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Review article

Evaporation modeling with artificial neural network: A review

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ABSTRACT

Evaporation from the open pan as well as surface is a complex phenomenon of the hydrological cycle and influenced by many meteorological parameters, such as rainfall, temperature, relative humidity, wind speed and bright sunshine hours. Measurement of evaporation with accuracy is and continuous is a difficult operation. In such situations, it becomes an imperative to use neural network models that can estimate evaporation from available climatic data and may give more accurate results than the measured pan evaporation. In this regard, a number of models for predicting the pan evaporation have been developed by several investigators for different locations of India and abroad. Most of the current models for predicting evaporation use the principles of the deterministically based combined energy balance – vapor transfer approach or empirical relationships based on climatological variables. This resulted in relationships that were often subjected to rigorous local calibrations and therefore proved to have limited global validity. Due to these limitations the conventionally applied regression modeling techniques need to be further refined to achieve improved performance by adopting new and advanced technique like neural networks. Evaporation process is complex and needs non-linear modeling and hence, can be modeled through Artificial Neural Networks (ANN). Large number of researchers have been established the applicability of artificial neural networks (ANNs) to the problems in agricultural, hydrological, meteorological and environmental fields. The review related to evaporation modeling using neural networks is discussed here in brief.

1. Introduction

Evaporation is one of the main processes of the hydrological cycle. The management of scarce irrigation water resources for sustainable crop production in the face of explosive growth of population is becoming more and more important. In hot climate, the loss of water by evaporation from rivers, canals and open-water bodies is a vital factor as evaporation takes a significant portion of all water supplies. Even in humid areas, evaporation loss is significant, although the cumulative precipitation tends to mask it due to which it is ordinarily not recognized except during rainless period. Design and management of water resources require knowledge of the magnitude and variation of evaporation losses. Therefore, the need for reliable models for quantifying evaporation losses from increasingly scarce water resources is greater than ever before. Water resource development projects and farm irrigation systems are basically designed on the basis of long term mean values of evaporation. Accurate estimation of evaporation is fundamental for effective management of water resources. The process of evaporation, however, is influenced by number of factors. Meteorological parameters such as solar radiation, temperature, humidity and wind speed are the major parameters affecting evaporation. Solar radiation affects the temperature and thus the evaporation by heating the air and the water surface. Usually, estimates of evaporation are needed in a wide array of problems in hydrology, agronomy, forestry and land resources planning, such as water balance computation, irrigation management, crop yield forecasting model, river flow forecasting, ecosystem modeling, etc. For example, the widely used Food and Agriculture Organization (FAO) crop monitoring and forecasting model is based on evaporation estimates which are related to crop growth and yield. Where there is a sufficient water resource, irrigation can substantially increase crop yields, but again the scheduling of the water application is usually based on evaporation estimates. Numerous investigators developed models for estimation of evaporation. The interrelated meteorological factors having a major influence on evaporation have been incorporated into various formulae for estimating evaporation. Unfortunately, reliable estimates of evaporation are extremely difficult to obtain because of complex interactions between the components of the land-plant-atmosphere system.

There is increasingly growing demand for evaporation data for studies of surface water and energy fluxes, especially for the studies, which address the impacts of global warming. Evaporation involves the transformation of water from its liquid state into a gas and the subsequent diffusion of water vapour into the atmosphere. However, the measurement of evaporation in the open environment is difficult and is usually done by proxy. Potential evaporation is the variable most often used. Potential evaporation is a measure of the ability of the atmosphere to remove water from a surface assuming no limit to water availability, whereas actual evaporation is the quantity of water that is removed from that surface by evaporation (Brutsaert, 1982). Therefore, actual evaporation is only equal to potential evaporation when a given surface is saturated. The most widespread measurement method for potential evaporation uses a pan evaporimeter, which quantifies water loss from the instrument itself and not from the surrounding environment. The standard US Class A pan is the most commonly used instrument. It consists of a metal container usually covered by an open wire bird guard that is 1,207 mm across and 254 mm high. Evaporation is the amount of loss (gain) in mm depth with rainfall from an adjacent rain-gauge subtracted. Pan evaporation records may contain many artifacts of measurement caused by equipment changes, exposure changes and location changes (Jones, 1992). More accurate estimates of potential evaporation can be obtained by applying other meteorological data to empirical, water budget, energy budget, and combination approaches. However, the most accurate approaches tend to be resource-intensive, site-specific and do not provide long-term estimates of change. Therefore pan evaporation records are the largest single source of data on historical evaporation trends and models can be helpful for agricultural research.

