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# Prediction of Evapotranspiration by Artificial Neural Network and Conventional Methods

**Sumit Sharma, Regulwar D.G.**
Government College of Engineering Aurangabad
Email: sharmansumit@gmail.com; regulwar@gmail.com

***Abstract:This study describes the conceptual framework and implementation to estimate the evapotranspiration by using computation technique artificial neural network. The objective of this study is to test an artificial neural network (ANN) to estimate reference evapotranspiration (ETo). Evapotranspiration is one of the main components of the hydrologic cycle. This complex process is dependent on climatic factors. There are many conventional methods to estimate evapotranspiration. Among them three methods that is Modified Penman Method, Thornthwaite method and Blaney-Criddle method equation perform the accurate results of estimating reference evapotranspiration (ETo) among the existing methods. However, the equation requires climatic data that are not always easily available. Artificial neural networks are one of the recent technique and studies for modeling complex systems and nonlinear features have shown very high ability. The major objective of this study is to estimate evapotranspiration using an artificial neural network (ANN) technique and to examine if a trained neural network with limited input variables can estimate evapotranspiration (ETo) efficiently.***

***Keywords: Evapotranspiration, ANN, Modified Penman Method, Thornthwaite method, Blaney-Criddle method***

I. Introduction

Evapotranspiration (ETo) is a term used to describe the sum of evaporation and plant transpiration from the Earth's land surface to atmosphere. Evaporation accounts for the movement of water to the air from sources such as the soil, canopy interception, and water bodies. Transpiration accounts for the movement of water within a plant and the subsequent loss of water as vapour through stomata in its leaves. ETo is a major component of the hydrological cycle and is involved to some degree in nearly all hydrological studies. It is an especially important factor in planning and developing river basins, water recourses and irrigation management. Evapotranspiration forms the foundation for planning and designing of most irrigation projects. It is usually starting point in determining the surface and subsurface water storage requirements, the capacity of the water delivery system, and general operation practices.

If meteorological data is available, we can directly estimate the evapotranspiration by lysimeter. This is direct method of evapotranspiration but due to the time consumption and requires accurate planning; it isn't always possible to use Lysimeter to measure evapotranspiration (George and Raghuwanshi 2012). Hence, indirect methods based on variable weather data and various empirical equations for estimating reference crop evapotranspiration are used. These methods include empirical equations or methods based on physical processes of complex. Out of the methods that are widely used to estimate evapotranspiration one method is Blaney-Criddle method in this method of estimation of ETo related to hours of sunshine and temperature. This method largely used by irrigation engineering to calculate water requirements of crop. The second method is Modified Penman Method. According to Chen *et al.* (2005), the Modified Penman Method is accurate method of estimating ETo. According to Chen *et al.* (2005) another method to estimate ETo is Thornthwaite equations which is developed in eastern USA in which heat index and mean monthly temperature are considered. Thus there is scope for alternative techniques to estimate ETo. Artificial neural network is one of the alternate techniques which can be used to estimate evapotranspiration (Kale *et al.* 2013). Artificial neural networks are a useful tool for modeling nonlinear systems. Artificial neural networks offer Simplified mathematical models of biological neuron networks.

An application of the conventional methods i.e. Blaney-Criddle, Modified Penman Method and Thornthwaite requires l data of solar radiation, wind speed, temperature, saturation vapour pressure, sunshine hours and humidity, heat index However, all these input variables may not be easily available at a given location. If all these climatic data is available then only it is possible to estimate ETo by conventional Methods. Among the inputs needed, temperature data are routinely measured and solar radiation can be estimated with sufficient accuracy. But the other variables are generally measured at only a few locations. Automatic weather stations (AWS), which are commonly used these days in developed countries to measure climatic variables, are rare in many other countries. Often there may not be even a single AWS over an area of thousands of square kilometers. In such circumstances, one may be forced to use data from the 'nearest' station, which may in fact be far away, often in completely different hydro meteorological settings. In view of the above, it is necessary to develop techniques that can be employed to estimate accurately (ETo) for situations where values of some of the variables are not available. Artificial neural networks (ANN), which is a modern data-driven technique, may be well suited for this purpose.

Objective

The main objective of the present study is to predict evapotranspiration by conventional methods like Modified Penman Method (MP), Thornthwaite method (TW), Blaney-Criddle method (BC) and also with the help of alternative technique i.e. Artificial Neural Network (ANN). In Modified Penman Method (MP), Thornthwaite method (TW) and Blaney-Criddle method (BC), evapotranspiration (ETo) is been calculated by using all the variables of climatic data whereas in case of Artificial Neural Network (ANN) technique evapotranspiration is to be calculated with the help of available climatic data.

