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RESEARCH ARTICLE

ESTIMATION OF POMEGRANATE EVAPOTRANSPIRATION FOR ORCHARD MANAGEMENT USING ARTIFICIAL NEURAL NETWORK

*Bhagat, A. D. and Popale, P. G.

Department of Irrigation and Drainage Engineering, Mahatma Phule Krishi Vidyapeeth, Rahuri – 413 722

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ABSTRACT

The study has been undertaken to investigate the utility of artificial neural networks (ANNs) for comparison of weekly values of pomegranate evapotranspiration (ETp) estimated by ETr and Kc approach and that of estimated by ANNs for 1st to 5th year pomegranate orchards. Feed forward network has been used for prediction of ETr using resilient back-propagation method. For the purpose of this study, the meteorological data of 25 years from 1983 to 2007 were used as input. For training of ETp, crop coefficient values were also taken as input to the networks along with meteorological parameters. The results revealed that, the values of correlation coefficient between estimated ETp using crop coefficient approach and ANN estimated ETp which are 0.998, 0.999, 0.9999, 1 and 1 for 1st year to 5th year pomegranate orchards, respectively and the value of MSE 0.0021, 0.0128, 0.0628, 0.0043 and 0.0001 for 1st year to 5th year pomegranate orchards, respectively. Based on comparison, it can be concluded that in the study ANN model is suitable for prediction of ETp.

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INTRODUCTION

Evapotranspiration is one of the major components of the hydrologic cycle. Evapotranspiration is simply a component of an energy budget of activities occurring at crop surface. An energy budget is used to identify the individual components. Its accurate estimation is of paramount importance for many studies such as hydrologic water balance, irrigation system design and management, crop yield simulation and water resources planning and management. The estimation of evapotranspiration from vegetated surface is a basic tool to compute water balances and to estimate water availability and requirements. Evapotranspiration from vegetated surface is the result of several processes like radiation exchanges, vapour transport and biological growth operating within a system involving the atmosphere, plants and soil. Evapotranspiration data is essential for estimating water yields from watersheds, safe yield of ground water basins or stream flow depletion in river basins. Evapotranspiration can either be measured with a lysimeter or water balance approach, or estimated from climatological data. However, these are a time consuming methods and need precisely and carefully planned experiments. A common practice for estimating evapotranspiration from a well-watered agricultural crop is to first estimate reference crop evapotranspiration (ETr) from a standard surface and then to apply an appropriate crop coefficient, which accounts for the difference between the standard surface and crop evapotranspiration. Thus, indirect methods based on climatological data are used for ETr estimation. Crop evapotranspiration differs distinctly from reference evapotranspiration as the ground cover, canopy properties and aerodynamic resistance of the crop are different from grass. Differences in leaf anatomy, stomatal characteristics, aerodynamic properties and even albedo cause crop evapotranspiration to differ from reference evapotranspiration under the same climatic conditions. Consequently, different crops will have different crop coefficient. The crop coefficient integrates the effect of characteristics that distinguish a typical field crop from the grass reference, which has a constant appearance and a complete ground cover. Consequently, different crops will have different crop coefficient. The changing characteristics of the crop over the growing season also affect the crop coefficient (Allen *et al*., 1998). Many scientists have studied the reliability of the Penman-Monteith method for estimation ETr. The Penman-Monteith method was ranked as the best method under all climatic conditions. Evapotranspiration is a complex and nonlinear phenomenon because it depends on several interacting climatological factors, such as temperature, humidity, wind speed, radiation, type and growth stage of the crop, etc.

