977.463**	422.120
SSH_STG_1	695.609***	392.477
R^2 = 0.33		

(*, ** and *** - Significant at 1, 5 and 10 per cent level of profitability respectively.)

Part IV -
Forecast models for rice production by Aridity Index Method

Table No. 15 Parameter estimates of Aridity index model for Raigad district.

Sr. No.	Equation No.	Index	Coefficient	P value	R^2
1.	6	P	-0.11	0.23	0.25
		T	2.11	0.92	
2.	7	(P/T)	-1.94	0.23	0.23
3.	8	[P/(T+10)]	-3.32	0.18	0.24
4.	9	$(P/1.07^T)$	-0.33	0.28	0.22
5.	10	(P/0.1T)	-0.19	0.23	0.23

Table No. 16 Parameter estimates of Aridity index model for Ratnagiri district.

Sr. No.	Equation No.	Index	Coefficient	P value	R^2
1.	6	P	0.08	0.43	0.23
		T	10.07	0.73	
2.	7	(P/T)	0.75	0.70	0.20
3.	8	[P/(T+10)]	1.63	0.59	0.21
4.	9	$(P/1.07^T)$	0.07	0.84	0.20
5.	10	(P/0.1T)	0.07	0.70	0.20

Table No. 17 Parameter estimates of Aridity index model for Sindhudurg district.

Sr. No.	Equation No.	Index	Coefficient	P value	R^2
1.	6	P	0.09	0.41	0.64
		T	5.87	0.79	
2.	7	(P/T)	0.68	0.70	0.62
3.	8	[P/(T+10)]	1.53	0.60	0.63
4.	9	$(P/1.07^T)$	0.07	0.82	0.62
5.	10	(P/0.1T)	0.07	0.70	0.62

Table No. 18 Parameter estimates of Aridity index model for Thane district.

Sr. No.	Equation No.	Index	Coefficient	P value	R^2
1.	6	P	-0.24	0.42	0.07
		T	-28.84	0.77	
2.	7	(P/T)	-2.48	0.56	0.04
3.	8	[P/(T+10)]	-4.40	0.51	0.05
4.	9	$(P/1.07^T)$	-0.38	0.62	0.04
5.	10	(P/0.1T)	-0.25	0.56	0.04

Table No. 19 Parameter estimates of Aridity index model for Konkan region.

Sr. No.	Equation No.	Index	Coefficient	P value	R^2
1.	6	P	0.72	0.33	0.20
		T	687.40	0.51	
2.	7	(P/T)	14.59	0.43	0.17
3.	8	[P/(T+10)]	20.53	0.42	0.17
4.	9	$(P/1.07^T)$	3.08	0.46	0.16
5.	10	(P/0.1T)	1.46	0.43	0.17

Part V - Forecast models for rice production by ARIMA modeling

Methodology

```
/* Creating a differenced variable*/
       data dataset;
       set dataset;
       dY=dif(Y);
       run;
/* Plotting the data*/
       proc gplot data=dataset;
       plot Y*t;
       plot dY*t;
       run;
/* ARIMA (p,d,q) */
       proc arima data=dataset;
       identify var=d crosscorr =(inputs);
       estimate input=(inputs) p=p q=q plot;
       run;
/* ARIMA (p,d,q) forecasting*/
       proc arima data=dataset;
       identify var=d crosscorr=(inputs);
       estimate input=(inputs) p=p q=q ;
       forecast lead=10;
       run;
```

Table No. 20 Results of some selected ARIMA models for Raigad district.

