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A novel weather parameters prediction scheme and their effects on crops

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ABSTRACT

Weather forecast is significantly imperative in today's smart technological world. A precise forecast model entails a plentiful data in order to attain the most accurate predictions. However, a forecast of future rainfall from historical data samples has always been challenging and key area of research. Hence, in modern weather forecasting a combo of computer models, observation, and knowledge of trends and patterns are introduced. This research work has presented a fitness function based adaptive artificial neural network scheme in order to forecast rainfall and temperature for upcoming decade (2021-2030) using historical weather data of 20 different districts of Karnataka state. Furthermore, effects of these forecasted weather parameters are realized over five major crops of Karnataka namely rice, wheat, jowar, maize, and ragi with the intention of evaluation for efficient crop management in terms of the passing relevant messages to the farmers and alternate measures such as suggesting other geographical locations to grow the same crop or growing other suitable crops at same geographical location. A graphical user interface (GUI) application has been developed for the proposed work in order to ease out the flow of work.

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1. INTRODUCTION

Weather forecasting in the domain of meteorology is one of the key applications of modern science and technology in order to envisage the state of the Earth's atmosphere for the particular geographical area. Moreover, the most accurate weather predictions are facilitated by making the extensive usage of wide range historical weather data and then evolving the efficient algorithms in order to project the weather parameters in current and future state of time. Hence, the forecast models derived from machine learning, soft computing and data mining are qualitatively employed here in current scenarios [1]-[4]. As a result, weather forecasting has turned out to be an imperative and vital area of research in the today's smart world of internet of things (IoTs).

Weather is embraced of various parameters such as temperature, rainfall, relative humidity, wind speed, and moisture. Hence, an accurate weather prediction model requires an ample amount of data on these weather parameters to achieve the higher order precisions in forecasts. Although as a result of meteorological data imprecision, the collected database is exaggerated by various types of improbabilities, uncertainties and perturbations. Hence, with the intension of resolution these dilemmas and nuisances, extra refined and specific stochastic models are enhanced further. Furthermore, the frenzied and chaotic character of the environment, the immense and considerable amount of computational algorithms are required in order to

decipher and hence work out the mathematical equations portraying the atmosphere in conjunction with the inaccuracy implicated during measurement of the initial situations, an imperfect and curtained perceptive of the atmospheric processes resulting in forecasts with degraded accuracy. Various types of machine learning based algorithms are employed in order to avail the predictions with higher accuracy such as Regression models, support vector machine (SVM), artificial neural network (ANN), deep neural network (DNN), and Segmentation and clustering [5]-[7].

In this research work, author has worked on the prediction of the key weather parameters temperature and rainfall using adaptive artificial neural network based on fitness function evaluation for upcoming ten years using past years weather data of various districts across Karnataka state. Furthermore, based on the forecasted parameters, author has worked on various crop models in order to evaluate their effects on crop yields. In addition to this if forecasted weather parameters are not met with ideal weather conditions for crops, author has also worked on alternate measures such as suggesting other geographical locations to grow the same crop or growing other suitable crops at same geographical location in order to boost crop yield and production and hence elevate economy in upcoming years decade.

The rest of the paper is planned as follows: Section 2 presents the brief literature survey over the various types of weather prediction models. Section 3 presents the proposed work of weather prediction model and crop management system. Section 4 presents detailed results and analysis of work discussed in section 3. Sections 5 present the conclusion of the paper.

2. LITERATURE SURVEY

Daily weather forecast is intensified with the help of a vast number of observers and meteorologists universally right through the whole world. Meteorologists actually make use of a merge of a little inimitable technique in order to consider the collected daily basis weather data. Various types of forecasting are computer forecasting, statistical forecasting, synoptic forecasting, and persistence forecasting. With the help of these forecasting schemes, among these forecasters consider the optimized scheme in regard of the weather conditions in order to be predicted all the way through everyday data. Furthermore, most of the researchers have carried out the works while setting up a linear relationship flanked by the weather data input and the subsequent target data. Moreover, due to the innovation of nonlinearity in weather data, the prime objective the researches have budged towards the nonlinear weather data forecasting.

