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Integration of Feed Forward Back Propagation Neural Network (FFBPNN) and Curve Expert software to predict rice production in Tamilnadu, India

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ABSTRACT: The study reported the development of FFBPNN architecture and its corresponding software to predict the rice production data in different districts of Tamilnadu, India. In order to get high accuracy of prediction, the curve expert software was integrated into the FFBPNN software. The curve fitting software developed the best fitting models among the 30 different linear and non linear models for Kuruvai, Samba and Kodai seasons of different districts of Tamilnadu. The test data and training data was fed as input to the FFBPNN software, it was found that the there was zero error between the observed data and the predicted data. The RMSE is zero and the ARE is also zero at 18th iteration. The curve expert produced the best fitting model to different districts during the three seasons. It was found that the best predicted models and their predicted data gives 1 to 9% higher than the observed data. It is due to natural increase in area of cultivation for every year or it may be improvement in rice production technology.

KEYWORDS: Neural Network, Curve Expert, Prediction of rice production, best fitting models.

I. INTRODUCTION

The most striking feature of FFBPNN for predicting the pattern of behavior is data-driven self-adaptive propagation method for the prediction of data. FFBPNN has the ability to learn from the past experience from the supplied data than from the theoretical laws. The authors [1] discussed the building up of the FFBPNN architecture to predict data and reported that the FFBPNN software accurately predict the observed pattern with the threshold value of 10^{-9}. The authors [2] discussed the FFBPNN architecture to predict data coupled with Rice Data Simulator, which is software to develop multiple linear regression models. It is planned that more accuracy of prediction can be obtained by incorporating the efficient curve expert software, which comprises of 30 different linear and non linear models. The main focus of the paper is to give brief discussion of developing FFBPNN architecture and the integration of Curve Expert Software to develop the best fitting models and to predict the data pertaining to area of rice cultivation and rice production in different districts of Tamilnadu, which are useful to policy makers of Government of Tamilnadu. The overall objective of the present research is the integration of FFBPNN and Curve Expert software to provide solution of the best fitting linear and nonlinear regression models for prediction of area of rice cultivation and rice production in different districts of Tamilnadu for three seasons using the five years of data captured from 2005-06 to 2009-10. The specific objectives of this research are:

1. To develop the FFBPNN software to predict the area of rice cultivation and rice production in different districts of Tamilnadu for Kuruvai, Samba and Kodai seasons.
2. To develop the best fitting linear and nonlinear regression models between the years and FFBPNN method of predicted area of rice cultivation / rice production using curve expert software.
3. To predict the area of rice cultivation and rice production from the best fitting linear and nonlinear regression models developed.
4. To compute the relative error (RE) between the FFBPNN method of prediction and the best fitting linear and nonlinear regression models and its analysis.

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II. Related work

According to [3], the Multilayered Feed Forward Artificial Neural Network (MLFANN) has predicted the maize yield quite close to the actual values of maize yield and concluded that artificial neural network methodology is successful in describing the given data. According to [4], the ANN model was compared to stepwise multiple regression model to predict rice production in Phimai district of Thailand. It was found that the prediction under ANN is better than stepwise multiple regression model. ANN are one of the best solutions to predict crop yield because ANN plays a crucial role in precision agricultural and its impacts towards crop yield must be conducted to ensure sustainability of future food needs according to [5]. According to [6], an ANN model was used in prediction of cotton leaf area. Best fitting results were obtained with 4 input nodes. ANN model performance was tested successfully to describe the relationship between measured and predicted cotton leaf area and coefficient of determination (R2) was 0.9232. The developed ANN model produced satisfied correlation between measured and predicted value and minimum inspection error. Thus, the model can be used in easy way for agronomists and plant scientists in cotton crop research. ANN models are more accurate technique for crop monitoring and yield forecasting. With information of the soil types, cropping system, crop management should broaden the usefulness, and possibly increase the predictive capabilities of ANN-based yield prediction in mountain areas. It was reported by [7]. The researcher [8] stated that regression and ANN prediction models have been developed with eight most dominating parameters which have found most significant effect on livelihood security. The comparison study of these two models have indicated that, the statistical yield predicted through ANN models performed better than that predicted through regression models. The study has recommended the use of such models for improvement of similar degraded watershed for future reference. According to [9], Artificial Neural Network is used to predict the crop yield based on various parameters like pH, N, P and K. By calculating deficiency of N, P and K, the system suggests the fertilizer recommendation. This system is useful for farmers who are economically weak and can't afford the lab soil test. The report from [10] stated that ANN and Adaptive Neuro-Fuzzy Inference System (ANFIS) techniques could be used in many fields including scheduling, design, and various other analyses. These models can also be integrated into modules for application in general economic models. Prediction is making claims about something that will happen, often based on information from past and from current state.

III. METHODOLOGY

3.1 Variables used

Tamilnadu state of India has 31 districts. Each district cultivates rice in three seasons namely Kuruvai, Samba and Kodai. The area of rice cultivated in hectares in three seasons of each district and the corresponding rice production in tonnes for the 5 years starting from 2005-06 to 2009-10 are selected as data variables. Hence the total variables selected were 2 variables viz: area and production multiplied by 3 seasons gives 6 variables.

3.2 Collection of data

The published data by the Government of Tamil Nadu was used. Training data was collected from the area and rice production of 31 districts for the year 2005-06. The test data of the area of cultivation and rice production was collected for the remaining years starting from 2006-07 to 2009-10 for all the 31 districts of the state.

3.3 Pre-processing of data

The training and test data collected had some missing data marked with 0 values. If the study uses these 0 values in computation, this 0 may divide any real number leading to infinity condition. Computer cannot compute such infinity conditions. There are many data cleaning techniques available for data pre-processing. The present study adopted the use of a global constant 0.01 in place of 0 in training and test data. This replacement avoids the computational problem of avoiding infinity during computations.

3.4 Design of FFBPNN Architecture

FFBPNN is an interconnected neurons used for processing the data for prediction. The neurons are connected in three layers namely, input layer, hidden layer and the output layer. Input in to a neuron is the weighted sum of outputs from the nodes connected to it. The output from a neuron is the weighed sum of inputs into the neuron. The ability of data prediction depends upon the weights obtained by the process of supervised learning. The supervised learning is adopted

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by computing the Root Mean Squared Error (RMSE) and Absolute Relative Error (ARE) between the predicted and observed data within a threshold value of ARE. The basic element of a neural network is shown in fig. 1 below.

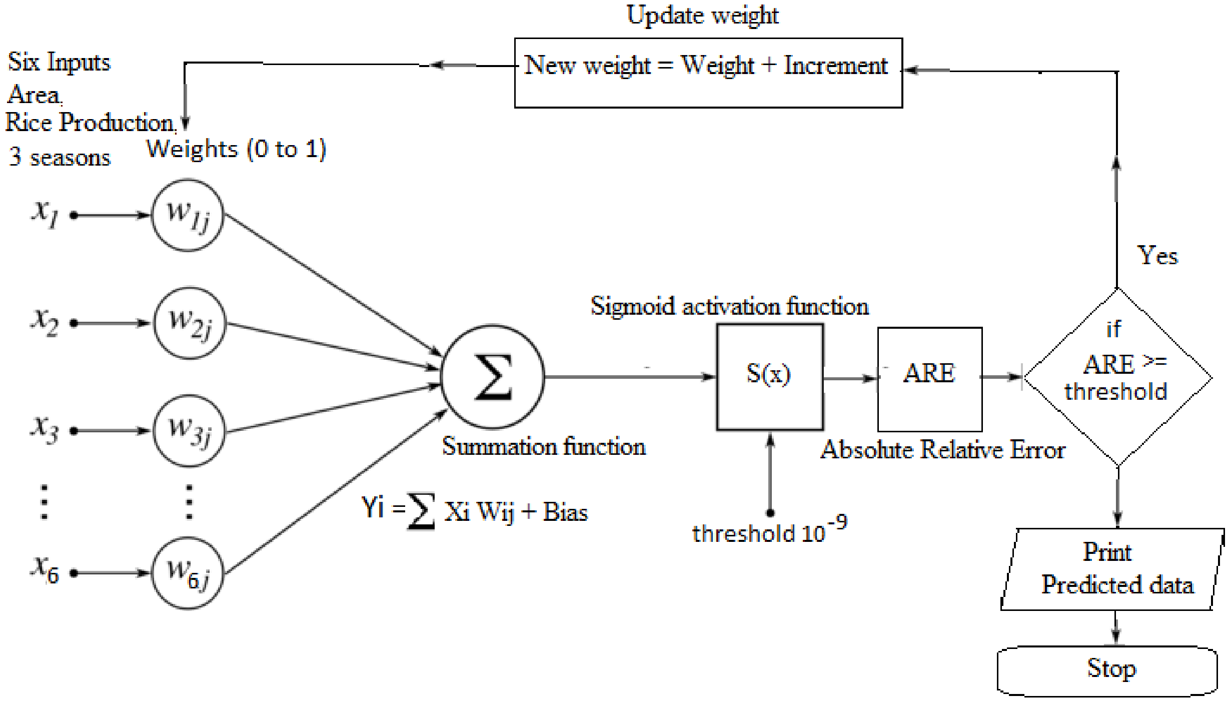

Fig. 1 A simple Feed Forward Back Propagation Neural Network

3.4.1 Input layer

The input layer converts the area of rice cultivation in hectare and the rice production in tonnes for three seasons into sigmoid values between 0 to 1 using the sigmoid activation function. The sigmoid values were fed to the hidden layer where the data is multiplied by the assumed initial weights, which is varying from 0 to 1.

3.4.1.1 Sigmoid Function

A sigmoid function is a mathematical function having an "S" shape (sigmoid curve). Sigmoid function is given by the following formula:

$$S(x) = \frac{1}{1+e^{-x}} \quad \text{eq. (1)}$$

Sigmoid functions are very similar to the input-output relationships of biological neurons, although not exactly the same

3.4.2 Hidden layer

The function of the hidden layer is to compute the summation of the sigmoid values and the weights coming from each nodes of the input layer and produces something that the output layer can use. An assumed bias is also added to the summation to prevent negative values. The equation for summation is given below:

$$Yi = \sum Xi\,Wij + Bias\,(+1) \quad \text{eq. (2)}$$

Where Y_i is the summation of each node X_{ij} with corresponding initially assumed weights W_i plus bias. Bias used is +1. Bias is added to the summation to make the summation a number other than 0. It is essential to avoid 0 so that subsequent computations may not face division by zero (infinity).

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3.4.3 Root Mean Squared Error (RMSE)

The performance of FFBPNN is studied by updating the weights during back propagation. The effect of iterations on error reduction between the observed data and the predicted data is measured using the Root Mean Squared Error (RMSE). The formula for the RMSE is given below:

$$\text{Root Mean Squared Error (RMSE)} = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(t_i - y_i)^2} \qquad \text{eq. (3)}$$

Where
N is the total number of data points,
t_i is the observed data and
y_{ii} is the model's predicted datat.
.

3.4.4 Absolute Relative Error (ARE)

ARE is used with supervised learning. It is the technique of comparing the FFBPNN's output to the observed data. The error is used to train the system for better performance. The error values can be used to directly adjust the weights, using an algorithm such as the back propagation algorithm. If the system output is FFBPNN output and the desired system output is known observed data supplied. The ARE can be computed using the formula given below:

$$\text{Absolute Relative Error} = \frac{\text{Observed Data} - \text{FFBPNN predicted data}}{\text{Observed Data}} \qquad \text{eq. (4)}$$

Compare the ARE with threshold value of 10^{-9}. If the error was greater than threshold value then calculate the updated weights and compute the summation using back propagation. This process is repeated until error is zero.

3.4.5 Output layer

The hidden layer computes the summation by multiplying each input with its corresponding weights and adds them together with the bias and applies the sigmoid action function. The output layer gets its input from the hidden layer. It also computes ARE and test it with the prescribed threshold value to improve the accuracy of prediction. If ARE ≥ threshold value then the updating of weights and the back propagation starts from the beginning else the desired accuracy of prediction is achieved and it can be printed.

3.4.6 Development of FFBPNN software and data processing

A computer program is written in turbo C++ language. It reads the test data from a file. It also reads the initial weights for the six neurons. The initial feed forward network is carried out. The summations in the hidden layer forms the input to the output layer after passing through the sigmoid activation function. The predicted output was computed. ARE was computed and the checking of ARE with threshold was also carried out. According to the conditions laid out, back propagation of network continued until the predicted data has desired accuracy and it was printed in a output file. The program was executed for the test data of 2005-06 and the training set of data for the years 2006-07 to 2009-10.