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II. Study Area

The present study area consists in the area of the Jayakwadi reservoir for prediction of Evapotranspiration with past available data. The Case study is located in latitudes 19º27'055" North and longitudes 75º24'27" East. The data for the study has been collected from Pategaon station on downstream side of Dam. The average annual rainfall in reservoir catchment area is 734mm. The average temperature of study area is 25$^0$C.

III. Methodology

The Data was collected from IMD pune. The Evapotranspiration with the help of conventional method was calculated. The methodology followed for given study is shown in figure 1. The statistical analysis was performed for given data before using for calculation of ETo. The result of statistical analysis is shown in Table 1.Given data for estimation of ETo by ANN are Temperature, Humidity, Wind velocity, sunshine and evaporation. The Table 1 shows the mean, mode and standard deviation for given parameter. The standard deviation value for wind velocity is higher as compared with other parameters. The Table 2 shows

the formula used in different conventional method for estimation of ETo

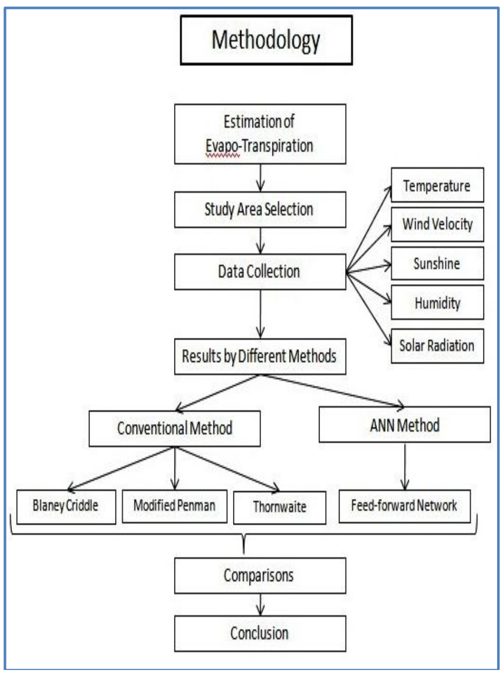


Fig 1. Methodology for Estimation of Evapotranspiration

Table 1. Statistical Analysis for given input parameters

| | Temp | Humidity | Wind Velocity | Sunshine | EVP |
|---|---|---|---|---|---|
| Mean | 25.623 | 66.750 | 124.964 | 7.720 | 3.870 |
| Median | 25.565 | 67.755 | 112.800 | 8.015 | 3.449 |
| Mode | 27.160 | 67.650 | 112.800 | 8.940 | 2.406 |
| Standard | 3.869 | 13.032 | 53.127 | 1.790 | 1.721 |
| Minimum | 16.350 | 41.030 | 47.920 | 3.080 | 0.870 |
| Maximum | 32.660 | 92.360 | 364.900 | 11.070 | 9.248 |
| Confidence | 0.699 | 2.356 | 9.603 | 0.324 | 0.311 |

Table 2. Formula for method used for calculation of Evapotranspiration

| Method | B.C. Method | M.P. Method | TW Method |
|---|---|---|---|
| Formula | $ET_o = 2.54\,K \sum 0.01\,P_h \bar{T}_f$ | $ET_o = \frac{(AH_n + E_a\gamma)}{(A+\gamma)}$ | $ET_o = 1.6 L_a \left(\frac{10T}{It}\right)^a$ |
| | K = empirical coefficient<br>$P_h$ = monthly % of annual day time<br>$T_f$ = mean monthly temperature | A = Slope of saturation vapour pressure vs temperature curve<br>$H_n$ = Net Radiation (mm)<br>$E_a$ = Wind velocity<br>γ = Psychometric constant (0.49) | La = adjustment of number of daylight<br>T = mean monthly air temperature<br>It = mean heat index |
| Output | Evapotranspiration | Evapotranspiration | Evapotranspiration |

Artificial Neural Network and Training Algorithms

ANNs employ mathematical simulation of biological nervous systems in order to process acquired information and derive predictive outputs after the network has been properly trained for pattern recognition. The network topography consists of a set of nodes (neurons) connected by links and are usually organized in a number of layers. The basic structure of an ANN usually consists of three layers an input layer, an output layer, and hidden layer(s) between the input and output layers. Figure 2 shows the Layout of Feedforward network.

