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RESEARCH ARTICLE

PREDICTION OF RAINFALL, MAXIMUM AND MINIMUM TEMPERATURE IN SUMMER MONSOON MONTHS USING ARTIFICIAL NEURAL NETWORK

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ABSTRACT

Artificial neural networks (ANNs), are computer based mathematical processing systems inspired by the biological neural networks on which the animals brain works and is being used by state of the art computer technology for faster computing systems. In this paper this advanced computing system has been utilized for forecasting rainfall, maximum and minimum temperature during summer monsoon months from ANN models that has been generated by inputting 8 years(2014 to 2021) relevant and available meteorological data. Rainfall amount, maximum and minimum temperature in summer monsoon months are important inputs for crops in kharif season, and if forecasted with accuracy with substantial lead time, then it will be helpful in optimization of crop yield which subsequently will boost the economy of our country. The rainfall, maximum and minimum temperature of year 2022 & 2023 of summer monsoon months was predicted by five best fit models by using twelve meteorological parameters data of previous day and the results found were encouraging. ANN-based forecasting model formula has been created by constructing three layer networks. The data, on analysis, revealed small deviation in forecast values during the event of normal rainfall, maximum and minimum temperature and the model captures nicely the normal trend except in the event of sudden steep change of occurrence of rainfall or maximum and minimum temperature, in which case ensemble forecast of NWP and ANN can be explored.

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INTRODUCTION

Forecasting of meteorological parameters in the tropical belt is challenging as stated by Holton (1972), Gadgil *et al*. (2005). As the weather systems of this tropical belt is filled with complexity and non-linearity, resort has been taken by the forecasters to incorporate complex soft computing process in the sphere of forecasting. This incorporation of complex computing system has opened up new avenues for research in weather and has brought precision in forecasting weather events. The three prime components e.g. ANN, Fuzzy Logic and Genetic Algorithm has been introduced in recent times along-with Numerical Weather Prediction (NWP) methods to capture the erratic nature of the weather events.. In this research work ANN has been used for predicting rainfall, maximum and minimum temperature of this region for summer monsoon months as this process, if fine-tuned, can be used for automation of all weather related services and also can envelope in its fold, the other avenues related to public services. ANN, is performing complex computation by use of cutting edge computer technology for the situations where chaotic nature of the environment is exemplified byNagendra *et al* (2006). The ANN was conceptualized to mimic the functions of neurons with the help of mathematics by Hornik(1991), Maqsood *et al*.(2002). The process can be used where the chaotic nature of the event is the predominant factor. The advantage is that no prior knowledge of the system is required in the ANN and is very much useful in generating mathematical models of dynamical systems on a real time basis. ANN has the capability to adapt itself to the observed events by constantly drawing relationships with multi-parameters and trains itself to predict optimum values of the parameters. The interesting part is, it is ever machine learning process and the initial defects are removed with temporal field enhancement. This robustness of the system makes it a useful tool, in real time analysis e.g in forecasting of weathe, in different fields of predictions, etc. As mentioned earlier, forecasting of weather events, is a more complex process than predictions of planetary movements because of the turbulent nature of the weather system. The chaotic nature in the weather system is due to the instability of the atmosphere and the weather systems which affect the weather phenomena are the outcome of the unstable atmosphere and involvement of various chaotic interactions between varied spatial scales by Holton (1972), Gardner *et al*.(1998), Sahai *et al*. (2000, 2003) who showed nicely that the changes in the summer monsoon rainfall pattern and intensity in India, is mainly caused by the anomaly in temperature of the sea surface over the Indian Ocean. The anomalies in the extra tropical circulation shows dispersion of energy by diverging from the area of tropical convection anomalies which is considered to be, due to Rossby wave reciprocation to latent heat given out in association with tropical convection. The regions which is subjected to anomaly in tropical heating, counteracts dynamically with abnormal large scale ascent of water vapor and divergence in upper troposphere, which behaves as a source of Rossby wave for extra tropical waves. On the contrary, the regions where there is small convection and abnormal cooling, the tropical reciprocation is of abnormality in descending and convergent inflow in upper troposphere. So, it is clear, that temperature of surface greatly impacts the summer monsoon rainfall as per Gardner *et al*. (1998), Sahai *et al*. (2000, 2003) and maximum and minimum temperature of the region. The present paper studies the patterns of rainfall, maximum and minimum temperature inGangetic West Bengal region of India during the monsoon months using ANN. Gardner *et al*. (1998), Hsieh *et al*.(1998), De *et al*. (2009), Subhajini (2018), stressed on using ANN in the field of atmospheric science which they claim to have error below 5 %. This prompted to include as much as available parameters, which directly or indirectly affects the occurrence of rainfall, maximum and minimum temperature, for developing a robust predictive model for the summer monsoon rainfall, maximum and minimum temperature of this region, because it's correct prediction can boost up the Indian economy which to a large extent, circulates around agriculture by Nguyen *et al*. (2019). Here June to September's, daily ten meteorological parameters, which have a strong impact on rainfall, maximum and minimum temperature at a place were taken as input to develop powerful ANN model for predicting rainfall, maximum and minimum temperature. Also other avenues like using Deep Neural Network for improving Rainfall forecast by Trivedi *et al*. (2023) can be explored and a juxtaposed ensemble Neural Network forecasting method can be devised for optimization of weather forecasting.

METHODOLOGY

June to September are identified as summer monsoon months in India. In this study ten relevant meteorological parameters, namely, Daily Mean sea level pressure, Dry bulb temperature, Wet bulb temperature, Relative Humidity, Dew point temperature, Saturated Vapor pressure, Wind direction, Wind speed, Maximum temperature and Minimum temperature data of June to September of 8 years i.e. 2014-2021 was used as input to find five best fit models for predicting rainfall generated by ANN and subsequently it was validated for summer monsoon season rainfall of 2022 and 2023. Similarly the same process was followed for generating five best fit models for maximum temperature by interchanging the maximum temperature data with rainfall data and keeping other nine met data same, for getting maximum temperature as output and generating five best fit models for minimum temperature by interchanging the minimum temperature data with rainfall data and keeping other nine met data same, for getting minimum temperature as output. Here month-wise ANN models were generated to keep the optimum homogeneity of the weather system of the season, so that better results can be obtained. This research paper tries to develop ANN model, in steps, so that rainfall, maximum and minimum temperature over Gangetic West Bengal during summer monsoon can be forecasted by using the meteorological data from IMD archive.