	ARIMA (0,0,3)	ARIMA (1,0,3)	ARIMA (1,0,4)	ARIMA (0,0,4)	ARIMA (0,0,1)
Constant	3174.0* (13.35)	3175.4* (11.15)	3182.6* (17.38)	3174.5* (15.41)	3173.8* (6.65)
MA1,1	0.35 (0.29)	0.27 (0.39)	0.40 (31.48)	0.36 (0.31)	1.00* (0.20)
MA1,2	-0.09 (0.24)	-0.08 (0.24)	-0.30 (3.45)	-0.11 (0.28)	-
MA1,3	0.74* (0.27)	0.81* (0.25)	0.99 (8.26)	0.68** (0.29)	-
MA1,4	-	-	-0.27 (28.57)	0.08 (0.32)	-
AR1,1	-	-0.13 (0.39)	0.29 (31.52)	-	-
(T_MIN_ STG_2)	85.7*** (42.67)	96.9** (43.13)	141.5* (40.65)	90.71*** (44.69)	57.24 (34.42)
(RN_FL_ STG_1)	-183.6* (39.14)	-194.3* (39.60)	-169.7* (36.40)	-183.73* (41.42)	-219.1* (21.48)
AIC	299	300	301	301	302
SBC	306	308	309	309	306
R^2	0.40	0.37	0.29	0.40	0.39
Chi-Square	12.49	12.31	14.33	13.06	25.29
P-value	0.64	0.58	0.35	0.52	0.09

Table No. 21 Results of some selected ARIMA models for Ratnagiri district.

	ARIMA (0,0,2)	ARIMA (2,0,0)	ARIMA (1,0,2)	ARIMA (0,0,3)	ARIMA (1,0,0)
Constant	1934.2* (39.16)	1935.1* (39.96)	1933.2* (42.75)	1933.5* (42.03)	1942.1* (27.69)
MA1,1	0.26 (0.22)	-	0.36 (0.45)	0.24 (0.26)	-
MA1,2	-0.52** (0.24)	-	-0.55** (0.23)	-0.52*** (0.26)	-
MA1,3	-	-	-	-0.05 (0.29)	-
AR1,1	-	-0.18 (0.23)	0.12 (0.53)	-	-0.25 (0.24)
AR1,2	-	0.38 (0.28)	-	-	-
(T_MIN_ STG_1)	-62.89*** (34.12)	-65.52 (42.19)	-63.74*** (34.17)	-63.77*** (34.61)	-88.52** (40.24)
(RN_FL_ STG_2)	110.89* (36.83)	120.87* (35.05)	114.08* (38.93)	113.41* (38.99)	127.70* (40.87)
AIC	287	289	289	289	290
SBC	293	294	296	296	294
R^2	0.47	0.30	0.23	0.36	0.32
Chi-Square	15.01	16.75	14.75	14.72	23.96
P-value	0.52	0.40	0.40	0.47	0.12

Table No. 22 Results of some selected ARIMA models for Sindhudurg district.

	ARIMA (0,0,1)	ARIMA (0,0,2)	ARIMA (1,0,2)	ARIMA (3,0,2)	ARIMA (4,0,0)
Constant	1948.4* (5.49)	1948.3* (6.77)	1861.2* (98.94)	1765.4* (106.42)	1739.2* (111.83)
MA1,1	1.00** (0.39)	0.88** (0.40)	0.67*** (0.32)	0.28 (0.62)	-
MA1,2	-	0.11 (0.42)	-1.00** (0.3)	-1.00 (0.66)	-
AR1,1	-	-	0.75* (0.27)	0.34 (0.65)	0.19 (0.27)
AR1,2	-	-	-	0.13 (0.48)	1.03* (0.24)
AR1,3	-	-	-	0.31 (0.59)	0.34 (0.28)
(T_MAX_ STG_2)	-102.70* (31.26)	-95.38** (36.20)	-73.72*** (36.53)	-59.45*** (32.36)	-77.55* (26.06)
(T_MAX_ STG_5)	222.45* (26.28)	216.65* (32.21)	93.93** (35.79)	115.34** (42.09)	122.73* (30.31)
(RH_M_ STG_6)	180.50* (25.54)	181.94* (35.82)	40.23 (58.02)	17.81 (60.50)	-17.64 (33.12)
(RN_FL_ STG_3)	132.90* (43.97)	129.14** (51.76)	83.24* (25.36)	71.48** (26.77)	64.91** (24.54)
AIC	281	284	285	289	289
SBC	288	293	295	301	300
R^2	0.53	0.58	0.46	0.12	0.10
Chi-Square	9.96	9.89	4.69	10.72	6.61
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Table No. 23 Results of some selected ARIMA models for Thane district