3.5 Development of the best fitting models using Curve Expert software

Curve Expert 1.3 is a comprehensive curve fitting system for Windows. It was developed by Daniel Hyams and is available as a shareware for all users without any license. XY data can be modelled using a toolbox of linear regression models, nonlinear regression models, interpolation, or splines. Over 30 models are built-in, but custom regression models may also be defined by the user. Full-featured graphing capability allows thorough examination of the curve fit. The process of finding the best fit can be automated by letting Curve Expert compare the given data to each model to choose the best curve. This program was designed to be simple but powerful, so that all users can obtain a model for their data quickly and easily. Documentation is provided in the form of a Windows help file. The on-line manual of the software is complete and does not need the supplement of a printed copy. Data files were created by keeping the years of rice cultivation of a district as x and the area of cultivation in hectare / rice production in tonnes as y. Each district

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has 6 data files. They are 1) Years (x) and Area of cultivation for Kuruvai season (y) for a district 2) Years (x) and Area of cultivation for Samba season (y) for a district 3) Years (x) and Area of cultivation for Kodai season (y) for a district 4) Years (x) and Rice Production for Kuruvai season (y) for a district 5) Years (x) and Rice Production for Samba season (y) for a district and 6) Years (x) and Rice Production for Kodai season (y) for a district. There are 31 districts which gives rise to 31 x 6 = 186 data files.

When data files created were processed to get the best fitting model, it fits more than 30 linear and nonlinear regression models including the built-in user defined custom regression models defined by the user. The package gives the complete details like the ranks of the best fitting models. The first ranked best fit was recorded with the type of model, its coefficients, covariance matrix, standard error and the correlation coefficient. The different best fitted models for the research data of the author is explained below:

3.5.1 Linear Fit

Linear regression is an approach for modelling the relationship between an independent variable (year of rice production) as x and the dependent variable (area of rice cultivation / rice production) as y. It is found that for each unit increase in the value of *x*, the conditional expectation of *y* increases by *b* units. The correlation coefficient varies from 0 to 1. If the correlation coefficient is close to 1 then it is the best fit else if the correlation coefficient is nearer to 0 then it may be poor fit.

$$y = a + bx \qquad \text{eq. (5)}$$

Where
x– Years of rice cultivation in a district
y– Area of rice cultivation or rice production in a district
a and b are coefficient data

3.5.2 Quadratic Fit

Quadratic fitting is an approach for modelling the relationship between an independent variable (years of rice production) as x and the dependent variable (area of rice cultivation / rice production) as y. It is found that for each unit increase in the value of *x by (x+1)*, the conditional expectation of *y* increases by $b(x+1) + c(x+1)^2$ units. It means when x increases then y increases in a non linear form.

$$y = a + bx + cx^2 \qquad \text{eq. (6)}$$

Where
x– Years of rice cultivation in a district
y– Area of rice cultivation or rice production in a district
a, b and c are coefficient data

3.5.3 Saturation Growth-Rate Model

A saturation-growth-rate equation is a nonlinear model that is sometimes fitted to data. The form of the Saturation Growth-Rate Equation:

$$y = \frac{ax}{(b+x)} \qquad \text{eq. (7)}$$

Where
x– Years of rice cultivation in a district
y– Area of rice cultivation or rice production in a district
a and b are constant coefficients.

3.5.4 Logarithmic Fit

The logarithmic fit calculates the least squares fit through points by using the following equation:

$$y = a + b * log(x) \qquad \text{eq. (8)}$$

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Where
x– Years of rice cultivation in a district
y– Area of rice cultivation or rice production in a district
a and b are constant coefficients.
log – natural logarithm function
This model requires that x>0 for all data points. This will result in better accuracy of the calculation compared to using linear regression.

3.5.5 Exponential Fit

The exponential fit calculates the least squares fit through points by using the following equation:

$$y = ae^{bx} \quad \text{eq. (9)}$$

Where
x– Years of rice cultivation in a district
y– Area of rice cultivation or rice production in a district
a and b are constant coefficients.
e –the base of the natural logarithm
Exponential models are commonly used in biological applications, for example, for exponential growth of crop production. It is a nonlinear regression method and result in better accuracy than linear regression method.

3.5.6 Gaussian Model

The Gaussian curve fit calculates a bell curve suitable to describe normal distributions using the following equation:

$$y = ae^{\frac{-(b-x)^2}{2c^2}} \quad \text{eq. (10)}$$

Where
x– Years of rice cultivation in a district
y– Area of rice cultivation or rice production in a district
a,b and c are constant coefficients.
e –the base of the natural logarithm

3.5.7 Hyperbolic Fit

A hyperbolic curve has a discontinuity at certain x value. This prevents a "traditional" curve fitting of the entire curve, but it is easily fit the curve if there is a transformation of the equation into a linear version, solve for the linearized coefficients, and then use those coefficients to fit the non-linear data. The general format of the hyperbolic equation is given below:

$$y = a + \frac{b}{x} \quad \text{eq. (11)}$$

Where
x– Years of rice cultivation in a district
y– Area of rice cultivation or rice production in a district
a and b c are constant coefficients.

3.6 Prediction of the area of rice cultivation and rice production from the best fitting models

The prediction of area of rice cultivation in hectare is obtained by inserting x = (2005, 2006, 2007, 2008 and 2009) in the best fitted area model developed for different districts in three seasons. Similarly, the prediction of rice production in tonnes is obtained by inserting x = (2005, 2006,2007,2008 and 2009) in the best fitted production model developed for different districts in three seasons.

3.7 Relative Error (RE) between FFBPNN predicted data and the predicted data from the best fitted model

The FFBPNN method of predicted data is compared with the predicted data from the best fitted model for area of cultivation / rice production for different districts during the Kuruvai, Samba and Kodai seasons for the years 2005-06

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to 2009-10. The mean relative errors for the five years were also computed. The relative error can be computed using the formula given below:

$$\text{Relative Error} = \frac{\text{FFBPNN Method predicted data} - \text{Prediced data from the best fitted model}}{\text{FFBPNN method of predicted Data}} \text{ x } 100 \qquad \text{eq. (12)}$$

IV. EXPERIMENTAL RESULTS

The results obtained from the integration of FFBPNN and Curve Expert software and its discussions are given in the following headings:

1. Performance evaluation of FFBPNN on testing and training data
2. Development of the best fitting models using Curve Expert software
3. Prediction from the best fitting models developed
4. Relative error between the predicted data of FFBPNN and the best fitted models

4.1 Performance evaluation of FFBPNN on testing and training data

The FFBPNN software was used to predict the area of cultivation and rice production for the testing set of data collected for 2005-06 and the training set of data for 2006-07 to 2009-10. The data set consisted of the area of cultivation of rice and rice production in different districts of Tamilnadu for the Kuruvai, Samba and Kodai seasons. The RMSE between the observed data and the predicted data were recorded for 18 iterations until the predicted data is exactly equal to observed data with the threshold value of 10^{-9} by updating the weights in each back propagation. The RMSE reduction pattern until it get zero is shown in fig 2 to fig 6 below:

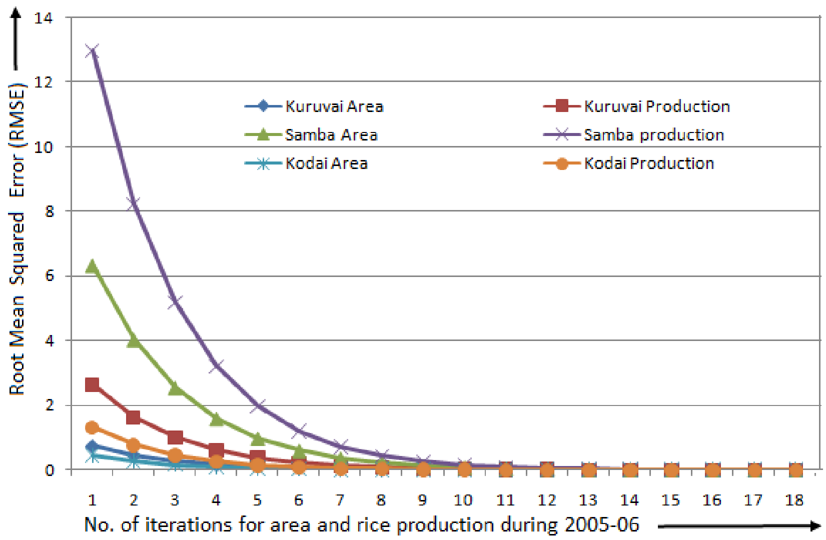

Fig. 2 RMSE reduction pattern for testing data (area and production of rice) for 2005-06

Fig 2 shows that the maximum RMSE of 12.99 is found for the Samba rice production. It is followed by the RMSE of 6.34 for the Samba area of rice cultivation. Similarly, the minimum RMSE of 0.44 is found for the Kodai area of rice cultivation, which is followed by the second minimum RMSE of 0.73 for the Kuruvai area of rice cultivation. However, the RMSE is zero at the 18th iteration due to back propagation of FFBPNN.

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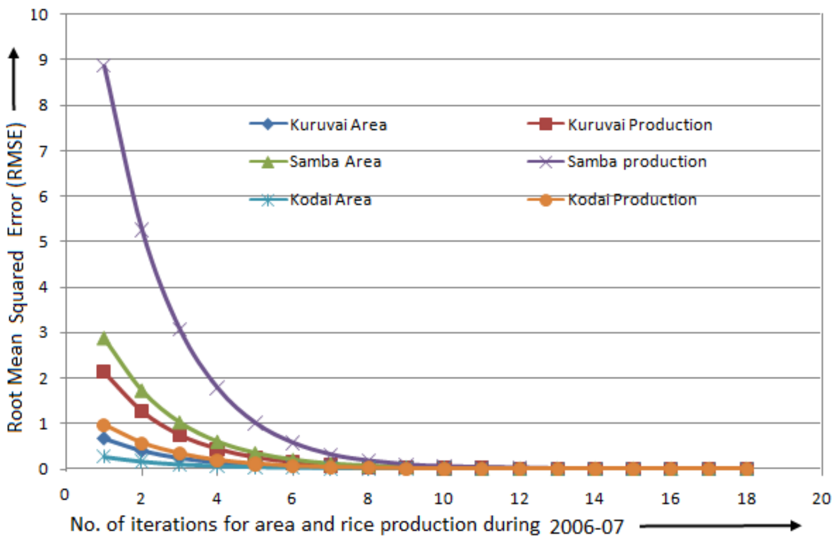

Fig. 3 RMSE reduction pattern for training data (area and production of rice) for 2006-07

Fig 3 shows that the maximum RMSE of 8.87 is found for the Samba rice production. It is followed by the RMSE of 2.87 for the Samba area of rice cultivation. Similarly, the minimum RMSE of 0.26 is found for the Kodai area of rice cultivation, which is followed by the second minimum RMSE of 0.66 for the Kuruvai area of rice cultivation. However, the RMSE is zero at the 18^{th} iteration, which makes the error between the observed data and the FFBPNN predicted data is zero.

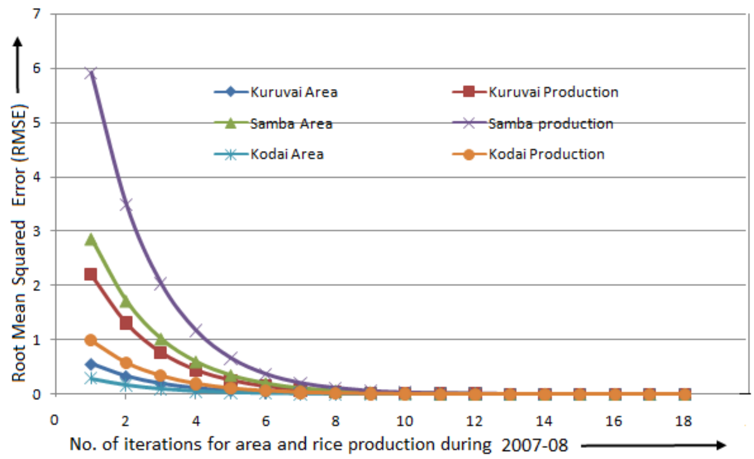

Fig. 4 RMSE reduction pattern for training data (area and production of rice) for 2007-08

Fig 4 shows that the maximum RMSE of 5.91 is found for the Samba rice production. It is followed by the RMSE of 2.86 for the Samba area of rice cultivation. Similarly, the minimum RMSE of 0.29 is found for the Kodai area of rice cultivation, which is followed by the second minimum RMSE of 0.55 for the Kuruvai area of rice cultivation. The range of RMSE variation is from 0.29 to 5.91. However, the RMSE is zero at the 18^{th} iteration due to back propagation of FFBPNN due to updating of weights. This back propagation makes the error between the observed data and the FFBPNN predicted data is zero.

