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Performance Evaluation of Hybrid Feed Forward Back Propagation Neural Network system for prediction of rice production in Cauvery River Basin of Tamilnadu

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Abstract: This paper discuss the use of hybrid Feed Forward Back Propagation Neural Network (FFBPNN) in predicting the area of rice cultivation and rice production in the seven districts of Cauvery River Basin (CRB) in Tamilnadu. The hybrid FFBPNN was already designed and developed by the researcher was put into use for the seven districts of CRB. This paper provides the various best fitting models incorporated with the FFBPNN system. It compares the observed area of rice cultivation with the predicted area of rice cultivation and also observed rice production with the predicted rice production the seven districts of CRB. The Average Relative Error (ARE) between the observed and predicted data from the hybrid system was computed for 3 seasons each having 5 years for 7 districts totaling 210 data items. The computed ARE % was arranged as a frequency distribution and discussed. It was found that 49% of the ARE % computed between the observed and predicted data is having 0 to 10% error and 18.1% of the ARE % are within the class interval of 10 to 20% error. It was found that only 5.2% of ARE % between the observed and predicted data is having more than 100% error. The high error percent was a small portion of the study carried out. It can be reduced if more input data are taken for predictions.

Keywords: Cauvery River Basin, Hybrid FFBPNN, Rice prediction system.

I. INTRODUCTION

The Cauvery River Basin (CRB) is an important river basin in India in terms of agriculture and food security. The basin spans two southern Indian states, Karnataka and Tamil Nadu. The TamilNadu Cauvery River Basin (CRB) contributes 40% of the food grain production of Tamil Nadu. Rice is the major crop and is primarily irrigated using water from the Cauvery River. During the season of Kuruvai (June-October), the beginning of crop activity depends upon the release of water from the Mettur Reservoir.

Due to large variations in rainfall in the catchment as well as in the delta area of the basin, water availability during rice cultivation is becoming highly uncertain in Kuruvai, Samba and Kodai seasons. The effect of global warming is also one of the reason for increasing the variability of rainfall distribution [Bhuvaneswari et al. [5]. Rice production and its prediction are very important input for the state planners for food security [ArunBalaji et al. [1]]. Hence, cultivating rice in the Kuruvai, Samba and Kodai seasons are challenging issues in the CRB. In this context, a research was conducted with the overall objective of using the Feed Forward Back Propagation Neural Network (FFBPNN) to predict the rice production in Kuruvai, Samba and Kodaiseasons in the seven districts of CRB. The specific objectives of this paper are 1) To use the hybrid FFBPNN system developed by the researcher for the seven districts of CRB 2) To predict the area of rice cultivation and rice production in the seven districts of CRB and 3) To carry out the statistical testing of predicted data with observed data using Absolute Relative Error (ARE).

II. RELATED WORKS

The researcher has published papers for the development of FFBPNN to predict area of cultivation of rice and rice production for three seasons in Tamilnadu [ArunBalaji et al. [1] to [4]. The brief results of the research published by the authors are given.

ArunBalaji et al. [1] stated that prediction of annual rice production in all the 31 districts of Tamilnadu is an important decision for the Government of Tamilnadu. Rice production is a complex process and nonlinear problem involving soil, crop, weather, pest, disease, capital, labourand management parameters. ANN software was designed and developed with Feed Forward Back Propagation (FFBP) network to predict rice production. The input layer has six independent variables like area of cultivation and rice production in three seasons like Kuruvai, Samba and Kodai. The sigmoid activation function was adopted to convert input data into sigmoid values. The hidden layer computes the summation of six sigmoid values with six sets of weights. The final output

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was converted into sigmoid values using a sigmoid transfer function. ANN outputs are the predicted results. The error between original data and ANN output values were computed. A threshold value of 10^{-9} was used to test whether the error is greater than the threshold level. If the error is greater than threshold then updating of weights was done all summations were done by back propagation. This process was repeated until error equal to zero. The predicted results were printed and it was found to be exactly matching with the expected values. It shows that the ANN prediction was 100% accurate

ArunBalaji et al. [2]stated the development of Multiple linear regression (MLR) equations between the years of rice cultivation and FFBPNN method of predicted area of rice cultivation / rice production for different districts pertaining to Kuruvai, Samba and Kodai seasons in Tamilnadu. The paired t test between the FFBPNN and MLR methods of predicted area of cultivation in Kuruvai shows that there is no significant difference between the two types of prediction for certain districts however it has significant variation for years.

ArunBalaji et al. [3] stated that 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. 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.

ArunBalaji and ManimegalaiVairavan, [4] reported that statistical error analyses have been used to assess the performance of the error reduction pattern of the FFBPNN model. It was found that R^2 is a poor statistical measure in the reduction of error for the prediction of rice production. It was also found that RMSE is a much better statistical measure compared to MSE because more data sets get zero error compared to MSE. It was established that ARE is zero for all the data items for the three seasons at the 9th iteration itself. Hence, ARE is the best statistical measure used in FFBPNN system to predict rice production. The predicted results were printed and it was found to be matching with the expected values columns.