Artificial neural networks

Artificial Neural Networks (ANNs) are effective tools to model nonlinear systems. A neural network model is a

***Corresponding author:* Bhagat, A. D.**
Department of Irrigation and Drainage Engineering, Mahatma Phule Krishi Vidyapeeth, Rahuri – 413 722

mathematical construct whose architecture is essentially analogous to the human brain. Basically, the highly interconnected processing elements, arranged in layers are similar to the arrangement of neurons in the brain. ANNs have found successful applications in the areas of science, engineering, industry, business, economics and agriculture. Studies on ANN application include rainfall-runoff relationship (Hsu Kuo-tin *et al*., 1993); water table depth simulation (Yang *et al*., 1996); Pesticide concentrations in agriculture soils (Yang *et al*., 1997); soil water content at a given depth prediction (Altendrof *et al*., 1999); land drainage design (Shukla *et al*., 1996); hydraulic roughness coefficients estimation for overland flow (Lopez *et al*., 2002); forecasting of reference evapotranspiration (Trajkovic *et al*., 2003); daily flows modelling (Rajurkar *et al*., 2004). It is evident from the literature, the study has been carried out to utilize input-output mapping capability of ANN in the prediction of ET. The present study describes the utility of artificial neural networks (ANNs) for comparative study between the ANN estimated values of pomegranate evapotranspiration (ETp) and that of estimated values of ETp by ETr and Kc approach for 1^{st} to 5^{th} year of pomegranate orchard.

MATERIALS AND METHODS

Study Area

The study carried out for Solapur district of Maharashtra which is under water scarcity zone having Latitude $17^0 40'$N, Longitude $75^0 54'$E and Altitude 484 m above mean sea level.

Data Collection

Meteorological data of 25 years (1983-2007): Daily parameters (i.e. maximum temperature (T_{max},^{0}C) and minimum temperature (T_{min},^{0}C), maximum relative humidity (RH_{max}, %) and minimum relative humidity (RH_{min}, %), pan evaporation (E_{pan}, mm), wind speed (WS, kmhr^{-1}) at height of 2.0 m, sun shine hours (SSHr, hr), rainfall (R, mm)) etc. collected from Indian meteorological department, Pune and crop coefficient (kc) values collected from unpublished PhD thesis submitted at MPUAT, Udaipur.

Estimation of Reference Crop Evapotranspiration

The most common FAO-56 Penman-Monteith equation was used for the estimating ETr for the present study. The daily values of ET_r were calculated by given equation,

$$ET_r = \frac{0.408\Delta(R_n - G) + \gamma\left(\frac{900}{T+273}\right)u_2(e_s - e_a)}{\Delta + \gamma(1 + 0.34u_2)} \quad \ldots (1)$$

Where,

ET_r = reference evapotranspiration, (mm/day)
G = soil heat flux density, (MJ/m^2 /day)
R_n= net radiation, (MJ/ m^2/day)
T = mean daily air temperature, (^{0}C)
γ = Psychometric constant, (kPa/^{0}C)
Δ= Slope of saturation vapour pressure function, (kPa/^{0}C)
e_s= saturation vapour pressure at air temperature T, (kPa)
e_a= actual vapour pressure at dew point temperature, (kPa)
u_2= average daily wind speed at 2 m height, (m/sec).

Crop Coefficient (k_c)

The week wise crop coefficient values (1^{st}, 2^{nd}, 3ed, 4^{th}, and 5^{th} years orchard) used for different phenological stages i.e. new leaf initiation, crop development, crop maturity and crop harvesting (Meshram, 2010).

Pomegranate Evapotranspiration (ET_p)

The weekly values of ETr and kc (1^{st}, 2^{nd}, 3ed, 4^{th}, and 5^{th} years orchard) used to obtain weekly values of Pomegranate evapotranspiration (ET_p) by equation,

$$ET_p = ET_r * K_c \quad \ldots (2)$$

Where,

ET_p = Pomegranate evapotranspiration (mm/day),
ET_r = Reference crop evapotranspiration (mm/day),
k_c = Crop coefficient of pomegranate

Artificial neural network methodology

During training of ETr, daily meteorological parameters were taken as input to the network and PM estimated ETr as output. But for training of ETp, crop coefficient values were also considered as input along with meteorological parameters, as crop coefficients are of1^{st} to 5^{th} year orchard. The networks were trained with estimated ETp using crop coefficient approach. One of the problems that occur during neural network training is called over fitting. The error on the training set is driven to a very small value, but when new data is presented to the network the error is large. One of the major advantages of neural networks is their ability to generalize. During training, the ANNs provides information on mean square error with each epoch (iteration). Reference evapotranspiration (ET_r) and crop coefficient (k_c) values at different stages have been taken as input to network and pomegranate evapotranspiration (ET_p) estimated using crop coefficient approach method for pomegranate, was considered as output of the network. The graphs have been drawn of error variation with each epoch of training, comparison between estimated values of ET_p using crop coefficient approach method and ANN estimated ET_p. The regression analysis between these two has also been made.

