Reference Evapotranspiration Assessment Techniques for Estimating Crop Water Requirement

N. Seenu, R M Kuppan Chetty, Taarun Srinivas, K M Adithya Krishna, Ashish Selokar

***Abstract:** Water scarcity is a serious issue that has to be addressed in order to face the increasing water demands. Due to this issue, agricultural crops do not receive the required amount of water. So, it is necessary to have a proper technique to determine the water requirement for a particular crop. Evapotranspiration (ET), a process which is reliant on numerous climatic conditions, quantifies the loss of water from soil and crops through evaporation and transpiration processes respectively. Reference evapotranspiration ET is a concept of estimating ET from the reference surface which resembles an in-depth surface of green grass of stable height, actively growing, fully shading the surface with sufficient water. The amount of water required for a crop is thus determined by multiplying ET_o with the crop coefficient (K_c) which depends on the growth stages and duration of a crop. So, evapotranspiration is considered to be one of the successful approaches to optimize the usage of water for crops. A literature survey is carried out on the popular methods of estimating ET_o and their merits, demerits are discussed in this paper. Also, the impact of various climatic factors on ET_o is presented. From the survey, it is known that ET_o is estimated using conventional and non-conventional methods like Penman-Monteith, Blaney-Criddle, Hargreaves, ANN and WNN, regression and fuzzy logic. Humidity, temperature, wind speed, and solar radiation are the factors that have a major impact on estimating ETo. Generally, conventional methods are tedious since it requires experimental setups and more climatic data to determine ETo which are not available in many under developing countries. Thus, in this case, non-conventional methods are found to yield better results from the survey.*

***Keywords:** Artificial neural networks, conventional, non-conventional, Penman-Monteith, reference evapotranspiration, regression.*

I. INTRODUCTION

Water is a precious gift that is used universally by humans, plants, and animals. Without water, there can be no life. Due to rapid growth in population, the use of water is increasing nowadays. People are facing a shortage of surface and underground waters in many parts of the country [1]-[3]. Hence, it is necessary to know the efficient and effective use of water in order to face the increasing water demands in the field of industrial, domestic, environmental and especially in agricultural sectors [4]. Geographically, India is a vast country. Agriculture alone contributes 17.4% of the total gross domestic product and 58% of the total employment in India [5]. Cereals like wheat are grown in Uttar Pradesh, Punjab and Madhya Pradesh, while, rice is grown in West Bengal and Uttar Pradesh, the gram is grown in Madhya Pradesh and Tamil Nadu, barley is grown in Maharashtra, Uttar Pradesh and Rajasthan and finally bajra is grown in Maharashtra, Uttar Pradesh, and Gujarat. Cash crops like sugarcane are grown in Uttar Pradesh and Maharashtra while poppy is grown in Uttar Pradesh and Himachal Pradesh. Oil seeds like coconut are grown in Kerala and Tamil Nadu, while, groundnut is grown in Tamil Nadu, Gujarat, and Andhra Pradesh. Tea is grown in Assam and Kerala. Spices like pepper are grown in Kerala, Karnataka and Tamil Nadu, ginger is grown in Kerala and Uttar Pradesh.

Irrigation is necessary to minimize the dependency on rain throughout monsoon season and also to support the agricultural production during non- monsoon season [6]. Thus, the water requirement of crops can be determined effectively using an approach called Evapotranspiration. It is a process of loss of water from the soil by evaporation and also by transpiration. The element that contributes to this process is called as Evapotranspirator [7], [8]. When the crop is small, most of the water is dissipated from soil through evaporation. But once the crop is grown and reaches a well-developed stage, it fully covers the soil and loss of water occurs majorly through transpiration [9].

Once the Reference Evapotranspiration (ET_o) is estimated, the water requirement for crops can be calculated by using the formula given in equation (1) [10].

$$ET_C = K_C * ET_o \tag{1}$$

Where,

ET_o - Reference Evapotranspiration or Potential Evapotranspiration

ET_C - Evapotranspiration rate of the crop under standard conditions

K_C - Crop-specific coefficient.

Revised Manuscript Received on November 15, 2019.

N. Seenu*, Centre for Automation and Robotics, Hindustan Institute of Technology and Science,Chennai,India.Email: nseenu@hindustanuniv.ac.in

Dr. R M Kuppan Chetty, Centre for Automation and Robotics, Hindustan Institute of Technology and Science, Chennai, India Email: kuppanc@hindustanuniv.ac.in

Taarun Srinivas, B. tech Mechatronics, Hindustan Institute of Technology and Science, Chennai, India. Email: taarun19@gmail.com

K M Adithya Krishna, B. tech Mechatronics, Hindustan Institute of Technology and Science,Chennai,India. Email: madhu5karigiri@gmail.com

Dr. Ashish Selokar, Accendere, CL Educate India Ltd., New Delhi, India.