III. METHODOLOGY ADOPTED

3.1 Description of study area

The Cauvery River Basin (Fig. 1.) is located in southern India and covers an area of 81,155km^2. Of this area, 44,016km^2 lies in the state of Tamil Nadu from 10.00 to 11.30° N latitude and 78.15 to 79.45° E longitude; the rest is located in the state of Karnataka. The Cauvery River Basin (CRB) includes seven districts like Cuddalore, Trichirapali, Perambalur, Pudukottai, Thanjavur, Thriuvarur and Nagappatinam.

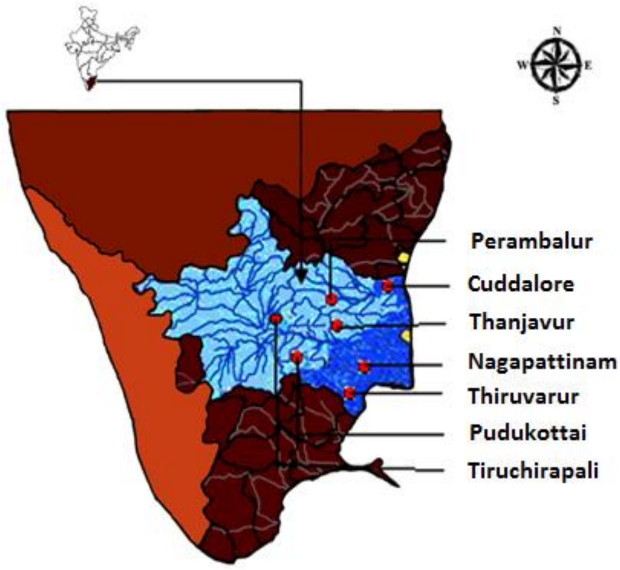

Fig. 1. Location of Cauvery river basin in India
(Courtesy: Bhuvaneswari et al. (2013))

3.2 Methodology adopted

The methodology adopted as per Arun Balaji et al. [1] to [4] and Makinde et al. [6] were used in this study also. Readers of this paper are requested to refer the author's publications cited in reference.

IV. RESULTS AND DISCUSSIONS

The main purpose of this research is to get more realistic prediction by incorporating best fitting models from the curve expert software into the FFBPNN prediction system. The curve expert fits more than 30 models and rank them with highest correlation coefficient. The output from the FFBPNN was given as input into the curve expert so as to produce the best fitting models. The predicted data from the best fitting models were compared with the observed data.

4.1 Use of hybrid FFBPNN system developed with incorporation of best fitting models

The hybrid FFBPNN system was developed by incorporating the best fitting models prepared from Curve Expert Software into the output of FFBPNN system as shown in Fig. 2. The predicted output from FFBPNN system contains the area of rice cultivation and rice production for different districts of CRB. The predicted output from FFBPNN was given as input into the best fitting models so as to get the more realitic prediction of area of rice cultivation and rice production for the seven districts of CRB in three seasons. A software program developed by the resercher [Arun Balaji et al. 2013, 2014 and 2015] in C language was used to predict the data using

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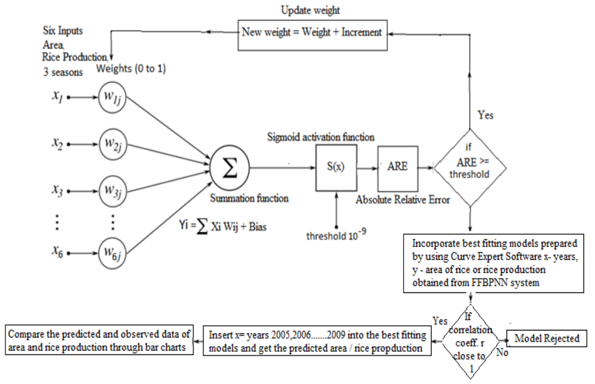
FFBPNN archetecture developed. The intermediate and final predictions were stored in a output file for detailed analysis.



`Fig. 2. Development of Hybrid FFBPNN system

4.1.1 Best fitting models for area of rice cultivation and rice production in CRB

The best fitting model connecting years (x) as independent variable and the area of rice cultivation (y) as dependent variable or rice production as dependent variable for different districts during Kuruvai, Samba and Kodai seasons were done using curve expert software for the in 7 districts of the CRB and is shown in Table A1 in the Appendix. From table A1, 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 or rice production in tones with respect to years of rice cultivation.

4.2 Prediction of area of rice cultivation and rice production from the hybrid system

The FFBPNN output containing the area of rice cultivation and rice production in 7 districts of CRB for the three seasons were computed by inserting x (years) from 2005 to 2009 and the results were compared with the observed data in this section.

4.2.1 Prediction of area of rice cultivation from the hybrid system

The observed and predicted area of rice cultivation from the hybrid system for five years with three seasons for all the seven districts of Cauvery River Basin was compared by preparing a bar charts from Figure 3 to Figure 9 below:

4.2.1.1 Comparison of area of rice cultivation for Cuddalore district

The observed and predicted area of rice cultivation from the hybrid system for Cuddalore district is shown in Fig. 3.

