Determination of Evapotranspiration Rates In Semi-Arid Region

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Abstract- *In this work, FAO-56 Penman Monteith, Thornthwaite, Blaney-Criddle and Lysimeter method were applied to evaluate the actual evapotranspiration for Tomato crop in the semi-arid region of Davanagere district. A reliable and accurate estimation of evapotranspiration are required for proper water balance and to define water-crop requirement. For this purpose, Lysimeter was set up in the field using sandy soil with a density1.861*10-3 which implies 98.48kg ofsoil and Tomato seeds were sown in it, for which 3500 ml of water was added for every 2days and corresponding percolation was observed to find potential water balance deficit and surplus. In this research work, an attempt is made to estimate daily evapotranspiration for Tomato crop, for which 1000ml of water was added on daily basis and corresponding percolation was observed to find thepotential water balance deficit and surplus. Tomato is a local crop of Davanagere district which is grown throughout the year. For FAO-56 Penman Monteith, Thornthwaite and Blaney-Criddle equation, crop coefficients of 0.45, 0.75, 1.15 and 0.80 is adopted to estimate the actual evapotranspiration. FAO-56 Penman Monteith method gave nearer value whose correlation coefficient is about 0.94. The other two method also gave good results with correlation of about 0.90 and 0.84 respectively and these methods found to be simple and reliable to estimate the evapotranspiration in semi-arid region.*

Keywords- Evapotranspiration, Lysimeter, FAO-56 Penman Monteith, Thornthwaite, BlaneyCriddle.

I. INTRODUCTION

Water is the principle need for all life forms, whose availability defines how and where the Flora and Fauna exist on the earth. Rivalry for water among people and between people and other living things is the unavoidable result of blossoming populaces and a constrained resource. Goals of contending needs requires choices dependent on science just as societal values. Informed decisions are created with a comprehension of the Hydrological cycle, the procedure by which water transfer from air to surface of land as precipitation, infilteration in the subsurface or streaming along land surface to the aeas, and in the long run coming back to the environment by evapotranspiration. All water on the earth dwells in one of the three sections of hydrologic cycle: the climate, the land surface, and the subsurface. A budgeted water plan is the bookkeeping of water stored inside and water traded among some subset of the sections, for example: watershed, lake or aquifer.

In the advanced world, the water demand is expanding due to a result of developing populace just as the urbanization increase. Subsequently, water to be used for agriculture is getting to be constrained. Thus, exact estimation of water prerequisite of crop is significant. The issue of over water irrigation or under water irrigation will be limited in the event that we can precisely gauge crop water requirement or crop evapotranspiration (ETc, mm/d).

Ecological control of production system of plants influences crop efficiency and quality. The effectiveness of plant generation or nurseries essentially relies upon altering a few segments, especially the inner temperature, relative humidity, concentratons of carbon dioxide (CO2), and management of water. Streeamlining of these parts can prompt better systems of cultivation. The “plant speaking approach” is an idea that controls and deals with the ideal condition for development based on the analysis of the development status of a plant (Hasimoto, 1989).

A main component in management is irrigation of water system. A well irrigation management will help the executives sustain the crops life and result in good quantity and quality of yield. Mistaken watering is the primary driver of overabundance irrigation; be that as it may, this isn’t the fundamental issue, especially in a “closed system” of development. Be that as It may, decreasing overabundance irrigation can assist cultivators with minimizing chemical use and enhance on-farm water use productivity.

Water use of crop is identified as evapotranspiration (ET). ET is the overall loss of water into the atmosphere by means of evaporation and transpiration (the water loss from the plant). Evaporation and transpiration happen at the samr time and there is no simple method for recognizing the two procedures. The estimation of ET regularly includes computing the reference evapotranspiration (ETo). Hence, an appropriate crop coefficient (Kc) is connected. Crop coefficients differ with the type of crop and development stages. There are four development stages: initial, development, mid and final stage. The motivation behind the present study was to assess the exhibition of the ET model which speaks about the plant water necessities inside the nursery plant system to counteract nutrient draining, in this way decreasing the generation costs.

RESEARCH OBJECTIVES

1. To Estimate the Reference Evapotranspiration (ETo) rates by various ETo Models.
2. To Estimate the Actual Evapotranspiration Rates by using the Suitable Crop Coefficients for Tomato crop.
3. To measure the Actual Evapotranspiration Rates on Site by Lysimeter Method.
4. To compare the Actual Evapotranspiration rates of Lysimeter Readings with the various Empirical .
5. To carry out the regression analysis of ET models wit respect to the Lysimeter method.