RESULTS

It is observed that, all the models has mostly captured the trend of the rainfall, maximum and minimum temperature and it's quantitative amount during the summer monsoon months barring the quantitative amount during sudden steep change of rainfall, maximum and minimum temperature due to underlying extreme weather events. The month-wise statistical performance of five optimum ANN models is given in tabular form Table- 1 for rainfall, in tabular form Table- 2 for maximum temperature and in tabular form Table- 3 for minimum temperature along-with their computed varied statistical data in graphical displays in Fig-1 - Fig-24.The schematic diagram of best ANN model among the five best ANN models which is inferred by comparing the correlations reveals how much networking complexity is involved in finding the optimized output by repeated back propagation calculation of input matrices. The month-wise graphical representation of comparative study of observed Rainfall, Maximum temperature and Minimum temperature with the predicted Rainfall, Maximum temperature and Minimum temperature for 2022 and 2023 has been carried out for best five models namely RF_ANN1, RF_ANN2, RF_ANN3, RF_ANN4 and RF_ANN5 which is given from Fig-25 to Fig-48 respectively, by highlighting observed data (in blue color) with the best ANN model (in red color) out of five best ANN model selected by the system to make the visible comparison prominent. It can be inferred that though the optimum neural network model strive to keep the value of Data Mean and Data SD same by undergoing complex neural network processes in the background by back propagation method, the models efficiency can be determined by observing it's correlation values. The month-wise best ANN model efficiency from June to September can be found out from Table-1 for Rainfall, from Table-2 for Maximum temperature and from Table-3 for Minimum temperature.

DISCUSSION

To develop the ANN model, four sequential steps has been followed:

- Input and output selection for the supervision of Back-propagation learning.
- Best activation function selection.
- Training with a set of data and validation of the ANN model
- Goodness of fit test of the ANN model

Table 1. Statistics related to monthwise best five ann for rainfall

RAINFALL					
JUNE	RF_ANN1	RF_ANN2	RF_ANN3	RF_ANN4	RF_ANN5
DATA MEAN	7.78919	7.78919	7.78919	7.78919	7.78919
DATA SD	17.43162	17.43162	17.43162	17.43162	17.43162
ERROR MEAN	-1.36381	-1.21716	-0.65076	-0.57086	-0.67647
ERROR SD	13.75404	13.52165	12.47152	14.91397	15.19481
ABSOLUTE ERROR MEAN	7.29989	6.57856	6.33548	7.90339	7.91820
SD RATIO	0.78903	0.77570	0.71545	0.85557	0.87168
CORRELATION	0.61807	0.65006	0.70630	0.51819	0.49609
JULY	RF_ANN1	RF_ANN2	RF_ANN3	RF_ANN4	RF_ANN5
DATA MEAN	11.7003	11.7003	11.70033	11.70033	11.70033
DATA SD	20.0990	20.0990	20.09899	20.09899	20.09899
ERROR MEAN	7.0409	6.8756	1.01165	0.94551	0.50121
ERROR SD	16.2095	13.7758	17.38007	14.95630	14.34705
ABSOLUTE ERROR MEAN	16.6917	16.5468	9.01897	9.86351	9.22886
SD RATIO	5.7819	5.6608	0.86472	0.74413	0.71382
CORRELATION	0.4726	0.4922	0.57717	0.66879	0.70121
AUGUST	RF_ANN1	RF_ANN2	RF_ANN3	RF_ANN4	RF_ANN5
DATA MEAN	11.52092	11.52092	11.52092	11.52092	11.52092
DATA SD	17.58651	17.58651	17.58651	17.58651	17.58651
ERROR MEAN	-0.02423	0.70211	0.10600	-0.49793	-0.46564
ERROR SD	16.56735	13.37321	14.34995	15.12443	15.03685
ABSOLUTE ERROR MEAN	9.95537	8.82141	9.29823	9.40096	9.42710
SD RATIO	0.94205	0.76042	0.81596	0.86000	0.85502
CORRELATION	0.48738	0.65087	0.57850	0.52022	0.52680
SEPTEMBER	RF_ANN1	RF_ANN2	RF_ANN3	RF_ANN4	RF_ANN5
DATA MEAN	10.26321	10.26321	10.26321	10.26321	10.26321
DATA SD	19.66071	19.66071	19.66071	19.66071	19.66071
ERROR MEAN	-1.15769	-0.56315	-0.22836	-0.48432	-0.27494
ERROR SD	15.72786	14.90911	13.59559	15.79031	14.64134
ABSOLUTE ERROR MEAN	9.03606	9.07095	7.89635	8.85520	8.85654
SD RATIO	0.79996	0.75832	0.69151	0.80314	0.74470
CORRELATION	0.60519	0.65193	0.73192	0.59587	0.66822

