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Analysis of Evapotranspiration for Pune District

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Abstract: ***The exact amount of water used by various crops in different climatic conditions is necessary step for design, planning and management of irrigation schemes, water resources, scheduling of irrigation systems. Evaporation and transpiration is combinly called as evapotranspiration. Water loss from trees during photosynthesis is called as transpiration and when water gets converted into gaseous state is called evaporation. For calculation of correct evapotranspiration we have to choose method in such way that it should be suitable and require minimum climatic data and should be applicable for wide range of climatic conditions. In hydrology there are multiple correlation and regression is generally used to develop relationships between three or more hydrological variables by knowing the dependence between them. This research work includes study of various methods for calculation of evapotranspiration and select suitable one for Pune region (Maharashtra state). As field methods are very costly ,time consuming and not give appropriate results if suitable climate is not maintained. Data required to calculate evapotranspiration is collected from Pune Metrological Department. With the help of Radiation Method (RAD) , Modified Penman Method (MPM) , Thornthwaite Method (THW) ,Blaney-Criddle (BCL) , Christiansen Equation (CNM) ,Hargreaves Method (HGM) evaporatranspiration is calculated . From which Hargreaves and Thornthwaite are temperature based methods. Performance of all these methods are compared with Modified Penman method and method which showing less variation with standard Modified Penman method (MPM) is selected suitable one. Evapotranspiration values are estimated on monthly basis. Comparative analysis in this research used for selection for raw data dependent methods in case of missing data.***
Keywords: blaney-criddle , christiansen equation, hargreaves method ,precipitations, penman method, water use efficiency

I. INTRODUCTION

Evapotranspiration is the process of evaporation and plant transpiration from the land and water surface to the atmosphere. It refers to the process of water (moisture) moving from the soil and the plant, and entering the earth's atmosphere. Estimatimation of evaporation & transpiration seperately is difficult. Evapotranspiration consists of mainly two processes: the evaporation of water from the land, and the transpiration of water moisture from the plant's surfaces. The value of evapotranspiration is differs from crop to crop. The values of evapotranspiration daily or monthly are generally determined for required crop and at a required place. The actual evapotranspiration in the field can be measured by an instrument called a lysimeter. A lysimeter, like a phytometer is special water tank, containing a block of soil, and is installed in a field of growing plants. The rate of evapotranspiration is rapid at sowing stage and decreases with growing crops. The measurement of evapotranspiration is carried by either direct or by analyzing hydrological data. The direct measurement is of expensive and required more accuracy. In actual practice there is no such method which is globally adaptable in all climatic conditions. Therefore use of specific method for specific region is essential. So some time available data itself is a limitation for the work. This research work deals with study of evapotranspiration for Pune by different methods. By studying evapotranspiration and interrelationship of various method we conclude which is best method.

II. NEED OF WORK

An estimation of crop water requirement is an integrated aspect of the design, planning and management of an irrigation system. The yield of a crop is maximum when water is applied optimally and any deficient or excess amount of water usually reduces the output. The minimum crop water requirement mainly depends on the accurate estimation of evapotranspiration. The formula selected for use, however, should produce good result with a minimum of climatic data and represent the one, which has been calibrated and applied over a wide range of climatic condition. Methods of direct measurement of evapotranspiration are often expensive and demanding in terms of accuracy of measurement. No single existing method using meteorological data is universally acceptable under all climatic regions. Therefore, use of specific method is limited by the conditions in which they have been developed. Large data requirement also limits the application of many of these methods. Usually limited meteorological data are

available. Under such condition, use of specific method become very difficult and application of an alternative method (for which data are easily available) may not yield results with desired accuracy.
Therefore, by determining the interrelationships between the methods enable the user to easily convert values from different methods.To find out suitable method for pune district