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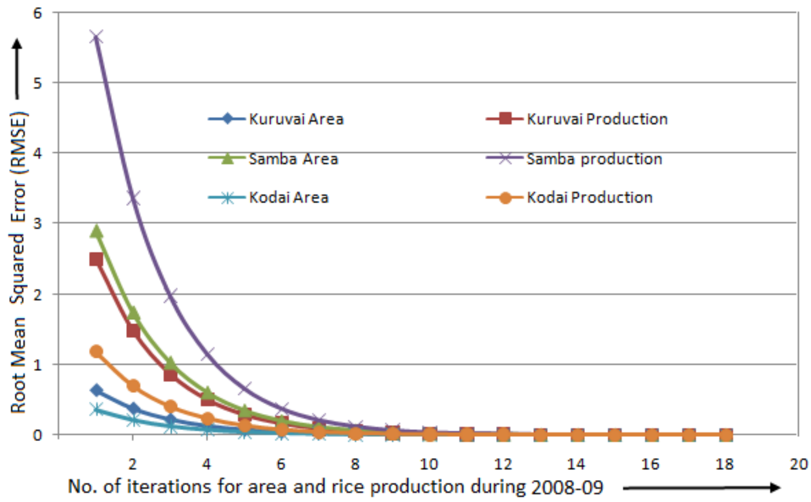

Fig. 5 RMSE reduction pattern for training data (area and production of rice) for 2008-09

Fig 5 shows that the maximum RMSE of 5.56 is found for the Samba rice production. It is followed by the RMSE of 2.90 for the Samba area of rice cultivation. Similarly, the minimum RMSE of 0.36 is found for the Kodai area of rice cultivation, which is followed by the second minimum RMSE of 0.64 for the Kuruvai area of rice cultivation. However, the RMSE is zero at the 18th iteration, which makes the error between the observed data and the FFBPNN predicted data is zero.

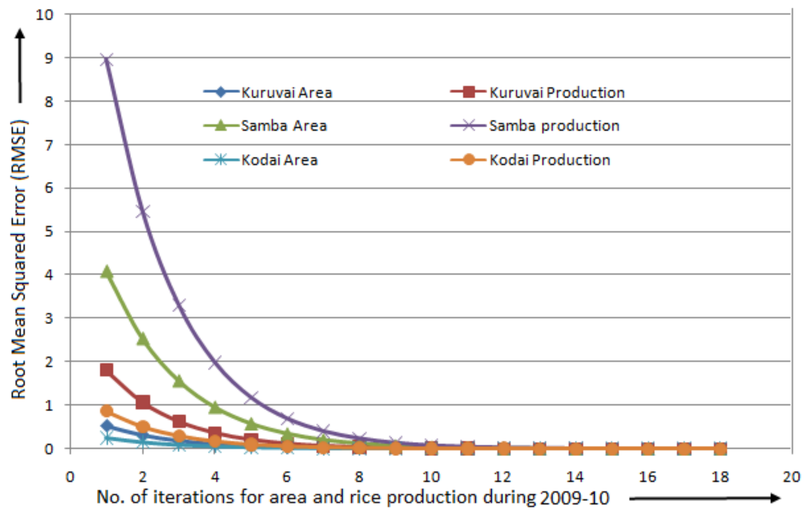

Fig. 6 RMSE reduction pattern for training data (area and production of rice) for 2009-10

Fig 6 shows that the maximum RMSE of 8.96 is found for the Samba rice production. It is followed by the RMSE of 4.08 for the Samba area of rice cultivation. Similarly, the minimum RMSE of 0.25 is found for the Kodai area of rice cultivation, which is followed by the second minimum RMSE of 0.52 for the Kuruvai area of rice cultivation. The range of RMSE variation is from 0.25 to 8.96. However, the RMSE is zero at the 18th iteration due to back propagation of FFBPNN because of updating of weights. This back propagation makes the error between the observed data and the FFBPNN predicted data is zero.

Fig 2 to Fig 6 shows that the maximum RMSE of 12.99 is found for the Samba rice production. Similarly, the minimum RMSE of 0.25 is found for the Kodai area of rice cultivation during the year 2009-10. This trend of highest

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starting RMSE is found for the Samba rice production in all the years of data from 2005-06 to 2009-10 and the lowest RMSE is found for the Kodai area of rice cultivation in all the years of data from 2005-06 to 2009-10. However, the RMSE is zero at the 18th iteration, which makes the error between the observed data and the FFBPNN predicted data is zero. The major aim of the present research is to find an accurate prediction system, which was achieved. However, the author plan to incorporate the FFBPNN predicted data and the years of rice cultivation into the curve expert software to get the best fitting linear or non linear model connecting years (x) as independent variable and the area of rice cultivation / rice production (y) as dependent variable, so that the developed model will help to predict the area of cultivation of rice and rice production, which is varying every year.

4.2 Development of the best fitting models using Curve Expert software

The best fitting model connecting years (x) as independent variable and the area of rice cultivation (y) as dependent variable for different districts of rice cultivation during Kuruvai, Samba and Kodai seasons were done using curve expert software.

4.2.1 Best fitting models for area of rice cultivation for all the districts during three seasons

The best fitting model connecting years (x) as independent variable and the area of rice cultivation (y) as dependent variable for different districts of rice cultivation during Kuruvai, Samba and Kodai seasons were done using curve expert software and is shown in Table 1.

Table 1: Best fitting model for area of rice cultivation

	District	Kuruvai season -area of rice	Samba season- area of rice	Kodai season- area of rice
1	Kancheepuram	Linear Fit: $y = a + bx$ Where: a = 1743686.1 b = -859.1 SE=2589.6788153 r=0.5180583	Quadratic Fit: $y = a + bx + cx^2$ Where: a =2.584097e+009 b =-2573281.5 c =640.64286 SE=1387.7771642 r=0.9505217	Quadratic Fit: $y = a + bx + cx^2$ Where: a =7.996972e+009 b =-7965705.5 c =1983.6429 SE=2694.2101729 r=0.9594494
2	Thiruvallur	Linear Fit: $y = a + bx$ Where: a = 1819791.2 b = -886.8 SE=2800.7836284 r=0.5004716	Quadratic Fit: $y = a + bx + cx^2$ Where: a = 6.1498e+009 b = -6126986.2 c = 1526.0714 SE=2346.3276227 r=0.9059931	Quadratic Fit: $y = a + bx + cx^2$ Where: a =4.3037151e+009 b = -4286962.5 c = 1067.5714 SE=1325.0531737 r=0.9638211
3	Cuddalore	Quadratic Fit: $y = a + bx + cx^2$ Where: a =2.8493559e+009 b = -2838075.3 c = 706.71429 SE= 784.3524899 r =0.9758233	Quadratic Fit: $y = a + bx + cx^2$ Where: a =6.4814269e+009 b = -6459923.7 c = 1609.6429 SE=2360.9653233 r =0.9046873	Saturation Growth-Rate Model: $y = \frac{ax}{(b+x)}$ Where: a = 68.805182 b = -1979.2248 SE= 171.0517925 r =0.8834125
4	Villupuram	Saturation Growth-Rate Model: $y = \frac{ax}{(b+x)}$	Quadratic Fit: $y = a + bx + cx^2$ Where: a = 8.5909598e+009	Saturation Growth-Rate Model: $y = \frac{ax}{(b+x)}$

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		Where: a = 157.01568 b = -1995.8502 SE=1848.8717797 r =0.9285353	b = -8560802.7 c = 2132.7143 SE=1392.5897565 r=0.9709031	Where: a = 39.275129 b = -1999.7409 SE=2803.5182283 r=0.6824962
5	Vellore	Quadratic Fit: $y = a + bx + cx^2$ Where: a =-2.1056772e+009 b = 2097829.3 c = -522.5 SE= 503.0429405 r=0.9630275	Quadratic Fit: $y = a + bx + cx^2$ Where: a =2.7606796e+009 b = -2751172.1 c = 685.42857 SE= 828.8159713 r=0.9117379	Saturation Growth-Rate Model: $y = \frac{ax}{(b+x)}$ Where: a = 44.279487 b = -2001.8562 SE=4982.8750880 r=0.7877935
6	Thiruvannamalai	Quadratic Fit: $y = a + bx + cx^2$ Where: a =4.7570186e+009 b = -4738750.2 c = 1180.1429 SE= 992.4629248 r=0.9796578	Quadratic Fit: $y = a + bx + cx^2$ Where: a =1.3046268e+010 b = -12994865 c = 3235.9286 SE=8826.9221320 r=0.8707363	Linear Fit: $y = a + bx$ Where: a = 1971864.3 b = -965.99987 SE=9115.0129493 r=0.1899669
7	Salem	Quadratic Fit: $y = a + bx + cx^2$ Where: a =2.1471009e+009 b = -2139103.6 c = 532.78571 SE= 918.9074103 r=0.8908108	Saturation Growth-Rate Model: $y = \frac{ax}{(b+x)}$ Where: a = 89.042528 b = -1996.771 SE=3034.1732766 r=0.7136509	Quadratic Fit: $y = a + bx + cx^2$ Where: a =2.2547174e+009 b = -2246629.3 c = 559.64286 SE= 867.6229927 r=0.8742354
8	Namakkal	Quadratic Fit: $y = a + bx + cx^2$ Where: a =-3.389562e+009 b = 3378194.3 c = -841.71429 SE=1087.3815468 r=0.9134530	Quadratic Fit: $y = a + bx + cx^2$ Where: a =4.3700042e+009 b = -4353683.3 c = 1084.3571 SE= 538.0465195 r=0.9898150	Quadratic Fit: $y = a + bx + cx^2$ Where: a =6.0526458e+008 b = -602913.43 c = 150.14286 SE= 83.2613784 r=0.9923142
9	Dharmapuri	Quadratic Fit: $y = a + bx + cx^2$ Where: a =3.2453323e+009 b = -3233498.9 c = 805.42857 SE=2049.8040186 r=0.7624569	Saturation Growth-Rate Model: $y = \frac{ax}{(b+x)}$ Where: a = 102.2878 b = -1989.9121 SE=1427.7431696 r=0.6705804	Quadratic Fit: $y = a + bx + cx^2$ Where: a =2.3771725e+009 b = -2368283.4 c = 589.85714 SE= 141.2503349 r=0.9976424
10	Krishnagiri	Saturation Growth-Rate Model: $y = \frac{ax}{(b+x)}$ Where: a = 48.74027	Quadratic Fit: $y = a + bx + cx^2$ Where: a =2.5389341e+009 b = -2529302.2	Quadratic Fit: $y = a + bx + cx^2$ Where: a =9.4119911e+008 b = -937735.71