A worldwide numerical weather prediction based on the differential conditions was proposed in [8]. The polynomial neural systems based on the partial differential schemes tolerating the display progressively more composite authentic plan capability as of discrete time observations as compared to the support of standard insubstantial registering schemes. A hybrid calculation in order to accordingly construct a spread-out hypothesis work based on neural system was proposed in [9]. The hybrid scheme proposed was based on genetic algorithm, particle swarm optimization scheme and worldwide improvement execution scheme. A MOS scheduling scheme based on an extroverted assembly of meteorological features was proposed in [10]. This scheme was derived from a stepwise direct relapse computation mushy a relapse displays with an assembly of factors.

The conjecture against ET0 judged by hourly basis collected data using the 40 various involuntary weather stations all across Australia country was proposed in [11]. The support of numerical weather prediction (NWP) estimate for daily basis ET0 was found to be of better-quality while incorporating the available data to monthly and hence yearly basis data. A germ-grain scheme was proposed in [12]. In this work, the grains were usually interpreted more likely to be precipitation cells. Moreover, the germ-grain display was absolutely represented as combination of the close by relative forces along with the grain measure. A novel scheme observed from the twist estimations arising due to sea winds jumble meter was proposed in [13]. An experimental assessment derived from the mean square error (MSE), root mean square error (RMSE) and the astonishing and standard reliable correlation was sophisticated from spatial, momentary and directional viewpoint.

Bustami *et al.* [14] proposed a fully connected, feed forward multi-layer preceptor (MLP) network consisting of three layers-based temperature prediction schemes. The error calculated here was found to be minimal. For training back propagation algorithm was incorporated. Furthermore, the predictions are constrained with an upper head, which can further be regarded as tumbling down the different geographical locations interchangeabilities. A novel temperature forecast model for maximum and minimum temperature forecasting along with the relative humidity prediction was performed by making the extensive use of time series analysis. The incorporated network model was multilayer feed forward artificial neural network with training algorithm of back propagation. For both maximum and minimum temperature forecast quarterly based database was utilized. The estimated error was found to be less than 3%.

Artificial neural network based optimization based on the multivariate forecasting [15], global solar radiation estimation based on artificial neural network [16], radial basis function neural network derived from an improved exponential decreasing inertia weight-particle swarm optimization algorithm [17], particle swarm optimization (PSO) based Gaussian radial basis function networks [18], neuro-fuzzy inference system and subsequent learning mechanisms [19] are few other forecasting schemes proposed in literatures.

3. PROPOSED WORK

This work is extension of the work carried out for rainfall prediction and crop management carried out in [20], [21] motivated from the various literatures surveyed in [22] by author in order to carry out the weather forecast (based on temperature and rainfall) along with the effects of forecasted weather parameters on various crops for various districts across Karnataka state for upcoming decade (2021-2030). Hence, the forecast of impending crop sculpts derived from the forecasted weather associated data enables an upper hand to the farmers in order to get hold of every imperative step for necessary protections or preventive/alternate measures for specified crops. As a result, the proposed work can be further subdivided in three major stages namely, weather (temperature and rainfall) and crops related data collection, weather (temperature and rainfall) forecast, evaluation of forecasted weather parameters on crops (effects on crops) and suggesting alternative measures. The detailed flow diagram for proposed work is presented in Figure 1.