III. LITERATURE REVIEW

Following are the research papers which are studied to assess comparative evaluation of ETo methods for Chaskaman command area in Pune region, India. The review of all the paper will help to generate the new next best suitable alternative method (after FAO-56 PM method) for the study area if meteorological data are missing. This research study will be beneficial for all the farmers and people coming under this area. Dr. M. V. S. S. Giridhar, Dr. G.K. Viswanadh [1] Penman- Monteith equation for calculation of RET is recommended as the standard equation by the Food And Agriculture Organisation (FAO). FAO-56 requires very large data for calculation which may not be available in all meteorological stations, is the basic difficulty for using it. Hence all other methods require local calibration with FAO- 56 PM equation. Bhaskar R. Nikam et. Al [2] This paper suggests that calculation of Evapotranspiration is very important aspect. FAO-56 version of PM method has been established as sole standard method for calculation of RET. There are some other old methods which requires less data for calculation of RET which gives result close to that of FAO-56 PM method for different climatic condition. To select the best alternate method after FAO-56 PM method, performance evaluation of each method for calculation of RET is done with respect to available data at Pantnagar in Uttarakhand, India. Two methods on temperature based approach (Hargreaves and Thornthwaite method) and two methods on radiation based approach (Priestley-Taylor and Turc method) are used to calculate RET values and are compared with standard FAO-56 PM method. Gupta and Goyal (2001) compared performance of various methods of ET estimation and presented their interrelationships with respect to each other for arid region of Rajasthan State. Kannpan et al. (2002) developed a “reference evapotranspiration model” for certain locations in Tamilnadu with PMM as the standard method. Water and Energy Research Digest of CBIP (2002) indicated that the PMM gave the best results in this sub-humid region. Vasan and Shrinivasa Raju (2004) used the CROPWAT model to compare the results of the Decision Support System with other methods developed for the area of Pilani, Rajsathan. Bhakar and Singh (2004) concluded that air temperature is the main factor influencing evaporation. The study also indicated that the influence of relative humidity on evaporation is negative whereas that of wind speed is positive.

IV. ESTIMATION OF EVAPOTRANSPIRATION

A. Thornthwaite Method

Thornthwaite found that under conditions of limited availability of water there is an explicit relation between the evapotranspiration and the temperature of atmosphere, longitude and the season .The empiric equation he gave is as

$$ET0 = 16\ d\ (10T / I)a$$

Where T is the mean temperature for the month (in °C),
I is the annual thermal index, i.e. the sum of monthly indices
i [i = (T/5) 1.514]
d is a correction factor which depends on latitude and month
a is 0.49 + 0.0179 I – 0.0000771 I 2 + 0.000000675 I 3 .

B. Hargreaves et. al.(1985) Method

$$ET = 0.0023RA\ TD\ 0.5\ (Tm+17.8)$$

Where,
RA = extra-terrestrial radiation (mm day-1)
TD = difference between maximum and minimum temperature (°C)
Tm = mean temperature (°C

C. Christiansen (1968) Pan Evaporation Method

$$ET = 0.755\ Eo\ CT2\ CW2\ CH2CS2$$

Where,
Eo = open pan evaporation (mm)
CT2 = 0.862 + 0.179 (Tm/20) – 0.041 (Tm/20) 2 Where, Tm is the mean temperature in °C

Cw2 = 1.189 – 0.240 (W/6.7) + 0.051 (W/6.7) 2 Where, W = mean wind speed 2 m above ground level in km per hour
CH2 = 0.499 + 0.620 (Hm/0.60) - 0.119 (Hm/0.60) 2 Where, Hm = mean relative humidity, expressed decimally
CS2 = 0.904 + 0.0080 (S/0.8) + 0.088 (S/0.8) 2 Where,
S is the percentage of possible sunshine, expressed decimally

D. Blaney-Criddle (1977) Method

The Blaney – Criddle method gives the value of the evapotranspiration factor from mean temperature[MT] and percentage of the total annual sunshine [n] hours occurring during the period being considered. But the effect of the climate on crop water requirement is insufficiently defined by temperature and day length. Evapotranspiration also differs widely with the climatic conditions, which are humidity, sunshine hour, and wind velocity. The relation recommended by FAO representing mean value over the given month is expressed as ETo = cp (0.46 T +8))
ETo reference crop evapotranspiration
T- daily temperature for the month in C
p- Daily percentage of total annual daytime hours
c – Adjustment factors only the
This method is useful where only the temperature data is available. The ETo should be adjusted 10% downward for each 1000m altitude changes above sea level.

