Estimation of Some Meteorological Parameters Using Hard and Soft Computing Tools

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Abstract— Study of meteorological parameters is essential in deciding the effect on each other while finding out the best possible solution and the estimations for hydrological and meteorological parameters. The study involves in correlating all the measured parameters at Shivade catchment area of Narmada basin. The correlation on the observed parameters is carried out to perform overall sensitivity analysis. Out of al metrological parameters two of them are analyzed in this paper namely Dry bulb temperature and wet bulb temperature. The Dry Bulb and Wet Bulb Temperatures are important to determine the state of humid air. The knowledge of only two of these values is enough to determine the state including the content of water vapour and the sensible and latent energy. The meteorological parameters have been estimated using Multiple linear regression and artificial neural network (ANN). The meteorological parameters collected from Shivade catchment area. The data extended over a period from January 2002 to December2010 including only the monsoon months. Amongst the two methods, the ANN model exhibited better estimation values of the meteorological parameters.

Index Terms— Meteorological Parameters, Wet Bulb Temperature, Dry Bulb Temperature

I. INTRODUCTION

The estimation of meteorological parameters is a challenging task. Meteorological processes are dynamic, chaotic and non–linear. Estimation of these parameters depends on the measurement of parameter with reference to each other. The accuracy in the estimation can be increased by using greater data length. It is difficult to analyze vast data manually but this can be done efficiently by soft tool i.e. Artificial Neural Network. The dependability of the meteorological process is important to decide upon role which parameter is having more influence and vice versa on each other. The same is analyzed by statistical tool and compared with ANN in this process. The meteorological factors that affect runoff are temperature, relative humidity, wind velocity, pressure difference. Meteorological phenomena are observable weather events that illuminate, and are explained by the science of meteorology. Those events are bound by the variables of Earth's atmosphere: temperature, air pressure, water vapor, and the gradients and interactions of each variable, and how they change over time. Different spatial scales are studied to determine how systems on local, regional, and global levels impact weather and climatology. The meteorological parameters are discussed below to understand their significant role in the process. Meteorological parameters include evaporation, average air temperatures, average wind speed and relative humidity. Meteorological phenomena are observable weather events which illuminate, and are explained by the science of meteorology. Those events are bound by the variables that exist in Earth's atmosphere; temperature, air pressure, water vapor, and the gradients and interactions of each variable, and how they change in time. Pan Evaporation is the amount of water which evaporates from an open pan called a Class A evaporation pan. Relative Humidity is the ratio between the actual amount of water vapor in the air and the maximum amount of water vapor that the air can hold at that air temperature. Dry Bulb Temperature is the temperature of air measured by a thermometer freely exposed to the air but shielded from radiation and moisture. Minimum Temperature the lowest temperature recorded—diurnally, monthly, seasonally, or annually, or the lowest temperature of the entire record. Wet Bulb Temperature is the temperature a parcel of air would have if it were cooled to saturation (100% relative humidity) by the evaporation of water into it, with the latent heat being supplied by the parcel. Maximum Temperature this is the highest temperature recorded during a specified period of time. Common time periods include 6, 12 and 24 hours. The most common reference is to the daily maximum temperature, or "high."Average Wind Speed Time-averaged wind speed, averaged over a specified time interval. The mean wind speed varies with elevation above mean sea level and the averaging time interval; a standard reference elevation is 10 m and a standard time interval is 1 h.

The best model for meteorological parameters can be developed with Jordan Elman Network as recommended by M.Afzali et al in [1] as and Multilayer Perceptron as recommended by K.Abhishek et al in [2] Network with 2000 epochs as recommended by Baboo and I.K.Shereef in [3]. A comparison between the MLR model and the

ANN model for the same input shows that the ANN models give higher correlation between the estimated parameter and the observed parameter with small errors as recommended by S.S.De and A.Debanth in [4]. From this we can expect ANN is better estimation method than the traditional MLR method as recommended by A.S.Mohammed in [5] and by A.El. Shafie et al in [6]. The following section gives an idea about the best correlation of the metrological parameters and their importance in the process. The Dry Bulb and Wet Bulb Temperatures are important to determine the state of humid air. The knowledge of only two of these values is enough to determine the state including the content of water vapor and the sensible and latent energy. This paper discusses estimation of these two parameters using other metrological parameters wit influence and correlation criteria. The correlations of the Models are found out with traditional statistical methods and then MLR and ANN models are developed by studying the influence of each parameter.