This crop-specific coefficient value depends on the initial, mid-season, and end- season periods of the crop [11].

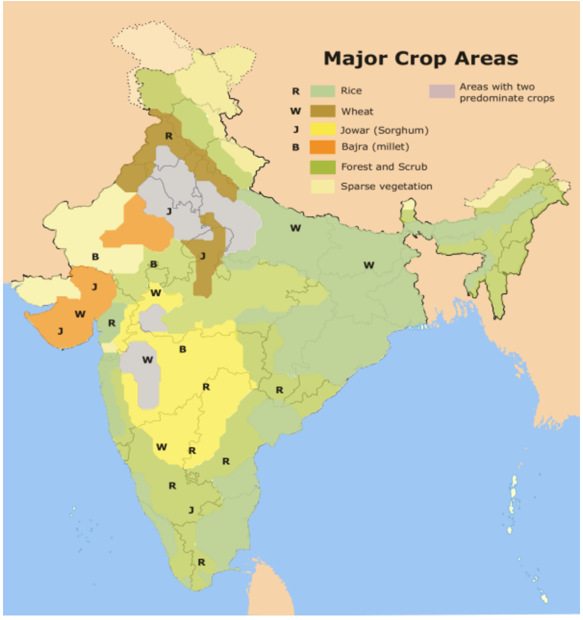

Fig. 1. Major crop areas in India

The main objective of this paper is to (i) perform a literature survey on existing techniques for estimating ET_o (ii) to discuss the merits and demerits of both conventional and non-conventional methods and (iii) to determine the factors on which evapotranspiration rate depends.

II. CONVENTIONAL METHODS FOR ESTIMATING REFERENCE EVAPOTRANSPIRATION

Conventional methods are those methods which use empirical and semi-empirical formulae for estimating evapotranspiration. These methods are used for estimating Evapotranspiration directly by applying the climatic data on the formulae associated with each method. Penman-Monteith, Hargreaves, Blaney-Criddle, Thornthwaite, Turc, Jensen- Haise, Lysimeter and FAO-56 are some of the conventional methods for estimating evapotranspiration. Among these, Penman-Monteith, Blaney-Criddle, and Hargreaves method are found to be the most popularly used.

A. Penman-Monteith Method

The Penman-Monteith method is a conventional method for estimating ET_o in any region during any season. The input parameters associated with the Penman- Monteith method are solar radiation, minimum and maximum air temperature, pressure, wind speed and soil heat flux. The formula used for estimating ET_o using Penman-Montieth method is given in equation (2) [4].

$$ET_o = \frac{0.408\Delta(\square_{\square}-G) + \gamma\, 900\, (T+273)\, \square_2(\square_{\square} - E_a)}{\Delta+\gamma(1+0.34\, \square_2)} \quad (2)$$

Where,

$R_{\square}$ = Net radiation at the crop surface
G = Soil heat flux density
$\square_{\square} - \square_{\square}$ = The vapor pressure deficit of the air
$\square_2$=Wind speed at 2m height
T =Mean daily air temperature at 2m height
Δ=Slope of saturation vapor pressure temperature relationship
γ=Psychrometric constant

Dalai et al., [4] studied the water requirement for crops in Khurda district, Odisha through DSS_ET version 4.1 software. Relative humidity, Minimum and maximum temperature, solar radiation, wind speed and rainfall were available at Bhubaneswar climatic station. This software identifies the best method for estimating ET_o based on the given climatic condition. As all the parameters required for the Penman-Monteith equation were available, ET_o was calculated using the PM method. It was concluded that during Kharif, there was necessary amount of water available surplus water available but in Rabi crops required irrigation since rainfall was not regular. Also, it was found that water requirement was highest for Kharif long duration rice crop and water requirement was lowest for green gram.

Chattopadhyay et al., [12] analyzed ET_o for 10 stations for a period of 15 years in India using the Penman-Monteith method. During post-monsoon and monsoon season, the negative trend of 0.3 mm $day^{-1}decade^{-1}$ and 0.2 mm $day^{-1}decade^{-1}$ respectively was observed across the country. During the winter season, an increasing trend of 1% - 4% were observed across the southern and central part of India. The increasing and decreasing trends in potential evapotranspiration were strongly associated with a rise in relative humidity and a fall in solar radiation.

