**Synopsis**

**On the Research Work for the Degree of Doctor of Philosophy in Agricultural Statistics**

**FORECASTING MODELS FOR DAMAGE CAUSED BY KEY INSECT PESTS AND PRODUCTION OF RICE IN TELANGANA STATE**

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**THESIS SYNOPSIS**

FOR THE DEGREE OF DOCTOR OF PHILOSOPHY IN

**AGRICULTURAL STATISTICS**

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Topic of the thesis : **Forecasting Models for damage caused by Key Insect**

**Pests and Production of Rice in Telangana State**

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6. **INTRODUCTION**

The spectacular story of Indian agriculture is known throughout the world for its multi- functional success in generating employment, livelihood, food, nutritional and ecological security. Agriculture and allied sectors contribute about 17% of the Gross Domestic Product (GDP). Despite a steady decline of its share in the GDP, it is still the largest economic sector and plays a significant role in the overall socio-economic development of India.

Rice ( *Oryza sativa I.*.) is the most important cereal crop of the world both in respect to area and production. It is the important staple food for more than 50% of the world population and provides 60-70 per cent body caloric intake to the consumers. Rice is also the most important source for meeting the caloric and dietary protein needs as well as for generating employment and income particularly for low-income groups in rural areas. More than 135 million ha are used for rice cultivation world wide, 88% of which are paddy fields, (International Rice Research Institute World Rice Statistics, 2016)**.** The total Rice production in the world is 483.8 million metric tonnes as estimated by the United states Department of Agriculture in november 2016 (USDA). India ranks second in rice production in the world with the production of 106.5 million metric tonnes where as China ranks first with 465.5 million metric tonnes (USDA, 2016).

According to the  government ofIndia during 2015-16 kharif (June - December) rice production was around 90.6 milliontonnes, which was slightly less from around 90.86 million tonness of production in 2014-15. Further, it has been stated that total rice planted areaduring the 2015-16 kharif rice crop stood at around 36.841 million hectaresas on September, 2015 which was slightly more from around 36.651 million hectaresplanted during the same time last year.

Rice grows on the variety of soils like silts, loams and gravels. It can also tolerate alkaline as well as acid soils. However, clayey loam is well suited to the raising of this crop. Rice requires high temperature above 20 °C (68 °F) but not more than 35 to 40 °C (95 to 104 °F). Optimum temperature is around 30 °C (T**max**) and 20 °C (T**min**).

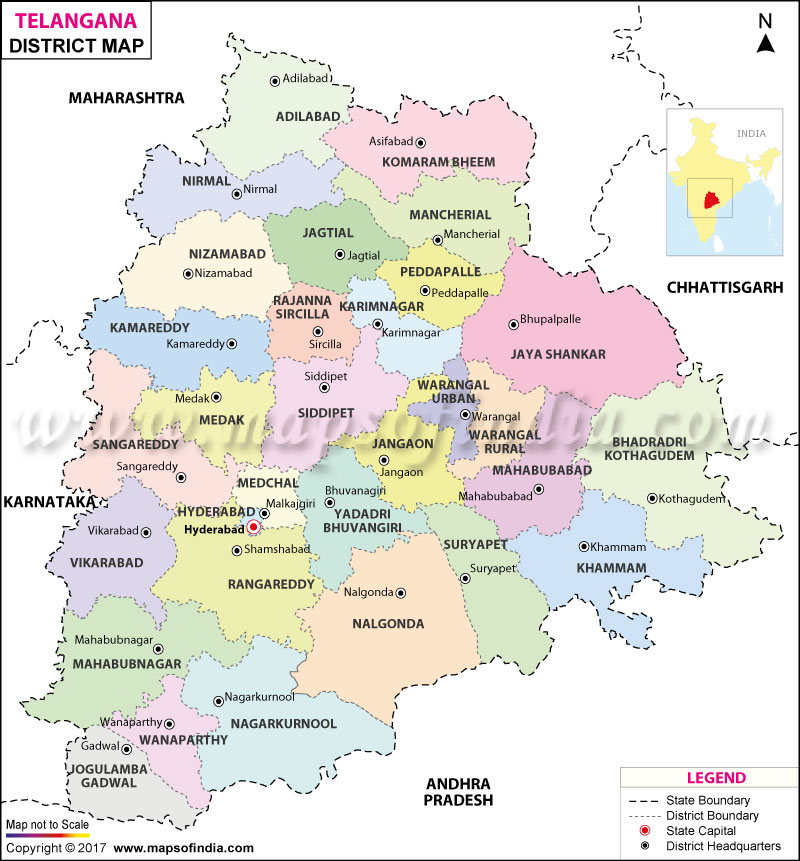
In India, Rice productivity in the irrigated ecosystem ranges from 2.3 t/ ha to 3.5 t/ha, while rainfed ecologies of shallow lowland, deep water and uplands, register average productivity of 1.6, 1.0 and 0.5 t/ha respectively. The gap in the yield levels between national demonstration average and national average is 0.6 t/ha in irrigated areas and 1.5 t/ha in rainfed areas. In order to achieve the target of increasing the productivity levels to meet the future demand, there is a need to raise productivity particularly in the rainfed production system. The average yield levels in the rainfed production systems are low ranging from 0.6 to 0.8 t/ha mainly due to vagaries of monsoon, poor soil fertility, undulating topography, biotic stresses and lack of adoption of improved technologies. Among the biotic stresses insect pests constitute the key factor since the warm and humid climate in the rainfed rice areas is conducive for the pest incidence and multiplication as well.