Empirical methods relate either of pan evaporation, actual lake evaporation or lysimeter measurements to meteorological factors using regression analysis. The most realistic method is to obtain direct evaporation from open water surface, be it from extensive water surface of a lake or from a pan. The evaporation pan is, however, the most widely used instrument for evaporation measurement today. Several types of evaporation pans are available, although the standard US Weather Bureau Class ‘A’ pan built of unpainted galvanized iron is currently the most popular throughout the world. For many years, measurements taken on evaporation pans are used to provide estimates of the amount of evaporation from lakes and reservoirs. It has also been used for estimating evapo-transpiration from agricultural crops using procedures relating evapo-transpiration to pan evaporation (Snyder, 1993). As pan evaporation combines the accumulated effects of all the climatic parameters, evaporation from a free water surface of an open pan is widely used as a climatic index for a particular region. Significant problems still exist in the measurement of evaporation. Many times reliable pan evaporation data are not available because of variations in the shape and size of pans, their exposure, the presence or absence of algae in water, the specific methods of measuring the loss of water from the pans and the protection against use of water by birds and animals. Many studies were therefore undertaken to determine reliable relation between pan evaporation and meteorological factors (Singh *et al.,* 1981). Based on this relationship, pan evaporation has been intensively studied for applications in irrigation scheduling. With the advancement of drip irrigation in horticultural crops like citrus, the irrigation scheduling based on pan evaporation is getting more popular due to improved yield (Shirgure *et al.*, 2001). The management of pan evaporation is proved to be useful in other climatological applications. Chattopadhaya and Hulme (1997) have linked trends in pan evaporation measurements to climate change in India. The effect of various weather parameters on pan evaporation was investigated by Xu and Singh (1998; 2001). Models developed to date are recognized procedures for estimating evaporation. Since no single model is universally adequate under all climatic conditions, it is difficult to select the most appropriate evaporation model for a given region. This is partly because of the availability of many equations for determining evaporation, the wide range of data types needed and the wide range of expertise needed to use the various equations correctly. More importantly, objective criteria for model selection are lacking. Consequently, the conditions under which one evaporation model would be more suitable are not always spelled out. The models developed from meteorological data involve empirical relationships to some extent. The empirical relationships account for many local conditions. Therefore, most models may give reliable results when applied to climatic conditions similar to those for which they were developed. Without some local or regional calibration, the use of such models for climatic conditions that are greatly different may give results that may differ considerably.

Evaporation is a complex and nonlinear phenomenon because it depends on several interacting climatological factors, such as temperature, humidity, winds speed, bright sunshine hours, etc. Artificial neural networks (ANN) are effective tools to model nonlinear systems (Kumar et. al. 2002, Sudheer *et. al.* 2003; Shirgure and Rajput, 2011). A neural network model is a 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. The ANN have found successful applications in the areas of science, engineering, industry, business, economics and agriculture. Recently, artificial neural networks have been applied in meteorological and agro ecological modeling and applications (Hoogenboom, 2000). Most of the applications reported in literature concern estimation, prediction and classification problems. Neural network applications have diffused rapidly due to their functional characteristics, which provide many advantages over traditional analytical approaches.