Kumar et al., [13] developed an extreme machine learning model for estimation of ET_o based on averaged daily data. ANNs were implemented twice using two different sets of parameters. One is using the Author's methodology with a daily pattern from average one year and the other one is using the original data set with non-averaged daily patterns data from 8 years. The ET_o accuracy of $\square\square\square_{\square\square}$ and $\square\square\square_{h\,\square}$ is 0.9883 and 0.8972 respectively on the basis of 8 years' time period and the accuracy of $\square\square\square_{\square\square}$ and $\square\square\square_{h\,\square}$ is 0.9955 and 0.9818 respectively on a time period of 1 average year. The higher accuracy of ET_o is strongly associated with the usage Penman- Monteith method.

Rajan et al., [14] utilized meteorological information, like radiation, mugginess, wind speed, dew point temperature, minimum and maximum temperature for breaking down Penman-Monteith display. Models like Blaney-Criddle, Priestley-Taylor, and Penman evaluated by these models were contrasted with the Penman-Monteith method. Subsequently, the Penman-Monteith display is viewed as better reasonable, contrasted with different models, for Karunguzhi in Kancheepuram District (R^2= 0.878). This model was appropriately altered by recalibrating the constants without influencing the model structure. The altered Penman-Monteith Model has better exactness for the expectation with an improved relationship coefficient (R^2 = 0.915).

Dabral et al., [15] gathered meteorological information from Indian Meteorological

Department (Pune) for Bikaner locale of Rajasthan from the year 1961 to 2005. Month to month ET_o was evaluated utilizing the Penman-Monteith FAO-56 technique. The month to month assessed ET_o values acquired utilizing the Penman- Monteith FAO-56 went from 49.0 mm to 347.5 mm for Bikaner. Month to month ET_o arrangement was having deterministic (pattern and occasional) and stochastic (reliant and autonomous) parts. The correlation coefficient (0.902) and Nash-Sutcliffe coefficient (0.977) indicated a high degree of model fitness to the observed data. Kashyap et al., [16] in his work conveyed that, though Penman-Monteith is an elaborate approach to estimate ET_0, it requires a greater number of climatic data. Often such data aren't available in many developing countries. So, this forces the user to switch over to some other alternative empirical methods for estimating ET_0.

From the survey, it is found that this method yields a good accurate value of ET_o. Among conventional methods, this method is found to be the best and popular one. But Penman-Monteith is a complex method and requires a greater number of climatic parameters.

B. Blaney Criddle Method

The Blaney Criddle method is used for determining the ET_o over the agricultural land considered. The Blaney Criddle method is a temperature-based method for determining *the* ET_o rate or in other words, we take the mean temperature as the input for determining the ET_o rate. The Blaney-Criddle formula for estimating ET_0 is given in equation (3) [17].

$$ET_o = p\,(0.457 \cdot T_{mean} + 8.128) \quad (3)$$

Where,

ET_o - Reference evapotranspiration [mm day^{-1}]

T_{mean} - Mean daily temperature [°C] given as $T_{mean} = (T_{max} + T_{min}) / 2$

p - Mean daily percentage of annual daytime hours.

Jayaram et al., [18] evaluated ET_o utilizing the Blaney Criddle technique and Lysimeter device for onion crops in the semi-arid region of Chitra Durga region, Karnataka. Estimation of ET_o by lysimeter device is observed to be 7.90 mm/day and 6.49 mm/day for the Blaney Criddle method. Blaney Criddle was found to be an easier and reliable method to estimate ET_o in the semi-arid region.

Blaney Criddle method can be applied in areas where only the temperature is available. It has less dependency on input parameters. But the results are found to be less accurate since the number of parameters is less.

C. Hargreaves Method

Hargreaves is one among the conventional methods which is used for ET_o estimation. Temperature is the only parameter that is used in this method for estimating ET_o. The Hargreaves formula for estimating ET_o is given in equation (4) [19].

$$ET_o = 0.0029\, R_a\, (TC+20)\, TR^{0.4} \quad (4)$$

$$TR = T_{max} - T_{min} \quad (5)$$

Where,

ET_o - Reference evapotranspiration

TR- Temperature range

□□ - Extra-terrestrial radiation

TC -Temperature in degree Celsius

T_{max} and T_{min} - Daily maximum and minimum temperature.

Adamala [20] developed a wavelet – Neural Network (WNN) primarily based model for estimating ET_o at 25 meteorological locations that have semi-arid, arid, sub-humid, and humid regions in India. This paper compared the WNN model with different standard models like Artificial Neural Network (ANN), Linear Regression (LR), Wavelet Regression and Hargreaves (HG) to check the simplest performed technique. The ANN and WNN models had a higher performance of 17–38% when compared to the HG technique. This method can be used in areas, where climatic parameters apart from air temperature doesn't seems to be available. Since this method uses less parameter, the results are less accurate.