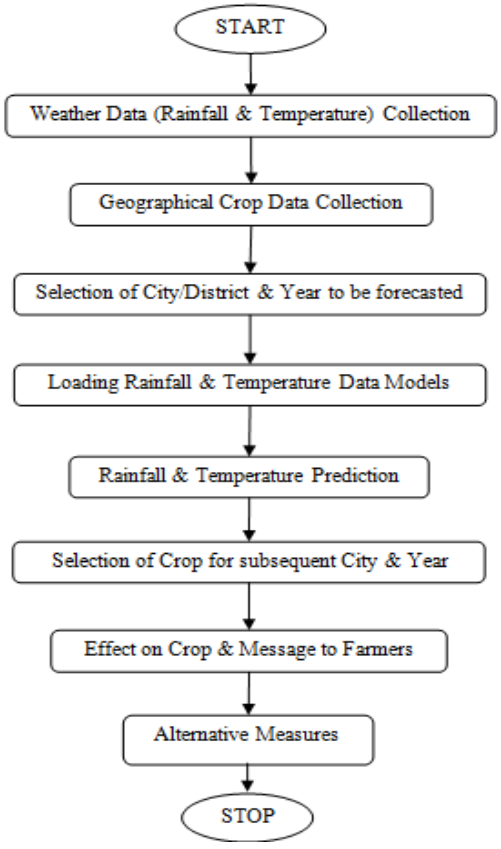

Figure 1. Flow diagram of proposed work

3.1. Adaptive artificial neural network (AANN)

Artificial neural networks are amongst one of the most promising machine learning algorithms motivated from the subsequent biological equivalencies. Moreover, adaptation is another key feature in these networks. Hence, these adaptive artificial neural networks are basically employed in dynamic and vibrant situations. They are usually exemplified and supported with the help of online learning further. The adaptive nature of networks is achieved by either updating weights or alteration in neurons characteristics or adaptation in network structure. Hence, adaptive characteristic is an indispensable and key element for the given artificial neural network in order to showcase the added cushion of independence. In case of dynamic

system environment, future predictions or forecasts are difficult and hence the learning mechanism for the corresponding environment turns out to be worthless. As a result, formulation of a methodology in order to adapt the changes or dynamics of surrounding in real time becomes essential where the new adaptive system reacts to each and individual input separately.

In the proposed weather forecast and crop management model during the training of conventional artificial neural network, the neural weights are revived during each epoch till the desired accuracy level is achieved. This is quite iterative, tedious and cost ineffective. Hence, introduction of adaptive modeling within artificial neural network to avail weather forecast for upcoming decade based on historical weather data is found to be handful. An intangible model for solitary level of adaptive artificial neural network processing system is shown in Figure 2. The model takes historical data as input and provides prediction data as output. Let's for input value of x(n) and with the set of values of x(n-1), the expected prediction is x*(n). In addition, this expected prediction x*(n) is compared with the actual value x(n) and correction value c(n) is calculated. Once the zero correction is achieved means prediction is achieved with superior accuracy. While the correction value is non-zero, model is still in progress to predict the correct value and data update is still in process. This correction signal is useful in order to regulate the network model in such a manner that it enables the perfect and precise prediction for the given situation. Hence, it adapts the environmental dynamics happening in real time applications.

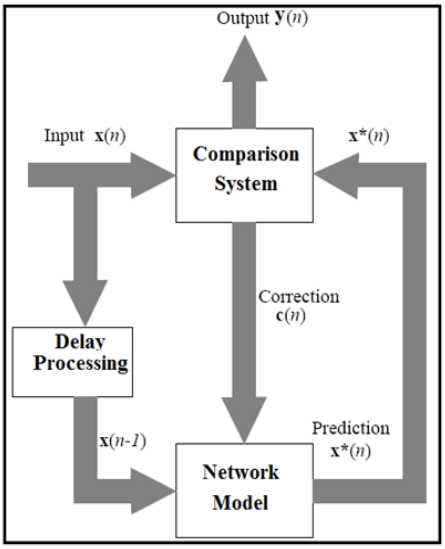

Figure 2. Structure of adaptive model

3.2. Proposed adaptive artificial neural network (AANN) with weight update and fitness function

The proposed artificial neural network uses weight update scheme in order to enable adaptive feature. This is achieved by stability i.e. the ability of the designed network for successful utilization of historical data and plasticity i.e. the ability of the designed network to adapt the updated or newly added features. There are two set of neuron layers namely input layer neuron or feature set layer neuron (N1) and output layer neuron or classified set layer neuron (N2). Neurons within both the layers are fully interconnected. Neurons of N2 layer are capable to hold corresponding input neurons from N1 layer through developed downward associated weights. Hence, during learning and recall, the weights are updated accordingly with the way of signal flow. A correct prediction is given by proper signal flow from N1 layer to N2 layer, which results in correctness of N2 layer. N2 further returns the prediction related expectation back to N1. This process will continue till the correctness is non-zero. Hence adaptation continue till the update in N1 layer neurons and further N2 layer neurons getting assigned to a formerly unexploited class to the new class and the corresponding weights are accustomed in order to explicitly distinguish the new class.