Among the biotic stresses insect pests cause major damage to the crop yields. The average yield losses in rice have been estimated to vary between 21-51 per cent. There are about more than 100 varieties of insect pests which cause damage to the Rice crop. Among them Yellow stem borer, brown planthopper, galmidge, leaf hopper and gundi bug are the key insect pests in rice causing 25-60%, 10-70%, 15-60%, 10-50% and 20-50% yield losses respectively.

Telangana State is the 29th state of India. It borders Maharashtra on North West, Karnataka on West and Rayalaseema region of Andhra Pradesh state on south. The region has an area of 114.62 lakh ha and a population of 352.87 lakhs as per 2011 census. It has 31 districts. Based on rainfall, type of soils and cropping pattern, etc., the State is divided into the following four agro- climatic zones.

1. Northern Telangana Zone
2. Central Telangana Zone
3. High altitude and tribal zone and
4. Southern Telangana zone

Figure 1. Map of Telangana State



In Telangana, total Geographical area is 114.84 lakh ha out of which gross cropped area is 62.88 lakh ha and net cropped area is 49.61 lakh ha. Number of farm holdings is 55.54 lakh nos. Average annual rainfall is 906.6 mm. In Telangana state, crops are grown in both Kharif and Rabi seasons put together covering an area of 53.15 Lakh hectares. The important crops grown are Rice 14.15 Lakh ha, Maize 6.91 Lakh ha, Pulses 3.11 Lakh ha, Groundnut 0.12 Lakh ha., Cotton 16.93 Lakh ha, Chillies 0.73 Lakh ha, and Sugarcane 0.72 Lakh ha,etc. 75% of area is grown in kharif and the remaining area of 25% is cultivated in Rabi season during 2014-2015.

In this state, the key insect pests which are causing yield loss to the farmers are Stem borer *Sciropophaga incertulas* and Brown plant Hopper *Nilaparvata lugens.* The damage caused by these pests is approximately 25-30% and 10-70% respectively.

Forecasting is used to provide an aid to decision making and in planning for the future effectively and efficiently. It is important aspect for a developing economy so that adequate planning is undertaken for sustainable growth, overall development and poverty alleviation. In other words, statistical forecasting is the likelihood estimation of an event taking place in the future, based on available data.

Crop yield forecasts are used to formulate different policies required for distribution, stock and agriculture produce supply to different areas in the country. It depends on many types of factors like weather variables, agricultural inputs, pests and diseases attack, biometrical characteristics of plant etc., One of the major constraints to good productivity of any crop is the damage by various insect-pests, which are a major cause of crop losses. In the present study, forecasting models for damage by key insect pests and production of rice, have been considered.