1. **METHODOLOGY and STUDY AREA:**

Artificial neural networks are 'biologically' inspired networks. They have the ability to learn from empirical data information. There are mainly two types of ANNs: feed forward neural networks (FFNNs) and recurrent neural networks (RNN s). Different types of neural network architectures can be used in the estimation process e.g. Single-layer feed forward networks, Multi-layer feed forward networks, recurrent neural networks, and Lattice networks. Artificial neural network (ANN) and MLR is used to develop various models. Now ANN has become recognized soft computing tools in hydrological and metrological estimations and predictions. Multiple linear regressions (MLR) are a method used to model the linear relationship between a dependent variable and one or more independent variables.

The dependent variable is sometimes also called the predictand, and the independent variables the predictors. Separate MLR and ANN models have been built and compared. The performance evaluation of the models developed is judged with Error measures like Mean Absolute Error (MAE), Mean Square Error (MSE), and Root Mean Square Error (RMSE).

The catchment selected for this study is Shivade catchment. It has been selected as it is a virgin catchment and there is no existing hydrologic structure on this river basin. There are no obstructions on the river and hence the hydrological and meteorological parameters could be measured and made available for analysis of estimation and prediction problems. Shivade is a village in Karad taluka in Satara district of Maharashtra State, India..The catchment area of gauge discharge site in Sq. Km: 3261.03 The length of river in watershed up to gauge discharge site in Km: 115.67. Catchments are located in the districts of Kolhapur and Sangli districts of the Maharashtra state in India. Fig 1 is a map showing Catchment details of Shivade .

Fig.1 Map showing Catchment details of Shivade (Source: Hydrological Project Division, Nashik)

II. RESULT ANALYSES AND DISCUSSION

Initialy data is analyzed by performing data trend analysis and gap filling by interpolation. Next the data is analyzed statistically by normalizing the data, finding the standard deviation, kurtosis, median, mean and correlation. The estimation process involves developing models to find the correlation of each parameter to decide upon the maximum impact of input parameter. This is done to check the influence of each parameter on the hydrological process. This will give an idea of which parameter has most influence on others and it will be

easy to build the models and the unnecessary data input will be reduced. The multiple linear regression models has been developed using the data of monsoon months from 2002 to 2010.70% of the observed data has been taken for training while 30% of the data is taken for testing. Therefore out of a total of 1377 data records 963 are taken for training while 414 are taken for testing.

The meteorological parameters considered for analyses are pan evaporation, relative humidity, dry bulb temperature, minimum temperature, wet bulb temperature, maximum temperature and average wind speed. Data of eight years have been processed to obtain the results and make a conclusion. The duration for which each parameter is studied is as shown in Table 1

Table1: Data Duration

Sr No.	Meteorological Parameters	Period
1	MEP- PAN EVAPORATION	1/1/2002-31/12/2010
2	MHS- RELATIVE HUMIDITY	1/1/2002-31/12/2010
3	MTD- DRY BULB TEMPERATURE	1/1/2002-31/12/2010
4	MTN- MINIMUM TEMPERATURE	1/1/2002-31/12/2010
5	MTW- WET BULB TEMPERATURE	1/1/2002-31/12/2010
6	MTX- MAXIMUM TEMPERATURE	1/1/2002-31/12/2010-
7	MWS- AVERAGE WIND SPEED	1/1/2002-31/12/2010

Table 2 Correlation of Parameters

Parameters	MEP	MHS	MTD	MTN	MTW	MTX	MWS
MEP		-0.53	0.778	0.33	0.523	0.820	0.043
MHS	-0.53		-0.71	0.09	0.045	-0.63	0.025
MTD	0.778	-0.71		0.17	0.653	0.907	-0.12
MTN	0.335	0.092	0.174		0.297	0.235	0.011
MTW	0.523	0.045	0.653	0.29		0.604	-0.07
MTX	0.820	-0.63	0.907	0.23	0.604		-0.12
MWS	0.043	0.109	-0.12	0.38	-0.07	-0.12	

Statistical analysis of database-Correlation

As seen in Table 2 Dry bulb temperature(MTD) has negative or no correlation with relative humidity(MHS) , average wind speed(MWS) while its correlation with minimum temperature(MTN), wet bulb temperature(MTW), pan evaporation (MEP), maximum temperature(MTX) keep on increasing as shown in the table. Dry bulb temperature (MTD) has the maximum correlation with maximum temperature (MTX). From Table 2 it is seen that Wet bulb temperature (MTW) has negative or no correlation with average wind speed (MWS). while its correlation with relative humidity(MHS) minimum temperature(MTN) , pan evaporation (MEP) maximum temperature(MTX),and dry bulb temperature(MTD) keep on increasing as shown in the table Wet bulb temperature (MTW).has the maximum correlation with dry bulb temperature (MTD).