RESULTS AND DISCUSSION

The main purpose of the study is to estimate ETp with ANN and Kc approach. Feed forward network has been used for prediction of ETp using resilient backpropagation method. During training of ETr, crop coefficient also need to be considered along with meteorological parameters and the values of Kc values changes for the 1^{st} to 5^{th} year's orchards.

Pomegranate Evapotranspiration (ETp) Estimated using ANN and Crop Coefficient Approach

1^{st} Year

ANN estimated ETp compared with Kc approach estimated ETp for 1^{st} year pomegranate orchard. The comparative study along with differences in these two is shown in Figure 1 and regression analysis between ANN estimated ETp and that of by Kc approach Estimated is shown in Figure 2. At the final point of training, the solution has been found after 35 epochs with mean square error0.0021 using 52 data sets for the study. The regression analysis between predicted and actual values of pomegranate evapotranspiration (ETp) has been done. The coefficient of correlation was found 0.998. The equation of best fitted line is y = (0.983) x + 0.129.

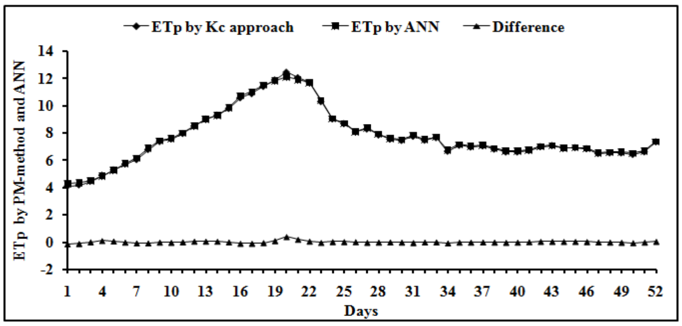

Fig. 1. Comparison between pomegranate ETp (1st year) by Penman Monteith method and ANN technique

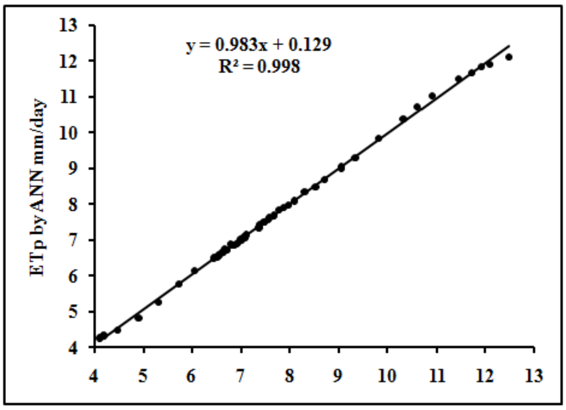

Fig. 2. Regression analysis between pomegranate ETp (1st year) by Penman Monteith method and ANN technique

2nd Year

ANN estimated ETp compared with Kc approach estimated ETp for 2nd year pomegranate orchard. The comparative study along with differences in these two are shown in Figure 3 and regression analysis between ANN estimated ETp and that of by Kc approach Estimated is shown in Figure 4. At the final point of training, the solution has been found after 37 epochs with mean square error0.0123 using 52 data sets for the study. The regression analysis between predicted and actual values of pomegranate evapotranspiration (ETp) has been done. The coefficient of correlation was found 0.999. The equation of best fitted line is y = (0.991) x + 0.129.