STUDY AREA

Devarabelekeri: This study area is a village in HariharaTaluk in davanagere district of Karnataka, India. This location is situated nearly 14 Kms afar as of davanagere whose co-ordinates lie between Latitude: 14.47^{o} N, longitude: 75.91^{o}E and at an elevation 602.5 mt above mean sea level. Usually in march the summer season starts, whose temperature may range between 30^{o} – 37^{o} and the monsoon starts at the end of May and stretches till October end. Discussing the physical features, it can be said that there is confined precipitation from April till October and the depth of rainfall ranges approximately about 633 mm. In summer, invariably the crops undergo into drought condition. Hence increasing the optimization of irrigation needs for semi-arid zone crops is very essential. The location is presented in the figure.

Fig. 3.1: Location of devarabelekere village at Davanagere.

II. MATERIALS

This project work deals with experimental program for estimation the Evapotranspiration rates of a tomato crop in a Semi-Arid Tropical climate. A field experiment is carried out by Lysimeter. Materials use in this project are Soil, Plastic drum, Plastic Container, water pipe and Tomato seeds.

1. Soil Sample: The physic-chemical parameters of the soil sample used in the lysimeteris.shown below in below table.

Table No. 1 Characteristics of soil used

Sl. No.	Characteristics	Values
1.	Type of soil	Sandy soil
2.	Ph	7.99
3.	Electrical conductivity (Ds/m)	0.36
4.	Density (kg/cm^{3})	$1.861*10^{-3}$
5.	Quantity of soil used (kg)	98.48
6.	Water Holding Capacity for 98.48kg (Lt)	39.39
7.	Moisture content	1.57
8.	Nitrogen (kg/Ha)	10.5
9.	Phosphorous (kg/Ha)	0.309
10.	Potassium (kg/Ha)	21.936

2. Seeds: A typical Tomato crop is used in this project to estimate the evapotranspiration. Tomato is a crop which is grown throughout the year. Hence Tomato is been used in this work.
3. Tank: A Plastic Drum is used as a Lysimeter. The tank is having a depth of about 52cm, usually in the construction

of a lysimeter tank, the depth should be sufficiently provided so that the roots of the plants can attain their maximum rooting depth and maximum rooting depth of Tomato plant is 40cm. The Tank is cylindrical in shape whose diameter is 36cm.

4. Drainage Tank: A polyethylene can of 10lt capacity is used as the drained water collection container. Graduations are marked on it so that there is an ease to measure the amount of water percolated.
5. Pipe: a small water pipe is used to connect the lysimeter tank and the collection tank.

Fig. No.1 Installation of Lysimeter on Site.

A small pit is dug on the ground for placing the Collection tank into it and the lysimeter drum is placed just at the edge of the pit. The collection tank is maintained to be placed below the bottom level of the lysimeter tank so that the water which is percolated can easily be drained in the collection tank. The final setup of the Lysimeter apparatus is as shown in the below fig 2

Fig. No 2 Lysimeter Unit on site.

After the installation is done the drum is filled with a measured quantity of soil. The quantity of soil is measured on the basis of density of soil. It is such that the field density is maintained into the lysimeter which is of about $1.861*10^{-3}$ and 98.48 kg of soil is filled in the lysimeter. Then a measured quantity of water is added and the tomato seeds are sown in the lysimeter and allowed for the seeds to germinate. A measured quantity of water is irrigated on a daily basis or in an interval of time. In this project the irrigation is provided about 3lts of water for every 2 days. the water loss due to evapotranspiration can be determined by simple calculation i.e. the difference of total water added by irrigation, rainfall or both and the excess water collected into the collecting tank at the bottom through percolation.

$$ETc = WA + R - WP$$

Where, ETc: Crop evapotranspiration, WA: Water added, R: Rainfall, WP: Water percolated.

III. EMPERICAL METHODS FOR ESTIMATING ETo

Evapotranspiration rates vary depending upon different issues like as temperature, Moistness, wind velocity and availability of water. These were primary factors, secondary factors are also responsible hugely for measurement of ET like type of crop, height or length, type of soil, growth time, salinity of soil, Nutrient components in soil, LAI, etc. Apart from these factors, there are several other parameters Climatological and meterological Factors like Soil Heat Flux, Latitude, Altitude, Longitude, Duration of sunshine, Atmospheric Pressure, etc.