The cumulative model for the proposed adaptive artificial neural network presented in Figure 3 is given by 'N' for resultant outcome of the designed network N_H for the respective hidden layer. In the proposed network, each input data grows by factor of updated respective weight in corresponding hidden layer data. Hence, the subsequent weighted inferences for the corresponding input data get summed up with the intention of the leaning of the respective neuron as shown in (1).

$$N_H'(i) = \left[\sum_{j=1}^{K} w_{ij} * X_j\right] + p_i \qquad (i = 1,2,\dots,L) \tag{1}$$

Where, p_i is steady state bias value and w_{ij} is updated weight getting multiplied with the corresponding input X_j. In addition, K represents number of input nodes and L represents number of hidden nodes in corresponding layer. Furthermore, the actual resultant network output is evaluated with respect to the predicted network output in order to calculate the error and hence to evaluate the performance of adaptive system as shown in (2). This error should be restricted in order to attain the optimal network structure. Hence, the weight update should be continued till this error gets settled within specified tolerance limits.

$$\alpha = \frac{1}{K} * \sum_{j=1}^{K} (Actual(N_j) - Predicted(N_j))^2 \tag{2}$$

Furthermore, the based this error fitness function during each cycle is evaluated in order to achieve the best forecast results which is obtained using (3). Once the best fit results are attained with minimum error, the updated weights can be used in order to train and hence simulated the designed network to obtain the forecasted weather parameters.