An Artificial Neural Networks (ANN) is a flexible mathematical structure, which is capable of identifying complex nonlinear relationships between input and output data sets. The ANN models have been found useful and efficient, particularly in problems for which the characteristics of the processes are difficult to describe using physical equations. An ANN model can compute complex nonlinear problems, which may be too difficult to represent by conventional mathematical equations. These models are well suited to situations where the relationship between the input variable and the output is not explicit. Instead, ANN, map the implicit relationship between inputs and outputs through training by field observations. The model may require significantly less input data than a similar conventional mathematical model, since variables that remain fixed from one simulation to another do not need to be considered as inputs. The ANN are useful, requiring fewer input and computational effort and less real time control. An ANN can quickly present sensitive responses to tiny input changes in a dynamic environment. Forecasting of pan evaporation particularly in water resource projects planning, design and operation is of paramount importance. Pan evaporation varies spatially and temporally. Spatial distributed measurements of pan evaporation are also beneficial for use in various water resources planning and development programs. The research review has been undertaken with the objectives to study the pan evaporation prediction models using various weather parameters as input variables with artificial neural networks (ANN) and validated with the independent subset of data to estimate the daily pan evaporation using three-layered feed forward neural network with error back propagation algorithm.

2. Research review

Evaporation is influenced by several meteorological parameters like maximum and minimum temperature, sunshine hours, wind velocity, relative humidity, solar radiation, rainfall and vapor pressure of desired locations. But measurement of pan evaporation with accuracy is and continuous is a difficult operation. In such situations, it becomes an imperative to use stochastic or neural network models that can estimate pan evaporation from available climatic data and may give more accurate results than the measured pan evaporation. In this regard, a number of models for predicting the pan evaporation have been developed by several investigators for different locations of India and abroad. Most of the current models for predicting evaporation use the principles of the deterministically based combined energy balance – vapour transfer approach or empirical relationships based on climatological variables. This resulted in relationships that were often subjected to rigorous local calibrations and therefore proved to have limited global validity. Due to these limitations the conventionally applied modeling techniques need to be further refined to achieve improved performance by adopting new and advanced technique. Evaporation is a complex process associated with non-linear model and hence, can be modeled through ANN. The artificial neural networks provide better modeling flexibility than the other statistical approaches with its successive adaptive features of error propagation, where each meteorological variables takes its share proportionally. Numerous researchers have shown applicability of multiple linear regression (MLR) for estimating the evaporation (Baier and Robertson, 1965; Hanson, 1989; Sharma, 1995; Jhajharia *et al.,* 2005) but very few have been seen on artificial neural networks in agricultural and hydrological processes in India. For instance multi-layered feed forward ANN with error back propagation techniques has been used for estimating air temperature (Cook and Wolfe, 1991; Dimri *et al.,* 2002; Smith *et al.,* 2006), wind speed (Mohandes *et al.,* 1998), rainfall (Lee *et al.,* 1998; Chattopadhya, 2006), solar radiation (Elizondo *et al.,* 1994; Dorvlo *et al.,* 2002; Irmak *et al.,* 2003; Reddy and Ranjan, 2003; Bocco *et al.,* 2006), evapo-transpiration (Kumar *et al.,* 2002), soil water content (Schaap and Bouten, 1996; Pachepsky *et al.,* 1996), soil temperature (Mehuys *et al.,* 1997, Tasadduq *et al.,* 2002), soil water evaporation (Han and Felkar, 1997) and various neuro-computing techniques for predicting the various atmospheric processes and parameters (Khan, 1992; Gardner and Dorling, 1998; Asharafzadesh, 1999; Maqsood *et al.,* 2002; Chaudhari and Chattopadhye, 2005; Shirgure, 2012).

The ANN is also widely used in number of diversified fields of soil and water engineering. A number of researchers have attempted to estimate the evaporation values from the climatic variables and most of these methods require data that are not easily available. The simpler methods that are reported to fit a linear relationship between variables is multiple linear regression. However the process of evaporation (pan) is highly non-linear in nature, as it is evidenced by many of the estimation procedures. Many researchers have emphasized the need for accurate estimates of evaporation modeling using better models that will consider the inherent non-linearity in the evaporation process. The comparison of automatically and manually collected pan evaporation data was done by Bruton *et al.,* (2000). Recent researchers have reported that ANN may offer a promising alternative to the conventional methods for estimating the evaporation (Clayton, L. H., 1989; Arca *et al.,* 1998; Gavin and Agnew, 2004; Ozlem and Evolkesk, 2005; Terzi and Keskin., 2005; Keskin and Terzi, 2006; Shirgure and Rajput, 2012) and the lake evaporation (Bruin, 1978; Anderson and Jobson, 1982; Reis and Dias, 1998; Coulomb *et al.,* 2001; Murthy and Gawande, 2006; Shirgure *et al.,* 2011b). Evaporation reflects the influence of several meteorological parameters like air temperature, sunshine hours, wind velocity, relative humidity, solar radiation, evaporating power of the air and vapour pressure deficit of a locality. But measurement of evaporation with accuracy is difficult task. In such cases, it becomes assertive to use formulae or statistical model that can estimate pan evaporation from available climatic data, may give more accurate results than the measured pan evaporation. In this regard, a number of models have therefore been proposed and developed by several investigators for different locations in India and abroad.