By referring Fig. 3, it is noticed that there is no matching of observed area of rice cultivation with the predicted area of cultivation for the Cuddalore district. The minimum difference of 38 hectare was found between the observed area of rice cultivation and the predicted area of cultivation for the year 2009-10 for Kuruvai season.

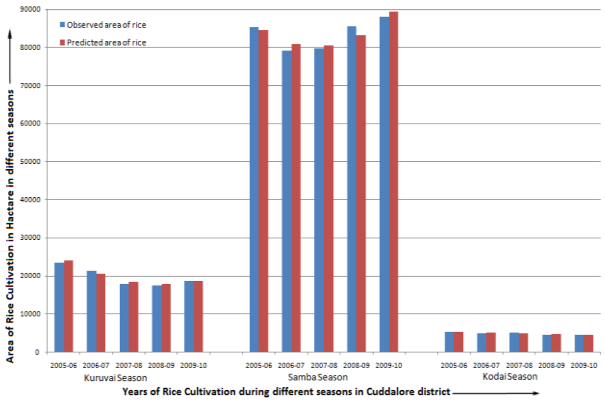


Fig 3 Comparison of observed and predicted area of rice cultivation in Cuddalore district

It is followed by the Samba season with 52 hectare during the year 2005-06. The maximum difference of 2248 hectare was found between the observed area of rice cultivation and the predicted area of cultivation for the year 2009-09 for Samba season. The average difference of area was found to be 649.9 ha. Hence, there is a need to take more input data for better convergence between the observed and predicted data.

4.2.1.2 Comparison of area of rice cultivation for Tiruchirapali district:

The observed and predicted area of rice cultivation from the hybrid system for Tiruchirapali district is shown in Fig. 4.

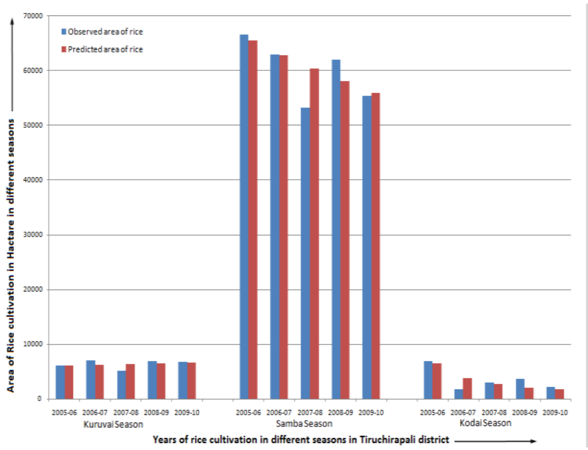


Fig. 4. Comparison of observed and predicted area of rice cultivation in Tiruchirapali district

By referring Fig. 4, it is noticed that there is no matching of observed area of rice cultivation with the predicted area of cultivation for the Tiruchirapali district. The minimum difference of 25 hectare was found between the observed area of rice cultivation and the predicted area of cultivation for the year 2006-07 for Samba season. It is followed by the Samba season with 37 hectare during the year 2005-06 for the Kuruvai season. The maximum difference of 7200 hectare was found between the observed area of rice cultivation and the predicted area of cultivation for the year 2007-08 for Samba season. The

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average difference of area was found to be 649.9 ha. Hence, there is a need to take more input data for better convergence between the observed and predicted data.

4.2.1.3 Comparison of area of rice cultivation for Perambalur district

The observed and predicted area of rice cultivation from the hybrid system for Perambalur district is shown in Fig. 5.

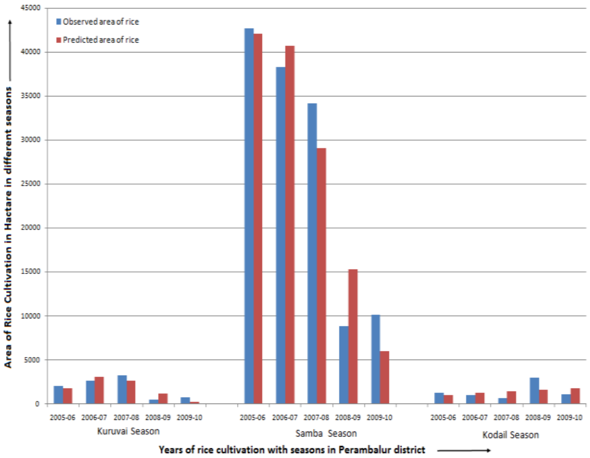

Fig. 5.Comparison of observed and predicted area of rice cultivation in Perambalur district

By referring Fig. 5, it is noticed that there is no matching of observed area of rice cultivation with the predicted area of cultivation for the Perambalur district. The minimum difference of 184 hectare was found between the observed area of rice cultivation and the predicted area of cultivation for the year 2005-06 for Kodai season. It is followed by the same Kodai season with 216 hectare during the year 2006-07. The maximum difference of 6491 hectare was found between the observed area of rice cultivation and the predicted area of cultivation for the year 2008-09 for Samba season. The average difference of area was found to be 1627.9 ha.