To determine the evapotranspiration rates by the mathematical models the various data required are the daily temperature, Humidity and Wind speed. These data are collected online from the website of Karnataka State Natural Disaster Monitoring Centre (KSNDMC). KSNDMC creates and distributes the daily or weekly or Monthly or Seasonal and annual reports for Hobli level and also circulates the Rainfall data and information of weather for grampanchayat level also.

1. FAO-56 Penman Monteith Equation: This method is considered as the sole ETo method for determining reference Evapotranspiration.

FAO 56 Penman Monteith Equation is as:

$$ETo = \frac{0.4080 * \Delta * (R_n - G) + \gamma \frac{900}{(T + 273)} * u_2 * (e_s - e_a)}{\Delta + \gamma * (1 + 0.34u_2)}$$

Where,

ETo	:	Reference evapotranspiration (mm/day),
Rn	:	Remainingradiation atcrop surface(MJ/m^2/day),
G	:	soil heatflux density (MJ/m^2/day),
T	:	mean everyday air temperature at two meter height (°C)
U_2	:	Wind speed at two mtr height (m/s),
e_s	:	saturations vapour pressures (kPa),
e_a	:	Actual vapour pressure (kPa),
e_s-e_a	:	saturation vapour pressure deficit (kPa),
Δ	:	slope vapour pressure curve (kPa/ °C),
□	:	psychrometric constant (kPa /°C).

2. Thornthwaite Equation: To calculate Potential Evapotranspiration by thornthwaite method firstly the monthly thornthwaite Heat Index (i) is required:

$$i = \left(\frac{t}{5.0}\right)^{01.5140}$$

Where t: The mean monthly temperature.

Next the Annual Heat index (I) is calculated as:

$$I = \sum_{i=1.0}^{12.0} i$$

Then the Potential Evapotranspiration is obtained for each month, considering a month is 30 days long and with 12 theoretical sunshine hours per day

$$PET_{uncorected} = 16.0 * \left(\frac{10.0 * t}{I.}\right)^{\alpha}$$

Where α is

$$\alpha = (675.0 * 10.0^{-9} * I) - (771.0 * 10.0^{-7} * I^2) + 0.492390$$

The values obtained are corrected with respect to their real days in month and duration of sun shine hours.

$$P.E.T = P.E.T_{uncorected} * \frac{N}{12.0} * \frac{d}{30.0}$$

3. BlaneyCriddle Equation: This method uses only mean daily temperatures of the month.

$$ET_o = p * (0.460 * T + 8.0)\ millim/24hrs$$

Where p: mean daily percentage of total annual daytime hour, T: Mean daily temperature of the month.

IV. RESULTS AND DISCUSSIONS

The evapotranspiration rates are calculated by the various methods mentioned above whose results are tabulated below:

1. Average Reference Evapotranspiration rates by different empirical formulae's for the summer season of 2019:

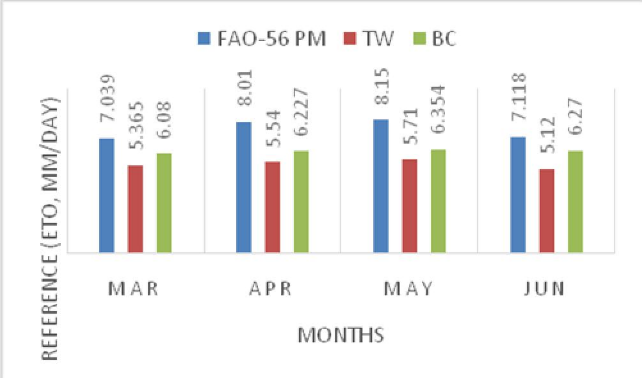

Fig. No. 3 ETo rates by different methods in summer. Note: PM- Penman Monteith, TW- Thornthwaite, BC- BlaneyCriddle

The reference evapotranspiration rates are high during the month of May to a maximum value of about 8.15 mm/day by FAO-56 PM method and is low during the month of March of about 5.365 mm/day by Thornthwaite method. The penman Monteith method is giving the higher values whereas the thornthwaite is giving the least values.

2. Actual Evapotranspiraion Rates of tomato crop is estimated by lysimeter method on site and caliberated by the equation:

$$ETc = WA + R - WP$$

Where,

ETc: Crop evapotranspiration, WA: Water added, R: Rainfall, WP: Water percolated.