Conventional methods like Penman-Montieth provide high accuracy of ET_o, but it is a complex method and can be applied only when all the input parameters are known. Blaney Criddle method a simple and reliable method to estimate ET_o but does not provide accurate results. Due to fewer parameters, it provides just rough estimates. Hargreaves method is a direct method for estimating ET_o. Since it has less dependency on the input parameters, this method also does not provide satisfactory results when compared to other methods.

III. NON-CONVENTIONAL METHODS FOR ESTIMATING REFERENCE EVAPOTRANSPIRATION

Non-conventional methods are a way to estimate ET_o through prediction algorithms like ANN, WNN, and regression. These methods have a good generalizing capability and also have a high ability to study complex modeling system and non-linear features. Wavelet Neural Network (WNN), Artificial Neural Network (ANN), Fuzzy Logic, Regressions are popular among the non-conventional methods.

A. Artificial Neural Network (ANN)

Artificial Neural Networks (ANN) are computational models that are based on the biological neural networks, with a similar operation to human procedures. These systems learn to perform tasks by considering examples, in other words, they learn through training sets and testing sets [21]. This ability demonstrates that ANN can go far beyond a simple mapping of input and output relations. In recent decades, ANN has shown a high ability to study modeling complex systems and non-linear features [22]. ANN's can be used to estimate ET_o in a systematic and logical manner.

Kumar et al., [23] estimated daily ET_o using the ANN technique and compared it with the Penman-Monteith method and value obtained through the lysimeter device. It was found that the ANN architecture gave minimum WSEE (Weighted standard Error of Estimate) value (less than 0.3 mm/day), while the WSEE value for PM and lysimeter measured ET_o were between 0.74 to 0.97 mm/day. It was concluded that ANN can be used to estimate ET_o better than conventional PM methods.

Alves et al., [24] determined ETo by the Penman-Monteith method and to forecast it, a feed-forward Multi-Layer Perceptron (MLP) was adopted. In his study, ANN showed a high accuracy as the minimum R^2 was 0.925. They concluded that day-to-day ET_o can be determined by using ANN. Khoshhal et al., [25] conducted a research study to develop an ANN based model to estimate ET_o from limited climatic data. He concluded that neural networks also perform well when inputs are incomplete or affected by measurement error. ANN approach may open a new opportunity for the rapid estimation of accurate ET_o value.

ANNs can determine the accuracy of ET_o during the non-availability of climatic data. ANNs can produce better accuracy when compared to conventional methods for estimating ET_o.

B. Wavelet Neural Network (WNN)

Wavelet Neural Networks, a tool for accurately modeling ETo preserves the property of being a universal function approximator just like other neural network models. This method uses various hydro-climatic variables which are non-stationary in nature.

Adamala [20] developed a generalized neural network model and ANN model similar to the Hargreaves method to estimate ET_o with input parameters, solar radiation, minimum and maximum air temperature. These models were compared with the Hargreaves method and were found that WNN and ANN were 17 to 38% more accurate than the Hargreaves method. These models can be used where the availability of parameters required to estimate ET_o is less for a region.

WNN has an excellent generalizing property and capable to study complex non- linear systems. Non-conventional methods yield a better result of ET_o value compared to conventional methods. But these methods depend on the data determined from conventional techniques.

C. Fuzzy Logic (FL)

Fuzzy Logic is an approach by modern computers to compute the degrees of truth where the truth value ranges from completely true to completely false, rather than the Boolean logic where the truth values of variables are either zero or one. This technique is essentially used in the development of human-like capabilities for Artificial Intelligence.

It is possible to fuse FL and ANN technique to determine ET_o in an accurate manner. This strategy is utilized by Odhiambo et al., [26] where optimized model of FL and ANN fused together was applied to estimate ETo using, wind speed, solar irradiance, air temperature difference, and relative humidity as it's inputs. The estimates were compared with ET_o estimated from FAO Penman-Monteith equation. The coefficient of determination (r^2) value for the optimized model was 0.88 whereas, for the Penman-Monteith estimated ET_o, it was 0.85. It was concluded that, these results showed that this optimized network of fuzzy-neural model is accurate and provides an efficient way of improving fuzzy ET models.