4.2.1.4 Comparison of area of rice cultivation for Pudukottai district

The observed and predicted area of rice cultivation from the hybrid system for Pudukottai district is shown in Fig. 6. By referring Fig. 6, it is noticed that there is no matching of observed area of rice cultivation with the predicted area of cultivation for the Pudukottai district. The minimum difference of 2 hectare was found between the observed area of rice cultivation and the predicted area of cultivation for the year 2005-06 for Kodai season. It is followed by the same Kodai season with 7 hectare during the year 2009-10. There is little variation between the observed and predicted data for Kodai and Kuruvai seasons. The maximum difference of 3496 hectare was found between the observed area of rice cultivation and the predicted area of cultivation for the year 2008-09 for Samba season. The average difference of area was found to be 615.7 ha.

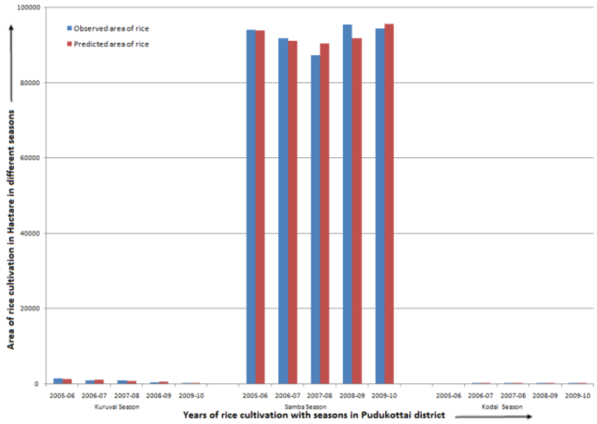

Fig. 6. Comparison of observed and predicted area of rice cultivation in Pudukottai district

4.2.1.5 Comparison of area of rice cultivation for Thanjavur district

The observed and predicted area of rice cultivation from the hybrid system for Thanjavur district is shown in Fig. 7.

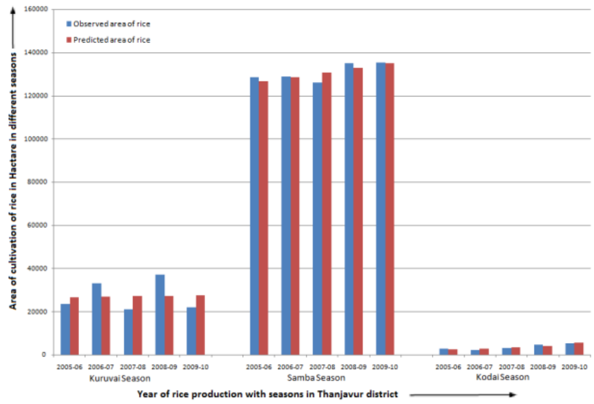

Fig.7. Comparison of observed and predicted area of rice cultivation in Thanjavur district

By referring Fig. 7, it is noticed that there is no matching of observed area of rice cultivation with the predicted area of cultivation for the Thanjavur district. With regard to the Kuruvai season, the minimum difference of 3304 hectare was found between the observed area of rice cultivation and the predicted area of cultivation for the year 2005-06 and the maximum difference of 9797 hectare was found for the year 2008-09.

With regard to the Samba season, the minimum difference of 95 hectare was found between the observed area of rice cultivation and the predicted area of cultivation for the year 2006-07 and the maximum difference of 4656 hectare was found for the year 2007-08. With regard to the Kodai season, the minimum difference of 164 hectare was found between the observed area of rice cultivation and the predicted area of cultivation for the year 2009-10 and the maximum difference of 698 hectare was found for the year 2006-07. Hence, it is concluded that the variation of observed and predicted area is not so high in Thanjavur district.

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4.2.1.6 Comparison of area of rice cultivation for Thiruvarur district

The observed and predicted area of rice cultivation from the hybrid system for Thiruvarur district is shown in Fig. 8.

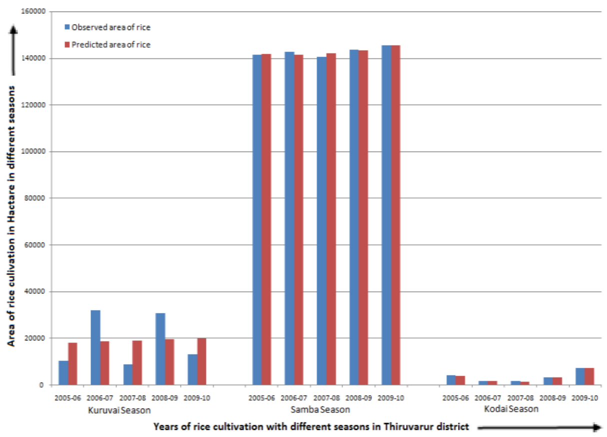

Fig. 8. Comparison of observed and predicted area of rice cultivation in Thiruvarur district

By referring Fig.8, it is noticed that there is no matching of observed area of rice cultivation with the predicted area of cultivation for the Thiruvarur district. With regard to the Kuruvai season, the minimum difference of 6797 hectare was found between the observed area of rice cultivation and the predicted area of cultivation for the year 2009-10 and the maximum difference was found to be 13488 hectare for the year 2006-07. With regard to the Samba season, the minimum difference of 10 hectare was found between the observed area of rice cultivation and the predicted area of cultivation for the year 2009-10 and the maximum difference was found to be 1322 hectare for the year 2007-08. With regard to the Kodai season, the minimum difference of 2 hectare was found between the observed area of rice cultivation and the predicted area of cultivation for the year 2006-07 and is followed by 91 hectare in 2005-06 and the maximum difference was found to be 286 hectare for the year 2007-08. Hence, it is concluded that the variation of observed and predicted area is very less in Thiruvarur district during the Samba and Kodai seasons but the variation is high for the Kuruvai season.