Table 2. Statistics related to monthwise best five ann for maximum temperature

MAXIMUM TEMPERATURE					
JUNE	MAX_ANN1	MAX_ANN2	MAX_ANN3	MAX_ANN4	MAX_ANN5
DATA MEAN	34.36926	34.36926	34.36926	34.36926	34.36926
DATA SD	2.51055	2.51055	2.51055	2.51055	2.51055
ERROR MEAN	-0.01975	0.01330	0.04904	0.01150	0.00598
ERROR SD	1.92241	1.83383	1.85496	1.84171	1.85777
ABSOLUTE ERROR MEAN	1.48735	1.44669	1.44223	1.44101	1.43811
SD RATIO	0.76573	0.73045	0.73887	0.73359	0.73999
CORRELATION	0.64339	0.68799	0.67426	0.67998	0.67330
JULY	MAX_ANN1	MAX_ANN2	MAX_ANN3	MAX_ANN4	MAX_ANN5
DATA MEAN	32.92680	32.92680	32.92680	32.92680	32.92680
DATA SD	1.90107	1.90107	1.90107	1.90107	1.90107
ERROR MEAN	0.01122	-0.06379	-0.03773	-0.03748	0.00793
ERROR SD	1.52835	1.50164	1.50710	1.46005	1.53553
ABSOLUTE ERROR MEAN	1.19182	1.16474	1.17536	1.14170	1.20744
SD RATIO	0.80394	0.78989	0.79276	0.76801	0.80772
CORRELATION	0.60529	0.63502	0.62688	0.64252	0.59055
AUGUST	MAX_ANN1	MAX_ANN2	MAX_ANN3	MAX_ANN4	MAX_ANN5
DATA MEAN	32.68660	32.68660	32.68660	32.68660	32.68660
DATA SD	1.87297	1.87297	1.87297	1.87297	1.87297
ERROR MEAN	0.12200	0.15498	0.10669	0.10153	0.09868
ERROR SD	1.44041	1.72133	1.41049	1.39674	1.37226
ABSOLUTE ERROR MEAN	1.12429	1.33839	1.08379	1.07007	1.08140
SD RATIO	0.76905	0.91904	0.75308	0.74574	0.73267
CORRELATION	0.64084	0.39618	0.66461	0.67393	0.68059
	32.68660	32.68660	32.68660	32.68660	32.68660
SEPTEMBER	MAX_ANN1	MAX_ANN2	MAX_ANN3	MAX_ANN4	MAX_ANN5
DATA MEAN	33.05953	33.05953	33.05953	33.05953	33.05953
DATA SD	2.10456	2.10456	2.10456	2.10456	2.10456
ERROR MEAN	0.07182	0.00470	-0.02799	0.03481	0.02993
ERROR SD	1.41177	1.50546	1.57187	1.54051	1.54565
ABSOLUTE ERROR MEAN	1.04457	1.17134	1.20671	1.18352	1.18890
SD RATIO	0.67082	0.71533	0.74689	0.73199	0.73443
CORRELATION	0.74340	0.69909	0.67107	0.68132	0.67871

Table 3. Statistics related to monthwise best five ann for minimum temperature

MINIMUM TEMPERATURE					
JUNE	MIN_ANN1	MIN_ANN2	MIN_ANN3	MIN_ANN4	MIN_ANN5
DATA MEAN	27.47939	27.47939	27.47939	27.47939	27.47939
DATA SD	1.64736	1.64736	1.64736	1.64736	1.64736
ERROR MEAN	-0.07163	-0.04386	-0.04348	-0.04050	-0.05627
ERROR SD	1.02673	1.03954	1.03907	0.96505	0.95917
ABSOLUTE ERROR MEAN	0.78843	0.78663	0.78629	0.71065	0.71276
SD RATIO	0.62326	0.63104	0.63075	0.58581	0.58225
CORRELATION	0.78204	0.77579	0.77602	0.81086	0.81316
JULY	MIN_ANN1	MIN_ANN2	MIN_ANN3	MIN_ANN4	MIN_ANN5
DATA MEAN	27.12680	27.12680	27.12680	27.12680	27.12680
DATA SD	1.05762	1.05762	1.05762	1.05762	1.05762
ERROR MEAN	0.04562	0.04650	0.04693	-0.04547	0.01797
ERROR SD	0.62740	0.87933	0.87925	0.66705	0.59674
ABSOLUTE ERROR MEAN	0.47766	0.53638	0.53630	0.48476	0.45812
SD RATIO	0.59322	0.83142	0.83135	0.63070	0.56423
CORRELATION	0.80649	0.64964	0.64962	0.77652	0.82636
AUGUST	MIN_ANN1	MIN_ANN2	MIN_ANN3	MIN_ANN4	MIN_ANN5
DATA MEAN	26.88203	26.88203	26.88203	26.88203	26.88203
DATA SD	0.95430	0.95430	0.95430	0.95430	0.95430
ERROR MEAN	-0.02209	-0.00073	-0.01692	-0.01693	-0.02149
ERROR SD	0.65045	0.54707	0.56874	0.56858	0.54502
ABSOLUTE ERROR MEAN	0.49271	0.41412	0.42962	0.42965	0.42315
SD RATIO	0.68159	0.57327	0.59597	0.59581	0.57112
CORRELATION	0.73325	0.81986	0.80324	0.80336	0.82119
SEPTEMBER	MIN_ANN1	MIN_ANN2	MIN_ANN3	MIN_ANN4	MIN_ANN5
DATA MEAN	26.67525	26.67525	26.67525	26.67525	26.67525
DATA SD	1.06989	1.06989	1.06989	1.06989	1.06989
ERROR MEAN	0.03900	0.00548	0.00796	0.01969	0.03464
ERROR SD	0.53605	0.62604	0.61562	0.60097	0.55802
ABSOLUTE ERROR MEAN	0.40377	0.47296	0.46411	0.44816	0.41154
SD RATIO	0.50103	0.58514	0.57541	0.56171	0.52156
CORRELATION	0.86545	0.81274	0.81946	0.82746	0.85358