D. Regression

Regression is a statistical analysis to understand the relationship between a dependent variable and two or more independent variable. It includes many techniques for modelling and analyzing like linear regression, binary regression, general linear model. Sanford et al., developed a water-balance method to estimate long term evapotranspiration across US during 1971 to 2000. This method was combined with climate and land-cover regression equation. Temperature and precipitation were used as inputs for climate data set and land-cover data were obtained from USGS National Land Cover dataset.

It was concluded that the climatic factors are the most influential in determining evapotranspiration, since an error of 13% occurred from the climate-only regression. Using regression analysis, maps showing estimates of evapotranspiration can be generated from climate and land-cover data [27].

IV. COMPARISION OF CONVENTIONAL AND NON-CONVENTIONAL METHODS

Evapotranspiration is one of the effective techniques to estimate the water requirement for a particular crop. Evapotranspiration is usually estimated using various conventional and non-conventional methods. It is found that Penman- Monteith is the most effective method among the conventional methods since high parameter demanding methods yields better accurate ET_o values when compared to less parameter demanding methods. But these conventional methods have some disadvantages too. These methods require a greater number of meteorological data for estimating ET_o. They consume more time; also, they are prone to human errors. Many weather stations don't contain all the necessary sensors required to calculate the climatic parameters. Even if they are present, they often provide data of low quality [24]. Lysimeter, a conventional device to estimate ET_o is time-consuming and requires accurate planning.

So, to overcome these issues non-conventional techniques like ANN, WNN, FL, Regression analysis can be used to estimate ETo in a better manner. These methods have a good generalizing capability and also have a high ability to study complex modeling system and non-linear features. They also do not consume more time and does not require any experimental setup. But these methods depend on the data from conventional methods.

The table given below discuss the advantages and disadvantages of some conventional and non-conventional methods.

Table- I: Pros and cons of conventional and non-conventional methods

Conventional Methods	Pros	Cons
Penman-Montieth	It provides high accuracy of evapotranspiration.	Penman-Montieth method is a complex method and can be applicable only when all the input parameters are known.

Blaney-Criddle	It is a simple and reliable method to estimate evapotranspiration	Blaney Criddle method does not provide accurate results. It provides just rough estimates.
Hargreaves	It is a direct method for estimating evapotranspiration. It has less dependency on the input parameters.	Hargreaves method does not provide satisfactory results when compared to other methods.
Non-Conventional Methods	**Pros**	**Cons**
ANN and WNN	ANNs can be applied where the during the non-availability of parameters. WNNs have a good generalizing capability and also has a high ability to study complex modelling system and non-linear features. They also do not consume more time and the results are accurate than conventional methods.	ANN and WNN work on climatic data from the conventional methods like Penman-Montieth, Blaney-Criddle, Hargreaves.
Fuzzy logic	Fuzzy Logic can produce high accurate results because of generalization and learning capabilities.	Fuzzy Logic models can be made effective only through neural training.
Regression	Regression can be used to determine ET rate using non-linear parameters	Regression produces inaccurate results in some cases.

V. IMPACTS AND USAGE OF CLIMATIC PARAMETERS

A. Impacts of Climatic Parameters on ET_o

The value of ET_0 has been found to vary in various regions during different climatic seasons. During the monsoon and post-monsoon season, the West – Central regions of India experienced a fall in the value of ET_o while South and North-East India experienced a slight increase in the ET_o rate [12]. Similarly, Dabral, in his study found a fall in the value of ETo during monsoon season in Rajasthan from 2001 to 2005 [15]. From these studies, it can be understood that climatic factors have a major impact on ET_o.

Pandey et al., found an increase of ET_o by 4-12% in the Narmada river basin during the period 1901-2000. It was found that temperature was the major factor for the rise in ET_o value [28]. Rajan et al., in their paper conveyed that surface water loss occurs primarily through ET_o which is the atmospheric demand of moisture that occurs through evaporation [14]. So, an increase in soil moisture content increases the rate of Evapotranspiration. Chattopadhyay et al., in his study, conveyed the relationship between relative humidity and ET_o [12]. As relative humidity increases, the solar radiation decreases, a fall in ET_o occurs.

As evaporation takes place, the encompassing air slowly becomes saturated. If the wet air is not transferred to the atmosphere, then, this process will gradually slow down and possibly stop. Thus, it is necessary to replace the saturated air with drier air, which highly depends on wind speed [9]. So, relative humidity, soil moisture, solar radiation, temperature, and wind speed are the important parameters that have a major impact on estimating ET_o.

B. Effective use of climatic parameters for estimating ET_0

Evapotranspiration can be determined using the parameters such as, relative humidity, solar radiation, wind speed, atmospheric pressure, mean maximum and minimum temperature, land surface temperature, rainfall, soil, and vegetation. Though all these parameters are not available for some region and stations, it is possible to estimate ET_o with the available parameters by selecting the suitable method.