Different statistical linear models approach which are used for forecasting are: Time series forecasting models like Auto Regressive Integrated Moving Average (ARIMA), Multiple Linear Regression (MLR) etc. Non-linear forecasting model like Artificial Neural Network (ANN) is generally used for noisy data and it has the advantage to model complex non-linear relationship among the data over a span of time period.

**OBJECTIVES:**

1. To develop statistical model(s) for forecasting of damage caused by Yellow Stem borer *Sciropophaga incertulas* in Rice .
2. To develop statistical model(s) for forecasting of damage caused by Brown plant

hopper *Nilaparvata lugens* in Rice .

1. To develop statistical model(s) for forecasting of production of rice.
2. To assess the prediction accuracy of the models under study.

**REVIEW OF LITERATURE:**

A review of the available literature relevant to the scope of the objective has been presented here with a view to survey the various methodologies considered by the researchers.

**Agrawal and Jain (1982)** developed forecasting models for rice yield in Raipur district of Madhya Pradesh based on weekly data of weather parameters. It was observed that weather variables with time trend accounted more than 70 per cent of the variation in yield at about two and a half months before the harvest.

**Agrawal and Mall (2002)** studied climate change in agro environment of India. Their study based on grain yields of irrigated rice with two popular crop simulation models – Ceres – Rice and ORYZAIN at different levels of N management.

**Agrawal and Mehta (2007)** developed weather based models for forewarning of important pests/diseases in rice, mustard etc., at various locations using regression analysis, complex polynomials through GMDH technique and Artificial Neural Network technique. The forewarnings through these models will be very useful in taking timely control measures.

**Box et al. (1970)** discussed the various techniques of Time series Analysis, forecasting and control.

**Boken (2000)** described a procedure for applying time series analysis for forecast yield. A few techniques (linear, trend, quadratic trend, simple exponential smoothing, double exponential smoothing, simple moving averaging, and double moving averaging) were tested to model the average spring wheat yield series for Saskatchewan, Canada. Using 1975-1995 spring wheat yield data, yields were forecasted for 1994, 1995 and 1996 respectively.

**Billah *et* al. (2005)** proposed a new Empirical Information Criterion (EIC) for model selection. Comparison was made among EIC with other model selection criterion including Akaike’s Information Criterion (AIC) and Schwarzs Bayesian Information Criterion (BIC). The comparison showed that the EIC outperformed both the AIC and BIC, particularly for longer forecast horizons.

**Chatfield *et* al. (2001)** reviewed and compared a variety of potential models for Exponential Smoothing as well as autoregressive integrated moving average and structural models.

**Chegini G.R. *et* al. (2007)** developed prediction of process and product parameters in an orange juice spray dryer using artiﬁcial neural networks. The ﬁnal selected ANN model was able to predict the seven output parameters with RMSE lower than 0.042, R**2** higher than 0.93, and t value higher than 0.97.

**Coa and Boosarawongseb (2007)** compared the performance of artificial neural networks (ANNs) with exponential smoothing and ARIMA models in forecasting rice exports from Thailand. The results revealed that while the Holt-Winters and the Box-Jenkins models showed satisfactory goodness of fit, the models did not perform well in predicting unseen data during validation. On the other hand, the ANNs performed relatively well as they were able to track the dynamic non-linear trend and seasonality, and the interactions between them.

**Dagum *et* al. (1995)** developed a probability forecasting methodology, Dynamic Network Models (DNMs), through a synthesis of belief network models and classical time-series models. The DNM methodology is based on the integration of fundamental methods of Bayesian time-series analysis, with recent additive generalizations of belief network representation and inference techniques.

**Dewolf *et* al. (1997)** developed forecasting model based on an artificial neural network for forecasting disease on wheat. Neural networks were found to be more accurate than stepwise logistic regression and multivariate discriminant analysis for plant disease forecasting.