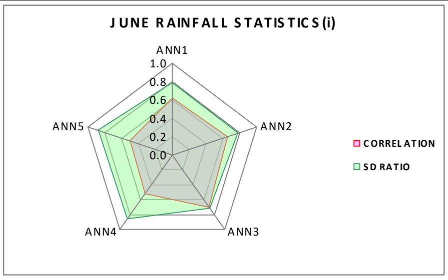

FIG-1

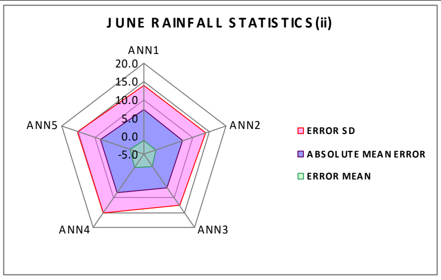

FIG-2

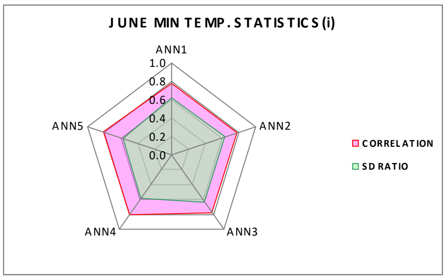

FIG-3

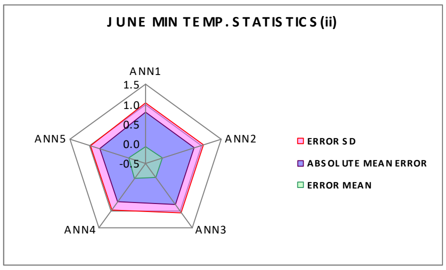

FIG-4

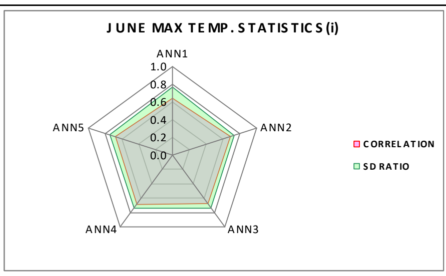

FIG-5

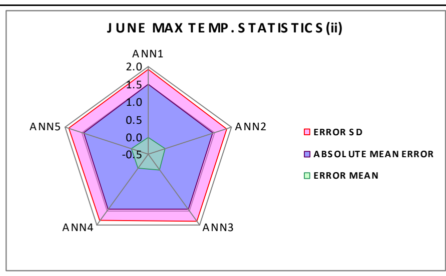

FIG-6

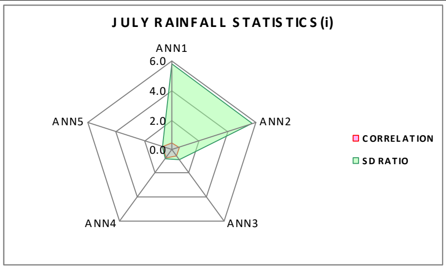

FIG-7

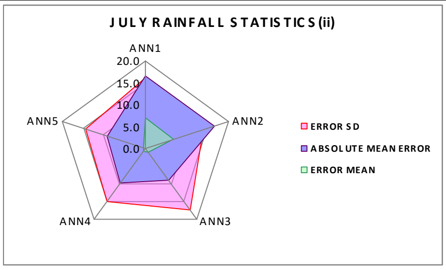

FIG-8

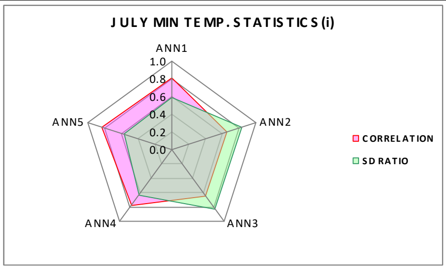

FIG-9

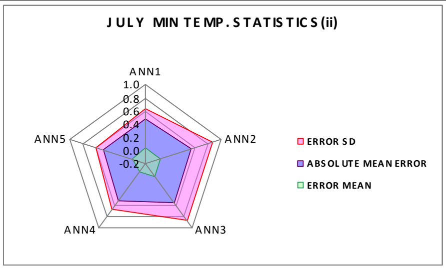

FIG-10

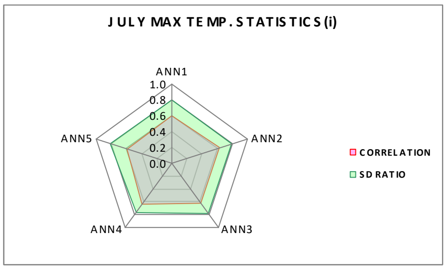

FIG-11

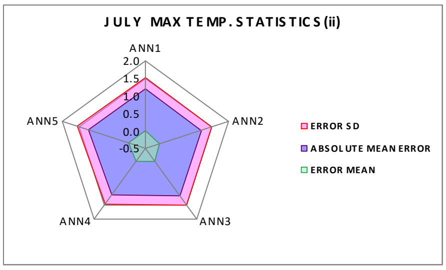

FIG-12

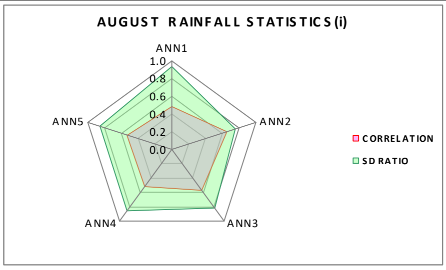

FIG-13

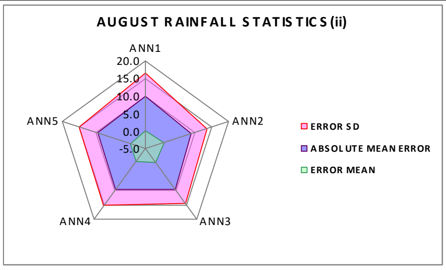

FIG-14

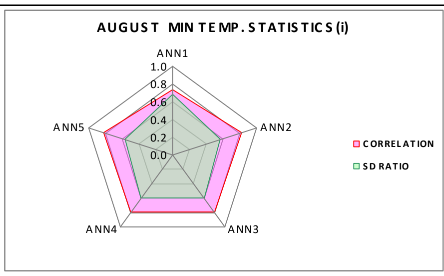

FIG-15

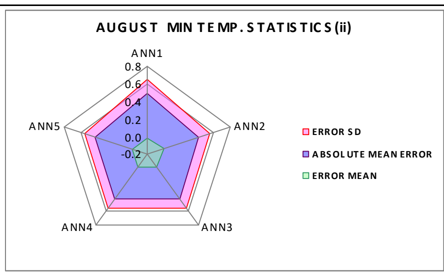

FIG-16

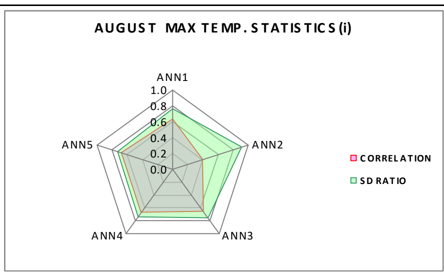

FIG-17

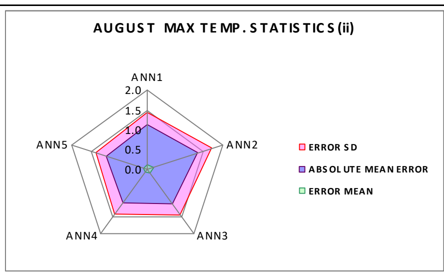

FIG-18

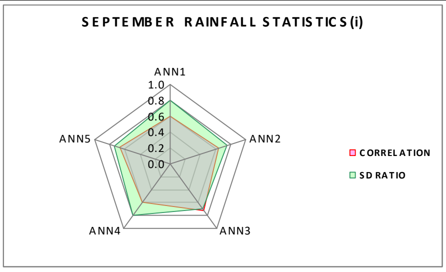

FIG 19

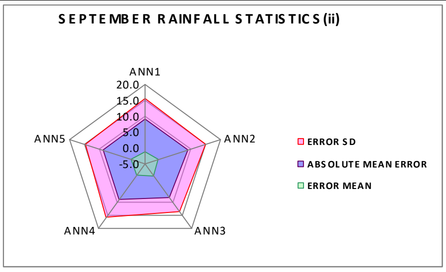

FIG-20

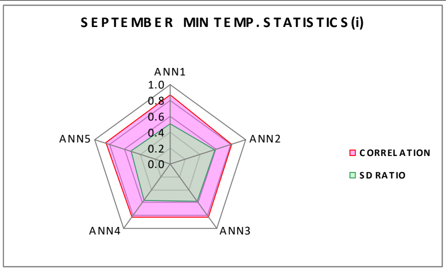

FIG-21

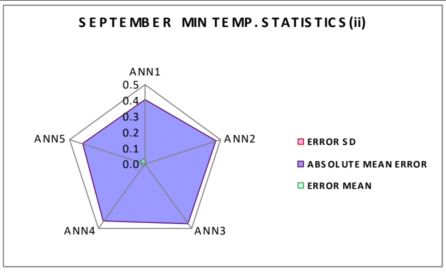

FIG-22

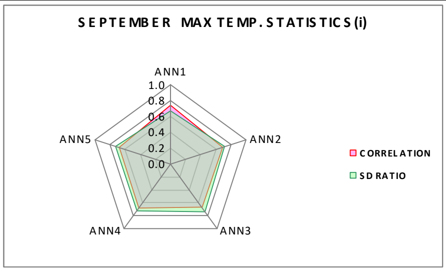

FIG-23

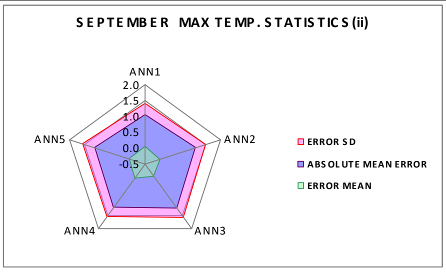

FIG-24

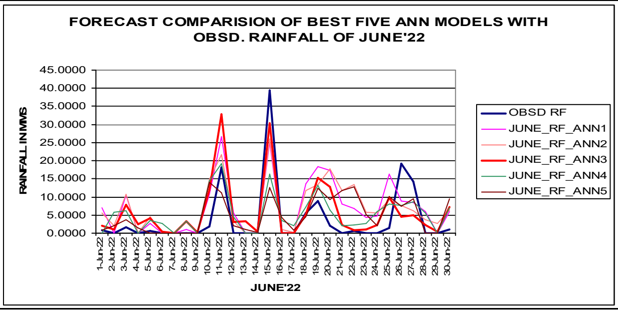

FIG-25

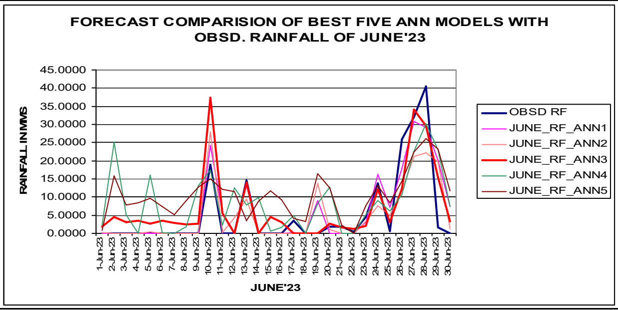

FIG-26

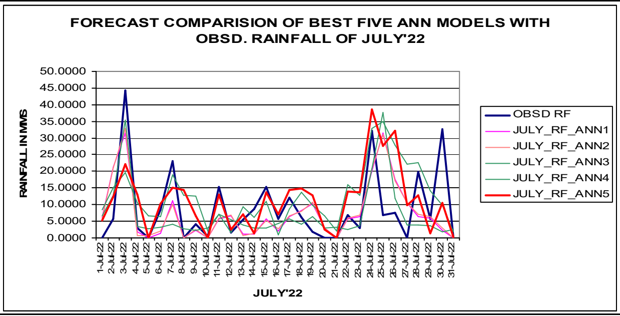

FIG-27

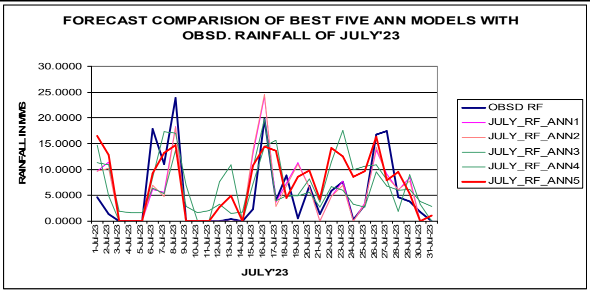

FIG-28

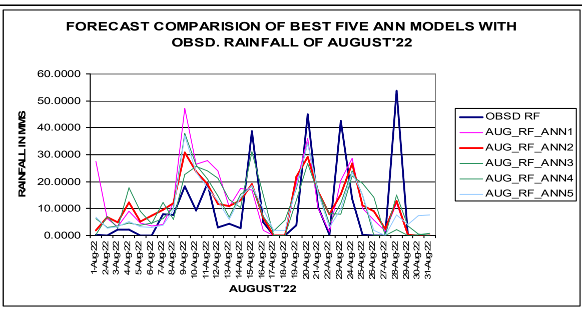

FIG-29

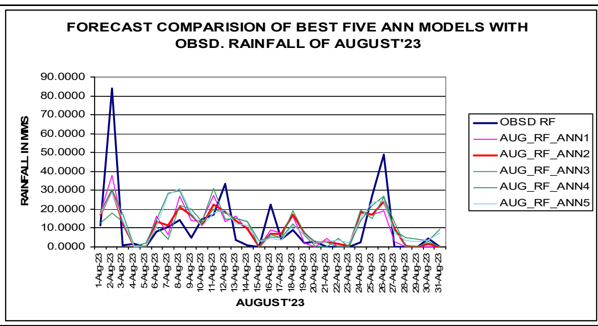

FIG-30

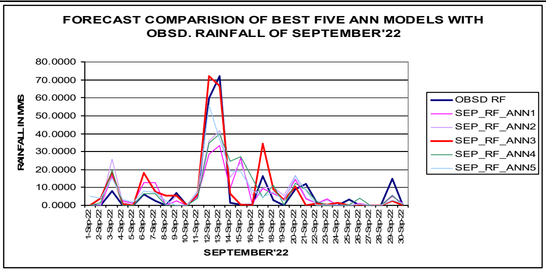

FIG-31

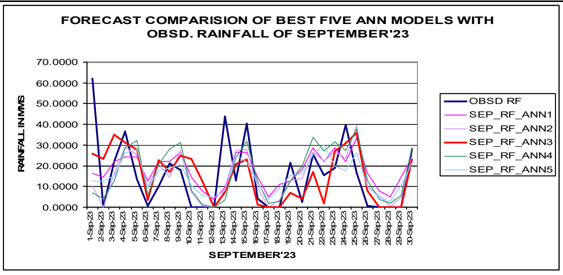

FIG-32

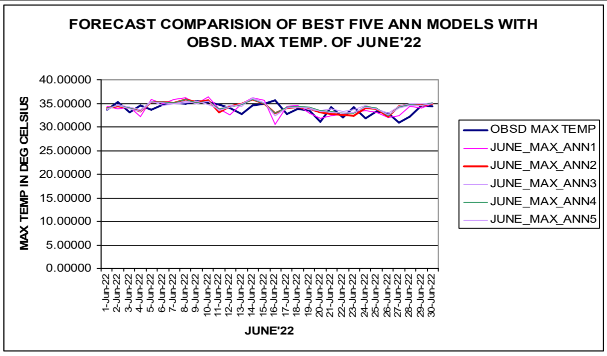

FIG-33

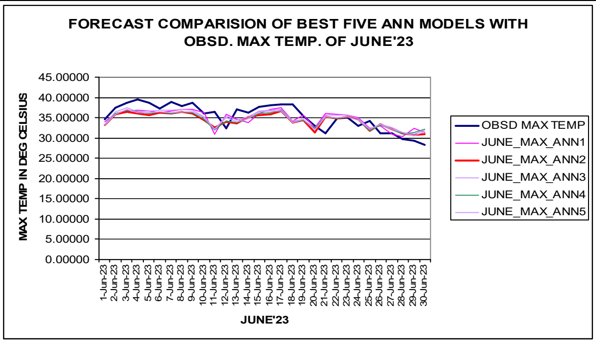

FIG-34

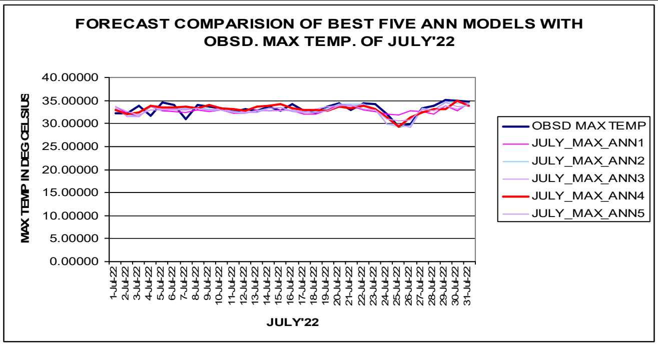