Regions where the air temperature is the only available factor, ET_o can be determined effectively using ANN and WNN techniques. In a study, Adamala. S [20] determined ET_o value with 17 to 38% more accurate than conventional HG method using ANN and WNN models where the air temperature was the only available data. Similarly, Hargreaves et al., [29] in his work recommended that, considering the problems due to the non-availability of climatic data in many developing countries, Hargreaves method which considers only temperature and solar radiation as its input, is found to be the most simple and practical method for estimating ET_o.

Also, it is possible to identify a suitable method for the given parameters using the software. DSS_ET version 4.1 is such a software that consists of 22 most popularly used and ET_o estimation methods that are accepted internationally. This software selects the best method for estimating ET_o based upon the given climatic condition. It identifies the data demanded by any method and if the available method satisfies the data requirement of the first-rank method (Penman-Monteith), the system estimates ET_o with that method, if not, it finds for the next suitable method. Using this software, Dalai et al., [4] studied the water requirement for crops in Khurda district, Odisha and found that during Kharif, long duration rice crop required more water and during Rabi, Green gram required less water.

High parameter demanding methods yields better accurate ET_o values when compared to less parameter demanding methods. This can be understood through a study by Rajan et al., who estimated ET_o using the Penman-Monteith method which demands radiation, humidity, wind speed, minimum and maximum temperature as it's input parameters. When compared the value obtained from PM method with less parameter demanding methods like Blaney-Criddle and Priestly Taylor, it was found that PM model had a high correlation coefficient (0.636) which indicates better accuracy of ET_o when compared to the values (0.308) obtained from less parameter demanding methods [14]. Similarly, McKenny et al., [30] in his work conveyed that temperature-based methods produces estimates are generally less reliable than those methods which take many climatic factors into account. Among all the methods considered, accurate results were produced by Penman-Monteith method.

So, the accuracy of less parameter demanding methods can be increased by multiplying the correction factor with the estimated ET_o value from any method. The formula for correction factor is given in equation (6) [4].

$$\text{Correction factor} = 1/n^{*} (ET_{op} / ET_{oa}) \quad (6)$$

Where,

n = number of years used
correction factor = Average of daily ET_0 data for 'n' years.
ET_{0p}= ET_0 from FAO 56, Penman-Montieth method
ET_{0a} = ET_0 from any method

In this way, we can get the results equivalent to FAO 56, Penman-Montieth method using correction factor for any estimation method.

VI. DISCUSSIONS

The implication of this study is to discuss the various techniques used to estimate reference evapotranspiration, to determine the water required for a crop. Many conventional and non-conventional methods are available to estimate ET_o. Among conventional methods, Penman-Monteith method which is a high parameter demanding method, stands first as it yields accurate values of ET_o. Since, all these parameters are not available for some region and stations, it is not possible to estimate ET_o with this method for all the regions. Blaney Criddle and Hargreaves methods are also a simple and reliable method to estimate ET_o. But, as they use fewer parameters, their results are not very accurate when compared to Penman-Monteith. So, in order to overcome this issue, correction factor is used to improve the accuracy of less parameter demanding methods. Non-conventional methods like ANN, WNN are a kind of computational models that have an excellent generalizing property and capable to study complex non-linear systems. Fuzzy logic is a method to determine ET_o based on the degree of truth. Fusing FL with ANN, it is possible to get an accurate ET_o value. Also, regression, a statistical approach is being widely used to determine ET_o. From the survey, it is found that non-conventional methods yield a more accurate results than conventional methods. Also, it is found that relative humidity, soil moisture, solar radiation, temperature, and wind speed are the factors that have a major impact on estimating the value of ET_o. Since many regions doesn't contain all the parameters required to estimate ET_o it is necessary to choose the method based on the parameters available in the region. Temperature is one such parameter which is available at all the regions. Thus, using Hargreaves method or ANN it is possible to estimate ET_o using only temperature as its input. Finally, its accuracy can be increased using correction factor.

VII. CONCLUSION AND FUTURE SCOPE

Evapotranspiration is a popular approach to solve the water shortage issue in India. It is a procedure reliant on numerous climatic components. Estimation of ET_o value depends on various climatic factors like humidity, temperature, solar radiation, the moisture content in soil and also rainfall. It is important to choose suitable methods based on the available parameters in a particular region. Among conventional methods, Penman-Monteith methods yields accurate and better results when compared to others. Since conventional methods are tedious in estimating ET_o like constructing and operating a lysimeter device and also due to the non-availability of climatic data for various regions, non-conventional methods are recommended over conventional. Artificial Neural Network is an effective method for estimating reference evapotranspiration when compared to other conventional and non conventional methods as they are less dependent on the input parameters and yield better results.