2.1. Evaporation models

Evaporation data are not always available for a particular climatic region. Prediction models for evaporation are often used. Accurate estimation of evaporation is difficult because of the complex interaction between the components of the land-plan-atmosphere system. Evaporation rate from the water surface is a function of meteorological conditions of the overlying air, the energy state of the air-water interfacial zone, and the amount of energy stored in the water body. In the absence of measured evaporation rate, the alternative is to use estimation methods. A large number of ANN models have been proposed for estimating evaporation from water surface using climatic data.

2.2. Evaporation models with Artificial Neural Network (ANN)technique

The conventional model requires many input parameters and variables, some of which cannot be obtained easily from the field and may vary from site to site even within the same geographical region. An artificial neural network has found successful applications in the areas of science, engineering, industry, business, economics and agriculture. For example, artificial neural networks have improved the technique of satellite images and patterns recognition, wastewater treatment, remote sensing and seawater pollution classification. Neural Networks (NN) have been used to model a variety of biological and environmental processes (Altendorf *et al.,* 1999). Artificial neural networks models compute complex non-linear problems, which may be difficult to represent by conventional mathematical equations. These models are well suited to situations, where the relationships between the input variable and the output are not explicit. The model may require significantly less input data than a similar conventional mathematical model, since variables that remain constant from one simulation to another, do not need to be considered as inputs. The advantage of the artificial neural networks approach in estimating evaporation is that it requires only limited climatic data. Pan evaporation data are limited and methods are required to estimate evaporation with a minimum of climatic data. Most of the available models for estimation of evaporation may be reliable and most appropriate for use in climates similar to where they were developed. It is likely that errors may occur when these models are used under climatic conditions that are different under which they were developed. Since no evaluation of the different ANN evaporation models has been undertaken there is a need to determine the applicability of these models under the different agro-climatic regions of India. The different methods of estimating pan evaporation approaches reviewed generally performed better when solar radiation and relative humidity were included as input variables. However these data are often not available. Models of pan evaporation are required to be established that corresponds to the relatively minimum weather data variable for most of the locations. In earlier research work of empirical modeling and equation were fit to the data and the correlation was determined with same data set. No attempt was made to apply those models to the other independent data set of different location. The evaporation prediction also highly depends upon the quality of the pan evaporation measurements used in the ANN modeling.

Large number of researchers have been established the applicability of artificial neural networks (ANNs) to the problems in agricultural, hydrological, meteorological and environmental fields. Hu (1964) initiated the implementation of ANN, an important soft computing methodology in weather forecasting. Linacre (1994) used temperature to predict pan evaporation for Australia. He found that daily mean and dew point temperature were able to estimate pan evaporation with a mean absolute error of 1.7 mm/day. Daily soil water evaporation has been estimated using a radial basis function ANN (Han and Felkar, 1997). The ANN models were implemented to establish daily soil water evaporation from average relative humidity, air temperature, and wind speed and soil water content in cactus field study. This ANN had an average absolute percent error of 21.0 % and a root mean square error (RMSE) of 0.17 mm/day. This was better than a multiple linear regression models with values of 30.1 % and 0.28 mm/day for the same parameters. They used daily values of average temperatures, relative humidity and wind speed as inputs to the model. This study was based on only 40 daily evaporation observations. It was also limited in that the weather data were obtained from a weather station 40 km from the site of evaporation measurements. They concluded that the ANN technique appeared to be an improvement over multi-linear regression technique for estimating soil temperature. Gardner and Dorling (1998) discussed the proficiency of the Multi-layer Perceptron as a suitable model for atmospheric prediction.