FIG-35

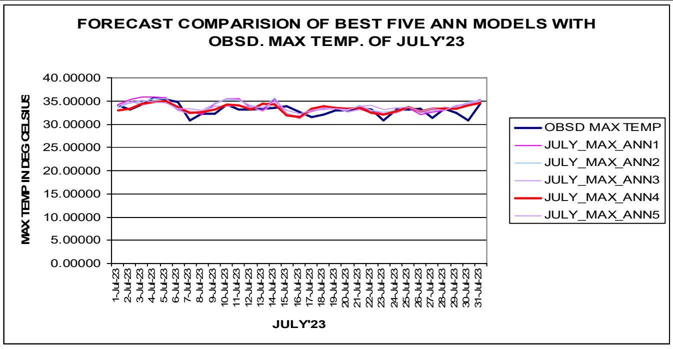

FIG-36

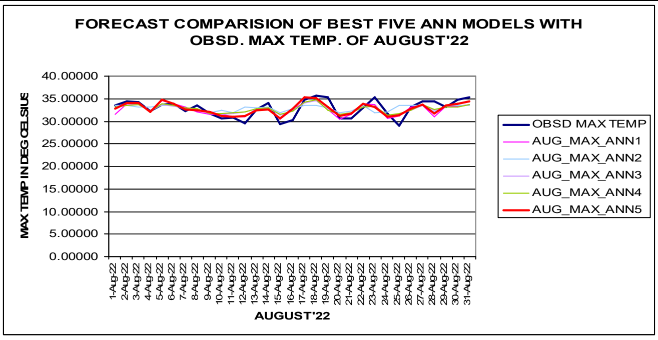

FIG-37

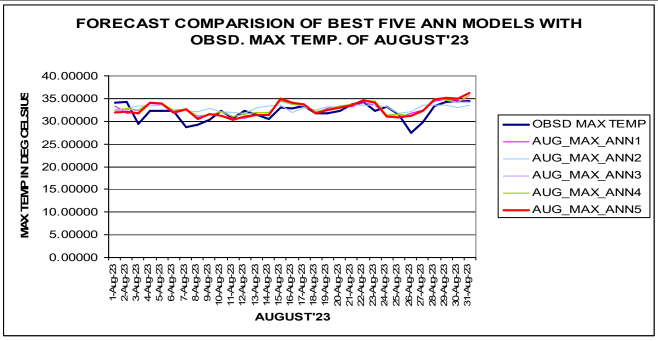

FIG-38

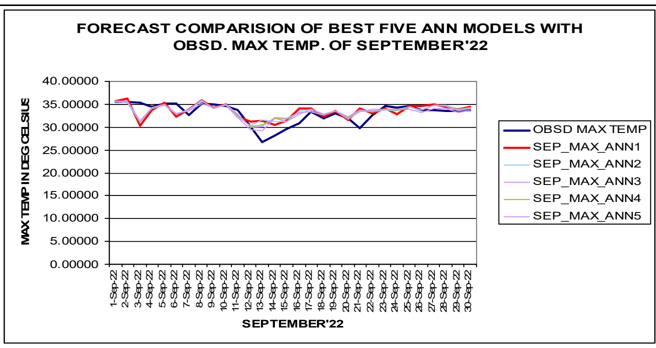

FIG-39

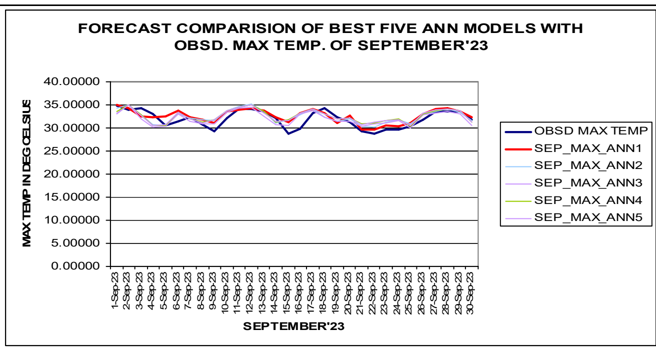

FIG-40

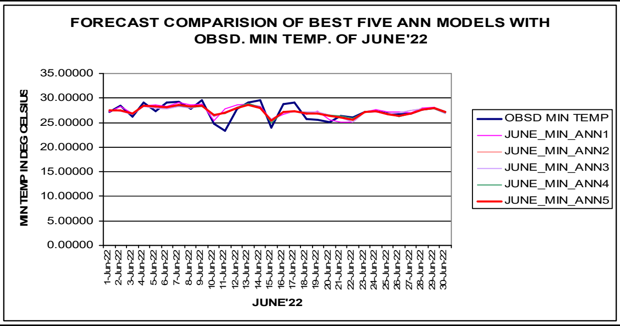

FIG-41

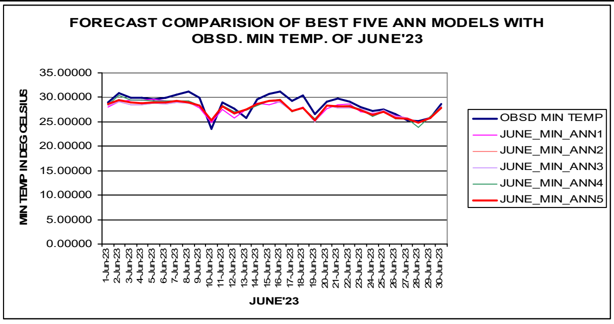

FIG-42

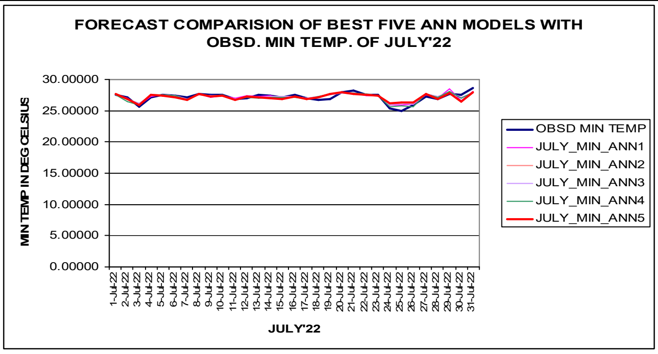

FIG-43

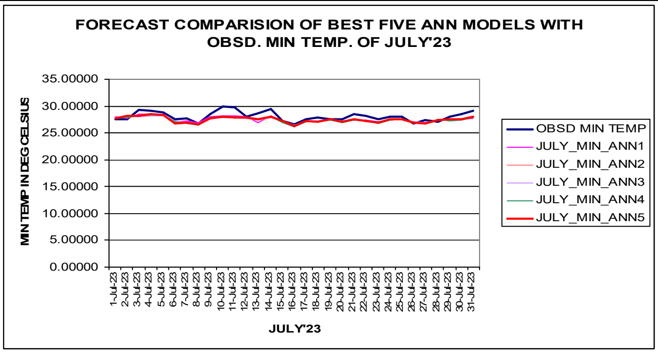

FIG-44

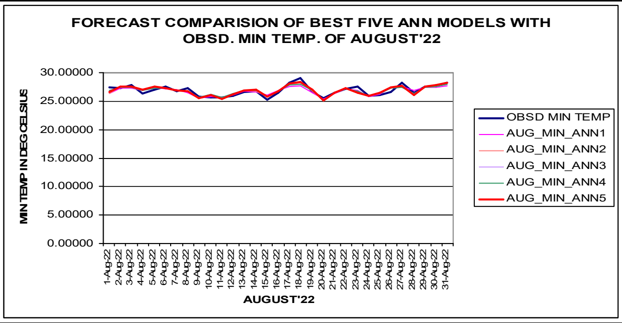

FIG-45

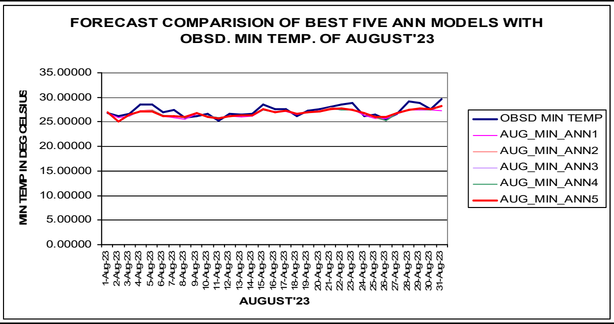

FIG-46

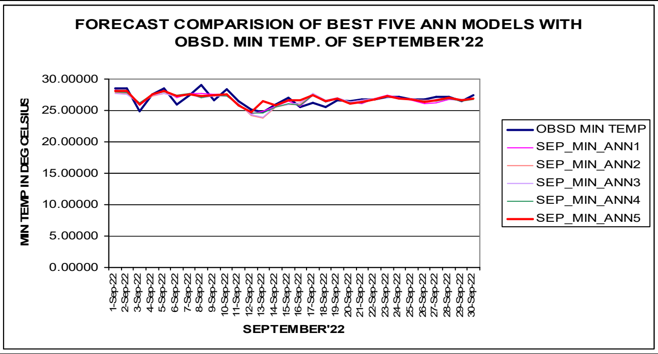

FIG-47

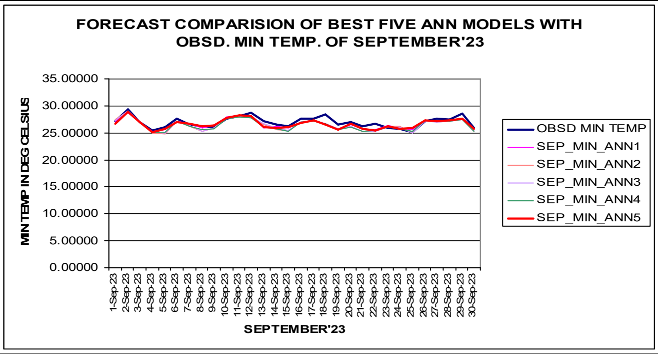

FIG-48

The Back-propagation Algorithm (BP) and the process by which plummeted descent can be found out , unfurled the application of Multilayered ANN to be imposed in many practical problems by Sahai *et al*. (2000,2003), Kamarthi *et al*. (1999), Sejnowski *et al*.(1987), Widrow *et al*. (1990). A multi-layered ANN consists of three main types of layers: first is input layer, then is hidden layer and lastly the output layer. Basically, the Back-propagation learning takes into account the backward movement of error which is generated from the output layers back to the hidden layers in order to find suitable weightage leading to the values in the hidden layer so that an optimized output layer is found out after iterative process. The schematic diagram of the process generated by the software application which is followed in ANN brings out the complex statistical method it follows to generate outputs.