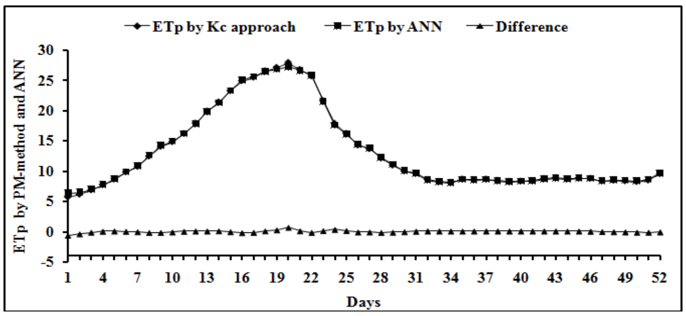

Fig. 3. Comparison between pomegranate ETp (2nd year) by Penman Monteith method and ANN technique

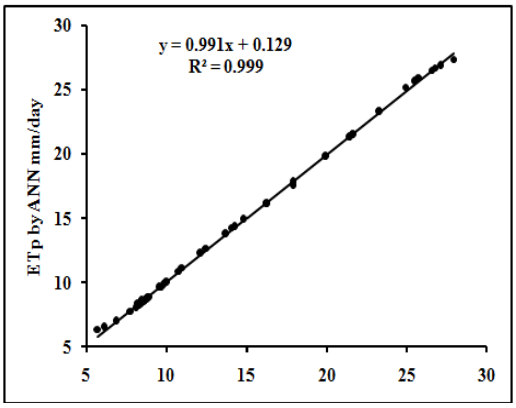

Fig. 4. Regression analysis between pomegranate ETp (2nd year) by Penman Monteith method and ANN technique

3rd year

ANN estimated ETp compared with Kc approach estimated ETp for 3rd year pomegranate orchard. The comparative study along with differences in these two is shown in Figure 5 and regression analysis between ANN estimated ETp and that of by Kc approach Estimated is shown in Figure 6. At the final point of training, the solution has been found after 137 epochs with mean square error0.0628using 52 data sets for the study. The regression analysis between predicted and actual values of pomegranate evapotranspiration (ETp) has been done. The coefficient of correlation was found 0.9999. The equation of best fitted line is y=0.996)x+0.098.

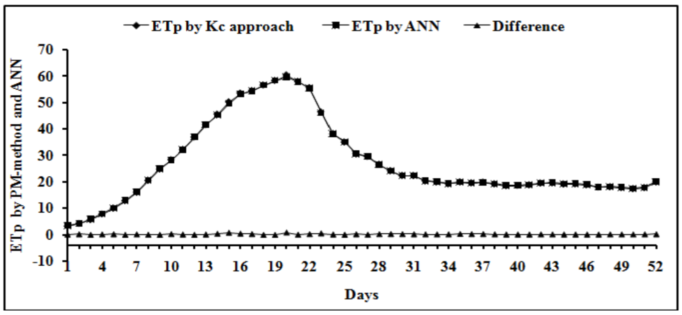

Fig. 5. Comparison between pomegranate ETp (3rd year) by Penman Monteith method and ANN technique

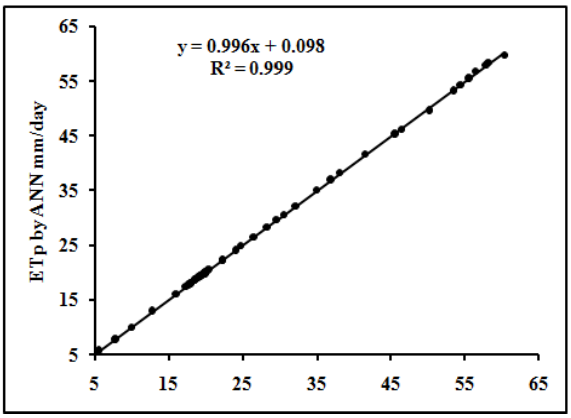

Fig. 6. Regression analysis between pomegranate ETp (3rd year) by Penman Monteith method and ANN technique

4th Year

ANN estimated ETp compared with Kc approach estimated ETp for 4th year pomegranate orchard. The comparative study along with differences in these two are shown in Figure 7 and regression analysis between ANN estimated ETp and that of by Kc approach Estimated is shown in Figure 8. At the final point of training, the solution has been found after 26 epochs with mean square error0.0043using 52 data sets for the study. The regression analysis between predicted and actual values of pomegranate evapotranspiration (ETp) has been done. The coefficient of correlation was found 1.000. The equation of best fitted line is y = (0.999) x + 0.016.