Bruton *et al.* (2000) developed ANN models to estimate daily pan evaporation using measured weather variables as inputs. Weather data from Rome, Plains and Watkinville, Georgia, consisting of 2044 daily records from 1992 to 1996 were used to develop the models of daily pan evaporation. Additional weather from these locations, which included 720 daily records from 1997 and 1998, served as an independent evaluation data set for the models. The measured variables included daily observations of rainfall, temperature, relative humidity, solar radiation, and wind speed. Daily pan evaporation was also estimated using multiple linear regressions and compared to the results of the ANN models. The ANN models of daily pan evaporation with all available variables as a inputs was the most accurate model delivering an r^2 of 0.717 and a root mean square error 1.11 mm for the independent evaluation data set. ANN models were developed with some of the observed variables eliminated to correspond to different levels of data collection as well as for minimal data sets. The accuracy of the models was reduced considerably when variables were eliminated to correspond to weather stations. Pan evaporation estimated with ANN models was slightly more accurate than the pan evaporation estimated with a multiple linear regression models. Trajkovic *et. al.*, (2000) presented the application of radial basis function (RBF) network to estimate the FAO Blaney-Criddle b factor. Tabular b values are given in the United Nations FAO Irrigation and Drainage Paper Number 24. The b values obtained by the RBF network compared to the appropriate b values produced using regression equations. An example was given to illustrate the simplicity and accuracy of the RBF network for b factor. Trajkovic *et. al.*, (2001) studied the application of RBF (Radial Basis Function) networks to estimate the FAO Penman c factor. The values of the c factors obtained by RBF networks were compared to the appropriate c values produced using regression expressions. It was shown that the RBF networks ensure a better agreement with table c values, thus improving the accuracy of the estimation of reference crop evapo-transpiration. An example that demonstrated the simplicity of the use of RBF networks and the accuracy of the c factor estimation was presented. Kumar *et. al*., (2002) investigated the utility of artificial neural networks (ANNs) for estimation of daily grass reference crop Evapo-transpiration (ET_0) and compared the performance of ANNs with the conventional method (Penman-Monteith) used to estimate ET_0. Several issues associated with the use of ANNs were examined, including different learning methods, number of processing elements in the hidden layer(s), and the number of hidden layers. Three learning methods, namely, the standard back-propagation with learning rates of 0.2 and 0.8, and back propagation with momentum were considered. The networks were trained with climatic data (solar radiation, maximum and minimum temperature, maximum and minimum relative humidity and wind speed) as input and the Penman-Monteith estimated ET_0 as output. The best ANN architecture was selected on the basis of weighed standard error of estimate (WSEE) and minimal ANN architecture. The ANN architecture of 6-7-1 (six, seven and one neuron(s) in the input, hidden and output layers, respectively) gave the minimum WSEE (less than 0.3 mm/day) for all learning methods. That value was lower than the WSEE (0.74 mm/day) between the Penman-Monteith and lysimeter measured ET_0. Similarly, ANNs were trained, validated and tested using the lysimeter measured ET_0 and corresponding climatic data. Again, all learning methods gave less WSEE (less than 0.6 mm/day) as compared to the Penman-Monteith method (0.97 mm/day). Based on these results, it can be concluded the ANN can predict ET_0 better than the conventional method. Maqsood *et al.