4.2.1.7 Comparison of area of rice cultivation for Nagapattinam district

The observed and predicted area of rice cultivation from the hybrid system for Nagapattinam district is shown in Fig. 9. By referring Fig. 9, it is noticed that there is no matching of observed area of rice cultivation with the predicted area of cultivation for the Nagapattinam district. The minimum difference of 22 hectare was found between the observed area of rice cultivation and the predicted area of cultivation for the year 2005-06 for Kodai season. It is followed by the same Kodai season with 39 hectare during the year 2009-10. There is little variation between the observed and predicted data for Kodai season. The maximum difference of 5055 hectare was found between the observed area of rice cultivation and the predicted area of cultivation for the year 2008-09 for Kuruvai season.

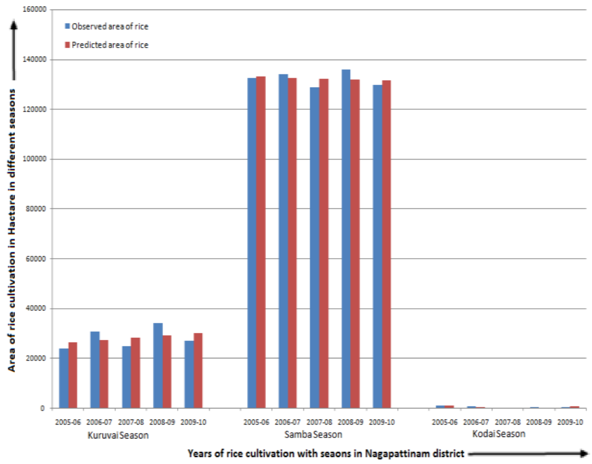

Fig. 9. Comparison of observed and predicted area of rice cultivation in Nagapattinam district

The minimum variation in Kuruvai is 2210 ha during 2005-06. With regard to the Samba season, the maximum difference of 3939 hectare was found between the observed area of rice cultivation and the predicted area of cultivation for the year 2008-09 and the minimum variation is 380 hectare during 2005-06. Hence, it is concluded that the variation of observed and predicted area is very little in Nagapattinam district during the Kodai season. There is a variation of 380 to 5055 hectare during Kuruvai and Samba seasons because of late onset of monsoon and water storage level in Mettur dam etc.

4.2.2 Prediction of area of rice production from the hybrid system

The observed and predicted rice production from hybrid system for five years with three seasons for all the seven districts of CRB was compared by preparing charts from Fig. 10 to 16.

4.2.2.1 Comparison of rice production for Cuddalore district

The observed and predicted area of rice production from the hybrid system for Cuddalore district is shown in Fig. 10. By referring Fig. 10, it is noticed that there is no matching of observed rice production with the predicted rice production for the Cuddalore district. The minimum difference of 125 tonnes was found between the observed rice production and the predicted rice production for the year 2009-10 for Kodai season. It is followed by the Samba season with 1475 tonnes during the year 2006-07 and 1477 tonnes during 2005-06 in the same Kodai season. The minimum and maximum difference of 10456 tonnes during 2009-10 and 95167 tonnes during 2006-07 was noticed in the Samba season. With regard to Kuruvai season, it was found that the minimum rice production is 1706 tonnes during 2005-06 and the maximum rice production is 2973 tonnes during 2006-07.

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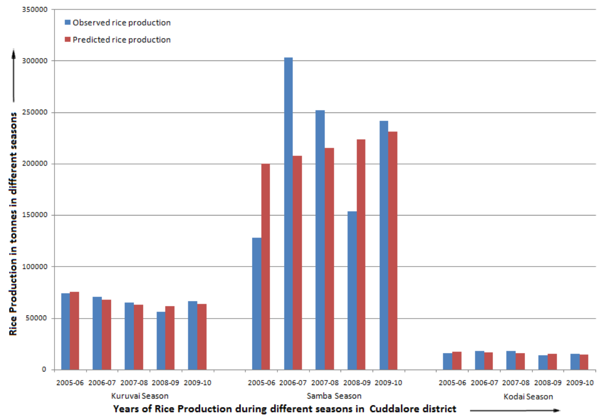

Fig. 10.Comparison of observed and predicted rice production in Cuddalore district

The average difference of rice production was found to be 20324.3 tonnes in Cuddalore district. Hence, there is a need to take more input data for better convergence between the observed and predicted data during the Samba season.