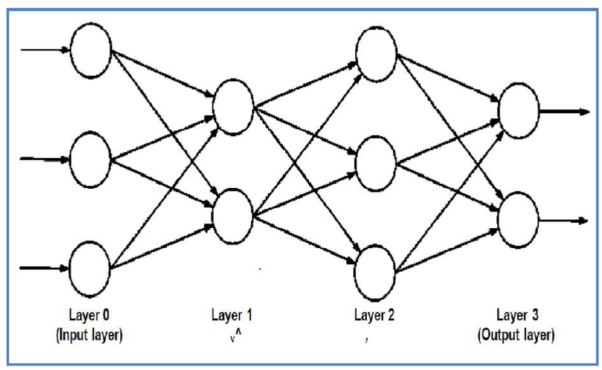


Fig 2. General Layout of Feedforward network

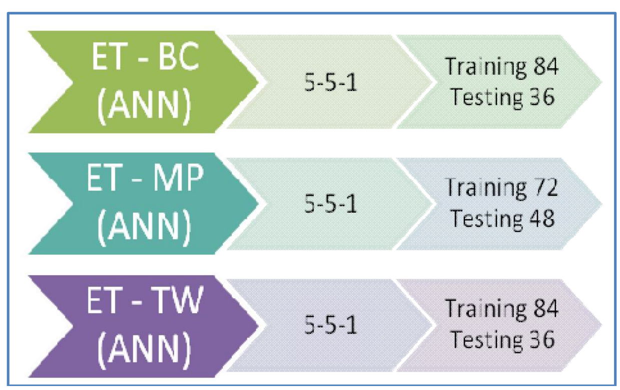


Fig 3. Layer used for different method with training and testing


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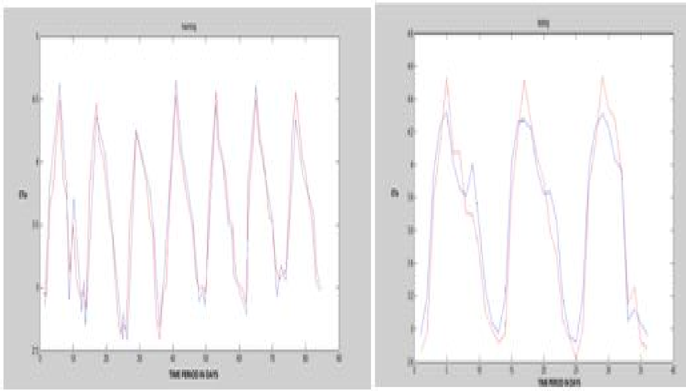

Fig 4. Results of Training and Testing of BC Method and ANN

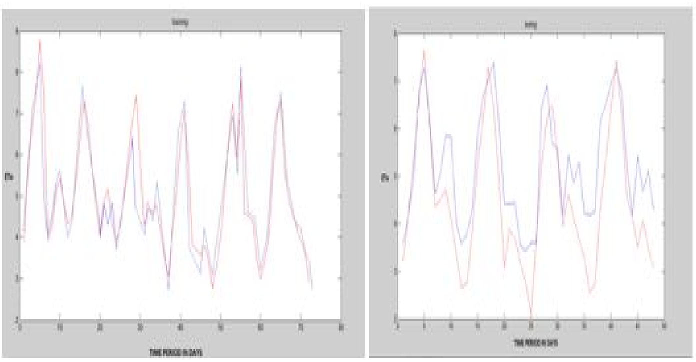

Fig 5. Results of Training and Testing of MP Method and ANN

**data set**

The ANN was performed in Neural Network Toolbox in Matlab 2012a. The Feedforward network is used with Levenberg Marquardt algorithm and Logsig transfer function was used. The five number of hidden layer was used for calculation of Evapotranspiration. The Training and testing.