Scientific research will continue by performing a comparative analysis of different machine learning algorithms to estimate ET_o. These techniques can be applied in a real-time situation by developing an optimal water usage control system which can be used by farmers to estimate the water required for a crop. This ensures that the crop will receive the exact amount of water it needs for its healthy growth. Thus, evapotranspiration provides a solution for water scarcity in the field of agriculture.

VIII. ACKNOWLEDGEMENT

We would like to express our sincere gratitude and thanks to Dr. Ashish Selokar, Accendere, CL Educate Ltd., New Delhi, India for his valuable suggestions. We express our sincere gratitude and thanks for his help in the whole duration of executing this research work.

REFERENCES

1. P.A.M. Kumar, N.J. Dalal, "Estimation and comparison of evaporation losses by different empirical methods," International Research Journal of Engineering and Technology 5, 2018, pp. 5058-5059.
2. B.A George, S.A Shende, N.S Raghuwanshi," Development and testing of an irrigation scheduling model", Elsevier, Agricultural Water Management 46, 2000, pp. 121-136
3. S Jamshidi, S Zand-Parsa, M.N Jahromi, D Niyogi," Application of a simple landat-modis fusion model to estimate evapotranspiration over a heterogenous sparse vegetation region", Remote Sensing 11(741), 2019, pp. 1-19
4. A Dalai, C.R Subudhi, B Dalai, R.R Mohanty," Comparative study of water requirement with seasonal rainfall for cereals, pulses, and oilseed of Khurda district of Odisha", International Journal of Chemical Studies 6(3), 2018, pp. 1377-1381
5. S.K Goroshi, R Pradhan, R.P Singh, K.K Singh, J.S Parhar," Trend Analysis of Evapotranspiration over India: Observed from long-term satellite Measurement 126", J. Earth Syst. Sci. (113), 2017, pp. 1-21
6. H.L Shah, T Zhou, M Huang, V Mishra," Strong influence of irrigation on water budget and land surface temperature in Indian sub-continental river basins", Research Gate 124 (3), 2019, pp. 1449-1462
7. W.B Shoemaker, C.D Lopez, M.J Duever, "Evapotranspiration over Spatially Extensive Plant Communities in the Big Cypress National Preserve, Southern Florida", 2011.
8. Z.L Li, R Tang, Z Wan, Y Bi, C Zhou, B Tang, G Yan, X Zhang," A review for current methodologies for regional evapotranspiration estimation from remotely sensed data", Sensors 9, 2009, pp. 3801-3853
9. http://www.fao.org/3/X0490E/x0490e04.html
10. https://www.smart-fertilizer.com/articles/water-requirements-of-crops
11. L.S Pereira, R.G Allen, M Smith, D Raes," Crop evapotranspiration estimation with FAO 56: past and future", Elsevier, Agricultural Water Management 147, 2015, pp. 4-20
12. N Chattopadhyay, M Hulme," Evaporation and Potential Evapotranspiration in India under conditions of recent and future climate change", Agricultural and Forest Meteorology 87, 1997, pp. 55-73
13. D Kumar, J Adamowski, R Suresh, B.O Zielinski, P Marti," Discussion of Estimating evapotranspiration using an extreme learning machine