4.2.2.2 Comparison of rice production for Tiruchirapali district

The observed and predicted area of rice production from the hybrid system for Tiruchirapali district is shown in Fig. 11.

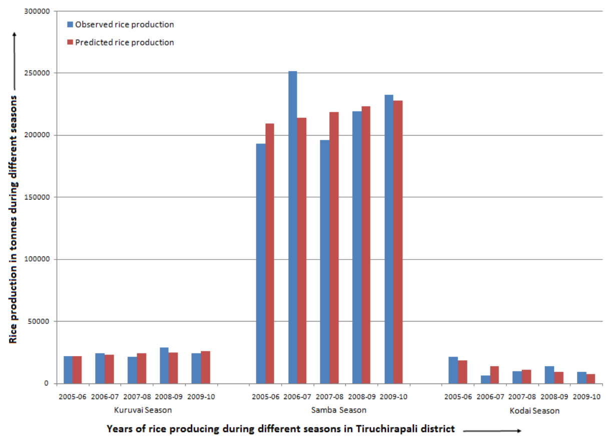

Fig. 11. Comparison of observed and predicted rice production in Tiruchirapali district

By referring Fig. 11, it is noticed that there is no matching of observed rice production with the predicted rice production for the Tiruchirapali district. The minimum difference of 328 tonnes was found between the observed rice production and the predicted rice production for the year 2005-06 for Kuruvai season. It is followed by the Kodai season with 855 tonnes during the year 2007-08. The minimum and maximum difference of 3624 tonnes during 2008-09 and 37622 tonnes during 2006-07 was noticed in the Samba season. With regard to Kuruvai season, it was found that the minimum rice production is 328 tonnes during 2005-06 and the maximum rice production is 3796 tonnes during 2008-09. The average difference of rice production was found to be 7456.8 tonnes in Tiruchirapali district. Hence, there is a need to take more input data for better convergence between the observed and predicted data during the three seasons.

4.2.2.3 Comparison of rice production for Perambalur district

The observed and predicted area of rice production from the hybrid system for Perambalur district is shown in Fig. 12.

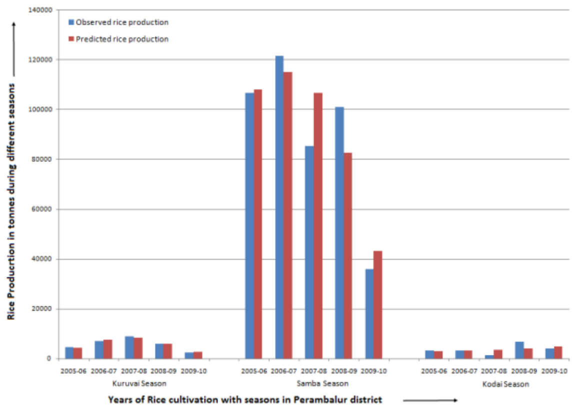

Fig. 12.Comparison of observed and predicted rice production in Perambalur district

By referring Fig. 12, it is noticed that there is no matching of observed rice production with the predicted rice production for the Perambalur district. With regard to the Kuruvai season, the minimum difference of 52 tonnes was found between the observed rice production and the predicted rice production for the year 2008-09 and the maximum difference was found to be 535 tonnes during 2006-07. With regard to the Samba season, the minimum difference of 1466 tonnes was found between the observed rice production and the predicted rice production for the year 2005-06 and the maximum difference was found to be 18339 tonnes during 2008-09. With regard to the Kodai season, the minimum difference of 110 tonnes was found between the observed rice production and the predicted rice production for the year 2006-07 and the maximum difference was found to be 2589 tonnes during 2008-09. The average difference of rice production was found to be 4182.1 tonnes in Perambalur district.

4.2.2.4 Comparison of rice production for Pudukottai district

The observed and predicted area of rice production from the hybrid system for Pudukottai district is shown in Fig. 13.By referring Fig. 13, it is noticed that there is no matching of observed rice production with the predicted rice production for the Pudukottai district. With regard to the Kuruvai season, the minimum difference of 41 tonnes was found between the observed rice production and the predicted rice production for the year 2009-10 and the maximum difference was found to be 516 tonnes during 2007-08. With regard to the Samba season, the minimum difference of 8220 tonnes was found between the observed

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rice production and the predicted rice production for the year 2008-09 and the maximum difference was found to be 57764 tonnes during 2007-07. With regard to the Kodai season, the minimum difference of 13 tonnes was found between the observed rice production and the predicted rice production for the year 2009-10 and the maximum difference was found to be 179 tonnes during 2007-08. The average difference of rice production was found to be 9886.2 tonnes in Pudukottai district.