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		b = -1992.9109 SE= 564.9581785 r=0.8452760.	c = 629.92857 SE= 315.1166679 r=0.9914517	c = 233.57143 SE= 75.8004900 r=0.9947594
11	Coimbatore	Quadratic Fit: $y = a + bx + cx^2$ Where: a =-3.611354e+008 b = 359851.93 c = -89.642857 SE= 78.8850882 r=0.9514829	Linear Fit: $y = a + bx$ Where: a = 1792512.4 b = -891.6 SE=1140.2577486 r=0.8190485	Quadratic Fit: $y = a + bx + cx^2$ Where: a =4.7931096e+008 b = -477222.36 c = 118.78571 SE= 59.8867980 r=0.9981491
12	Thiruppur	Newly formed district. It has no data to process and hence omitted		
13	Erode	Quadratic Fit: $y = a + bx + cx^2$ Where: a =1.2303838e+009 b = -1225176.4 c = 305 SE= 224.7536429 r=0.9947346	Quadratic Fit: $y = a + bx + cx^2$ Where: a =1.8457344e+009 b = -1838841.2 c = 458 SE= 654.9238124 r=0.9207655	Logarithm Fit: $y = a + b * log(x)$ Where: a = -3067687.1 b = 403605.58 SE= 579.8141688 r=0.5350237
14	Tiruchirapalli	Exponential Fit: $y = ae^{bx}$ Where: a = 9.2118133e-017 b = 0.022763071 SE= 888.3654415 r=0.2898737	Saturation Growth-Rate Model: $y = \frac{ax}{(b+x)}$ Where: a = 755.8135 b = -1981.8883 SE=3358.8309585 r=0.7895731	Saturation Growth-Rate Model: $y = \frac{ax}{(b+x)}$ Where: a = 4.6025674 b = -2003.5755 SE=1499.9498967 r=0.7727203
15	Karur	Rice not cultivated in this season	Quadratic Fit: $y = a + bx + cx^2$ Where: a =3.3985579e+009 b = -3386250.3 c = 843.5 SE=1710.0211694 r=0.8189261	Quadratic Fit: $y = a + bx + cx^2$ Where: a =2.1588863e+008 b = -215085.51 c = 53.571429 SE= 81.5666248 r=0.9110592
16	Perambalur	Gaussian Model: $y = ae^{\frac{-(b-x)^2}{2c^2}}$ Where: a = 3155.3325 b = 2006.2877 c = 1.223665 SE= 803.1227162 r=0.8776631	Gaussian Model: $y = ae^{\frac{-(b-x)^2}{2c^2}}$ Where: a = 43055.881 b = 2005.3882 c = 1.8182356 SE=6782.4260734 r=0.9545845	Hyperbolic Fit: $y = a + \frac{b}{x}$ Where: a = 366562.7 b = -7.3282097e+008 SE=1011.8276980 r=0.3118982
17	Ariyalur	Newly formed district. It has no data to process and hence omitted		
18	Pudukottai	User-Defined Model: $y = a + b * x$ Where: a = 544601.52 b = -270.90001	Quadratic Fit: $y = a + bx + cx^2$ Where: a =4.4404662e+009 b = -4425305.1	Quadratic Fit: $y = a + bx + cx^2$ Where: a = -47800181 b = 47614.171

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		SE= 105.6609357 r=0.9779332	c = 1102.5714 SE=3448.2304612 r=0.6640203	c = -11.857143 SE= 37.0898523 r=0.8237899
19	Thanjavur	Hyperbolic Fit: $y = a + \frac{b}{x}$ Where: a = 452075.03 b =-8.5278799e+008 SE=8265.1625434 r=0.0467154	Saturation Growth-Rate Model: $y = \frac{ax}{(b+x)}$ Where: a = -4290.354 b = -2072.7895 SE=3179.7561814 r=0.7603522	Saturation Growth-Rate Model: $y = \frac{ax}{(b+x)}$ Where: a = -8.1583351 b = -2012.0108 SE= 602.0275783 r=0.9229136
20	Thiruvarur	Logarithm Fit: $y = a + b * log(x)$ Where: a = -6801594.8 b = 896950.64 SE=13174.5365883 r=0.0613353	Quadratic Fit: $y = a + bx + cx^2$ Where: a =1.744785e+009 b = -1739456.9 c = 433.57143 SE=1382.8651829 r=0.8584080	Quadratic Fit: $y = a + bx + cx^2$ Where: a =4.105273e+009 b = -4091756.3 c = 1019.5714 SE= 207.5579782 r=0.9979556
21	Nagapattinam	Hyperbolic Fit: $y = a + \frac{b}{x}$ Where: a = 1975008 b = -3.9069138e+009 SE=4518.4469613 r=0.3648908	Linear Fit: $y = a + bx$ Where: a = 909925.1 b = -387.5 SE=3259.3085514 r=0.2121232	Quadratic Fit: $y = a + bx + cx^2$ Where: a =7.2240924e+008 b = -719771.06 c = 179.28571 SE= 345.8650439 r=0.8434410
22	Madurai	Quadratic Fit: $y = a + bx + cx^2$ Where: a =-6.3849087e+009 b = 6362707 c = -1585.1429 SE=1795.3686133 r=0.9193692	Saturation Growth-Rate Model: $y = \frac{ax}{(b+x)}$ Where: a = 310.53959 b = -1994.8174 SE=3181.0254633 r=0.924904	Hyperbolic Fit: $y = a + \frac{b}{x}$ Where: a = 353497.84 b =-7.0222335e+008 SE= 357.0785864 r=0.6653966
23	Theni	Quadratic Fit: $y = a + bx + cx^2$ Where: a =2.8209436e+008 b = -281186.01 c = 70.071429 SE= 37.0069492 r=0.9899238	Quadratic Fit: $y = a + bx + cx^2$ Where: a =4.5825371e+008 b = -456404.33 c = 113.64286 SE= 229.1105784 r=0.9377955	User-Defined Model: $y = a + b * x$ Where: a = -326720.79 b = 162.99999 SE= 219.9733317 r=0.8041618
24	Dindigul	Saturation Growth-Rate Model: $y = \frac{ax}{(b+x)}$ Where: a = 5.4841938 b = -2001.5997	Saturation Growth-Rate Model: $y = \frac{ax}{(b+x)}$ Where: a = 319.68103 b = -1961.5876	Saturation Growth-Rate Model: $y = \frac{ax}{(b+x)}$ Where: a = 6.3306584 b = -2002.0926

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		SE= 155.9981397 r=0.9811653.	SE=1683.4326684 r=0.3027815	SE= 349.1344564 r=0.9572692
25	Ramanathapuram	Rice not cultivated in this season	Quadratic Fit: $y = a + bx + cx^2$ Where: a =5.7880025e+009 b = -5768621.3 c = 1437.3571 SE=2787.2685660 r=0.8411164	Saturation Growth-Rate Model: $y = \frac{ax}{(b+x)}$ Where: a = 6.7862166 b = -1999.2383 SE= 119.2505911 r=0.9648408
26	Virudhunagar	Rice not cultivated in this season	Linear Fit: $y = a + bx$ Where: a = 1377377.5 b = -672.5 SE=2447.3137314 r=0.4484271	Linear Fit: $y = a + bx$ Where: a = 420703.8 b = -208.4 SE= 469.5595099 r=0.6295630
27	Sivagangai	Rice not cultivated in this season	Quadratic Fit: $y = a + bx + cx^2$ Where: a =5.5541552e+009 b = -5532138.5 c = 1377.5714 SE=3143.8364961 r=0.9076624	Rice not cultivated in this season
28	Tirunelveli	Gaussian Model: $y = ae^{\frac{-(b-x)^2}{2c^2}}$ Where: a = 26376.013 b = 2007.136 c = 2.4711389 SE=2200.3048107 r=0.9106846	Saturation Growth-Rate Model: $y = \frac{ax}{(b+x)}$ Where: a = -1068.1103 b = -2043.1922 SE=5652.0152824 r=0.4697381	Saturation Growth-Rate Model: $y = \frac{ax}{(b+x)}$ Where: a = 5.9480122 b = -2004.0868 SE=2315.1486255 r=0.8938372
29	Thoothukudi	Saturation Growth-Rate Model: $y = \frac{ax}{(b+x)}$ Where: a = 151.58641 b = -1965.9526 SE= 990.7883960 r=0.3041219	Saturation Growth-Rate Model: $y = \frac{ax}{(b+x)}$ Where: a = -100.4256 b = -2026.1233 SE=1593.2949601 r=0.5357672	Gaussian Model: $y = ae^{\frac{-(b-x)^2}{2c^2}}$ Where: a = 3603.8834 b = 2006.4299 c = 1.2971632 SE= 637.4731849 r=0.9171349
30	The-Nilgiris	Quadratic Fit: $y = a + bx + cx^2$ Where: a =-1.0483882e+008 b = 104705.83 c = -26.142857 SE= 42.9378288	Rice not cultivated in this season	Rice not cultivated in this season

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		r=0.9966401		
31	Kanyakumari	Gaussian Model: $y = ae^{\frac{-(b-x)^2}{2c^2}}$ Where: a = 10771.465 b = 2004.4443 c = 6.4430537 SE= 284.0898809 r=0.9782834	Hyperbolic Fit: $y = a + \frac{b}{x}$ Where: a =-1433906.2 b =2.8981968e+009 SE= 114.2776838 r=0.9962374	Rice not cultivated in this season

Where SE – Standard Error and r – correlation coefficient

From table 1, it was found that the best fitting equation various from seasons to seasons and from the district to district depending upon the nature of area of rice cultivation in hectare with respect to years of rice cultivation. The more number of fits are found in the order of 1) Quadratic Fit, 2) Linear Fit 3) User-Defined Model 4) Saturation Growth-Rate Model 5) Logarithm Fit 6) Hyperbolic Fit 7) Exponential Fit and 8) Gaussian Model.

The nature of fit depends upon the coefficient of correlation (r). The value of r is 0.9981491 for Kodai season of Coimbatore district, which is very close to 1, it means the nature of fit is a perfect with highest reliability of 99.81% for prediction and simulation using the quadratic model developed. If the value of r is close to zero, then the model is not the best model and its reliability for prediction is poor. In the table 1, for Kuruvai season of Thanjavur district, the value of r is 0.0467154. It means the reliability of prediction using the hyperbolic fitting is only 4.67%. It is found that most of the fitting has more than 50% reliability and very few cases has poor fitting, which needs more input data for analysis to find the correct pattern of behaviour.

4.2.2 Best fitting models for rice production for all the districts during three seasons

The best fitting model connecting years (x) as independent variable and the rice production (y) as dependent variable for different districts of rice production during Kuruvai, Samba and Kodai seasons were done using curve expert software and is shown in Table 2.

.

Table 2: Best fitting model for rice production

	District	Kuruvai – rice production	Samba– rice production	Kodai – rice production
1	Kancheepuram	Quadratic Fit: $y = a + bx + cx^2$ Where: a =-1.3871188e+010 b = 13821687 c = -3443.0714 SE=3464.7662421 r=0.9394151	Quadratic Fit: $y = a + bx + cx^2$ Where: a =-5.1022184e+010 b = 50836157 c = -12662.643 SE=41198.7937160 r=0.6809555	Quadratic Fit: $y = a + bx + cx^2$ Where: a =1.7715959e+010 b = -17645532 c = 4393.8571 SE=2914.8146511 r=0.9916769
2	Thiruvallur	Quadratic Fit: $y = a + bx + cx^2$ Where: a =-3.4400411e+010 b = 34281651 c = -8540.7857 SE=10180.2940032 r=0.9125863	Quadratic Fit: $y = a + bx + cx^2$ Where: a =-1.8002776e+010 b = 17937323 c = -4468 SE=13217.5046363 r=0.7105419	Saturation Growth-Rate Model: $y = \frac{ax}{(b+x)}$ Where: a = 197.42837 b = -1998.2679 SE=8301.4791891 r=0.7588055

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3	Cuddalore	Quadratic Fit: $y = a + bx + cx^2$ Where: a =6.5116541e+009 b = -6485888.2 c = 1615.0714 SE=5163.3082530 r=0.8382550	Linear Fit: $y = a + bx$ Where: a = -15238047 b = 7700 SE=82719.8343873 r=0.1675473	Linear Fit: $y = a + bx$ Where: a = 1291200.9 b = -635.3 SE=1820.9775671 r=0.5372348
4	Villupuram	Saturation Growth-Rate Model: $y = \frac{ax}{(b+x)}$ Where: a = 386.34995 b = -1998.3419 SE=9987.8920141 r=0.8878347	Linear Fit: $y = a + bx$ Where: a = -2129409.4 b = 1237 SE=22359.6548214 r=0.1004939	Saturation Growth-Rate Model: $y = \frac{ax}{(b+x)}$ Where: a = 119.69224 b = -2000.0286 SE=8133.8383235 r=0.7363289
5	Vellore	Gaussian Model: $y = ae^{\frac{-(b-x)^2}{2c^2}}$ Where: a = 37502.553 b = 2008.003 c = 2.8587991 SE= 483.8331549 r=0.9985916.	Linear Fit: $y = a + bx$ Where: a = -3182795.2 b = 1613.9001 SE=6984.3258109 r=0.3887064	Saturation Growth-Rate Model: $y = \frac{ax}{(b+x)}$ Where: a = 219.76119 b = -1999.6333 SE=15111.6080050 r=0.6922441.
6	Thiruvannamalai	Saturation Growth-Rate Model: $y = \frac{ax}{(b+x)}$ Where: a = 715.87884 b = -1986.2656 SE=8549.1752757 r=0.5775305	Saturation Growth-Rate Model: $y = \frac{ax}{(b+x)}$ Where: a = 1118.2917 b = -1994.4858 SE=34863.8974163 r=0.6085882	Linear Fit: $y = a + bx$ Where: a = 1621076.5 b = -754.7 SE=24807.0350795 r=0.0554587
7	Salem	Quadratic Fit: $y = a + bx + cx^2$ Where: a =1.250018e+010 b = -12454424 c = 3102.2143 SE=4315.1006977 r=0.9104068	Saturation Growth-Rate Model: $y = \frac{ax}{(b+x)}$ Where: a = 1658.7837 b = -1958.9415 SE=16703.7801640 r=0.1412975	Quadratic Fit: $y = a + bx + cx^2$ Where: a =9.5186637e+009 b = -9484697.9 c = 2362.7143 SE=2428.7502611 r=0.9363828
8	Namakkal	Quadratic Fit: $y = a + bx + cx^2$ Where: a =-1.2402831e+010 b = 12359497 c = -3079.0714 SE=10734.9313600 r=0.6046721	Quadratic Fit: $y = a + bx + cx^2$ Where: a =1.4715317e+010 b = -14660975 c = 3651.7143 SE=4008.6395488 r=0.9464677	Quadratic Fit: $y = a + bx + cx^2$ Where: a =1.7260448e+009 b = -1719294.8 c = 428.14286 SE= 393.0412919 r=0.9809694
9	Dharmapuri	Quadratic Fit:	Gaussian Model:	Quadratic Fit:

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		$y = a + bx + cx^2$ Where: a =9.1154397e+009 b = -9084513.9 c = 2263.4286 SE=7664.0810610 r=0.6355731	$y = ae^{\frac{-(b-x)^2}{2c^2}}$ Where: a = 46655.287 b = 2006.8182 c = 3.9666421 SE=4848.4441875 r=0.6094944	$y = a + bx + cx^2$ Where: a =6.4592346e+009 b = -6435285 c = 1602.8571 SE= 345.1985763 r=0.9978800
10	Krishnagiri	Quadratic Fit: $y = a + bx + cx^2$ Where: a =6.0730068e+009 b = -6052458.6 c = 1508 SE= 972.2065622 r=0.9748071	Quadratic Fit: $y = a + bx + cx^2$ Where: a =5.1730376e+009 b = -5156050 c = 1284.7857 SE=1480.4048869 r=0.9423660	Quadratic Fit: $y = a + bx + cx^2$ Where: a =2.2338987e+009 b = -2225933.9 c = 554.5 SE= 255.3617042 r=0.9861086
11	Coimbatore	Gaussian Model: $y = ae^{\frac{-(b-x)^2}{2c^2}}$ Where: a = 6468.7172 b = 2007.3562 c = 1.9595669 SE= 264.8881852 r=0.9897040	Quadratic Fit: $y = a + bx + cx^2$ Where: a =-8.5114829e+009 b = 8483131.3 c = -2113.7143 SE=1321.7468093 r=0.9788308	Hyperbolic Fit: $y = a + \frac{b}{x}$ Where: a =-1974558.6 b =3.9688497e+009 SE=1658.7338162 r=0.7351699
12	Thiruppur	Newly formed district. It has no data to process and hence omitted		
13	Erode	Saturation Growth-Rate Model: $y = \frac{ax}{(b+x)}$ Where: a = 247.58621 b = -1996.2721 SE=2574.3466085 r=0.9519910	User-Defined Model: $y = a + b * x$ Where: a = -5146607.1 b = 2623.9004 SE=17124.3418355 r=0.2694082	User-Defined Model: $y = a + b * x$ Where: a = -1024356.7 b = 513.0999 SE=2121.7677143 r=0.4038979
14	Tiruchirapalli	Logarithm Fit: $y = a + b * log(x)$ Where: a = -14430152 b = 1900777.6 SE=3019.5668927 r=0.4969286	User-Defined Model: $y = a + b * x$ Where: a = -9006419.3 b = 4596.5 SE=27175.7867982 r=0.2950570	Saturation Growth-Rate Model: $y = \frac{ax}{(b+x)}$ Where: a = 26.145095 b = -2002.1593 SE=5427.8558798 r=0.5784679.
15	Karur	Rice not cultivated in this season	Quadratic Fit: $y = a + bx + cx^2$ Where: a =9.667602e+009 b = -9638306.3 c = 2402.2857 SE=6765.6708925 r=0.8682850	Quadratic Fit: $y = a + bx + cx^2$ Where: a =5.5265221e+008 b = -550607.43 c = 137.14286 SE= 217.5804613 r=0.8987622
16	Perambalur	Gaussian Model:	Quadratic Fit:	Saturation Growth-Rate

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		$y = ae^{\frac{-(b-x)^2}{2c^2}}$ Where: a = 8585.5609 b = 2006.7458 c = 1.4754603 SE= 540.9664491 r=0.9872764	$y = a + bx + cx^2$ Where: a =-3.1176081e+010 b = 31083675 c = -7747.8571 SE=21005.0044628 r=0.8929604	Model: $y = \frac{ax}{(b+x)}$ Where: a = -13.866651 b = -2014.7557 SE=2085.3351772 r=0.4087852
17	Ariyalur	Newly formed district. It has no data to process and hence omitted		
18	Pudukottai	Gaussian Model: $y = ae^{\frac{-(b-x)^2}{2c^2}}$ Where: a = 3898.5473 b = 2005.7047 c = 2.3179513 SE= 520.9259325 r=0.9422405	Saturation Growth-Rate Model: $y = \frac{ax}{(b+x)}$ Where: a = 1097.9956 b = -1996.0634 SE=45308.9709600 r=0.6078088	Quadratic Fit: $y = a + bx + cx^2$ Where: a =-2.2745933e+008 b = 226585.69 c = -56.428571 SE= 176.4180101 r=0.8002307
19	Thanajavur	Quadratic Fit: $y = a + bx + cx^2$ Where: a = -3.6123823e+010 b = 35995165 c = -8966.7143 SE=32878.4360089 r=0.5978485P	Linear Fit: $y = a + bx$ Where: a = 48308990 b = -23895.6 SE=108909.2751140 r=0.371857	Saturation Growth-Rate Model: $y = \frac{ax}{(b+x)}$ Where: a = -26.301516 b = -2011.9805 SE=1336.9649901 r=0.9626932
20	Thiruvarur	Hyperbolic Fit: $y = a + \frac{b}{x}$ Where: a = 14741116 b =-2.9458977e+010 SE=48251.8201462 r=0.2667021	Linear Fit: $y = a + bx$ Where: a = 2661561.4 b = -1181.8 SE=197553.5226417 r=0.0109213	Quadratic Fit: $y = a + bx + cx^2$ Where: a =1.227815e+010 b = -12239153 c = 3050.0714 SE= 222.3801128 r=0.9998217
21	Nagapattinam	Gaussian Model: $y = ae^{\frac{-(b-x)^2}{2c^2}}$ Where: a = 111755.2 b = 2007.6056 c = 2.1870287 SE=18839.4140761 r=0.8416800	Linear Fit: $y = a + bx$ Where: a = -20435712 b = 10306.9 SE=232688.8242229 r=0.0806077	Quadratic Fit: $y = a + bx + cx^2$ Where: a =2.0430858e+009 b = -2035671.6 c = 507.07143 SE=1351.6446702 r=0.7400011
22	Madurai	Quadratic Fit: $y = a + bx + cx^2$ Where: a =-2.752215e+010 b = 27425929 c = -6832.5 SE=7683.2588924 r=0.9204029	Saturation Growth-Rate Model: $y = \frac{ax}{(b+x)}$ Where: a = 2354.2097 b = -1982.455 SE=23528.8094029	Hyperbolic Fit: $y = a + \frac{b}{x}$ Where: a =2452383.5 b =-4.897007e+009 SE=2557.6749244 r=0.6554285

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			r=0.5154196	
23	Theni	Saturation Growth-Rate Model: $y = \frac{ax}{(b+x)}$ Where: a = -161.04523 b = -2019.236 SE=2594.7649256 r=0.8442289	Saturation Growth-Rate Model: $y = \frac{ax}{(b+x)}$ Where: a = -621.45162 b = -2037.0949 SE=3582.5315113 r=0.5705672	User-Defined Model: $y = a + b * x$ Where: a = -1099325.8 b = 548.50004 SE= 678.7312428 r=0.8277842
24	Dindigul	Linear Fit: $y = a + bx$ Where: a = 1220998.9 b = -604.3 SE=1759.8986619 r=0.5311614	Quadratic Fit: $y = a + bx + cx^2$ Where: a =6.6052998e+009 b = -6584592.2 c = 1641 SE=2858.3139088 r=0.9233027	User-Defined Model: $y = a + b * x$ Where: a = 3879971.4 b = -1927.2002 SE=2644.9761688 r=0.7993399
25	Ramanathapuram	Rice not cultivated in this season	Quadratic Fit: $y = a + bx + cx^2$ Where: a =1.4186619e+011 b =-1.4136616e+008 c = 35217 SE=86562.8849508 r=0.7351633	Saturation Growth-Rate Model: $y = \frac{ax}{(b+x)}$ Where: a = 19.827254 b = -2000.5996 SE= 620.4433723 r=0.9527623
26	Virudhunagar	Rice not cultivated in this season	Gaussian Model: $y = ae^{\frac{-(b-x)^2}{2c^2}}$ Where: a = 119166.47 b = 2006.3098 c = 2.1996714 SE=31888.6369435 r=0.7283510	Hyperbolic Fit: $y = a + \frac{b}{x}$ Where: a =-3087383.7 b =6.2128575e+009 SE= 330.8032185 r=0.9931708
27	Sivagangai	Rice not cultivated in this season	Quadratic Fit: $y = a + bx + cx^2$ Where: a =7.5903579e+010 b = -75630109 c = 18839.429 SE=26240.3193779 r=0.8976911	Rice not cultivated in this season
28	Tirunelveli	Gaussian Model: $y = ae^{\frac{-(b-x)^2}{2c^2}}$ Where: a = 108359.8 b = 2007.2511 c = 2.2487998 SE=8329.4578372	Exponential Fit: $y = ae^{bx}$ Where: a =1.0707657e-028 b = 0.038263333 SE=36748.0517464 r=0.4036699	Saturation Growth-Rate Model: $y = \frac{ax}{(b+x)}$ Where: a = 37.508174 b = -2002.5215 SE=9139.9342904

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		r=0.9440887		r=0.6549262
29	Thoothukudi	Saturation Growth-Rate Model: $y = \frac{ax}{(b+x)}$ Where: a = -384.50902 b = -2030.2731 SE=6031.8592010 r=0.3963505	Saturation Growth-Rate Model: $y = \frac{ax}{(b+x)}$ Where: a = -243.63815 b = -2017.4643 SE=9166.7550685 r=0.6730428	Linear Fit: $y = a + bx$ Where: a = 2873553.3 b = -1427.7 SE=4794.9353941 r=0.4776079
30	The-Nilgiris	Quadratic Fit: $y = a + bx + cx^2$ Where: a =-7.5158574e+008 b = 749649.79 c = -186.92857 SE= 413.6753730 r=0.9682446	Rice not cultivated in this season	Rice not cultivated in this season
31	Kanyakumari	Quadratic Fit: $y = a + bx + cx^2$ Where: a =-4.6177021e+009 b = 4602849.8 c = -1147 SE=1372.4398710 r=0.9474092	Saturation Growth-Rate Model: $y = \frac{ax}{(b+x)}$ Where: a = 247.19303 b = -1995.8921 SE= 869.4616473 r=0.9934423	Rice not cultivated in this season

Where SE – Standard Error and r – correlation coefficient

From table 2, it was found that the best fitting equation various from seasons to seasons and from the district to district depending upon the nature of rice production in tonnes with respect to years of rice production. The type of fits in table 2 in the order of 1) Quadratic Fit, 2) Linear Fit 3) User-Defined Model 4) Saturation Growth-Rate Model 5) Logarithm Fit 6) Hyperbolic Fit 7) Exponential Fit and 8) Gaussian Model.

The nature of fit depends upon the coefficient of correlation (r). The value of r is 0.9998217for Kodai season of Thiruvarur district, which is very close to 1, it means the nature of fit is a perfect with highest reliability of 99.98% for prediction and simulation using the quadratic model developed. If the value of r is close to zero, then the model is not the best model and its reliability for prediction is poor. In the table 2, for Samba season of Thiruvarur district, the value of r is 0.0109213. It means the reliability of prediction using the linear fitting is only 1.09%. It is found that most of the fitting has more than 50% reliability and few cases has poor fitting, which needs more input data for analysis to find the correct pattern of behaviour.