	ARIMA (0,0,2)	ARIMA (2,0,0)	ARIMA (1,0,2)	ARIMA (0,0,3)	ARIMA (1,0,0)
Constant	2946.8* (171.88)	2951.2* (145.24)	3028.1* (168.14)	3009.6* (21.46)	2971.3* (99.92)
MA1,1	-0.12 (0.24)	-	-0.81* (0.15)	0.27 (0.29)	-
MA1,2	-0.53** (0.26)	-	-1.00* (0.26)	0.003 (0.31)	-
MA1,3	-	-	-	0.73** (0.33)	-
AR1,1	-	-0.08 (0.25)	-0.52** (0.24)	-	-0.15 (0.25)
AR1,2	-	0.32 (0.25)	-	-	-
(RH_E_ STG_5)	-321.84** (133.24)	-235.25 (152.64)	-413.54* (131.95)	-257.32*** (126.96)	-179.77 (140.14)
(RN_FL_ STG_5)	293.14*** (141.98)	208.41 (128.15)	360.55** (171.95)	211.17*** (114.92)	193.04 (116.99)
AIC	334	335	336	337	338
SBC	344	342	343	346	347
R^2	0.52	0.39	0.20	0.53	0.28
Chi-Square	8.89	14.84	9.28	16.48	20.64
P-value	0.92	0.54	0.86	0.35	0.24

Table No. 24 Results of some selected ARIMA models for Konkan region.

	ARIMA (0,0,1)	ARIMA (1,0,1)	ARIMA (0,0,2)	ARIMA (1,0,2)	ARIMA (1,0,0)
Constant	10038.5* (21.42)	10038.3* (21.71)	10039.8* (22.43)	10035.8* (128.08)	10035.5* (117.71)
MA1,1	1.00* (0.28)	1.00** (0.46)	0.95* (0.30)	-0.47 (7.31)	-
MA1,2	-	-	0.05 (0.42)	-	-
AR1,1	-	-0.03 (0.43)	-	-1.06 (7.40)	-0.61* (0.21)
AR1,2	-	-	-	-0.26 (4.58)	-
(T_MAX_ STG_3)	657.31* (186.72)	656.00** (257.68)	674.80* (249.70)	334.58 (212.23)	333.82 (196.42)
(RH_M_ STG_1)	1173.70* (290.38)	1209.90* (309.81)	1161.00* (310.18)	999.34* (347.88)	1006.10* (301.56)
(SSH_ STG_1)	1356.00* (352.73)	1427.90* (367.64)	1333.60* (382.56)	1167.90* (395.02)	1183.80* (340.49)
AIC	361	362	363	364	365
SBC	366	369	369	372	370
R^2	0.30	0.39	0.36	0.30	0.29
Chi-Square	7.27	8.02	7.35	8.41	7.53
P-value	0.98	0.95	0.97	0.91	0.98

Part VI -

Forecast models for rice production by Artificial Neural Network (ANN)

Methodology

```
/*Data mining database Procedure*/
        proc dmdb batch data=dataset
        out= out dmdbcat=data_cat;
        var Inputs ;
        target output;
        run;
/*Neural network procedure*/
        proc dmneurl data=dataset dmdbcat=data_cat
        outclass=oclass outest=estout out=dsout outfit=ofit
        ptable maxcomp=7 maxstage=7;
        var inputs ;
        target output ;
        run;
```

Table No. 25 Predicted production obtained by Artificial Neural Network for Raigad District.