$$Fit[N_k] = \min(\alpha) \tag{3}$$

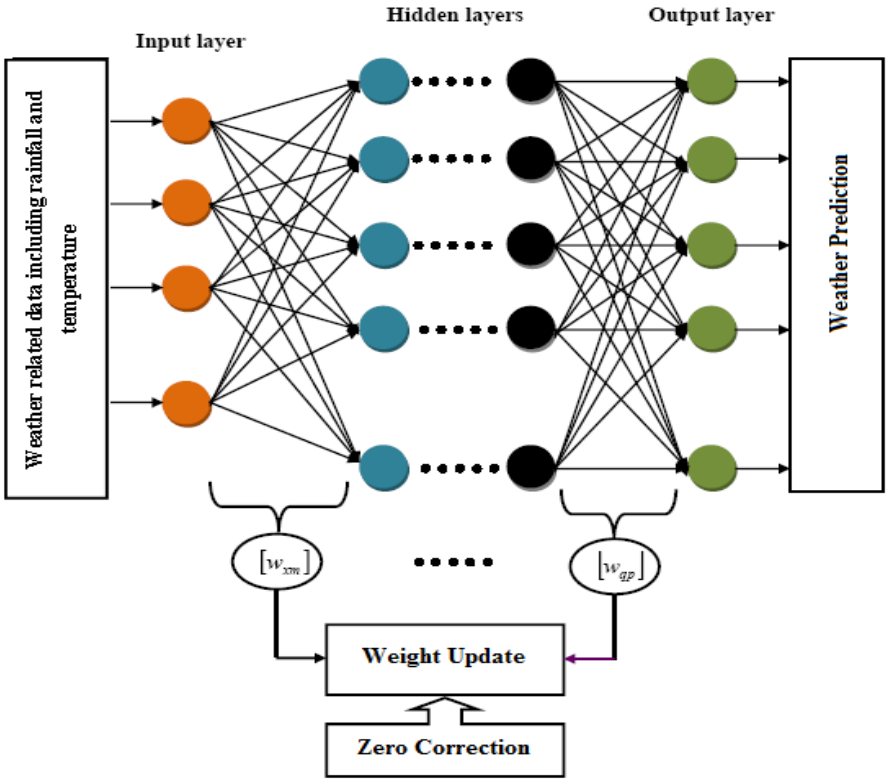

Figure 3. Architecture of proposed adaptive artificial neural network model

3.3. Proposed work flow

As shown in flow diagram in Figure 1 based on the historical weather data and crop data of various geographical locations, the designed network model is prepared with appropriate network training. Next, for the selected demographic location and respective year the weather parameters (rainfall, maximum temperature, average temperature and minimum temperature) are forecasted. Next, based on the forecasted weather parameters and selected crops, crops are evaluated against the forecasted weather parameters. Using these data, effects on crops are evaluated and respective messages are conveyed to farmers. Furthermore, the alternate measure such as suggestions for different geographical locations in order to grow same crop or for same geographical location in order to grow other crops are passed on to farmers in order to increase the crop yield and hence to boost country economy in upcoming decade.

4. RESULTS AND ANALYSIS

Author has collected a historical weather data of 20 districts across Karnataka state for rainfall (monthly average data for 23 years) and temperature (monthly maximum, average and minimum data for 10 years) from Karnataka State Natural Disaster Monitoring Centre through Department of Agriculture, Bangalore. In addition to this, author also collected a salient geographical Crop data (temperature, rainfall, soil type, districts producing and seasons) for 5 major crops (wheat, rice, ragi, jowar and maize) across Karnataka state.

The proposed research work has been solely implemented using matrix laboratory (MATLAB) tool. Furthermore, a graphical user interface (GUI) application has been designed in MATLAB in order to forecast the weather parameters and hence evaluate them for crop management as shown in Figure 4. Figures 5 and 6 show the forecasted rainfall profiles, forecasted temperate profiles and corresponding crop details along with relevant messages to farmers and alternative measure for 'Hassan' city for year 2026 for 'Maize' crop. Furthermore, in addition to this, Figures 7 and 8 show the forecasted rainfall profiles, forecasted temperate profiles and corresponding crop details along with relevant messages to farmers and alternative measure for 'Mysore' city for year 2021 for 'Ragi' crop.