The MLR and ANN models have been developed for seven Meteorological Parameters namely Pan Evaporation (MEP), relative humidity (MHS), dry bulb temperature (MTD), minimum temperature (MTN), wet bulb temperature (MTW), maximum temperature (MTX). The following section gives the analysis of some of the metrological parameters with reference to the input of other recorded meteorological Similar data division is taken to developed ANN model. ANN model has been developed with 5, 4, 3, 2 and 1 parameter as input. The network used to develop this model is Multilayer Perceptron. The transfer function employed is Linear Tanh Axon with 1 hidden layer. The correlation between the actual MTW and the estimated MTW is highest when the ANN parameters. The inputs are added by studying the influence mentioned above and the models are developed accordingly. In this paper only two parameters are discussed wise: Wet bulb temperature (MTW), Dry bulb temperature (MTD).

Estimation of Wet Bulb Temperature (MTW)

As seen in Table 2 MTW has positive correlation with five parameters namely dry bulb temperature (MTD), maximum temperature (MTX), pan evaporation (MEP), minimum temperature (MTN) and relative humidity (MHS). MLR models have been developed using all five parameters and also by eliminating the parameters having lower correlation one by one. It is observed the correlation between actual values of MTW and estimated values of MTW are maximum when MTD, MTX, MEP, MTN and MHS are used to develop the MLR. Hence the MLR model developed with MTD, MTX, MEP, MTN and MHS is considered as best model with correlation (r) for testing 0.91023 and mean absolute error 0.185.The equation of the MLR model developed is MTW= -12.0476 + 0.940556 MTD - 0.00851 MTX -0.01478 MEP+ 0.002857 MTN + 0.140059 MHS (1)

model is built using all the parameters having positive correlation. The correlation of testing for this model is 0.992016 and its MAE is 0.087603. The performance of ANN is better than MLR in estimating. The qualitative analysis of this model is as shown in Fig 2. The Quantitative analysis is given in Table 3.

Table 3 Results of Wet Bulb Temperature

INPUT	OUTPUT	TESTING							
		R		MAE		MSE		RMSE	
		MLR	ANN	MLR	ANN	MLR	ANN	MLR	ANN
MTD	MTW	0.475	0.479	1.264	1.2625	3.36403	3.4037	1.83413	1.8449
MTD,MTX,MEP	MTW	0.472	0.487	1.2554	1.2699	3.359	3.4568	1.832	1.8592
MTD,MTX,MEP,MTN	MTW	0.476	0.484	1.2555	1.2817	3.345	3.4300	1.829	1.8520
MTD,MTX,MEP,MTN,MHS	MTW	0.910	0.992	0.185	0.0876	0.101	0.0281	0.318	0.16763

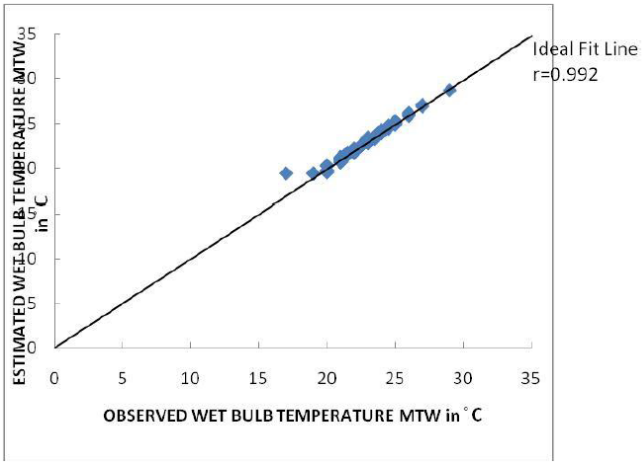

Fig 2 Scatter plot of observed wet bulb temperature versus wet bulb temperature estimated by ANN

Estimation of Dry Bulb Temperature (MTD)

As seen in Table 2 MTD has positive correlation with four parameters namely maximum temperature (MTX), pan evaporation (MEP), wet bulb temperature (MTW) and minimum temperature (MTN). MLR models have been developed using all four parameters and also by eliminating the parameters having lower correlation one by one. It is observed the correlation between actual values of MTD and estimated values of MTD, is highest when MTX and MEP, are used to develop the MLR. Hence the MLR model developed with MTX and MEP is considered as best model with correlation (r) for testing 0.859 and mean absolute error 1.069.