(Production in "00" Tonnes)

Year	Actual production	Predicted production	Error
1990	2975	2973.58	1.4237
1991	2503	2495.29	7.7119
1992	3356	3358.62	-2.6151
1993	2945	2942.93	2.0694
1994	3284	3275.26	8.7434
1995	2985	2983.2	1.7959
1996	3215	3229.01	-14.0095
1997	3315	3313.36	1.6367
1998	3343	3336.75	6.2535
1999	3417	3411.92	5.0838
2000	3285	3290.65	-5.6509
2001	2917	2915.64	1.3554
2002	3568	3563.21	4.7946
2003	2778	2776.54	1.4575
2004	3763	3766.1	-3.0956
2005	2972	2967.73	4.2742
2006	2950	2947.37	2.6337
2007	3145	3147.82	-2.8184
2008	3372	3377.41	-5.4127
2009	3598	3600.38	-2.3838
2010	3294	3295.53	-1.5317
2011	2948	2947.39	0.6086

Table No. 26 Predicted production obtained by ANN for Ratnagiri District.

(Production in "00" Tonnes)

Year	Actual production	Predicted production	Error
1990	1871	1876.86	-5.86496
1991	1713	1718.06	-5.05519
1992	1881	1883.36	-2.3637
1993	1739	1746.43	-7.43451
1994	1934	1935.82	-1.82024
1995	1804	1804.83	-0.82818
1996	1943	1942.59	0.40947
1997	2043	2047.35	-4.34945
1998	1840	1837.98	2.01683
1999	2202	2204.11	-2.11306
2000	1928	1926.83	1.17065
2001	1671	1670.29	0.7122
2002	2102	2099.73	2.27369
2003	1491	1494.11	-3.11154
2004	2391	2392.2	-1.19983
2005	1872	1875.92	-3.91505
2006	1952	1953.22	-1.21956
2007	2112	2111.28	0.71975
2008	1968	1969.87	-1.86975
2009	2013	2015.11	-2.1084
2010	2030	2033.27	-3.27433
2011	2231	2232.57	-1.57042

Table No. 27 Predicted production obtained by ANN for Sindhudurg District.

(Production in "00" Tonnes)

Year	Actual production	Predicted production	Error
1990	1844	1846.83	-2.82561
1991	1588	1586.62	1.38261
1992	1413	1412.03	0.97446
1993	1593	1592.52	0.4765
1994	1616	1615.02	0.9817
1995	1887	1886.41	0.59425
1996	1811	1810.20	0.79705
1997	1929	1927.73	1.2744
1998	2051	2050.02	0.97508
1999	2183	2184.40	-1.39602
2000	1813	1814.64	-1.63583
2001	1975	1973.87	1.13049
2002	1974	1974.63	-0.62695
2003	1723	1722.66	0.34068
2004	2454	2455.07	-1.06861
2005	2193	2193.81	-0.81175
2006	2242	2241.95	0.05494
2007	2292	2293.77	-1.76681
2008	2138	2138.00	0.00412
2009	2158	2159.00	-1.00327
2010	2046	2046.04	-0.0441
2011	1970	1967.67	2.33317

Table No. 28 Predicted production obtained by Artificial Neural Network for Thane District.

(Production in "00" Tonnes)

Year	Actual production	Predicted production	Error
1990	2823	2825.52	-2.5224
1991	2879	2879.95	-0.9509
1992	2694	2693.32	0.6777
1993	2850	2844.00	5.9972
1994	3034	3031.17	2.8288
1995	2927	2932.77	-5.7673
1996	3258	3262.35	-4.3498
1997	3963	3959.66	3.3398
1998	3519	3531.52	-12.5237
1999	2728	2737.48	-9.4791
2000	3020	3027.13	-7.1283
2001	1753	1746.72	6.2836
2002	3451	3447.23	3.7665
2003	1598	1593.54	4.4597
2004	3975	3973.56	1.4426
2005	3354	3357.09	-3.0899
2006	3106	3103.68	2.3161
2007	2574	2578.17	-4.1719
2008	3092	3086.43	5.5748
2009	3034	3027.18	6.8208
2010	2908	2918.46	-10.4633
2011	2753	2755.41	-2.4117

Table No. 29 Predicted production obtained by Artificial Neural Network for Konkan region.