* (2002) established the usefulness of ANN in atmospheric modeling explained its potential over conventional weather prediction model. Jain et al. (2003) developed ANN models to forecast air temperature in hourly increments from 1 to 12 hours for Alma, Fort Valley and Blairsville in Georgia, USA. However, this study was limited by the fact that the model was not specifically developed to predict frosts. So, even though the model could give a good overall performance, a dedicated model might be able to perform better on the near freezing and freeing temperatures. Sudheer *et al.* (2002) investigated the prediction of Class A pan evaporation using the artificial neural network (ANN) technique. The ANN back propagation algorithm has been evaluated for its applicability for predicting evaporation from minimum climatic data. Four combinations of input data were considered and the resulting values of evaporation were analysed and compared with those of existing models. The results from this study suggest that the neural computing technique could be employed successfully in modeling the evaporation process from the available climatic data set. However, an analysis of the residuals from the ANN models developed revealed that the models showed significant error in predictions during the validation, implying loss of generalization properties of ANN models unless trained carefully. The study indicated that evaporation values could be reasonably estimated using temperature data only through the ANN technique. This would be of much use in instances where data availability is limited. Sudheer *et. al*., (2003) examined the potential of artificial neural networks (ANN) in estimating the actual crop evapotranspiration (ET_c) from limited climatic data. The study employed radial-basis function (RBF) type ANN for computing the daily values of evapotranspiration for rice crop. Six RBF networks, each using varied input combinations of climatic variables, had been trained and tested. The model estimates were compared with measured lysimeter evapotranspiration. The results of the study clearly demonstrated the proficiency of the ANN method in estimating the evapotranspiration. The analyses suggest that the crop ET could be computed from air temperature using the ANN approach. However, the study used a single crop data for a limited period, therefore further studies using more crops as well as weather conditions may be required to strengthen these conclusions. Trajkovic *et. al.*, (2003) applied a sequentially adaptive radial basis function network to the forecasting of reference evapotranspiration (ET_o). The sequential adaptation of parameters and structure was achieved using an extended Kalman filter. The criterion for network growing was obtained from the Kalman filter's consistency test, while the criteria for neuron/connection pruning were based on the statistical parameter significance test. The weather parameter data (air temperature, relative humidity, wind speed, and sunshine) were available at Nis, Serbia and