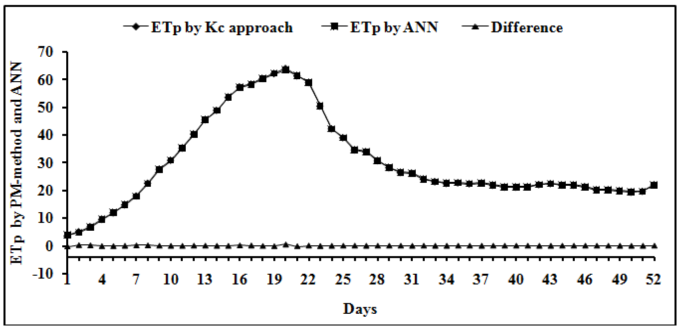

Fig. 7. Comparison between pomegranate ETp (4th year) by Penman Monteith method and ANN technique

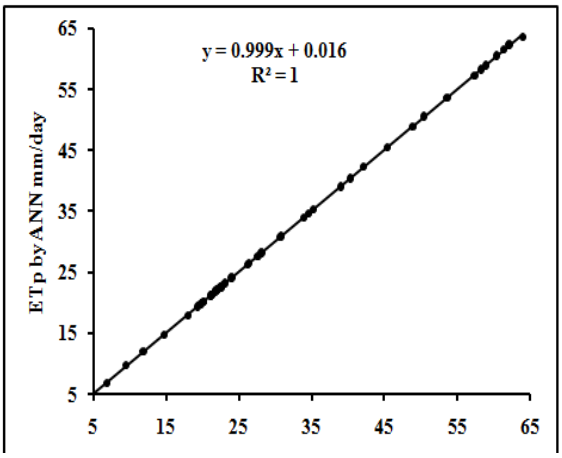

Fig. 8. Regression analysis between pomegranate ETp (4th year) by Penman Monteith method and ANN technique

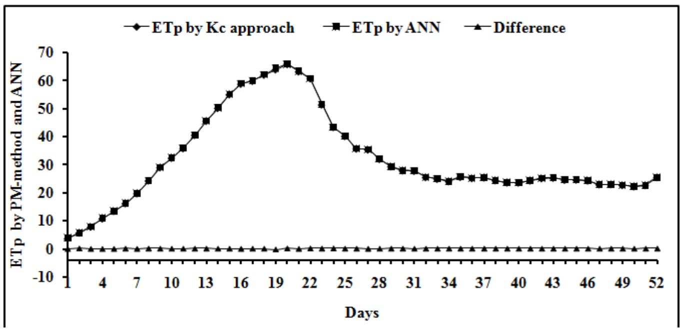

Fig. 9. Comparison between pomegranate ETp (5th year) by Penman Monteith method and ANN technique

5th Year

ANN estimated ETp compared with Kc approach estimated ETp for 5thyear pomegranate orchard. The comparative study along with differences in these two are shown in Figure 9 and regression analysis between ANN estimated ETp and that of by Kc approach Estimated is shown in Figure 10. At the final point of training, the solution has been found after 267epochs with mean square error0.0001using 52 data sets for the study. The regression analysis between predicted and actual values of pomegranate evapotranspiration (ETp) has been done. The coefficient of correlation was found 1.000. The equation of best fitted line is y = (1) x + 0.007. The comparisons of various approaches in respect to number of data sets, number of neurons in hidden layer, epochs for final solution, standard error of estimate, mean square error and correlation coefficient for 1st to 5th year of pomegranate approach have been shown in the Table 1 to 5.