(Production in "00" Tonnes)

Year	Actual production	Predicted production	Error
1990	9513	9511.43	1.5683
1991	8683	8687.67	-4.6668
1992	9344	9327.12	16.8846
1993	9127	9129.69	-2.6871
1994	9868	9876.95	-8.9496
1995	9603	9601.86	1.1393
1996	10227	10208.14	18.8567
1997	11250	11226.2	23.7996
1998	10753	10744.74	8.2603
1999	10590	10589.60	0.403
2000	10046	10046.18	-0.1754
2001	8316	8335.84	-19.8439
2002	11095	11096.44	-1.4429
2003	7590	7572.10	17.8951
2004	12583	12606.96	-23.9621
2005	10391	10402.42	-11.424
2006	10250	10240.68	9.3157
2007	10123	10123.51	-0.5142
2008	10570	10568.38	1.6249
2009	10803	10808.34	-5.3382
2010	10277	10259.95	17.0451
2011	9901	9906.23	-5.2315

Table No. 30 Summary across stages for Raigad district.

Stage	Activation	Link	SSE	RMSE	Accuracy
0	LOGIST	IDENT	512211	270.505	76.10
1	EXP	IDENT	323418	568.698	83.43
2	SQUARE	IDENT	37631.4	193.988	95.81
3	LOGIST	IDENT	12245.3	110.658	94.15
4	TANH	IDENT	2285.6	47.8077	98.07
5	TANH	IDENT	1270.6	35.645	100.00
6	TANH	IDENT	555.5	23.569	100.00

Table No. 31 Summary across stages for Ratnagiri district.

Stage	Activation	Link	SSE	RMSE	Accuracy
0	LOGIST	IDENT	222137	210.778	69.54
1	EXP	IDENT	61361.5	247.713	91.13
2	SIN	IDENT	22797.3	150.988	97.99
3	LOGIST	IDENT	20750	144.049	98.00
4	SIN	IDENT	11207.9	105.867	100.00
5	ARCTAN	IDENT	1485.9	38.547	99.02
6	LOGIST	IDENT	371.665	19.2786	100.00
7	SIN	IDENT	209.059	14.4589	100.00

Table No. 32 Summary across stages for Sindhudurg district.

Stage	Activation	Link	SSE	RMSE	Accuracy
0	SIN	IDENT	245856	187.409	81.00
1	TANH	IDENT	46594	215.856	94.97
2	EXP	IDENT	13519.9	116.275	99.01
3	SQUARE	IDENT	1324.2	36.3898	100.00
4	TANH	IDENT	163.681	12.7938	99.06
5	ARCTAN	IDENT	55.6129	7.45741	100.00
6	SIN	IDENT	33.3889	5.77832	99.04

Table No. 33 Summary across stages for Thane district.

Stage	Activation	Link	SSE	RMSE	Accuracy
0	EXP	IDENT	1675173	578.822	74.87
1	LOGIST	IDENT	568438	753.948	95.79
2	EXP	IDENT	403859	635.499	91.04
3	TANH	IDENT	75123.3	274.086	100.00
4	SQUARE	IDENT	25813.7	160.667	96.10
5	LOGIST	IDENT	5056.6	71.1099	99.03
6	ARCTAN	IDENT	1895.5	43.537	100.00
7	LOGIST	IDENT	713.397	26.7095	100.00

Table No. 34 Summary across stages for Konkan region.

Stage	Activation	Link	SSE	RMSE	Accuracy
0	SIN	IDENT	5375664	876.329	70.71
1	TANH	IDENT	2835383	1683.86	86.00
2	SIN	IDENT	662115	813.705	94.00
3	TANH	IDENT	202980	450.533	97.04
4	LOGIST	IDENT	69412.9	263.463	99.03
5	ARCTAN	IDENT	35597.5	188.673	100.00
6	SQUARE	IDENT	3245.2	56.9671	100.00

Table No. 35 Model fit statistics by Artificial Neural Network.