Montenegro, from January 1977 to December 1996. The monthly reference evapotranspiration data were obtained by the Penman-Monteith method, which was proposed as the sole standard method for the computation of reference evapotranspiration. The network learned to forecast $ET_{o,t+1}$ based on $ET_{o,t-11}$ and $ET_{o,t-23}$. The results showed that ANNs can be used for forecasting reference evapotranspiration with high reliability.

Taher (2003) estimated potential evaporation, especially in arid regions such as Saudi Arabia, has been of a great concern to many researchers. Its importance is obvious in many water resources applications such as management of hydrologic, hydraulic and agricultural systems. For this purpose, four three-layer back propagation neural networks were developed to forecast monthly potential evaporation in Riyadh, Saudi Arabia, based on four explanatory climatic factors. Observations of relative humidity, solar radiation, temperature, wind speed and evaporation for the past 22 years have been used to train and test the developed networks. Results revealed that the networks were able to well learn the events they were trained to recognize. Moreover, they were capable of effectively generalizing their training by predicting evaporation for sets of unseen cases. These encouraging results were supported by high values of coefficient of correlation and low mean square errors reaching 0.98 and 0.00015 respectively. The study has also evolved a comparison with traditional methods and has proven that the developed neural networks were superior. Li (2004) established the suitability of ANN model in establishing maximum surface temperature, minimum surface temperature and solar radiation over regression method at Tifton, Georgia and Griffin. Keskin *et al.,* (2004) concluded that evaporation is one of the fundamental elements in the hydrological cycle, which affects the yield of river basins, the capacity of reservoirs, the consumptive use of water by crops and the yield of underground supplies. In general, there are two approaches in the evaporation estimation, namely, direct and indirect. The indirect methods such as the Penman and Priestley-Taylor methods are based on meteorological variables, whereas the direct methods include the class A pan evaporation measurement as well as others such as class GGI-3000 pan and class U pan. The major difficulty in using a class A pan for the direct measurements arises because of the subsequent application of coefficients based on the measurements from a small tank to large bodies of open water. Such difficulties can be accommodated by fuzzy logic reasoning and models as alternative approaches to classical evaporation estimation formulations were applied to Lake Egirdir in the western part of Turkey. This study has three objectives: to develop fuzzy models for daily pan evaporation estimation from measured meteorological data, to compare the fuzzy models with the widely-used Penman method, and finally to evaluate the potential of fuzzy models in such applications. Among the measured meteorological variables used to implement the models of daily pan evaporation prediction are the daily observations of air and water temperatures, sunshine hours, solar radiation, air pressure, relative humidity and wind speed. Comparison of the classical and fuzzy logic models shows a better agreement between the fuzzy model estimations and measurements of daily pan evaporation than the Penman method. Ozlem *et al.* (2005) estimated daily pan evaporation are achieved by a suitable ANN model for the meteorological data recorded from the Automated *GroWheather* meteorological station near Lake Egirdir, Turkey. In this station six meteorological variables are measured simultaneously, namely, air temperature, water temperature, solar radiation, air pressure, wind speed and relative humidity. Since the purpose in the estimation of evaporation the ANN architecture has only one output neuron with up to 4 input neurons representing air and water temperature, air pressure and solar radiation. Prior to ANN model construction the classical correlation study indicated that the insignificance of the wind speed and the relative humidity in the Lake Egirdir area. Hence the final ANN model has 4 input neurons in the input layer with one at the output layer. The hidden layer neuron number is found 3 after various trial and error models running. The ANN model provides good estimate with the least Mean Square Error (MSE). Molina Martinez *et al.* (2006) developed and validated a simulation model of the evaporation rate of a Class A evaporimeter pan (E_{pan}). A multilayer model was first developed, based on the discretization of the pan water volume into several layers. The energy balance equations established at the water surface and within the successive in-depth layers were solved using an iterative numerical scheme. The wind function at the pan surface was identified from previous experiments, and the convective processes within the tank were accounted for by introducing an internal 'mixing' function which depends on the wind velocity. The model was calibrated and validated using hourly averaged measurements of the evaporation rate and water temperature, collected in a Class A pan located near Cartagena (Southeast Spain). The simulated outputs of both water temperature and E_{pan} proved to be realistic when compared to the observed values. Experimental data evidenced that the convective mixing process within the water volume induced a rapid homogenization of the temperature field within the whole water body. This result led us to propose a simplified version of the multilayer model, assuming an isothermal behavior of the pan. The outputs of the single layer model are similar to those supplied by the multilayer model although slightly less accurate. Due to its good predictive performances, facility of use and implementation, the simplified model may be proposed for applied purposes, such as routine prediction of Class A pan evaporation, while the multilayer model appears to be more appropriate for research purposes. Keskin and Terzi (2006) studied the artificial neural network (ANN) models and proposed as an alternative approach of evaporation estimation for Lake Eirdir. This study has three objectives: (1) to develop ANN models to estimate daily pan evaporation from measured meteorological data; (2) to compare the ANN models to the Penman model; and (3) to evaluate the potential of ANN models. Meteorological data from Lake Eirdir consisting of 490 daily records from 2001 to 2002 are used to develop the model for daily pan evaporation estimation. The measured meteorological variables include daily observations of air and water temperature, sunshine hours, solar radiation, air pressure, relative humidity, and wind speed. The results of the Penman method and ANN models are compared to pan evaporation values. The comparison shows that there is better agreement between the ANN estimations and measurements of daily pan evaporation than for other model.