Kartalopoulos (1996) and Perez (2000) proved that the delta rule which is generally followed, is one preferred learning rules of the model for feed forward data in Multi-layered ANN. A input value is givenand the generated output value is compared to the actual value. If the differential value is zero, then the program does not initiate learning process; or else, the weightage values are adjusted in iteration to lessen this differential value. The learning of the model is done by adopting minimization of least–square-error values. The least –square –error (E) between the model target output (T) and actual output (O) can be given by Yegnanarayana,(2000).

$$O_i^{l+1}(k) = f\left(\sum_{j=1}^{N_t} w_{ji}^{l} O_j^{l}(k) - \theta_i^{l+1}\right)$$

where, w_{ji}^{l}= weightage value between node i of layer l -1 and node j of layer l

$O_j^l(k)$ = actual output value (for k th pattern of the j^{th} node in layer l (after non- linear process)

θ_i^{l+1}= bias value of neuron i, which is considered as weightage of an input having value 1. The bias value is also termed as "free parameter ".

The total error value Efor the ANN and for all k patterns are defined as the summation of squared differences between the actual network output values and the target output layer value L. It is given by

$$E=\sum_{k=1}^{k} E_k=\sum_{k=1}^{k} \left(\frac{1}{2}\sum_{i=1}^{N_L} [T_i(k) - O_i^l(k)]^2\right. \quad (2)$$

The main aim is to calculate a set of weights in all layers of the neural network so that that E can be minimized. The ultimate weightage update equation for the m th step would be

$$w_{ji}^{h}(m+1)=w_{ji}^{h}(m)+\Delta w_{ji}^{h}(m) \quad (3)$$