	Stage	SSE	RMSE	Accuracy (%)	AIC	SBC
Raigad	7	555.50	23.569	100.00	281	396
Ratnagiri	8	209.06	14.459	100.00	322	470
Sindhudurg	7	33.39	5.778	99.04	219	334
Thane	8	713.40	26.709	100.00	349	497
Konkan	7	3245.25	56.970	100.00	320	434

Part VII -
Forecast of the rice production

Table No. 36 Forecasting of rice production by selected regression models.

(Production in "00" Tonnes)

Year	Lead	Raigad	Ratnagiri	Sindhudurg	Thane	Konkan
2015-16	1	3362.32	2129.78	2386.32	2939.20	10829.53
2016-17	2	3374.18	2160.43	2414.49	2937.35	10880.40
2017-18	3	3386.04	2162.69	2442.66	2935.50	10931.27
2018-19	4	3397.89	2181.76	2470.83	2933.65	10982.14
2019-20	5	3409.75	2190.87	2499.00	2931.80	11033.01

Table No. 37 Forecasting of rice production by ARIMA method.

(Production in "00" Tonnes)

Year	Lead	Raigad	Ratnagiri	Sindhudurg	Thane	Konkan
2015-16	1	3182.40	1920.96	1940.57	2953.86	10050.51
2016-17	2	3173.81	1953.66	1942.35	2980.54	10035.59
2017-18	3	3178.24	1931.79	1943.22	2949.18	10046.08
2018-19	4	3176.00	1945.93	1943.63	2985.29	10038.70
2019-20	5	3177.14	1936.62	1943.83	2945.76	10043.89

Table No. 38 Forecasting of rice production by Artificial Neural Network.

(Production in "00" Tonnes)

Year	Raigad	Ratnagiri	Sindhudurg	Thane	Konkan
2015-16	3284	1968	1974	3034	10227
2016-17	3294	2030	2046	3106	10277
2017-18	3343	2102	2138	3354	10570
2018-19	3372	2202	2183	3519	10753
2019-20	3568	2391	2242	3975	11095

Part VIII - Comparison of Various Forecast Models

Methodology

$$\mathrm{RMSE} = \left[\frac{1}{n}\sum_{i=1}^{n}(Y_i - \hat{Y}_i)^2\right]^{1/2} \qquad \mathrm{ME} = \frac{1}{n}\sum_{i=1}^{n}(Y_i - \hat{Y}_i)$$

$$\mathrm{MSE} = \frac{1}{n}\sum_{i=1}^{n}(Y_i - \hat{Y}_i)^2 \qquad \mathrm{MAE} = \frac{1}{n}\sum_{i=1}^{n}\left|Y_i - \hat{Y}_i\right|$$

$$\mathrm{MPE} = \frac{1}{n}\sum_{i=1}^{n}\left(\frac{Y_i - \hat{Y}_i}{Y_i}\right)\times 100 \qquad \mathrm{MAPE} = \frac{1}{n}\sum_{i=1}^{n}\left|\left(\frac{Y_i - \hat{Y}_i}{Y_i}\right)\times 100\right|$$

Table No. 39 Test results obtained by Regression model.

(Production in "00" Tonnes)

Year	Actual Production	Predicted Production	Error
Raigad			
2011-12	2943	3314.90	-371.90
2012-13	2943	3326.75	-383.75
2013-14	3233	3338.61	-105.61
2014-15	3425	3350.47	74.53
Average	3136.00	3332.68	-196.68
Ratnagiri			
2011-12	2217	1998.48	218.52
2012-13	2219	2156.54	62.46
2013-14	2024	2083.37	-59.37
2014-15	2115	2147.10	-32.1
Average	2143.75	2096.37	47.38

Table No. 39 Test results obtained by Regression model.

Sindhudurg			
2011-12	1982	2273.64	-291.64
2012-13	2012	2301.81	-289.81
2013-14	2000	2329.98	-329.98
2014-15	2141	2358.15	-217.15
Average	2033.75	2315.90	-282.15
Thane			
2011-12	2949	2946.60	2.4
2012-13	2949	2944.75	4.25
2013-14	3369	2942.90	426.1
2014-15	3521	2941.05	579.95
Average	3197.00	2943.83	253.18
Konkan			
2011-12	10091	10626.05	-535.05
2012-13	10123	10676.92	-553.92
2013-14	10626	10727.79	-101.79
2014-15	11202	10778.66	423.34
Average	10510.50	10702.36	-191.86

Table No. 40 Test results obtained by Aridity index model.