Actual evapotranspiration is also estimated by the empirical method by the equation:

ETc = k_c * ETo

Where

ETc: Actual evapotranspiration, k_c: Crop coefficient and ETo: Reference Evapotranspiration.

The calculations are performed and the results are shown below:

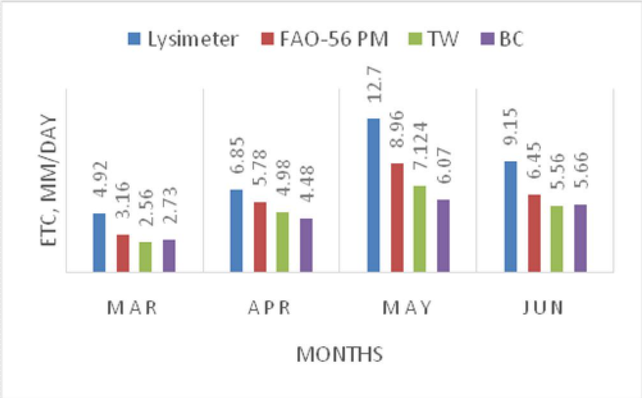

Fig. No. 4 Actual Evapotranspiration rates of Tomato for summer season of 2019.

The Actual evapotranspiration rates by the lysimeter method shows the maximum values amongst the other methods. The ETc is maximum during the month of May i.e. 12.7 mm/day and minimum during March i.e. 4.92 mm/day. The FAO-56 PM equation shows approximately nearby values to the Lysimeter values, the next is thornthwaite equation showing the nearby values after the FAO-56 PM equation and the Blaneycriddle equation shows very least values.

3. Correlation Coefficient: The correlation amongst two variables mathematically defines whether higher and lesser than average values of one variable are interrelated to higher or lesser than average values of other variable. The Correlation between the empirical methods and the lysimeter method is as shown below

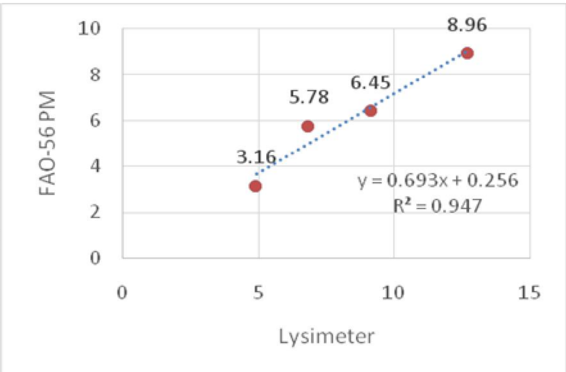

Fig. No. 5 Correlation of FAO-56 penman monteith method with the Lysimeter method.

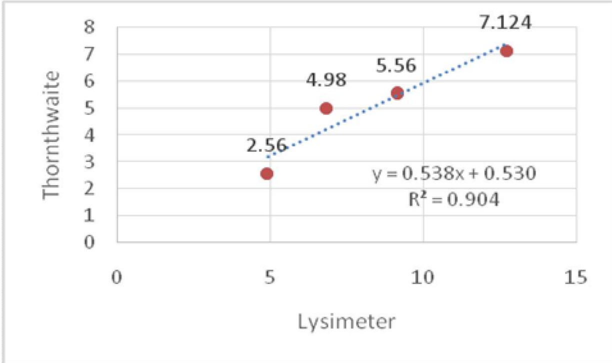

Fig. No. 6 Correlation of Thornthwaite method with the Lysimeter method.

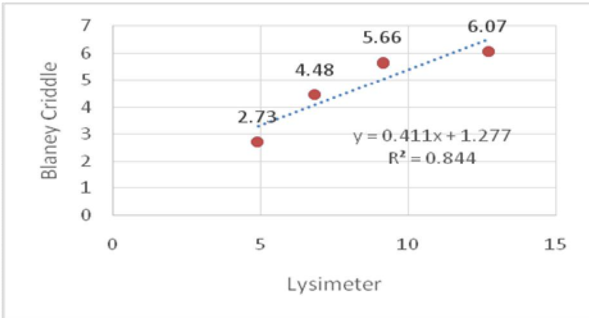

Fig. No. 7 Correlation of BlaneyCriddle method with the Lysimeter method.