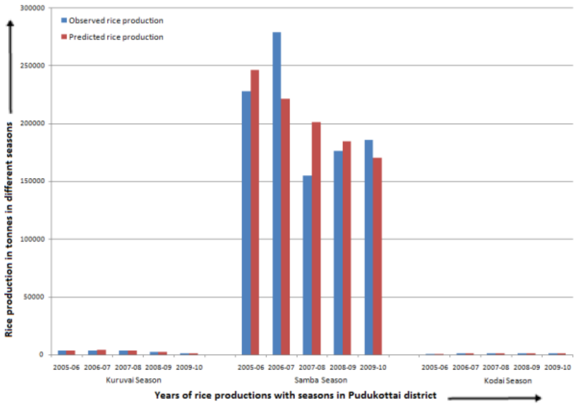

Fig.13. Comparison of observed and predicted rice production in Pudukottai district

4.2.2.5 Comparison of rice production for Thanjavur district

The observed and predicted area of rice production from the hybrid system for Thanjavur district is shown in Fig. 14.

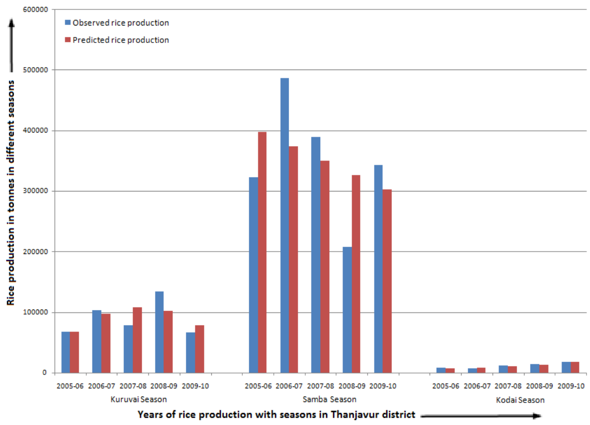

Fig. 14.Comparison of observed and predicted rice production in Thanjavur district

By referring Fig. 14, it is noticed that there is no matching of observed rice production with the predicted rice production for the Thanjavur district. With regard to the Kuruvai season, the minimum difference of 873 tonnes was found between the observed rice production and the predicted rice production for the year 2005-06 and the maximum difference was found to be 32282 tonnes during 2008-09. With regard to the Samba season, the minimum difference of 39714 tonnes was found between the observed rice production and the predicted rice production for the year 2007-08 and the maximum difference was found to be 118166 tonnes during 2008-09. With regard to the Kodai season, the minimum difference of 335 tonnes was found between the observed rice production and the predicted rice production for the year 2009-10 and the maximum difference was found to be 1922 tonnes during 2006-07. The average difference of rice production was found to be 31554.9 tonnes in Thanjavur district. The rice production varies widely because of late monsoon rainfall and scarcity of water during the growth stage of the crop.

4.2.2.6 Comparison of rice production for Thiruvarur district

The observed and predicted area of rice production from the hybrid system Thiruvarur district is shown in Fig. 15.

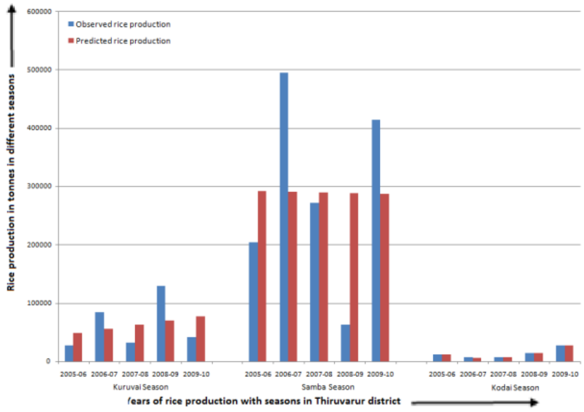

Fig 15 Comparison of observed and predicted rice production in Thiruvarur district

By referring Fig. 15, it is noticed that there is no matching of observed rice production with the predicted rice production for the Thiruvarur district. With regard to the Kuruvai season, the minimum difference of 20812 tonnes was found between the observed rice production and the predicted rice production for the year 2005-06 and the maximum difference was found to be 59041 tonnes during 2008-09. With regard to the Samba season, the minimum difference of 17843 tonnes was found between the observed rice production and the predicted rice production for the year 2007-08 and the maximum difference was found to be 225769 tonnes during 2008-09. With regard to the Kodai season, the minimum difference of 314 tonnes was found between the observed rice production and the predicted rice production for the year 2009-10 and the maximum difference was found to be 656 tonnes during 2008-09. The average difference of rice production was found to be 56052.7 tonnes in Thiruvarur district. The rice production varies widely because of late monsoon rainfall and scarcity of water during the growth stage of the crop.

4.2.2.7 Comparison of rice production for Nagapattinam district

The observed and predicted area of rice production from the hybrid system for Nagapattinam district is shown in Fig. 16.