**Dewolf and Franel (2000)** evaluated disease forecasts by artificial neural networks. The resulting data of 202 discrete periods was randomly assigned to 10 model development. Backpropagation neural networks, general regression neural networks, logistic regression and parametric and nonparametric methods of discriminant analysis were chosen for comparison. Due to high classification accuracy and consistently good performance neural network technology was found to be most appropriate for plant disease forecasting.

**Franc1 et al. (1997)**  developed forecasting models to estimate wetness duration on plant surfaces on wheat flag leaves. Artificial neural network (ANN) models with a backpropagation architecture were developed and compared with multivariate discriminant and stepwise logistic models correctly classified 93% and 90% of the validation cases and were more accurate than discriminant models.

**Gutirrez-Estrada *et* al. (2004)** examined the problem of forecasting ammonia concentration required to minimize the fish stress status, in the management of fishfarms with water recirculating system. They studied methodologies of prediction in a real-time environment for an eel intensive rearing system. Approaches based on linear multiple regression, univariate time series models (exponential smoothing and autoregressive integrated moving average (ARIMA) models) and computational neural networks were developed to predict the daily average ammonia concentration in rearing tanks with water recirculating. The neural network model approach was shown to provide a better prediction of daily average ammonia concentration than linear multiple regression and univariate time series analysis.

**Ho *et* al. (2002)** investigated suitable time series models for repairable system failure analysis. A comparative study of the Box-Jenkins autoregressive integrated moving average (ARIMA) model and the artificial neural network model in predicting failures were carried out. The neural network architectures were the multilayer feed-forward network and the recurrent neural network. Simulation results on a set of compressor failures showed that in modeling the stochastic nature of reliability data, both the ARIMA and the recurrent neural network models outperform the feed-forward model; in terms of lower predictive errors and higher percentage of correct reversal detection. However, both models perform better with short term forecasting.

**Kumar *et* al (2005)** used multiple linear regression model for forecasting yield of Indian mustard (*Brassica juncea L.*) at Hisar district of Haryana. They developed models for each growing phase of Mustard. It was reported that the reliable earliest forecasting could be achieved 6 weeks after sowing and the latest forecasting could be done 4-5 weeks before harvesting.

**Kaundal et al. (2006)** introduced a new prediction approach based on support vector machines for developing weather based prediction models of plant diseases. This modeling approach helped the plant researches or farmers in timely application of control measures.

**Kooner and Cheema (2006)** were screened eighty nine genotypes of pigeonpea in the field for four years (2001 to 2004) to isolate sources of resistance to pod borers. On the basis of per cent pod damage and Pest Susceptability Rating (PSR), the recommendation will be made.

**Kumari prity *et* al (2013)** developed Artificial Neural Network (ANN) model to forecast productivity (Kg/ha) and percent pod damage by key insect pest Helicoverpa armigera of long duration pigeonpea in North East Plain Zone (NEPZ) of India. The performance of the model was assessed by values of the mean squared error, and the model was found suitable for the problem.

**Kumari Prity *et* al (2013)** developed Artificial Neural Network (ANN) model to forecast productivity (Kg/ha) and percent pod damage by key insect pest pod Fly(*Melanagromyza obtusa*) and Yield of Pigeonpea *(Cajanus cajan)* for North East Plain Zone of India. The performance of the model was assessed by values of the mean squared error, and the model was found suitable for the problem.

**Kumari Prity *et* al (2014)** compared the forecasting ability of different statistical models for productivity of Rice (oryza sativa L.) in India. The performance of the models was assessed by values of the mean squared error and checked for suitable model.

**Kumari Prity *et* al (2014)** used time series forecasting of losses due to pod borer, pod fly and Productivity of pigeonpea (*Cajanus* *cajan*) for North west plain zone (NWPZ) by using Artificial Neural Network (ANN).

**Kumari Prity *et* al (2014)** used Auto regressive Integrated Moving Average (ARIMA) approach for prediction of Rice (oryza sativa L.) yield in India.