The equation of the MLR model developed is

MTD=7.89232 +0.610367 MTX+0.440602 MEP (2)

ANN models have been developed using all the parameters having positive correlation and then by eliminating the parameters with lower correlation one by one. Hence the ANN model has been developed with 4, 3, 2 and 1 parameter as input. We have built the ANN model using 70% data for training and 30% data for testing.2000 iterations were carried out to develop each model. The network used to develop this model is Jordan/Elman. The transfer function employed is Bias Axon with 1 hidden layer. The correlation between the actual MTD and the estimated MTD is highest when the ANN model is built using MTX and MEP only. The correlation of testing for this model is 0.85599 and its MAE is 1.087971.This correlation is greater than 0.85082977 which is the correlation of MLR for the same input. ANN model performed better in this case also. The qualitative analysis of this model is as shown in Fig 2 and Table 4 gives an idea about the inclusion of parameters in the modeling process to select best possible model.

Table 4 Results of Dry Bulb Temperature

INPUT	OUTPUT	TESTING							
		R		MAE		MSE		RMSE	
		MLR	ANN	MLR	ANN	MLR	ANN	MLR	ANN
MTX	MTD	0.79	0.852	1.098	1.1136	2.076	2.10573	1.440	1.451111
MTX,MEP	MTD	0.850	0.855	1.069	1.0879	2.001	2.03964	1.414	1.42815
MTX, MEP,MTW	MTD	0.770	0.816	1.484	1.2793	4.050	2.89840	2.012	1.7024
MTX,MEP,MTW,MTN	MTD	0.767	0.816	1.481	1.2820	4.058	2.89556	2.014	1.7016

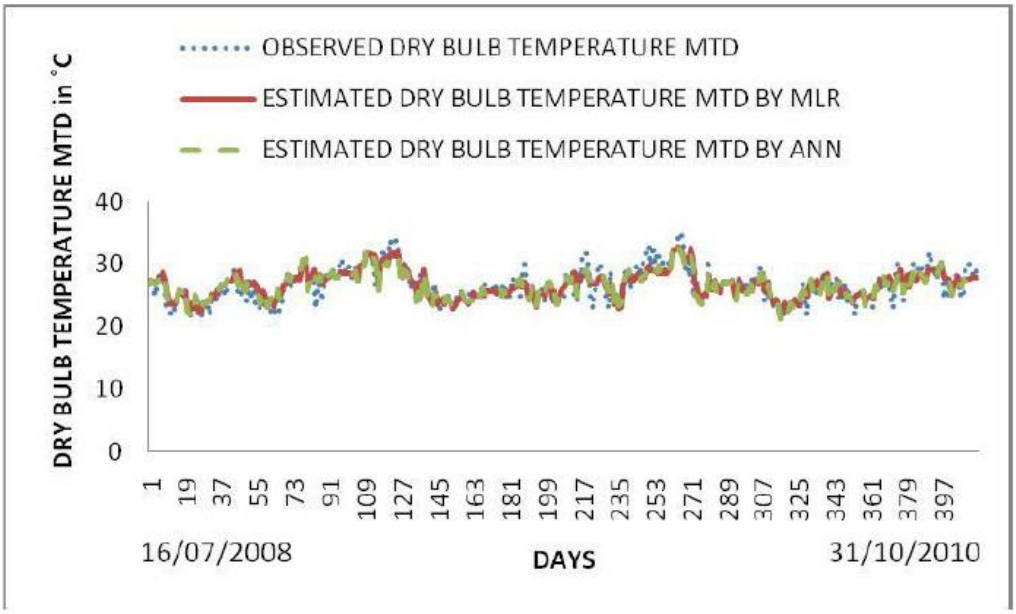

Fig 3 Time series plot of estimated dry bulb temperature by MLR and by ANN

III. CONCLUSIONS

The correlation amongst all the metrological parameters and their effect on each other was studied using simple correlation and statistical analysis. These parameters are important in hydrological process and their influence on each other is largely felt. According to correlation amongst some metrological parameters we have tried to model wet bulb and dry bulb temperature with addition of other recorded metrological inputs as one by one and those with positive correlation values. It is observed that ANN performed better in all the cases.

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