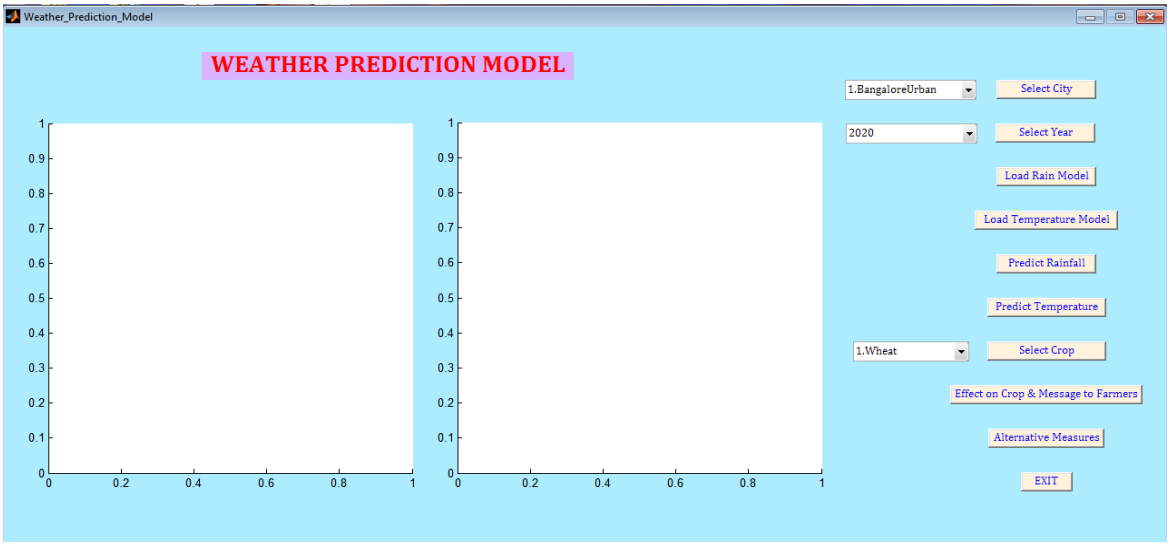

Figure 4. Designed graphical user interface (GUI) application for proposed work

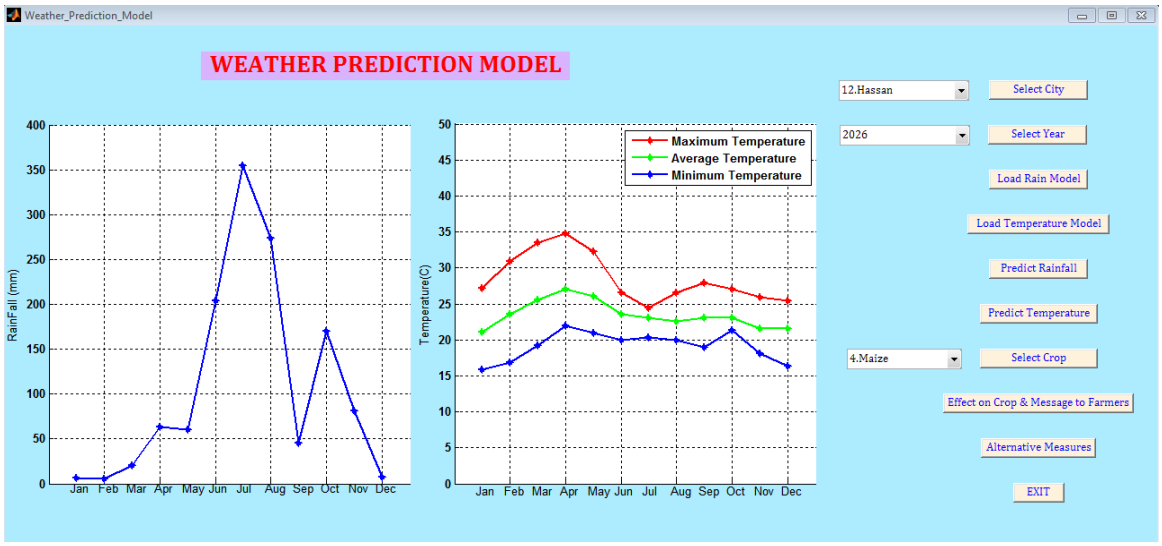

Figure 5. Forecasted rainfall and temperature profile for 'Hassan' city for 2026

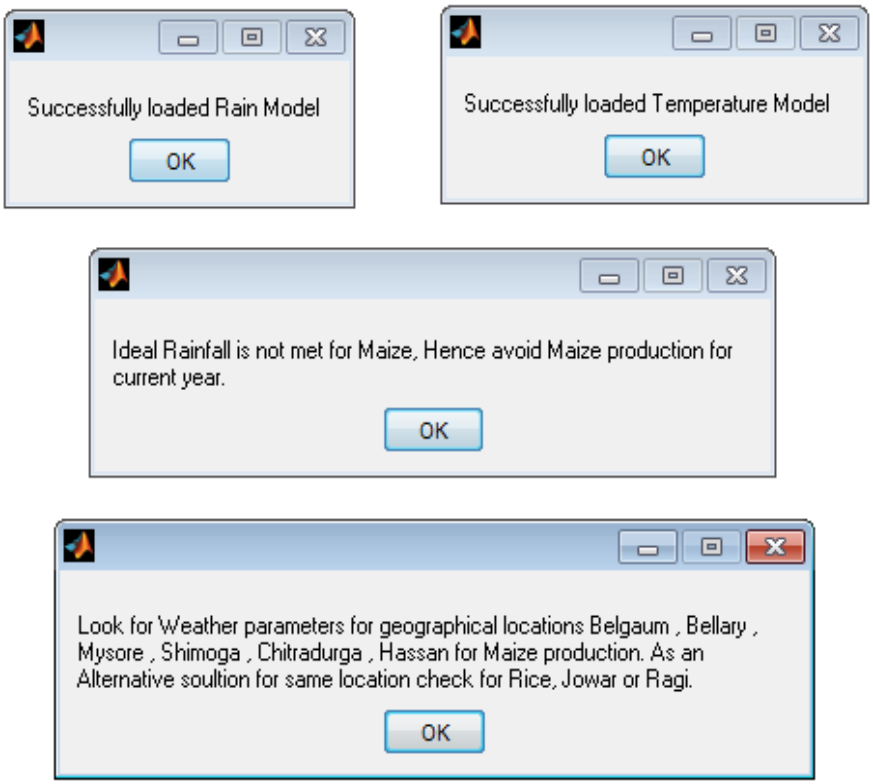

Figure 6. Effects of forecasted weather parameters on 'Maize' crop along with message to farmers and alternate measures for 'Hassan' city for 2026

From results shown in Figures 5-8, the effects of forecasted weather parameters on crops are well obvious. The effects have been further evaluated against ideal crop conditions along with the geographical data available in order to convey the relevant message to the farmers and suggesting alternate measure to them if needed. Tables 1-4 shows the comparison analysis of the proposed methodology with various relevant existing works [23]-[25] in terms of few performance parameters such as mean square error (MSE) and Pearson correlation coefficient (PCC) based accuracy during forecast of average rainfall and temperature respectively for the given five districts (Bangalore Urban, Belgaum, Hassan, Mysore and Tumkur) of Karnataka state as input for year 2020. From comparison analysis and graphical results, it is quite obvious that the proposed work outperforms in every aspect of performance as compared to the existing works.