**Kumar Rajan *et* al (2016)** discussed the forewarning systems for farmers.

**Liang (2009)** presented a hybrid forecasting method that combined the SARIMA (Seasonal AR Artificial neural network models of wheat leaf wetness IMA) model and neural networks with genetic algorithms. Analytical results generated by the SARIMA model was inputted as the input data of a neural network. Subsequently, the number of neurons in the hidden layer and the number of learning parameters of the neural network architecture were globally optimized using genetic algorithms. This model is subsequently adopted to forecast seasonal time series data of

the production value of the mechanical industry in Taiwan. The results obtained provided a valuable reference for decision makes in industry.

**Mathur *et* al. (2001)** developed stock market forecasting models using Neural Network & Multiple Regression Analysis. The models were based on a company’s stock price movement data for a complete calendar year and the data were pre processed to identify the hidden patterns. It was found that Neural Network model can provide better forecasts as compared to Multiple Regression Analysis.

**Mishra *et* al. (2004)** developed logistic regression models for forewarning powdery mildew caused by Oidium mangiferae Berthet. Weather data during 1987-2000 in Kakori and Malihabad mango (Mangifera indica L.) belt (Lucknow) of Uttar Pradesh were used to develop the model and were validated using data of recent years. The forewarning system thus obtained satisfactorily forewarned with the results obtained comparing well with the observed year-wise responses.

**Mishra and Singh (2013)** forecasted the price of groundnut oil in Delhi (India) by using ANN and ARIMA methodologies. They compared forecasting capabilities of these models with the help of Root Mean Square Error (RMSE), Mean Square Error (MSE) and Mean Absolute Percentage Error (MAPE).

**Pandey and Mishra (1991)** considered weighted estimators for a normal population variance by choosing weights as the function of test statistics. They studied the properties of the proposed estimators and made recommendations for their use.

**Pal *et* al. (2007)** made an attempt to forecast milk production using statistical time-series modeling techniques – Double Exponential Smoothing and Auto-regressive Integrated Moving Average (ARIMA). On validation of the forecasts from these models, ARIMA model performed better than the other one.

**Pradhan (2012)** has applied Autoregressive Integrated moving average model for forecasting the agricultural productivity in India.

**Reddy *et* al. (1983)** observed that podfly was the major insect pest affecting more the late cultivars and latter flushes in both the indeterminate and determinate pigeonpea. Higher pod and seed damages due to pod bug, Lepidoptera borer complex (LBC), were recorded in the determinates while the podfly damage was similar for both types. Accordingly, higher yield losses were seen in determinates.

**Reddy *et* al. (1990)** showed that significant positive correlations were recorded between seed index and present grain weight loss by podfly. An expected increase of 0.11% grain weight loss for an unit increase in seed index, was obtained.

**Srivastava (1980)** described the symptoms of attack and methods of pest control, where the main pulse crop during the Kharif season in Uttar Pradesh (India) is pigeon pea. *Melanagromyza obtuse* Malloch, Exelastis atomosaW., Heliothis armigeraHUbn., Euchrysops cnejus Fab., Maruca testulalis Geyer and Anarsia epippias Meyrick are the important pod borers which cause great damage to this pulse crop.

**Schwerk (1996)** presented some of the recent developments in artificial neural networks to tackle the problem of complex and noisy data, with an emphasis on the financial domain in which recurrent back propagation used in non-feed forward nets required more computational power but performed better than the others.

**Shabri *et* al. (2009)** investigated a hybrid methodology that combined the individual forecasts based on artificial neural network (CANN) approach for modeling rice yields. To assess the effectiveness of these models, they used 38 years of time series records for rice yield data in Malaysia from 1971 to 2008. The prediction by CANN gave better result as compared to conventional Artificial Neural Network (ANN) model, the autoregressive integrated moving average (ARIMA) and exponential smoothing models.

**Srivastava *et* al. (2010)** developed the region-specific prediction models by using the pheromone trap data, egg, and larval count in the fields, damage cause to the crops and meteorological data, especially rainfall and temperature and validated for Andhra Pradesh, Karnataka, Uttar Pradesh and Punjab. Important factor for forecasting *H.armigera* in Andhra Pradesh and Karnataka is Rainfall and Temperature is for U.P. Whereas in Punjab, the peak population of H. armigera during March-April was dependent on temperature and humidity in February, while the high population in October on the rainfall during the rainy season.