Dogan and Demir (2006) investigated that the evaporation amount from the lake surface is important in terms of drinking water, irrigation, demand of industrial water, cultivated plant. Generally, daily evaporation amount is calculated two ways. First way is directly evaporation pan estimation. Secondly way is indirectly depending on meteorological data like Penman-Monteith model (PM model). There are some difficulties in this methods, such as; long measurement times, difficulties in measurement, evaporation calculation equations are not universal, etc.. In this study, Genetic Algorithm (GA) and Back propagation Feed Forward Neural Network (FFNN) have been adapted to estimate daily evaporation amount for Lake Sapanca. FFNN and GA models have been applied to daily evaporation estimation depending on daily min and max temperature, wind speed, relative humidity, real solar period and maximum solar period. When performances of the ANN and GA models compared, it has been seen that ANN model yields best result. Tan Stephen Boon Kean *et al.,* (2007) studied evaporation rate estimation is important for water resource studies. Previous studies have shown that the radiation-based models, mass transfer models, temperature-based models and artificial neural network (ANN) models generally perform well for areas with a temperate climate. This study evaluates the applicability of these models in estimating hourly and daily evaporation rates for an area with an equatorial climate. Unlike in temperate regions, solar radiation was found to correlate best with pan evaporation on both the hourly and daily time-scales. Relative humidity becomes a significant factor on a daily time-scale. Among the simplified models, only the radiation-based models were found to be applicable for modeling the hourly and daily evaporations. ANN models are generally more accurate than the simplified models if appropriate network architecture is selected and a sufficient number of data points are used for training the network. ANN modeling becomes more relevant when both the energy- and aerodynamics-driven mechanisms dominate, as the radiation and the mass transfer models are incapable of producing reliable evaporation estimates under this circumstance. Deswal and Mahesh Pal (2008) studied an Artificial Neural Network based modeling technique has been used to study the influence of different combinations of meteorological parameters on evaporation from a reservoir. The data set used is taken from an earlier reported study. Several input combination were tried so as to find out the importance of different input parameters in predicting the evaporation. The prediction accuracy of Artificial Neural Network has also been compared with the accuracy of linear regression for predicting evaporation. The comparison demonstrated superior performance of Artificial Neural Network over linear regression approach. The findings of the study also revealed the requirement of all input parameters considered together, instead of individual parameters taken one at a time as reported in earlier studies, in predicting the evaporation. The highest correlation coefficient (0.960) along with lowest root mean square error (0.865) was obtained with the input combination of air temperature, wind speed, sunshine hours and mean relative humidity. A graph between the actual and predicted values of evaporation suggests that most of the values lie within a scatter of ±15% with all input parameters. The findings of this study suggest the usefulness of ANN technique in predicting the evaporation losses from reservoirs.

Shirgure *et al.,* (2011) and Shirgure and Rajput (2012) developed the models which can generalize for the diversified Indian conditions. The investigation was carried out to develop and test the daily pan evaporation prediction models using various weather parameters as input variables with ANN and validated with the independent subset of data for five different locations in India. The measured variables included daily observations of maximum and minimum temperature, maximum and minimum relative humidity, wind speed, sunshine hours and rainfall. In this GM model development and evaluation has been done for the five locations viz. Nagpur; Jabalpur; Akola; Hyderabad and Udaipur. The daily data of pan evaporation and other inputs for two years was considered for model development and subsequent 1-2 years data for validation. Weather data consisting of 3305 daily records from 2002 - 2006 were used to develop the GM models of daily pan evaporation. Additional weather from these five locations, which included 2066 daily records from 2004 - 2007, served as an independent evaluation data set for the performance of the models. From the studies it is concluded that three layered feed forward neural networks with *Levenberg Marquardt* minimization training function gave the best network training when used in the back propagation algorithm with hidden nodes as 2n+1 for GM modeling. The General ANN models of daily pan evaporation with all available variables as an input was the most accurate model delivering an R2 of 0.84 and a root mean square error 1.44 mm/day for the model development data set. The GM evaluation with NM model development data shown lowest RMSE (1.961 mm/d), MAE (0.038 mm) and MARE (2.30 %) and highest r (0.848), R2 (0.719) and d (0.919) with ANN GM with all input variables. The GM evaluation data has shown the lowest RMSE (1.615 mm/d) and highest R2 (0.781) with ANN GM model consisting of all inputs except sunshine hours (Model M-3). The General model evaluation with NRCC, Nagpur data has shown the lowest RMSE as 1.86 mm/day; with JNKVV, Jabalpur has shown the lowest RMSE as 1.547 mm/day; with PDKV, Akola as 1.572 mm/day RMSE; with ICRISAT, Hyderabad as 1.481 mm/day RMSE and with MPUAT, Udaipur as 2.069 mm/day.

3. Conclusion

In this research review paper the evaporation from open pan as well as surface evaporation modeling is discussed in brief. The process of evaporation is very much complex and non-linear in nature with respect to the meteorological parameter which influences the evaporation. The review related to general evaporation models is given in first section of this paper. The neural network is a new tool which can solve the more complex modeling problems like estimating evaporation from pan, which may be difficult to solve by conventional mathematical equations and multiple linear regression. It is observed from this review that the prediction model for of evaporation is superior with neural networks.

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