4.3 Prediction from the best fitting models developed

Table A.1 in the appendix shows the observed data of area of cultivation, which is same as the FFBPNN method of predicted area of cultivation due to zero absolute relative error and zero RMSE between the observed data and FFBPNN predicted data. In the best fitted models noted in the above section 4.2.1 for area of rice cultivation for different districts during the three seasons, the best predicted of area of rice cultivation in hectare is obtained by inserting x = (2005, 2006, 2007, 2008 and 2009). The best predicted area of cultivation from the best fitted model is shown in Table A.2 in the appendix.

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Similarly, Table A.4 in the appendix shows the observed data of rice production, which is same as the FFBPNN method of predicted rice production due to zero absolute relative error and zero RMSE between the observed data and FFBPNN predicted data. In the best fitted models noted in the above section 4.2.2 for rice production for different districts during the three seasons, the best predicted rice production in tonnes is obtained by inserting x = (2005, 2006, 2007, 2008 and 2009. The predicted rice production from the best fitted model is shown in Table A.5 in the appendix.

4.4 Relative error between the predicted data of FFBPNN and the best fitted models

The variation between the FFBPNN method of predicted data and the best fitted method of predicted data were studied by computing the percentage relative error. The relative error percent for area of cultivation for five years and their mean error percent are shown in Table A.3 in the appendix. From table A.3, the following information was found:

- During Kuruvai season, 25 districts are cultivating rice with the minimum relative error in area of cultivation is 32.10, the maximum relative error in area of cultivation is 1.51, the five year mean error in area of cultivation is -2.40. The standard deviation of relative error in the area of cultivation is 6.64.
- During Samba season, 28 districts are cultivating rice with the minimum relative error in area of cultivation is 19.08, the maximum relative error in area of cultivation is 3.06, the five year mean error in area of cultivation is -1.22. The standard deviation of relative error in the area of cultivation is 3.76.
- During Kodai season, 23districts are cultivating rice with the minimum relative error in area of cultivation is -25.14, the maximum relative error in area of cultivation is 3.82, the five year mean error in area of cultivation is -3.76. The standard deviation of relative error in the area of cultivation is 6.52.

The relative error percent for rice production for five years and their mean error percent are shown in Table A.6 in the appendix. From table A.6, the following information was found:

- During Kuruvai season, 25 districts are cultivating rice with the minimum relative error in rice production is -35.65, the maximum relative error in rice production is 2.19, the five year mean error in rice production is -2.33. The standard deviation of relative error in the rice production is 7.19.
- During Samba season, 28 districts are cultivating rice with the minimum relative error in rice production is -74.62, the maximum relative error in rice production is 1.14, the five year mean error in rice production is -8.80. The standard deviation of relative error in the rice production is 20.73.
- During Kodai season, 23 districts are cultivating rice with the minimum relative error in rice production is -31.22, the maximum relative error in rice production is 3.72, the five year mean error in rice production is -4.98. The standard deviation of relative error in the in rice production is 7.71.

The five years mean errors are in the range of -1.22 to -8.80%. The minus sign indicates that the observed data (FFBPNN predicted data) is lower than the predicted data from the best predicted models. The conclusion from the study reveals the fact that the best predicted models and their predicted data is 1 to 9% higher than the observed data. It may be a natural increase in area of cultivation and improvement in rice production technology.

V. CONCLUSIONS AND FUTURE WORKS

The prediction of rice production is a major information needed for the policy makers of the Tamilnadu Government. The present research successfully developed an architecture called FFBPNN. The software developed to implement the FFBPNN architecture was tested with the testing data and training data. It was found that at 18th iteration, there was zero error between the observed data and the predicted data because the RMSE is zero and the ARE is also zero. Rice production is a complex task of soil, water, crop variety, crop husbandry, crop protection etc. The rice production in the state varies every year. The variation in area of cultivation and rice production for 31 districts in three seasons are captured by integrating the curve expert software into the FFBPNN software. The curve expert produced the best fitting model to different districts during the three seasons. These developed models were used to simulate the best predicted area of rice cultivation and rice production. The type of fits are found to be 1) Quadratic Fit, 2) Linear Fit 3) User-Defined Model 4) Saturation Growth-Rate Model 5) Logarithm Fit 6) Hyperbolic Fit 7) Exponential Fit and 8) Gaussian Model.

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The value of r is 0.9981491 for area of cultivation data in the Kodai season of Coimbatore district, which is very close to 1, it means the nature of fit is a perfect with highest reliability of 99.81% for prediction and simulation using the quadratic model developed. Similarly, it is found that the value of r is 0.9998217for rice production data in the Kodai season of Thiruvarur district, which is very close to 1, it means the nature of fit is a perfect with highest reliability of 99.98% for prediction and simulation using the quadratic model developed. The low r value of 0.0467154 was found for the area of rice cultivation data in the Kuruvai season of Thanjavur district. It means the reliability of prediction using the hyperbolic fitting is only 4.67%. It is found that most of the fitting has more than 50% reliability and very few cases has poor fitting, which needs more input data for analysis to find the correct pattern of behaviour. It was also found that the best predicted models and their predicted data gives 1 to 9% higher than the observed data. It may be a natural increase in area of cultivation for every year or it may be improvement in rice production technology. The research has to be continued in future so as to predict the rice production, which is a complex process.

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Appendix

Table A.1: FFBPNN method of predicted area of rice cultivation in different districts for three seasons

S,No	Districts	Observed area of rice in Ha for Kuruvai					Observed area of rice cultivation in Ha for Samba					Observed area of rice cultivation in Ha for Kodai				
		2005	2006	2007	2008	2009	2005	2006	2007	2008	2009	2005	2006	2007	2008	2009
1	Kancheepuram	19408	23911	18453	17044	18546	67709	65034	60437	61791	60625	27603	14162	12466	12039	11849
2	Thiruvallur	39196	44682	39031	39812	37197	39047	29668	29615	31119	31644	18751	15317	10066	11309	12101
3	Cuddalore	23555	21336	17896	17646	18779	85331	79079	79760	85548	88010	5405	5025	5142	4623	4728
4	Villupuram	35918	28374	28594	25942	24880	115530	107964	105715	109978	114085	16987	8445	11094	10721	9489
5	Vellore	7245	10079	10489	10230	9741	19942	16728	17667	18110	16309	30976	14880	16170	19077	13715
6	Thiruvannamalai	27958	23108	20831	18540	21958	75525	63095	58947	40212	57727	39261	25256	32370	43134	25492
7	Salem	10058	8423	6072	7806	7858	23052	17771	14609	19749	13963	4218	1289	1030	2374	2561
8	Namakkal	5463	7023	6971	7613	2934	12174	7661	5197	6192	7540	1196	538	37	104	213
9	Dharmapuri	10082	7673	3890	8093	7329	14106	11089	13710	10919	10658	4835	2300	1201	1356	2323
10	Krishnagiri	8031	7910	6564	5930	6641	11935	8955	7662	7954	8591	2014	1025	756	737	1258
11	Coimbatore	1206	1470	1544	1623	1257	4545	3803	4550	939	1519	1655	948	385	11	41
12	Thiruppur	This district is started recently and hence there is no sufficient data for prediction analysis														
13	Erode	12787	10849	9962	8945	9207	29525	26745	27091	26607	27448	1227	954	1307	2501	1459
14	Tiruchirapalli	6066	6997	5120	6953	6816	66579	62906	53207	61962	55341	6931	1819	2962	3615	2139
15	Karur	Rice not cultivated in this season					17711	13341	12121	15190	14580	687	404	312	438	421
16	Perambalur	2033	2637	3262	512	764	42669	38261	34183	8854	10166	1250	1032	676	3033	1159
17	Ariyalur	This district is started recently and hence there is no sufficient data for prediction analysis														
18	Pudukottai	1499	1079	997	534	417	94268	91989	87396	95505	94593	219	297	272	347	292
19	Thanjavur	23440	33264	20922	37177	22037	128668	128954	126227	135261	135621	2793	2025	3079	4656	5280
20	Thiruvarur	10416	32214	9034	30932	13270	141455	142804	140645	143724	145489	4227	1882	1950	3384	7493
21	Nagapattinam	24213	30774	25189	34389	27252	132608	134051	128826	135764	129814	1279	889	25	687	789
22	Madurai	5564	8924	10342	11600	3944	62455	54353	48088	51371	43081	2977	3953	3434	3728	3961
23	Theni	5307	5161	5155	5372	5605	10204	9554	9054	9349	9097	183	200	191	858	669
24	Dindigul	3250	2451	2139	1520	1630	16092	12944	12785	15469	13421	4393	3212	2352	2649	1596
25	Ramanathapuram	Rice not cultivated in this season					127395	128005	122184	127196	132451	2346	2118	1587	1599	1434
26	Virudhunagar	Rice not cultivated in this season					27779	30503	25683	29434	24951	2997	2232	2520	2810	1666
27	Sivagangai	Rice not cultivated in this season					89924	81232	76623	80748	77332	Rice not cultivated in this season				
28	Tirunelveli	19131	22527	25551	27075	18604	53947	64760	54637	57651	65628	13319	4597	3523	6594	1762
29	Thoothukudi	7940	7970	6030	8168	6995	10167	9865	8663	12985	11317	1825	3541	3363	1248	1237
30	The-Nilgiris	1430	1249	1110	775	509	Rice not cultivated in this season					Rice not cultivated in this season				
31	Kanyakumari	10669	10538	10121	8928	8534	11566	10868	10228	9259	8773	Rice not cultivated in this season				
	No. of districts cultivating rice in Kuruvai season = 25						No. of districts cultivating rice in Samba season = 28					No. of districts cultivating rice in Kodai = 26				

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Table A.2: Predicted area of rice cultivation based on the best fitting model using Curve Expert software

S,No	Districts	Predicted area using best fitting model in Kuruvai					Predicted area using best fitting model in Samba					Predicted area using best fitting model in Kodai				
		2005	2006	2007	2008	2009	2005	2006	2007	2008	2009	2005	2006	2007	2008	2009
1	Kancheepuram	21191	20332	19472	18613	17754	67906	64243	61861	60761	60942	26522	17208	11861	10482	13070
2	Thiruvallur	41757	40870	39984	39097	38210	37849	31935	29073	29264	32506	19005	14071	11273	10609	12081
3	Cuddalore	24037	20593	18562	17945	18741	84581	80935	80508	83300	89312	5352	5155	4972	4801	4642
4	Villupuram	34407	31032	28263	25950	23989	115190	108705	106485	108530	114840	14973	12587	10859	9549	8522
5	Vellore	7484	9566	10603	9541	10594	19527	17609	17061	17885	20079	28240	21436	17277	14472	12452
6	Thiruvannamalai	28411	23214	20377	19900	21784	77545	61990	52906	50295	54155	35035	34069	33103	32137	31171
7	Salem	10056	7956	6921	6952	8049	21695	19354	17471	15923	14628	3942	2040	1257	3050	1594
8	Namakkal	5083	7161	7556	6267	3295	11834	7507	5349	5360	7539	1204	513	123	33	244
9	Dharmapuri	9993	7068	5754	6050	7958	13593	12754	12014	11355	10766	4732	2366	1179	1172	2345
10	Krishnagiri	8084	7470	6943	6486	6086	11789	9130	7731	7592	8713	1999	1119	705	759	1279
11	Coimbatore	1193	1488	1603	1539	1295	4854	3963	3071	2180	1288	1652	879	344	46	-14
12	Thiruppur	Newly formed district. It has no data to process and hence omitted														
13	Erode	12743	10922	9710	9109	9117	29244	27441	26554	26582	27527	1087	1289	1490	1691	1892
14	Tiruchirapalli	6103	6243	6387	6534	6685	65569	62881	60407	58122	56006	6478	3808	2697	2089	1705
15	Karur	Rice not cultivated in this season					17136	14164	12879	13282	15371	666	456	352	356	467
16	Perambalur	1814	3069	2664	1185	271	42086	40686	29067	15345	5987	1066	1248	1430	1612	1794
17	Ariyalur	Newly formed district. It has no data to process and hence omitted														
18	Pudukottai	1447	1176	905	634	363	94067	91176	90489	92009	95733	221	276	307	315	299
19	Thanjavur	26744	26956	27168	27380	27591	126895	128859	130883	132970	135121	2333	2723	3268	4084	5444
20	Thiruvarur	18279	18726	19173	19620	20067	141903	141501	141967	143299	145499	4136	1880	1664	3487	7349
21	Nagapattinam	26423	27394	28364	29334	30302	132988	132600	132213	131825	131438	1301	645	347	409	828
22	Madurai	4748	9447	10976	9334	4522	61147	55706	51159	47302	43989	3262	3436	3611	3785	3959
23	Theni	5306	5177	5187	5338	5629	10167	9584	9228	9100	9199	94	257	420	583	746
24	Dindigul	3234	2500	2038	1721	1489	14764	14439	14128	13831	13546	4366	3250	2589	2152	1841
25	Ramanathapuram	Rice not cultivated in this season					128269	124887	124380	126748	131990	2362	2013	1755	1555	1397
26	Virudhunagar	Rice not cultivated in this season					29015	28342	27670	26998	26325	2862	2653	2445	2237	2028
27	Sivagangai	Rice not cultivated in this season					88975	82275	78331	77141	78707	Rice not cultivated in this season				
28	Tirunelveli	18154	23731	26336	24812	19845	56073	57610	59231	60944	62758	13059	6237	4098	3052	2432
29	Thoothukudi	7784	7593	7412	7239	7074	9532	10011	10540	11127	11782	1963	3411	3272	1732	506
30	The-Nilgiris	1430	1277	1072	814	504	Rice not cultivated in this season					Rice not cultivated in this season				
31	Kanyakumari	10731	10462	9957	9250	8389	11578	10858	10138	9419	8700	Rice not cultivated in this season				
		No. of districts cultivating rice in Kuruvai = 25					No. of districts cultivating rice in Samba = 28					No. of districts cultivating rice in Kodai = 23				