The relationship between Field experiment by lysimeter method and all the ETo models significantly high, with a correlation coefficient of 0.94 by FAO-56 PM and 0.90 by Thornthwaite and 0.84 by BlaneyCriddle method for the Semi-Arid region (Fig. 5, 6, 7). Hence, depending upon the above relationship between the lysimeter experiment and the various methods we can conclude that the FAO-56 PM equation is well suitable the region. But this method due to large amount of data required it becomes difficult to carry out, if the data are available then this method gives good results. Apart from that Thornthwaite and BlaneyCriddlemethod which are temperature based method and Priestly Taylor method which is a Radiation based method, these methods are suitable to evaluate the ET rates in Semi-arid region.Thornthwaite method has good correlation than the BlaneyCriddle method hence gives more accurate results than the blaneycriddle method.

V. CONCLUSIONS

Water required for a particular crop from the point of sowing to the process of harvesting is nothing but the crop water requirement of that crop, in determination og this factor Evaluation of ETc rates is very essential. The various methods used in this work have come up with good results. The correlation coefficients of FAO-56 Penman Monteiths method fits good with the lysimeter(0.94<1), Thornthwaite method also relates good with the lysimeter method(0.90<1) and BlaneyCriddle method of about (0.84<1). These two methods can be used in place of FAO-56 Penman Monteith method because it requires lots of climatic data. Whereas the thornthwaite and BlaneyCriddle methods are temperature based models hence uses only Temperature data's Hence, these methods found to be simple and reliable to estimate the evapotranspiration in semi-arid region.

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REFERENCES

[1] AbhinayaSubedi& José L. Chávez (2015). "*Crop Evapotranspiration (ET) Estimation Models: A Review and Discussion of the Applicability and Limitations of ET Methods*", Journal of Agricultural Science, Vol. 7, No. 6.

[2] Ali S and Sharda V N, (2005). "Evaluation of the Universal Soil Loss Equation (USLE) in Semi-Arid and Sub-Humid Climates of India", Applied Engineering in Agriculture.21(2):217-225.

[3] Ankit K. Kulkarni et al. (2015), "*Comparative Study of Evaluation of Evapotranspiration Methods And Calculation Of Crop Water Requirements At Chaskaman Command Area In Pune Region, India*", International Journal of Research in Engineering and Technology, Vol. 04 Issue: 03.

[4] Daniel K. Fisher et al. (2013), "*Evaluation of alternative methods for estimating reference evapotranspiration*", Open Access Article Distributed under the Creative Commons Attribution License, Vol.4, No.8A, 51-60.

[5] Hashimoto, Y. 1989. "*Recent strategies of optimal growth regulation by the speaking plant concept*". ActaHortic. 260: 115-122.

[6] Jianbio Lu. (2005), "*A comparison of Six Potential Evapotranspiration Methods For Regional Use in Southeastern United States*", Journal of American Water Resources Asociation,, 293/03175.

[7] KoffiDjamana et al. (2015), "*Evaluation Of Sixteen Reference evapotranspiration Methods Under Sahelian conditions In The Senegal RiverValley*", Journal Of Hydrology: Regional Studies, 139–159.

[8] Lage. M. et al.(2003), "*Estimation of rice evapotranspiration using a microlysimeter technique and comparison with FAO Penman-Monteith and Pan evaporation methods under Moroccan conditions*", INRA, EDP Sciences Original article,) 625–631.

[9] Phene, C.J., McCormick, R.L., Miyamoto, J.M., 1985. "*Evapotranspiration and crop coefficient of trickle-irrigated tomatoes. In: Proceedings of the Third International Drip/Trickle Irrigation Congress*", Drip/Trickle Irrigation in Action, November 18–21, Fresno, CA.

[10] RajavardhanChowdhary M, (2016), "*Sufficiency of Water Distributory (HLBC)*", International Journal Of Research in Engineering and Technology. Vol: 05 Issue: 01, 2321-7308.

[11] Richard G. Allen et al. (1986), "*Rational Use Of The FAO Blaney-Criddle Formula*", Journal of Irrigation and Drainage Engineering, Vol. 112, No.2.

[12] Richard G. Allen et al. (1998), "*Crop evapotranspiration - Guidelines for computing crop water requirements*", FAO Irrigation and drainage paper 56.

[13] SurendraHalasuruJayaram et al. (2018), "*Estimation of Evapotranspiration for Onion Crop in Semi-Arid region: Experimental Field Setup using Lysimeter*", Urban and Regional Planning, Vol 3, No 1, PP: 1-5.

[14] Xu. C. Y. and V.P. Singh (2001), "*Evaluation and generation of temperature-based methods for calculating evapotranspiration*", Technical paper of Hydrological processes Hydro1. Process. 15, 305-31.