IV. Results and Discussion

The data collected from year 2003 to 2012 of Paithan region for the purpose of calculating Evapotranspiration using Blaney Criddle Method, Modified Penman Method, and Thornthwaite Method and also with the help of Artificial Neural Network with target value of each method. Following table indicates the results which were calculated using the available data which was collected from Institute of Meteorological Department, Pune (IMD, Pune

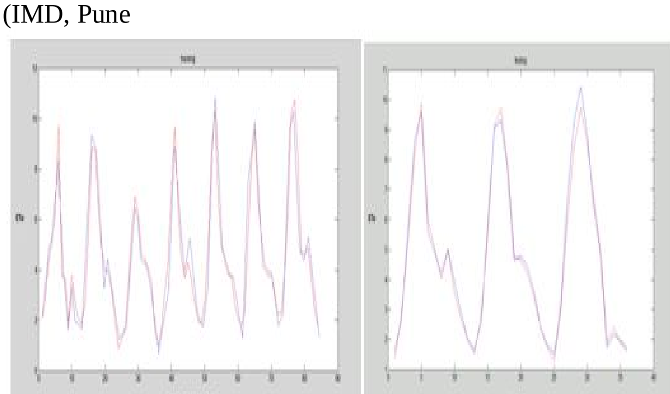

Fig 6. Results of Training and Testing of TW Method and ANN

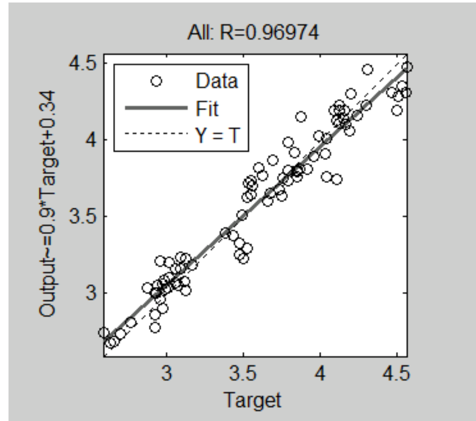


Fig 7. All R value of BC method and ANN

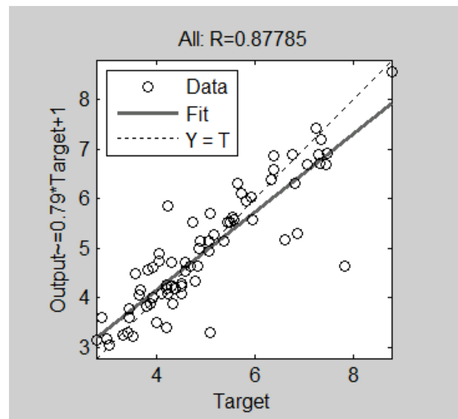


Fig 8. All R value of MP method and ANN

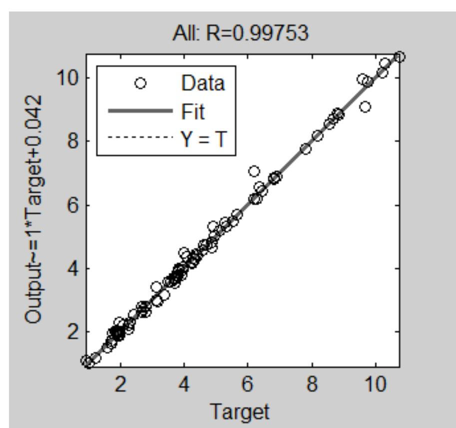


Fig 9. All R value of TW method and ANN

The Figure 4 shows the estimation of ETo with BC method and ANN for different Training and Testing data. The results highlight that training dataset show similar values as compared with conventional methods. Figure 5 shows the estimation of ETo with MP and ANN for different training and testing data. 72 training and 48 testing data was used for MP method and results are approaching towards lesser values than BC method. Figure 6 shows the estimation of ETo with TW method and ANN with 84 training and 36 testing values. Results of prediction TW method are better than other two methods. Figure 7, Fig 8 and Fig 9 shows the All R value for different methods. For BC all R value is 0.9674; for MP all R value is 0.8775 and TW all R value is 0.99753 respectively. The comparison of monthly average results of ETo by three different method are shown in Table 3.