(Production in "00" Tonnes)

Year	Actual Production	Predicted Production	Error
Raigad			
2011-12	2943	3224.00	-281.00
2012-13	2943	3203.33	-260.33
2013-14	3233	3164.27	68.73
2014-15	3425	3143.81	281.19
Average	3136.00	3183.85	-47.85
Ratnagiri			
2011-12	2217	1835.82	381.18
2012-13	2219	1839.82	379.18
2013-14	2024	1804.15	219.85
2014-15	2115	1827.53	287.47
Average	2143.75	1826.83	316.92

Table No. 40 Test results obtained by Aridity index model.

Sindhudurg			
2011-12	1982	1787.63	194.37
2012-13	2012	1793.76	218.24
2013-14	2000	1798.12	201.88
2014-15	2141	1823.27	317.73
Average	2033.75	1800.70	233.06
Thane			
2011-12	2949	2867.22	81.78
2012-13	2949	2868.90	80.10
2013-14	3369	2799.96	569.04
2014-15	3521	2782.30	738.70
Average	3197.00	2829.60	367.41
Konkan			
2011-12	10091	11860.86	-1769.86
2012-13	10123	11833.46	-1710.46
2013-14	10626	11871.72	-1245.72
2014-15	11202	11849.00	-647.00
Average	10510.50	11853.76	-1343.26

Table No. 41 Test results obtained by ARIMA modeling.

(Production in "00" Tonnes)

Year	Actual Production	Predicted Production	Error
Raigad			
2011-12	2943	3103.95	-160.95
2012-13	2943	3097.51	-154.51
2013-14	3233	3249.66	-16.66
2014-15	3425	3179.01	245.99
Average	3136.00	3157.53	-21.53
Ratnagiri			
2011-12	2217	1887.40	329.60
2012-13	2219	2088.80	130.20
2013-14	2024	1935.92	88.08
2014-15	2115	1935.92	179.08
Average	2143.75	1962.01	181.74

Table No. 41 Test results obtained by ARIMA modeling.

Sindhudurg			
2011-12	1982	1942.62	39.38
2012-13	2012	1913.27	98.73
2013-14	2000	1929.18	70.82
2014-15	2141	1936.86	204.14
Average	2033.75	1930.48	103.27
Thane			
2011-12	2949	2968.94	-19.94
2012-13	2949	2955.27	-6.27
2013-14	3369	2967.39	401.61
2014-15	3521	2963.91	557.09
Average	3197.00	2963.88	233.12
Konkan			
2011-12	10091	10077.59	13.41
2012-13	10123	10016.55	106.45
2013-14	10626	10059.47	566.53
2014-15	11202	10029.29	1172.71
Average	10510.50	10045.70	464.78

Table No. 42 Test results obtained by Artificial Neural Network.

(Production in "00" Tonnes)

Year	Actual Production	Predicted Production	Error
Raigad			
2011-12	2943	2947.23	-4.2255
2012-13	2943	2931.77	11.2282
2013-14	3233	3254.99	-21.9873
2014-15	3425	3415.66	9.3416
Average	3136.00	3137.41	-1.41
Ratnagiri			
2011-12	2217	2220.74	-3.7436
2012-13	2219	2230.03	-11.0252
2013-14	2024	2011.12	12.8846
2014-15	2115	2109.38	5.6182
Average	2143.75	2142.82	0.93

Table No. 42 Test results obtained by Artificial Neural Network.