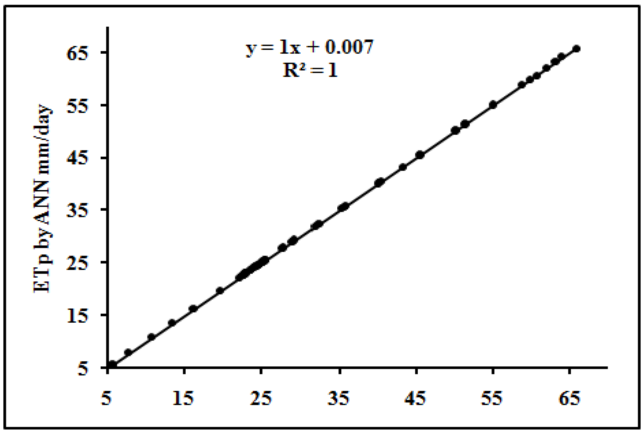

Fig. 10. Regression analysis between pomegranate ETp (5th year) by Penman Monteith method and ANN technique

Table 1. Comparison of pomegranate evapotranspiration (ETp) estimated by crop coefficient approach (1st year) and ANN technique for different neurons in hidden layer

Number of data sets	Number of neurons in hidden layer	Epochs for final solution	Mean square error	Coefficient of Correlation
52	1	23	0.0300	0.9916
52	2	11	0.0206	0.9941
52	3	18	0.0072	0.9988
52	4	35	0.0021	0.9993
52	5	49	0.0028	0.9928
52	6	1	16.39	0.2317

Table 2. Comparison of pomegranate evapotranspiration (ETp) estimated by crop coefficient approach (2nd year) and ANN technique for different neurons in hidden layer

Number of data sets	Number of neurons in hidden layer	Epochs for final solution	Mean square error	Coefficient of Correlation
52	1	144	0.7291	0.9968
52	2	37	0.0128	0.9996
52	3	1	66.506	0.7859
52	4	15	24.071	0.8962
52	5	66	0.3235	0.9972
52	6	37	0.3161	0.9988

Table 3. Comparison of pomegranate evapotranspiration (ETp) estimated by crop coefficient approach (3rd year) and ANN technique for different neurons in hidden layer

Number of data sets	Number of neurons in hidden layer	Epochs for final solution	Mean square error	Coefficient of Correlation
52	1	13	2.086	0.9917
52	2	177	0.3410	0.9986
52	3	90	0.2040	0.9998
52	4	17	0.4072	0.9997
52	5	137	0.0628	0.9999
52	6	27	0.3520	0.9998

Table 4. Comparison of pomegranate evapotranspiration (ETp) estimated by crop coefficient approach (4th year) and ANN technique for different neurons in hidden layer

Number of data sets	Number of neurons in hidden layer	Epochs for final solution	Mean square error	Coefficient of Correlation
52	1	114	0.8040	0.9947
52	2	83	4.9123	0.9957
52	3	19	0.2490	0.9995
52	4	130	1.4575	0.9963
52	5	26	0.0043	0.9999
52	6	7	990.48	0.5823

Table 5. Comparison of pomegranate evapotranspiration (ETp) estimated by crop coefficient approach (5th year) and ANN technique for different neurons in hidden layer

Number of data sets	Number of neurons in hidden layer	Epochs for final solution	Mean square error	Coefficient of Correlation
52	1	15	0.8179	0.99352
52	2	17	0.5327	0.99861
52	3	74	0.0602	0.99982
52	4	44	0.0211	0.9995
52	5	46	0.0045	0.99995
52	6	267	0.0001	0.99999

Conclusion

The results revealed the comparative study of ANN estimated ETp and ETp estimated using crop coefficient approach with Feed forward network for prediction of ETp using resilient backpropagation method. For training of ETp, crop coefficient values were also taken as input to the networks along with meteorological parameters. The values of correlation coefficient between estimated ETp using crop coefficient approach and ANN estimated ETp which are 0.998, 0.999, 0.9999, 1 and 1 for 1st year to 5th year pomegranate orchards, respectively and MSE are 0.0021, 0.0128, 0.0628, 0.0043 and 0.0001 for 1st year to 5th year pomegranate orchards, respectively. ANN has been proved suitable for estimation of pomegranate evapotranspiration.

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