**SiSi Sun *et* al (2015)** considered the three short term forecast models stepwise regression, backward propagation neural network and support vector machine to forecast the rate of plants affected by rice stripe disease per pentad by considering the three meteorological parameters wind speed, relative humidity and temperature and concluded that support vector machine gave accurate results than the other two methods.

**Shukla Garima *et* al (2015)** used the Kriging method for the estimation of micronutrients in the soil. The Kriging interpolation method (krige,1951) was used for preparing the maps to show spatial distribution of deficient micronutrients.

**Shukla Garima *et* al (2016)** forecasted the Zn and Fe micronutrients status in the soil of Araziline Block of Varanasi district of Uttar Pradesh (India). They used Krigging and IDW for spatial prediction of Zn and Fe in the soil. It has been found that maps and results obtained by spatial prediction methods which are the combination of the geostatistics and GIS provides a powerful tool to describe the spatial distribution of Zn and Fe content in the soil.

**Shukla Garima *et* al (2016)** estimated the zinc, boron and iron at different unsampled locations in Sevapuri block of Varanasi district. Exponential and spherical semivariograms models were found the best on the basis of the higher values of R2 and lower values of RSS. With the help of these variogram models and interpolating techniques spatial distribution maps of soil micronutrients were prepared.

**Trivedi *et* al. (2002)** used non-linear models for forecasting potato aphid [Myzus persicae (Sulzer)] population in India. The data for present study were collected at Pantnagar (Uttaranchal), Kalyani (West Bengal) and Deesa (Gujarat) during 1974-75 to 1996-97 under All India Co-ordinated Potato Improvement Project. Validation for these models were carried out using data collected in 1995-96 and 1996-97 and applied during the season 2000-2001 at Kalyani and Deesa and compared with the actual population of aphids.

**Tsaur (2003)** proposed a fuzzy double exponential smoothing model in order to enhance and enlarge the abilities of the short-term fuzzy forecasting methods. Finally, a forecasting example of Taiwan internet users is illustrated to describe performance of the proposal model.

**Tripathi *et* al (2014)** Univariate autoregressive integrated moving average (ARIMA) models are compared with the forecasted all Indian data on rice. The performances of models were validated by actual values and mean absolute percent error (MAPE), which was found to be 0.61 and 2.99% for the area under rice in Odisha and India, respectively. Prediction of rice production and productivity in Odisha and India, the MAPE was found to be less than 6%.

**Pandey and Mishra (1991)** considered weighted estimators for a normal population variance by choosing weights as the function of test statistics. They studied the properties of the proposed estimators and made recommendations for their use.

**Yang *et* al. (2009)** used Principal Component Analysis (PCA) and Back Propagation (BP) Artificial Neural Network (ANN) methods to analyze historical data on population occurrence to find out a non-linear relation between the pest occurrence and the meteorological factors and then to build a prediction model. Population data were collected from 2000 to 2008 by light trapping at the plan protection station of JianShui County Meteorological observatory. The new model successfully forecasted paddy stem borer population occurrence in 2006, 2007 and 2008.

**RESEARCH METHODOLOGY:**

**Study Area:**

The study will be carried out in Telangana State. The entire state of Telangana is divided into 4 Agroclimatic zones 1)Northern Telangana Zone: It includes Nizamabad,Adilabad, Karimnagar spreading over a geographical area of 35.5 sq km where the annual Rainfall is

900 mm to 1150 mm and Temperature is 21 to 25 degree celsius minimum and 32 to 37 maximum. Mostly red soils are predominant and Rice ,maize, soyabeen ,cotton, red gram are major crops. 2) Central Telangana Zone : It includes medak, warangal and khammam where the annual rainfall is between 800 to 1150 mm and temperature is between 21 to 25 degree celsius minimum and 22 to 37 maximum. Mostly red soils are predominant and the major crops grown are cotton, rice, maize , green gram, mango are important crops. 3) Southern Telangana Zone: It includes Rangareddy, Hyderabad, Mahabobnagar and Nalgonda. It spreads over 39.3 sq km where the annual rainfall is between 600 to 780 mm. Red soils are predominant and Cotton, rice, red gram, maize and green gram are important crops. 4) High altitude and Tribal zone: It includes Northern and Eastern borders of Adilabad and Khammam. It spreads over 4.66 sq km and rainfall is 1400 m. Red sandy soils, Red loams with classy base are predominant and the crops grown are Chilly, rice, cotton and horticultural crops.