Sindhudurg			
2011-12	1982	1961.25	20.7492
2012-13	2012	2008.90	3.0978
2013-14	2000	2023.75	-23.7533
2014-15	2141	2133.11	7.8942
Average	2033.75	2031.75	2.00
Thane			
2011-12	2949	2952.47	-3.4681
2012-13	2949	2965.44	-16.4403
2013-14	3369	3362.61	6.3871
2014-15	3521	3525.37	4.3751
Average	3197.00	3201.47	-2.29
Konkan			
2011-12	10091	10093.58	-2.5804
2012-13	10123	10144.48	-21.4831
2013-14	10626	10551.41	74.5885
2014-15	11202	11190.70	11.2973
Average	10510.50	10495.04	15.46

Table No. 43 Comparison of various forecast models.

	Regression	Aridity Index	ARIMA	ANN
Raigad				
RMSE	274.90	240.06	166.26	13.37
MAE	233.95	222.81	144.53	11.70
MSE	75570.47	57631.08	27641.72	178.70
ME	-196.68	-47.85	-21.53	-1.41
MPE	-6.69	-2.01	-1.01	-0.04
MAPE	7.78	7.18	4.60	0.37
Ratnagiri				
RMSE	118.54	324.06	203.36	9.13
MAE	93.11	316.92	181.74	8.32
MSE	14051.86	105012.17	41353.98	83.28
ME	47.38	316.92	181.74	0.93
MPE	2.06	14.68	8.39	0.06
MAPE	4.28	14.68	8.39	0.39
Sindhudurg				
RMSE	285.08	238.28	120.40	16.33
MAE	282.15	233.06	103.27	13.87
MSE	81271.16	56779.07	14496.75	266.62
ME	-282.15	233.06	103.27	2.00
MPE	-13.94	11.40	4.99	0.10
MAPE	13.94	11.40	4.99	0.69

Continued…

Table No. 43 Comparison of various forecast models.

	Regression	Aridity Index	ARIMA	ANN
Thane				
RMSE	359.84	469.73	343.54	9.25
MAE	253.18	367.41	246.23	7.67
MSE	129481.76	220647.05	118019.19	85.56
ME	253.18	367.41	233.12	-4.47
MPE	7.34	10.84	6.71	-0.15
MAPE	7.34	10.84	7.16	0.25
Konkan				
RMSE	442.35	1416.73	653.40	39.24
MAE	403.53	1343.26	464.78	27.49
MSE	195670.96	2007126.29	426929.10	1539.85
ME	-191.86	-1343.26	464.78	15.46
MPE	-1.99	-12.98	4.25	0.14
MAPE	3.88	12.98	4.25	0.26

Conclusions:

1. The area under rice cultivation decreased during study period in Konkan region.
2. Decline in area under rice in Raigad district was about 0.55 per cent per annum whereas in Thane district it declined at the rate of 0.37 per cent per annum.
3. The production and productivity of rice increased over the study period in Konkan region.
4. In Konkan region the production increased at the rate of 0.81 per cent per annum.
5. The production and productivity of Sindhudurg district increased at the rate of 1.80 and 1.89 per cent per annum respectively followed by Ratnagiri district.
6. The variability in area, production and productivity of Konkan region for overall study period was 3.42, 12.74 and 15.27 per cent, respectively.
7. In Konkan region, the area under rice cultivation was more unstable in period IV whereas, production and productivity was more unstable during period III.
8. It was observed that in Konkan region, among different weather parameters maximum temperature of stage III, relative humidity of Stage I and sunshine hours in Stage I of crop growth had influence on production of rice.
9. Aridity index method was found inefficient for forecasting of rice production in Konkan region. It could be because of Konkan region falls under high rainfall area and aridity indices were worked out for water scarcity area.
10. By ARIMA modeling, the models found best for Raigad, Ratnagiri, Sindhudurg and Thane district were ARIMA(0,0,3), ARIMA(0,0,2), ARIMA (0,0,1) and ARIMA (0,0,2), respectively.
11. The best fit model for Konkan region by ARIMA modeling was ARIMA (0,0,1) model.
12. Among the forecasting models studied, based on best model fit criteria, Artificial Neural Network (ANN) model was found to be most efficient for forecasting of rice production in Konkan region.

Thank You