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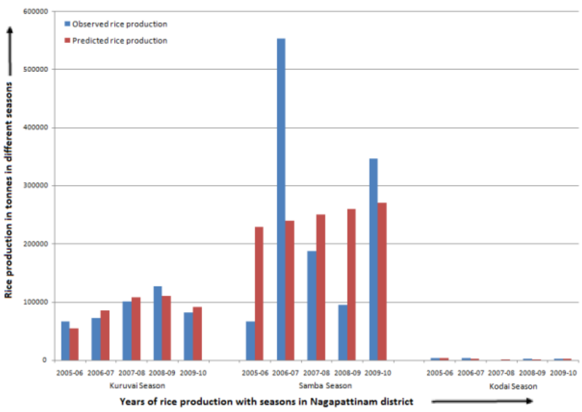

Fig. 16.Comparison of observed and predicted rice production in Nagapattinam district

By referring Fig. 16, it is noticed that there is no matching of observed rice production with the predicted rice production for the Nagapattinam district. With regard to the Kuruvai season, the minimum difference of 6005 tonnes was found between the observed rice production and the predicted rice production for the year 2007-08 and the maximum difference was found to be 17395 tonnes during 2008-09. With regard to the Samba season, the minimum difference of 62551 tonnes was found between the observed rice production and the predicted rice production for the year 2007-08 and the maximum difference was found to be 314300 tonnes during 2006-07. With regard to the Kodai season, the minimum difference of 150 tonnes was found between the observed rice production and the predicted rice production for the year 2005-06 and the maximum difference was found to be 1380 tonnes during 2007-08. The average difference of rice production was found to be 56120.7 tonnes in Nagapattinam district. The rice production varies widely during the Samba season because of late monsoon rainfall and scarcity of water during the growth stage of the crop.

4.3 Statistical testing of ARE between observed and predicted data from the hybrid system

The Average Relative Error (ARE) between the observed and predicted data from the hybrid system was computed for 3 seasons each having 5 years for 7 districts totaling 210 data items. The computed ARE % was arranged in a frequency distribution Table 1.

Table 1. ARE % frequency distribution for 3 seasons

Frequency Class	No. of observat	Percentage observatio
0-10	103	49.0
10-20	38	18.1
20-30	13	6.2
30-40	10	4.8
40-50	11	5.2
50-60	5	2.4
60-70	3	1.4
70-80	5	2.4
80-90	6	2.9
90-100	5	2.4
> 100	11	5.2
Total	210	100%

From table 1, it is found that 49% of the ARE % computed between the observed and predicted data is having 0 to 10% error and 18.1% of the ARE % are within the class interval of 10 to 20% error.

It was found that only 5.2% of ARE % between the observed and predicted data is having more than 100% error. It is a small portion of the study carried out. It also can be reduced if more input data are taken for predictionscontained.

V. SUMMANRY AND CONCLUSIONS

This research is explains the use of the hybrid FFBPNN system for predicting the area of rice cultivation and rice production. The predicted data from the best fitting models were compared with the observed data. The ARE between the observed and predicted data from the hybrid system was computed for 3 seasons each having 5 years for 7 districts totaling 210 data items.

The computed ARE % was arranged in a frequency distribution. it is found that 49% of the ARE % computed between the observed and predicted data is having 0 to 10% error only and 18.1% of the ARE % are within the class interval of 10 to 20% error. It was found that only 5.2% of ARE % between the observed and predicted data is having more than 100% error. It is a small portion of the study carried out. It also can be reduced if more input data are taken for predictions.

The rice production varies widely during the different seasons in a year because of late on set of monsoon rainfall, less quantity of rain fall and scarcity of water during the growth stage of the crop. It is concluded that the system performance can be further improved if more number of years of data is taken as input.

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Areas of Interest: Biosignal processing and image processing.

Publication: More than 20 national and international journals.

Areas of Interest: Biosignal processing and image processing.

APPENDIX

Table A1. Best fitting models for area of rice cultivation and rice production inCRB

	District	Best fitting models for the area of rice cultivation			Best fitting models for the rice production		
		Kuruvai season - area of rice	Samba season - area of rice	Kodai season - area of rice	Kuruvai season – rice production	Samba season - rice production	Kodai season - rice production
1	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	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
2	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	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.
3	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+0 08 SE=1011.8276980 r=0.3118982	Gaussian Model: $y = ae^{\frac{-(b-x)^2}{2c^2}}$ Where: a=8585.5609 b=2006.7458 c=1.4754603 SE= 540.9664491 r=0.9872764	Quadratic Fit: $y = a + bx + cx^2$ Where: a =-3.1176081e+010 b=31083675 c =-7747.8571 SE=21005.0044628 r=0.8929604	Saturation Growth-Rate Model: $y = \frac{ax}{(b+x)}$ Where: a =-13.866651 b =-2014.7557 SE=2085.3351772 r=0.4087852

4	Pudukottai	User-Defined Model: $y = a + b * x$ Where: a=544601.52 b =-270.90001 SE= 105.6609357 r=0.9779332	Quadratic Fit: $y = a + bx + cx^2$ Where: a =4.4404662e+009 b =-4425305.1 c=1102.5714 SE=3448.2304612 r=0.6640203	Quadratic Fit: $y = a + bx + cx^2$ Where: a =-47800181 b =47614.171 c =-11.857143 SE= 37.0898523 r=0.8237899	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
5	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	Quadratic Fit: $y = a + bx + cx^2$ Where: a =-3.6123823e+010 b=35995165 c =-8966.7143 SE=32878.4360089 r=0.5978485	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
6	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	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
7	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	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

Where SE – Standard Error and r – correlation coefficient