**Collection of Data:**

In the present study, secondary data on production and damage of rice caused due to key insect pests will be considered for the last two to three decades (as per the availability of data) for Telangana from All India Coordinated Research Project on Rice, Indian Institute of Rice Research, Rajendranagar, Hyderabad. Every effort will be made to collect the weather data like rainfall, maximum & minimum relative humidity and maximum & minimum temperatures, natural enemies and cropping patterns to determine the relationship of damage due to Yellow Stem borer *Sciropophaga incertulas* and brown plant hopper *Nilaparvata lugens* and production with weather indices, natural enemies and cropping pattern for the crop under study.

**Statistical Tools:**

Data analysis will be carried out by using following statistical techniques:

**Time Series Forecasting Models:**

In this model the past behavior of a time series data is analyzed in order to make inferences about its future behavior. The Time model to be used in the present study is:

**AUTOREGRESSIVE INTEGRATED MOVING AVERAGE MODEL (ARIMA)**

The most commonly used linear statistical model is Box-Jenkins ARIMA (1970) (Ho S L et al., 2002) . It has been successfully applied in many time series forecasting and is a good tool to develop empirical model which is dependent on their own successive time series values (Mishra et al., 2013). Generally a nonseasonal ARIMA model, denoted as ARIMA (p, d, q), is expressed as ( Liang et al., 2009)

Yet=Φ0 + Φ 1 Yt-1 + Φ 2 Yt-2 +. . + Φ p Yt-p + et- θ 1 et-1 -……..– θ qet-q

Where Yt the actual values,

Φ I and θ **j** model parameters,

et  random error

‘p’ number of autoregressive terms,

‘d’ number of nonseasonal differences and ‘q’ number of lagged forecast errors.

**ARTIFICIAL NEURAL NETWORK (ANN)**

An important modeling tool for the data where there is complex non-linear relationship

among the data (Shabri et al., 2009). Composed of many artificial Neurons (Gutierrez-

Estrada et al, 2004). The objective of the neural network is to transform the inputs into

meaningful outputs ( Prity Kumari et al., 2014).



where Y : output,

f : activation function,

wi : weights of the connections

xi : input to the neurons

**MULTIPLE LINEAR REGRESSION**

Multiple linear regressions are used when two or more independent factors are involved

**(**Liu Zhn-yul et al., 2007). It is widely used for short or intermediate term forecasting

(Mishra et al., 2004). It uses as few variables for prediction as necessary to get a reasonably

accurate forecast (Mathur et al., 2001).

Multiple Linear Regression Model is expressed as :

Y = b**o**+b1X1+b2X2+b3X3+………+bnXn+et

Where bo is the intercept, b1, b2, . . . bn are coefficients representing the contribution of the independent variables X1, X2, . . . Xn on the dependent variable Y and et is the error at time t which is independently and identically distributed with zero mean and finite variance.

**ACCURACY MEASUREMENT METHODS :**

Three criteria that are used to make comparison of forecasting ability among different models are:

1. **Mean Absolute Error:** The mean absolute error (MAE) value is the average absolute error value.

**MAE = (1/T) Σ |Pt -At|**

1. **Mean Relative Percentage Error (MRPE):** The MRPE is computed as the average of the absolute percentage error (APE) values.

**MRPE = (1/T) Σ |(Pt - At )/Pt| %**

1. **Mean Squared Error (MSE):** Mean squared error is computed as the sum (or average) of the squared error values. This is the most commonly used criteria in fitting statistical forecasting model.

**MSE = (1/T) Σ (Pt -At)2**

Where **Pt** is the predicted value for time t, **At** is the actual value at time t and T is the number of predictions. On the basis of the precision of the estimates, recommendations will be made.

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