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Table A.3: ARE percent between FFBPNN and the best fitting model of predicted area of rice cultivation in different districts for three seasons

S,No	Districts	% Error in Area of Kuruvai season					Mean	% Error in Area of Samba season					Mean	% Error in Area of Kodai season					Mean
		2005	2006	2007	2008	2009	Error	2005	2006	2007	2008	2009	Error	2005	2006	2007	2008	2009	Error
1	Kancheepuram	-9.18	14.97	-5.52	-9.21	4.27	-0.94	-0.29	1.22	-2.36	1.67	-0.52	-0.06	3.92	-21.51	4.85	12.93	-10.30	-2.02
2	Thiruvallur	-6.53	8.53	-2.44	1.80	-2.72	-0.27	3.07	-7.64	1.83	5.96	-2.73	0.10	-1.35	8.13	-11.99	6.19	0.16	0.23
3	Cuddalore	-2.05	3.48	-3.72	-1.69	0.20	-0.75	0.88	-2.35	-0.94	2.63	-1.48	-0.25	0.98	-2.58	3.31	-3.86	1.81	-0.07
4	Villupuram	4.21	-9.37	1.16	-0.03	3.58	-0.09	0.29	-0.69	-0.73	1.32	-0.66	-0.09	11.85	-49.05	2.12	10.93	10.19	-2.79
5	Vellore	-3.30	5.09	-1.08	-3.56	2.05	-0.16	2.08	-5.26	3.43	1.24	-23.12	-4.33	8.83	-44.06	-6.85	24.14	9.21	-1.74
6	Thiruvannamalai	-1.62	-0.46	2.18	-7.34	0.79	-1.29	-2.67	7.75	10.25	-25.07	6.19	-1.91	10.76	-34.89	-2.26	25.50	-22.28	-4.63
7	Salem	0.02	5.55	-13.99	10.94	-2.43	0.02	5.89	-8.91	-19.59	19.37	-4.76	-1.60	6.55	-58.26	-22.09	32.84	-19.11	-12.01
8	Namakkal	6.96	-1.97	-8.39	17.67	-12.32	0.39	2.79	2.00	-2.93	13.44	0.02	3.06	-0.64	4.61	-232.62	68.05	-14.40	-35.00
9	Dharmapuri	0.89	7.89	-47.91	25.24	-8.58	-4.50	3.64	-15.02	12.37	-4.00	-1.01	-0.80	2.13	-2.86	1.82	13.56	-0.94	2.74
10	Krishnagiri	-0.66	5.57	-5.78	-9.38	8.36	-0.38	1.23	-1.95	-0.90	4.55	-1.42	0.30	0.73	-9.13	6.74	-2.94	-1.70	-1.26
11	Coimbatore	1.04	-1.22	-3.82	5.18	-3.06	-0.37	-6.81	-4.20	32.50	-132.12	15.21	-19.08	0.18	7.26	10.69	-319.3	134.24	-33.39
12	Thiruppur	This district is started recently and hence there is no sufficient data for prediction analysis																	
13	Erode	0.34	-0.67	2.53	-1.83	0.97	0.27	0.95	-2.60	1.98	0.09	-0.29	0.03	11.39	-35.07	-13.98	32.40	-29.66	-6.98
14	Tiruchirapalli	-0.61	10.77	-24.75	6.03	1.93	-1.33	1.52	0.04	-13.53	6.20	-1.20	-1.40	6.53	-109.35	8.93	42.22	20.31	-6.27
15	Karur	Rice not cultivated in this season						3.25	-6.17	-6.26	12.56	-5.42	-0.41	3.01	-12.82	-12.96	18.67	-10.96	-3.01
16	Perambalur	10.78	-16.39	18.35	-131.52	64.59	-10.84	1.37	-6.34	14.97	-73.31	41.11	-4.44	14.72	-20.95	-111.56	46.85	-54.76	-25.14
17	Ariyalur	This district is started recently and hence there is no sufficient data for prediction analysis																	
18	Pudukottai	3.47	-9.00	9.21	-18.78	12.85	-0.45	0.21	0.88	-3.54	3.66	-1.20	0.00	-0.72	7.16	-12.94	9.24	-2.38	0.07
19	Thanjavur	-14.10	18.96	-29.85	26.35	-25.20	-4.77	1.38	0.07	-3.69	1.69	0.37	-0.03	16.46	-34.45	-6.13	12.28	-3.10	-2.99
20	Thiruvarur	-75.49	41.87	-112.24	36.57	-51.22	-32.10	-0.32	0.91	-0.94	0.30	-0.01	-0.01	2.16	0.09	14.66	-3.04	1.92	3.16
21	Nagapattinam	-9.13	10.98	-12.61	14.70	-11.19	-1.45	-0.29	1.08	-2.63	2.90	-1.25	-0.04	-1.72	27.45	-1289.84	40.53	-4.96	-254.7
22	Madurai	14.66	-5.86	-6.13	19.53	-14.66	1.51	2.09	-2.49	-6.39	7.92	-2.11	-0.19	-9.57	13.07	-5.15	-1.53	0.05	-0.62
23	Theni	0.01	-0.31	-0.63	0.63	-0.43	-0.14	0.37	-0.31	-1.92	2.66	-1.12	-0.07	48.53	-28.59	-119.99	32.03	-11.54	-15.91
24	Dindigul	0.50	-2.00	4.71	-13.20	8.66	-0.27	8.25	-11.55	-10.51	10.59	-0.93	-0.83	0.62	-1.19	-10.08	18.77	-15.37	-1.45
25	Ramanathapuram	Rice not cultivated in this season						-0.69	2.44	-1.80	0.35	0.35	0.13	-0.66	4.94	-10.57	2.74	2.61	-0.19
26	Virudhunagar	Rice not cultivated in this season						-4.45	7.08	-7.74	8.28	-5.51	-0.47	4.51	-18.88	2.98	20.41	-21.74	-2.55
27	Sivagangai	Rice not cultivated in this season						1.06	-1.28	-2.23	4.47	-1.78	0.05	Rice not cultivated in this season					
28	Tirunelveli	5.11	-5.35	-3.07	8.36	-6.67	-0.32	-3.94	11.04	-8.41	-5.71	4.37	-0.53	1.95	-35.67	-16.32	53.71	-38.03	-6.87
29	Thoothukudi	1.97	4.73	-22.91	11.37	-1.14	-1.20	6.24	-1.48	-21.66	14.31	-4.11	-1.34	-7.56	3.66	2.70	-38.81	59.08	3.82
30	The-Nilgiris	-0.03	-2.26	3.44	-5.04	0.97	-0.58	Rice not cultivated in this season						Rice not cultivated in this season					
31	Kanyakumari	-0.59	0.72	1.62	-3.61	1.70	-0.03	-0.11	0.09	0.88	-1.73	0.83	-0.01	Rice not cultivated in this season					
		Minimum Mean Error					-32.10	Minimum Mean Error					-19.08	Minimum Mean Error					-25.14
		Maximum Mean Error					1.51	Maximum Mean Error					3.06	Maximum Mean Error					3.82
		Average of 5 years mean errors					-2.40	Average of 5 years mean errors					-1.22	Average of 5 years mean errors					-3.76
		Std deviation of mean error					6.64	Std deviation of mean error					3.76	Std deviation of mean error					6.52
		No. of districts taken up for prediction					25	No. of districts taken up for prediction studies					28	No. of districts taken up for prediction					23

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Table A.4: FFBPNN method of predicted rice production in different districts for three seasons

S,No	Districts	Kuruvai Rice Production, tonnes					Samba Rice Production, tonnes					Kodai Rice Production, tonnes				
		2005	2006	2007	2008	2009	2005	2006	2007	2008	2009	2005	2006	2007	2008	2009
1	Kancheepuram	59873	75921	73959	75880	65885	150367	259966	224461	206455	218666	83635	59247	46709	46875	46883
2	Thiruvallur	131182	147022	155448	161389	118686	82774	112342	95886	114794	95404	57626	59104	34673	39681	42204
3	Cuddalore	73958	70800	65342	56311	66245	128440	303320	252016	153782	241709	15947	18264	17761	13789	15008
4	Villupuram	122825	86433	95498	81289	74401	335200	381646	348547	337294	363561	53906	28034	36284	32556	29869
5	Vellore	21859	28817	35617	37469	35249	53912	49127	58762	66332	53379	91680	51249	53988	68072	47206
6	Thiruvannamalai	80459	62284	78566	63224	63557	203421	213751	194535	117503	179153	109648	90016	112813	137217	82274
7	Salem	39236	30964	18766	27313	30384	82209	63971	49664	85384	65453	15846	4876	3653	7686	10627
8	Namakkal	20314	21444	24247	38457	12330	44973	34213	20928	28489	32868	3562	2021	125	355	748
9	Dharmapuri	29504	23617	14919	32687	29411	41917	44334	51007	39873	41900	13969	8121	4469	5167	8364
10	Krishnagiri	25197	20531	21302	21803	27828	27530	27012	24059	27407	32732	5070	3494	2311	3093	4416
11	Coimbatore	3636	5044	6190	6407	4403	11786	15139	16920	14859	5337	5243	3826	1346	4171	144
12	Thiruppur	This district is started recently and hence there is no sufficient data for prediction analysis														
13	Erode	58343	47898	48275	40890	40378	116124	109409	115005	146638	110629	5097	4292	3580	8793	5412
14	Tiruchirapalli	21891	24317	21150	28857	24356	193532	251782	196197	219729	232541	21317	6345	9985	13798	9375
15	Karur	Rice not cultivated in this season					46179	46754	39221	58664	62567	2046	1518	1058	1494	1478
16	Perambalur	4628	7021	8790	6034	2440	106671	121675	85408	101049	35864	3263	3287	1230	6711	4068
17	Ariyalur	This district is started recently and hence there is no sufficient data for prediction analysis														
18	Pudukottai	3861	3452	3851	2099	1460	228055	279417	154779	176487	185964	652	1116	922	1184	1025
19	Thanavur	68044	103851	78049	134675	66501	323251	487409	390235	208459	343248	8188	6900	11359	14027	17393
20	Thiruvarur	27547	84289	32232	129352	41548	203938	495508	271846	62738	414414	11965	6578	7228	14521	27163
21	Nagapattinam	66486	73038	101547	127348	81893	66445	554229	187685	95456	347366	3706	3340	85	2343	2770
22	Madurai	19811	35994	41112	47709	15325	207136	216704	161836	205990	174024	7545	14820	11932	13529	14267
23	Theni	24015	22611	24780	32100	30383	40615	40771	36069	45266	44979	655	827	813	2926	2348
24	Dindigul	8044	10706	8816	5805	7473	52116	54106	50050	54604	63776	15144	16436	8971	12252	7600
25	Ramanathapuram	Rice not cultivated in this season					247079	214277	24500	197535	229846	8931	7957	5379	5454	5034
26	Virudhunagar	Rice not cultivated in this season					87021	148896	84510	96928	59640	11461	9318	8541	6664	5076
27	Sivagangai	Rice not cultivated in this season					192738	108961	78566	131821	138095	Rice not cultivated in this season				
28	Tirunelveli	69911	87814	105078	110704	75424	206949	280193	207825	236438	272985	32205	17271	11041	27072	7468
29	Thoothukudi	32564	31668	25963	41726	34508	41360	45981	34165	60401	56256	7892	16351	4607	6036	5911
30	The-Nilgiris	4716	3995	4287	3046	1783	Rice not cultivated in this season					Rice not cultivated in this season				
31	Kanyakumari	43497	44059	46583	42399	38286	54111	50071	43627	41258	37951	Rice not cultivated in this season				
		No. of districts cultivating rice in Kuruvai = 25					No. of districts cultivating rice in Samba = 28					No. of districts cultivating rice in Kodai = 26				