The intention of this research paper is to predict the daily rainfall, maximum and minimum temperature in the summer monsoon months (June to September) over Gangetic West Bengal. An ANN model has been generated by using the supervised machine learned training process to forecast the rainfall, maximum and minimum temperature with the help of the study period. The month-wise data is fed in ANN module in matrix form with 11 columns with degree of freedom 10 and this data set of input values are separated into training (75 % of data) and validation set (25 % of data) to generate best five models. The ANN model that is generated here has hidden layer model and has nodes in these hidden layers. The model has been ran for 50 epochs and the results are tested with the validation set. The outcomes of the tested process has been furnished in the next section.

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The learning rate η has been taken to be 0.9 for good result which produced a triple layered feed forward neural network design. Best five models that are generated for rainfall, maximum and minimum temperature are only considered. There are five outputs from five models which predicts month-wise daily rainfall, maximum and minimum temperature, the initial weightage values are chosen randomly from -0.5 to +0.5. After rigorous iteration training process, the network generated is put to test with validation data set and it's performance in assessed. The iterated training process ends when the ANN model reaches the optimization level on validation data set. After machine learning training and testing, the forecasted error values were computed for each model. The various results are furnished in Tabular as well as Graphical form.

CONCLUSION

In the research paper, ANN with Back-propagation machine learning has been used to forecast summer monsoon rainfall, maximum and minimum temperature over this region in India. After running month-wise input matrix of ten weather parameters to get a single output namely rainfall, maximum and minimum temperature, five optimum predictor model have been generated by the Neural Network. After 50 epochs, the ANN assisted forecast value has been found to deviate a little from actual met. data in normal case and this process can be used to for district and block level forecast for benefit of end users like farmers, fishermen, etc in our future works. The integration of other significant weather parameters along with use of Recurrent neural networks (RNNs), long short-term memory networks (LSTMs), convolutional neural networks (CNNs), and hybrid models combining different architectures in weather forecasting can be explored to bring more accuracy in weather forecasting and capture extreme weather events which is not been captured in this research work as is being unfurled by the statistical outputs of this paper. Thus, we should strive to go for automation of weather forecasting by using ANN which is one of the basic components Artificial Intelligence (AI) for initially predicting summer rainfall, maximum and minimum temperature of these region for corresponding months. Along-with varied present Neural Network techniques other Artificial Intelligence (AI) techniques such as Heuristic search, Knowledge based expert system, Fuzzy petrinets and Kalman Filtering may be tested in future and if results are encouraging then these techniques can be incorporated to generate ensemble forecast for better weather forecasting.

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Ethics declarations: The authors declare that there was no conflict of interest regarding this paper.

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