Table 3. Comparison of Conventional results with ANN

| Year | Month | ETo B.C (mm/day) | ETo by ANN Tool B.C (mm/day) | ETo M.P (mm/day) | ETo by ANN Tool M.P (mm/day) | Eto by TW | ETo by ANN Tool TW |
|---|---|---|---|---|---|---|---|
| 2003-2012 | Jan | 2.9206 | 3.2910 | 3.3260 | 5.1228 | 1.6250 | 1.5921 |
| | Feb | 2.9415 | 3.1764 | 4.4250 | 5.4098 | 2.7747 | 2.6985 |
| | March | 3.7329 | 3.1755 | 5.5770 | 4.7452 | 5.0828 | 4.7459 |
| | April | 4.0900 | 3.6510 | 6.6520 | 4.9595 | 8.0240 | 7.5966 |
| | May | 4.4709 | 3.9700 | 7.3490 | 5.3553 | 9.1496 | 8.1012 |
| | June | 4.2199 | 4.1005 | 6.0480 | 5.4022 | 7.3311 | 6.6063 |
| | July | 4.0433 | 3.9602 | 4.7250 | 4.4820 | 4.8862 | 4.4549 |
| | Aug | 3.8319 | 3.7625 | 4.2090 | 4.2345 | 4.2477 | 3.8820 |
| | Sep | 3.5028 | 3.8106 | 4.3210 | 3.9322 | 3.7935 | 3.7692 |
| | Oct | 3.4511 | 3.7260 | 4.3360 | 4.5744 | 3.4729 | 3.4998 |
| | Nov | 3.0224 | 3.6154 | 3.7270 | 5.1413 | 2.4042 | 2.3078 |
| | Dec | 2.8997 | 3.3759 | 3.1510 | 5.3689 | 1.8136 | 2.1132 |

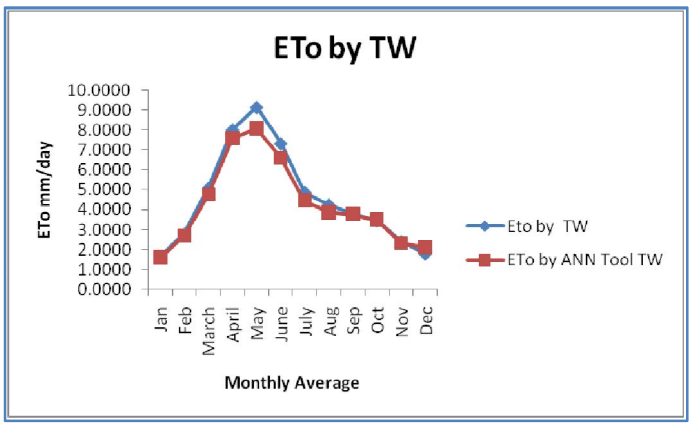


Fig 10. Graphical representation of ETo by TW method and ANN

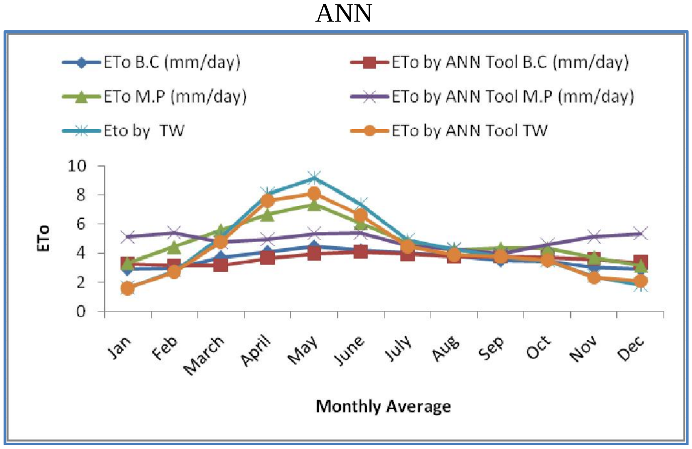


Fig 11. Graphical representation of ETo by conventional method and ANN

The monthly average value of predicted by different method were compared with each other in Graphical representation as shown in figure11. From figure it is clear that predicted value lies nearest to calculated value in case of Thornthwaite (TW) method. Figure 10 shows the monthly average values of predicted and calculated by TW method.

## V. Conclusion

The estimation of evapotranspiration was successfully calculated by three different conventional methods. The ETo values were also predicted with help of ANN model for three different methods. The results of predicted value by ANN and calculated value of conventional methods were compared. The accuracy of ANN method is seen for calculation of evapotranspiration using climatic variables present for study area. From conventional method; it has been observed that Thornthwaite method has great accuracy for calculating Evapotranspiration with comparison of ANN for same method. The TW method shows the successful application by using ANN with highest regression value R = 0.99753. The ANN can be used for estimation of Evapotranspiration from climatic data for given study area which would reduce the calculation time. However, different upgrading of network could be tried using ANN for better accuracy of estimation of Evapotranspiration.

## VI. Acknowledgement

Authors are thankful to Indian Meteorological Department, Pune (IMD, Pune) for providing data for the analysis.

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