model: case study in North Bihar, India", J. Irrig. Drain Eng 144(5), 2018, 07018017-1-07018017-5
14. S Rajan, D Vijayalakshmi, M.M Nagamani," Estimation of evapotranspiration using field measurements and modelling techniques on paddy crop water requirements in Kancheepuram District, Tamil Nadu, India", Water Utility Journal 18, 2018, pp. 51-60
15. P.P Dabral, NeizevonoMor, D Jhajharia," Time series modelling of monthly reference evapotranspiration for Bikaner, Rajasthan (India)", Indian Journal of Soil Conservation 46, 2018, pp. 42-51
16. P.S Kashyap, R.K Panda," Evaluation of evapotranspiration estimation methods and development of crop-coefficients for potato crop in a sub-humid region", Elsevier, Agricultural Water Management 50, 2001, pp. 9-25
17. https://www.revolvy.com/page/Blaney%E2%80%93Criddle-equation
18. S.H Jayaram, D.H Thippeswami, G.B Rajasekhar, L Raj, S Gowda," Estimation of evapotranspiration for onion crop in semi-arid region: experimental field setup using lysimeter", Urban and Regional Planning 3(1), 2018, pp. 1-5
19. G.H Hargreaves, F ASCE, R.G Allen," History and Evolution of Hargreaves Evapotranspiration equation", Journal of Irrigation and Drainage Engineering 129(1), 2003, pp. 53-63
20. S Adamala," Temperature based generalized wavelet –neural network model to estimate evapotranspiration in India", Information Processing in Agriculture 5, 2018, pp. 149–155
21. S Chauhan, R.K Shrivastava," Performance evaluation of reference evapotranspiration estimation using climate-based methods and artificial neural network", Springer, Water Based Manage 23, 2009, pp. 825-837
22. G Landeras, A Ortiz-Barredo, J.J Lopez," Comparison of artificial neural network models and empirical and semi-empirical equations for daily reference evapotranspiration estimation in the Basque country (Northern Spain)", Elsevier, Agricultural Water Management 95, 2008, pp. 553-565
23. M Kumar, N.S Raghuwanshi, R Singh, W.W Wallender, W.O Pruitt," Estimating Evapotranspiration using Artificial Neural Networks", Journal of irrigation and drainage engineering 128, 2002, pp. 224-233
24. B Walison, G.S Rolim, O Aparecido," Reference Evapotranspiration forecasting by Artificial Neural Networks", Journal of the Brazilian Association of Agriculture 37, 2017, pp. 1116-1125
25. J Khoshhal, M Mokarram," Model for prediction of Evapotranspiration using MLP neural Networks", International Journal of Environmental Sciences 3, 2012, pp. 1000-1009
26. L.O Odhiambo, R.E Yoder, L.E Yoder, J.W Hines," Optimization of fuzzy evapotranspiration model through neural training with input-output examples", American Society of Agricultural Engineers 44(6), 2001, pp. 1625-1633
27. W.E Sanford, D.E Selnick," Estimation of evapotranspiration across the conterminous united states using a regression with climate and land-cover data", Journal of the American Water Resource Association 49(1), 2013, pp. 217-230
28. B.K Pandey, D Khare," Identification of trend in long term precipitation and reference evapotranspiration over Narmada river basin (India)", Global and Planetary Change 161, 2017, pp. 172-182
29. G.H Hargreaves, Z.A Samani," Reference crop evapotranspiration from temperature", American society of agricultural engineers 1(2), 1985, pp. 96-99
30. M.S McKenny, N.J Rosenberg," Sensitivity of some potential evapotranspiration estimation methods to climate change", Elsevier, Agricultural and forest meteorology 64, 1993, pp. 81-110

AUTHORS PROFILE

N. Seenu is currently an Assistant Professor with Hindustan Institute of Technology and Science, Chennai, India. She received B.E degree in Computer Science and Engineering from Anna University, Chennai, India in 2011. She obtained her M.E degree in Mechatronics Engineering from Anna University, Chennai, India in 2013. Now she is working towards her PhD degree in Hindustan Institute of Technology and Science, Chennai, India. Her interests include path planning and optimization control for autonomous mobile robots and Artificial Intelligence.

Kuppan Chetty Ramanathan currently works as Associate Professor in Center for Automation and Robotics, School Mechanical Sciences, at Hindustan Institute of Technology and Science, Chennai. Prior to this, he worked as an academic/research faculty at Monash University Sunway campus, Malaysia. He has graduated with B. Tech in Instrumentation and Control Engineering, 2002, M. Tech in Sensors Systems Engineering, 2004 and PHD in Robotics, 2010 from IIT Madras. His interests are in the field of Intelligent Robotics, Path Planning and Navigation, Heurestic approaches, Electrostatic Actuators, Artificial Intelligence, Sensors and Artificial perception etc. He has around 30 Publications in peer reviewed International Journals and Conferences, three research grants, etc. He was also a recipient of prestigious award of National Doctoral Fellowship from AICTE during PHD and a research internship from National Institute of Informatics, JAPAN. He is an active member of IEEE Robotics and Automation Society.

Taarun Srinivas is currently pursuing his under graduation in mechatronics engineering at Hindustan Institute of Technology and Science. His interests include artificial intelligence and robotics.

K M Adithya Krishna is currently pursuing his under graduation in mechatronics engineering at Hindustan Institute of Technology and Science. His interests include robotics, machine learning and astrophysics.

Dr. Ashish Selokar is presently working in Accendere CL Educate Pvt Ltd., new Delhi, India. He has done his Ph.D. from IIT Roorkee. He has 6 years of Research experience. His research interests include metallurgical science, pollution survey and analysis software in mechanical engineering. He has published several research papers in referred international journals and conferences. His research interest includes Material science and Environmental Physics.