Table A.5: Predicted rice production based on the best fitting model using Curve Expert software

S,No	Districts	Predicted area using best fitting model in Kuruvai					Predicted area using best fitting model in Samba					Predicted area using best fitting model in Kodai				
		2005	2006	2007	2008	2009	2005	2006	2007	2008	2009	2005	2006	2007	2008	2009
1	Kancheepuram	61330	72858	77499	75255	66124	169359	215655	236625	232271	202591	82728	60957	47974	43778	48370
2	Thiruvallur	127221	151781	159259	149655	122970	84915	101090	108329	106632	95999	58799	51220	45377	40735	36958
3	Cuddalore	75664	67827	63220	61844	63697	200453	208153	215853	223553	231253	17424	16789	16154	15518	14883
4	Villupuram	116344	101202	89558	80325	72825	350776	352013	353250	354487	355724	48273	40209	34458	30151	26803
5	Vellore	21600	29340	35264	37503	35290	53075	54688	56302	57916	59530	82103	69242	59872	52742	47135
6	Thiruvannamalai	76615	72769	69294	66139	63261	213252	194828	179349	166161	154790	107903	107148	106394	105639	104884
7	Salem	38921	27479	22241	23207	30378	72210	70710	69273	67895	66572	14964	7114	3988	5588	11914
8	Namakkal	16480	25822	29005	26031	16898	44904	30955	24309	24967	32929	3727	1713	555	254	809
9	Dharmapuri	28888	22986	21612	24763	32442	42003	45673	46606	44630	40106	13788	7563	4544	4730	8122
10	Krishnagiri	25007	21136	20282	22443	27621	27984	25209	25004	27369	32303	5093	3259	2533	2917	4409
11	Coimbatore	3140	5091	6363	6129	4550	11028	16051	16847	13415	5756	4918	3931	2945	1960	976
12	Thiruppur	Newly formed district. It has no data to process and hence omitted														
13	Erode	56876	51055	46319	42391	39080	114313	116937	119561	122185	124809	4409	4922	5435	5948	6461
14	Tiruchirapalli	22219	23167	24114	25061	26007	209563	214160	218756	223353	227949	18454	13656	10840	8989	7678
15	Karur	Rice not cultivated in this season					46440	43701	45767	52638	64314	2039	1511	1258	1279	1575
16	Perambalur	4263	7556	8459	5982	2672	108137	115157	106681	82710	43243	2850	3177	3588	4122	4840
17	Ariyalur	Newly formed district. It has no data to process and hence omitted														
18	Pudukottai	3722	3867	3335	2388	1419	246344	221663	201496	184707	170514	712	963	1101	1126	1038
19	Thanjavur	67171	96845	108586	102393	78266	398312	374416	350521	326625	302730	7555	8822	10599	13268	17728
20	Thiruvarur	48359	55684	63001	70311	77613	292052	290871	289689	288507	287325	11515	6198	6982	13865	26849
21	Nagapattinam	54960	85356	107552	109953	91200	229622	239929	250236	260543	270850	4067	2259	1465	1686	2920
22	Madurai	16832	37604	44710	38152	17928	209368	200575	192499	185056	178173	9986	11204	12420	13635	14849
23	Theni	22682	24407	26415	28781	31608	38823	40091	41444	42890	44439	417	965	1514	2062	2611
24	Dindigul	9377	8773	8169	7564	6960	53464	50923	51664	55686	62991	15935	14008	12081	10153	8226
25	Ramanathapuram	Rice not cultivated in this season					259625	148852	108513	138608	239137	9034	7365	6217	5380	4742
26	Virudhunagar	Rice not cultivated in this season					99807	117990	113442	88705	56411	11298	9754	8210	6669	5129
27	Sivagangai	Rice not cultivated in this season					186021	120861	93381	103579	151457	Rice not cultivated in this season				
28	Tirunelveli	65656	92823	107686	102515	80082	222788	231477	240506	249887	259634	30343	21630	16809	13748	11631
29	Thoothukudi	30504	31777	33159	34665	36312	39191	42631	46729	51692	57827	11015	9587	8159	6732	5304
30	The-Nilgiris	4564	4444	3949	3081	1838	Discarded due to insufficient data					Rice not cultivated in this season				
31	Kanyakumari	43074	45307	45246	42890	38241	54417	49058	44663	40995	37886	Rice not cultivated in this season				
		No. of districts cultivating rice in Kuruvai = 25					No. of districts cultivating rice in Samba = 28					No. of districts cultivating rice in Kodai = 23				

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Table A.6: ARE percent between FFBPNN and the best fitting model of predicted rice production in different districts for three seasons

S,No	Districts	% Error in Area of Kuruvai season					Mean Error	% Error in Area of Samba season					Mean Error	% Error in Area of Kodai season					Mean Error
		2005	2006	2007	2008	2009		2005	2006	2007	2008	2009		2005	2006	2007	2008	2009	
1	Kancheepuram	-2.43	4.03	-4.79	0.82	-0.36	-0.54	-12.63	17.04	-5.42	-12.50	7.35	-1.23	1.08	-2.89	-2.71	6.61	-3.17	-0.22
2	Thiruvallur	3.02	-3.24	-2.45	7.27	-3.61	0.20	-2.59	10.02	-12.98	7.11	-0.62	0.19	-2.04	13.34	-30.87	-2.66	12.43	-1.96
3	Cuddalore	-2.31	4.20	3.25	-9.83	3.85	-0.17	-56.07	31.38	14.35	-45.37	4.33	-10.28	-9.26	8.08	9.05	-12.54	0.83	-0.77
4	Villupuram	5.28	-17.09	6.22	1.19	2.12	-0.46	-4.65	7.76	-1.35	-5.10	2.16	-0.23	10.45	-43.43	5.03	7.39	10.26	-2.06
5	Vellore	1.18	-1.82	0.99	-0.09	-0.12	0.03	1.55	-11.32	4.19	12.69	-11.52	-0.88	10.45	-35.11	-10.90	22.52	0.15	-2.58
6	Thiruvannamalai	4.78	-16.83	11.80	-4.61	0.47	-0.88	-4.83	8.85	7.81	-41.41	13.60	-3.20	1.59	-19.03	5.69	23.01	-27.48	-3.24
7	Salem	0.80	11.26	-18.52	15.03	0.02	1.72	12.16	-10.53	-39.48	20.48	-1.71	-3.82	5.56	-45.89	-9.17	27.29	-12.11	-6.86
8	Namakkal	18.87	-20.42	-19.62	32.31	-37.05	-5.18	0.15	9.52	-16.16	12.36	-0.18	1.14	-4.63	15.24	-344.38	28.38	-8.20	-62.72
9	Dharmapuri	2.09	2.67	-44.86	24.24	-10.31	-5.23	-0.20	-3.02	8.63	-11.93	4.28	-0.45	1.29	6.87	-1.67	8.46	2.89	3.57
10	Krishnagiri	0.75	-2.95	4.79	-2.94	0.75	0.08	-1.65	6.67	-3.93	0.14	1.31	0.51	-0.45	6.74	-9.61	5.70	0.15	0.50
11	Coimbatore	13.65	-0.93	-2.79	4.34	-3.34	2.19	6.43	-6.02	0.43	9.72	-7.85	0.54	6.21	-2.74	-118.80	53.00	-578.02	-128.07
12	Thiruppur	This district is started recently and hence there is no sufficient data for prediction analysis																	
13	Erode	2.51	-6.59	4.05	-3.67	3.22	-0.10	1.56	-6.88	-3.96	16.68	-12.82	-1.08	13.51	-14.67	-51.81	32.36	-19.38	-8.00
14	Tiruchirapalli	-1.50	4.73	-14.02	13.15	-6.78	-0.88	-8.28	14.94	-11.50	-1.65	1.97	-0.90	13.43	-115.22	-8.56	34.86	18.10	-11.48
15	Karur	Rice not cultivated in this season						-0.56	6.53	-16.69	10.27	-2.79	-0.65	0.36	0.45	-18.91	14.38	-6.54	-2.05
16	Perambalur	7.88	-7.62	3.76	0.86	-9.53	-0.93	-1.37	5.36	-24.91	18.15	-20.57	-4.67	12.66	3.35	-191.74	38.58	-18.98	-31.22
17	Ariyalur	This district is started recently and hence there is no sufficient data for prediction analysis																	
18	Pudukottai	3.59	-12.02	13.40	-13.75	2.80	-1.20	-8.02	20.67	-30.18	-4.66	8.31	-2.78	-9.25	13.71	-19.40	4.91	-1.26	-2.26
19	Thanjavur	1.28	6.75	-39.12	23.97	-17.69	-4.96	-23.22	23.18	10.18	-56.69	11.80	-6.95	7.74	-27.86	6.69	5.41	-1.93	-1.99
20	Thiruvarur	-75.55	33.94	-95.46	45.64	-86.80	-35.65	-43.21	41.30	-6.56	-359.86	30.67	-67.53	3.76	5.77	3.41	4.52	1.16	3.72
21	Nagapattinam	17.34	-16.86	-5.91	13.66	-11.37	-0.63	-245.58	56.71	-33.33	-172.95	22.03	-74.62	-9.75	32.36	-1623.9	28.06	-5.41	-315.73
22	Madurai	15.03	-4.47	-8.75	20.03	-16.99	0.97	-1.08	7.44	-18.95	10.16	-2.38	-0.96	-32.35	24.40	-4.09	-0.78	-4.08	-3.38
23	Theni	5.55	-7.94	-6.60	10.34	-4.03	-0.54	4.41	1.67	-14.90	5.25	1.20	-0.47	36.37	-16.72	-86.20	29.52	-11.19	-9.64
24	Dindigul	-16.58	18.05	7.34	-30.31	6.86	-2.93	-2.59	5.88	-3.22	-1.98	1.23	-0.14	-5.22	14.77	-34.66	17.13	-8.24	-3.24
25	Ramanathapuram	Rice not cultivated in this season						-5.08	30.53	-342.91	29.83	-4.04	-58.33	-1.15	7.44	-15.58	1.36	5.80	-0.43
26	Virudhunagar	Rice not cultivated in this season						-14.69	20.76	-34.24	8.48	5.41	-2.85	1.42	-4.68	3.87	-0.07	-1.04	-0.10
27	Sivagangai	Rice not cultivated in this season						3.49	-10.92	-18.86	21.42	-9.68	-2.91	Rice not cultivated in this season					
28	Tirunelveli	6.09	-5.70	-2.48	7.40	-6.18	-0.18	-7.65	17.39	-15.73	-5.69	4.89	-1.36	5.78	-25.24	-52.24	49.22	-55.75	-15.65
29	Thoothukudi	6.32	-0.34	-27.72	16.92	-5.23	-2.01	5.24	7.28	-36.77	14.42	-2.79	-2.52	-39.57	41.37	-77.11	-11.53	10.27	-15.31
30	The-Nilgiris	3.22	-11.23	7.88	-1.14	-3.11	-0.87	Rice not cultivated in this season						Rice not cultivated in this season					
31	Kanyakumari	0.97	-2.83	2.87	-1.16	0.12	-0.01	-0.56	2.02	-2.38	0.64	0.17	-0.02	Rice not cultivated in this season					
		Minimum to Maximum Mean Error					-35.65	Minimum Mean Error					-74.62	Minimum Mean Error					-31.22
		Maximum Mean Error					2.19	Maximum Mean Error					1.14	Maximum Mean Error					3.72
		Average of 5 years mean errors					-2.33	Average of 5 years mean errors					-8.80	Average of 5 years mean errors					-4.98
		Std deviation of mean error					7.19	Std deviation of mean error					20.73	Std deviation of mean error					7.71
		No. of districts taken up for prediction					25	No. of districts taken up for prediction studies					28	No. of districts taken up for prediction					23