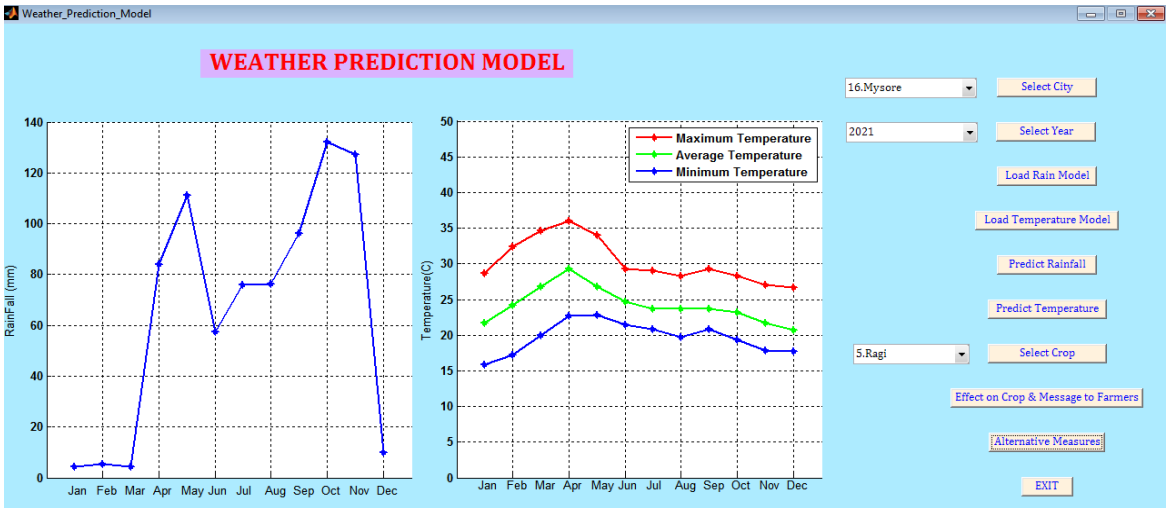

Figure 7. Forecasted rainfall and temperature profile for 'Mysore' city for 2021

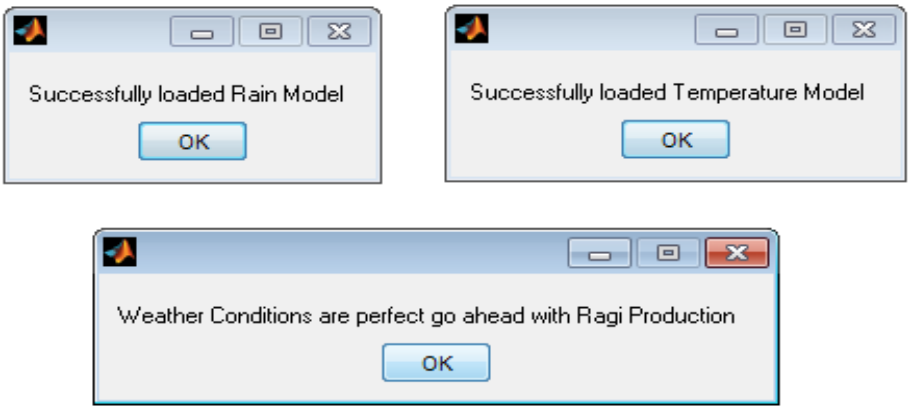

Figure 8. Effects of forecasted weather parameters on 'Ragi' crop along with message to farmers and alternate measures for 'Mysore' city for 2021

Table 1. Comparison of MSE for rainfall forecast

	Mishra *et al.* [23]	Jeongwoo *et al.* [24]	Kaitlin *et al.* [25]	Proposed Work
BangaloreUrban	35.14	31.67	33.58	30.85
Belgaum	37.85	29.22	36.28	27.25
Hassan	30.49	34.67	34.94	28.64
Mysore	39.5	32.5	37.77	25.71
Tumkur	33.29	36.45	32.78	29.38

Table 2. Comparison of PCC for rainfall forecast

	Mishra *et al.* [23]	Jeongwoo *et al.* [24]	Kaitlin *et al.* [25]	Proposed Work
BangaloreUrban	0.6925	0.7315	0.7098	0.7445
Belgaum	0.6695	0.7629	0.6845	0.7871
Hassan	0.7487	0.7007	0.6992	0.7746
Mysore	0.6253	0.7188	0.6711	0.7994
Tumkur	0.7134	0.6817	0.7216	0.7605

Table 3. Comparison of MSE for temperature forecast

	Mishra *et al.* [23]	Jeongwoo *et al.* [24]	Kaitlin *et al.* [25]	Proposed Work
BangaloreUrban	34.87	32.65	34.57	28.47
Belgaum	36.65	34.92	31.84	30.58
Hassan	38.18	33.05	33.69	31.48
Mysore	32.45	34.78	29.95	27.95
Tumkur	35.23	32.38	36.14	30.92

Table 4. Comparison of PCC for temperature forecast

	Mishra *et al.* [23]	Jeongwoo *et al.* [24]	Kaitlin *et al.* [25]	Proposed Work
BangaloreUrban	0.7002	0.7205	0.7167	0.7781
Belgaum	0.6813	0.7174	0.7291	0.7479
Hassan	0.6637	0.7111	0.7052	0.7304
Mysore	0.7229	0.7183	0.7582	0.7815
Tumkur	0.6946	0.7229	0.6839	0.7443

5. CONCLUSION

In this paper, author has presented a novel scheme for forecast of the key weather parameters such as temperature and rainfall by making extensive use of fitness function based adaptive artificial neural network for upcoming decade (2021-2030) using historical weather data of 20 different districts of Karnataka state. Moreover, these forecasted weather parameters have been involved in order to evaluate efficient crop management in terms of the effect of forecasted weather parameters on the crop yield, relevant messages to the farmers and alternate measures such as suggesting other geographical locations to grow the same crop or growing other suitable crops at same geographical location. The research is carried out over five major crops of Karnataka namely rice, wheat, jowar, maize, and ragi. Furthermore, this application can be developed in

hardware and set up as a kiosk to farmers where they can rely by reducing the need of agriculture and weather experts. This work can be extended with other weather parameters such as wind speed, and relative humidity with multiple crops at national level in order to enhance crop yield and hence boost up the Indian economy in upcoming decade.

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