E. Radiation Method

This method considers the radiation reaching the earth as the major contribution or the influence factor for evapotranspiration.
The FAO recommended

$$ETo = c\,(W \times Rs)$$

Where,
ETo = reference crop evapotranspiration in mm/day
Rs- Solar radiation in equivalent evaporation (mm/day)
Rs = (0.25 + 0.50 n/ N) Ra
Ra = extraterrestrial radiation in equivalent evaporation in mm/day
n=actual measured bright sunshine hours
N = maximum possible sunshine hours
W- Temperature and altitude dependent weightage factor
c- Adjustment factor made graphically on W
This method is used when the data of air temperature and sunshine hours are available and calculation should be done for each month of record and not for yearly records

F. Modified Penman method

This method can be easily adopted and provides most satisfactory result where measured data on temperature, humidity, wind and sunshine hours are available. It is a fairly accurate method for estimation of evapotranspiration as it utilizes almost all the metrological parameters responsible for the process of evapotranspiration .The FAO Modified Penman formula is given below:

$$ETo = c\,[W.Rn + (1-W).f\,(U)\,(ea - ed)]$$

Where
ETO = reference evapotranspiration
Rn = net radiation mm/day
W the temperature altitude related weight age factor for the effect of radiation on ETo.
f (U)= wind related function $f\,(U) = 0.27(1+U/100)$
Where
U = wind velocity in Km/day measured at 2m height
ea – ed = evaporation pressure deficit (m bar)
c = Adjustment factor (ratio of U day/Unight) to compensate for the day and night weather effect for RH maximum and for Rs

$$Rn = 0.75 - Rnl$$

Where

Rs = incoming short wave radiation either measured or estimated as in radiation method

Rnl net long wave radiation (mm/day)

which is a function of temperature, vapour pressure and sunshine duration = f (t) f(ed) f (n/N) ea = saturation vapour pressure at the mean air temperature in o /C (mbar) ed mean actual vapour pressure of air (m bar)

$$ed = ea\ (RH\ mean\ /100)$$

The modified Penman formula consists of a radiation term **W.Ro + (1-W)** and the aerodynamic term **f (U) (ea – ed).** The radiation term estimates the intensity of initiation of ET process while aerodynamic term measures the continuity of the process.

V. METHODOLOGY

A. Study Area

The study has been conducted for "PUNE DISTRICT" of Maharashtra state with longitude 18° 31' 0.2136" N latitude73° 51' 22.5180" E which is 562 m from mean sea level. The monthly average climatic data of PUNE for the period of 2015 was taken for calculation purpose. The data collected are maximum and minimum temperature, maximum and minimum relative humidity, sunshine hours, wind velocity.

B. Map of PUNE district

C. Data collection

The station characteristics and Hydrometrology data are collected from metrological department of PUNE The monthly average climatic data of PUNE for the period of 2015 is used .

Table No 1: Average Climatic Data of PUNE Station

Month	Max Temp	Min Temp	Max RH	Min RH	Wind Velocity [kmph]	n
Jan	30.1	11.6	93	42	2.3	7.81
Feb	35.1	12.8	79	29	2.9	9.1
March	38	16.6	72	31	3.3	8.3
April	40	19.4	53	29	5.2	9.3
May	40.8	22.7	59	37	6.7	9.3
June	38.6	22.4	76	65	8.3	5.7
July	32.2	22.4	80	73	9.8	5.4
Aug	31.3	21.7	82	73	8.2	4.4
Sept	35.5	20.8	83	64	4.7	6.5
Oct	34.4	20.1	80	60	2.3	7.3
Nov	34.6	16.7	78	49	2.1	7.8
Dec	33.8	13.4	86	42	1.8	9.1

VI. RESULT AND DISCUSSION

Table No 2: ETo Values In mm/day

Month	MPM	RDM	THM	CNM	HGM	BCM
Jan	3	2.52	2.61	3.50	3.04	3.15
Feb	4.13	2.65	2.86	4.24	3.76	4.3
March	4.78	3.73	4.94	4.65	5.44	6.06
April	6.27	3.80	7.17	5.30	7.86	8.81
May	6.91	3.92	9.62	6.35	7.36	8.06
June	5.51	4.60	8.37	3.26	7.28	4.83
July	4.67	3.21	5.4	1.62	4.08	4.4
Aug	4.10	3.27	4.69	1.86	2.8	4.1
Sept	4.46	2.98	5.64	2.36	3.36	3.64
Oct	3.92	2.82	4.81	4.25	4	5
Nov	3.48	2.30	3.63	4.1	3.68	3.81
Dec	3.29	2.16	2.57	3.73	2.96	4.14
Avg	4.54	3.16	5.10	3.76	4.63	5.02

From table no [2] it is observed that MPM gives average 1.98%, 10.57%, 12.83% lower value of ETo than by HGM, BCM, THM respectively. RDM and CNM gives 43.67% ,20.74% lower value of ETo than MPM. It is observed that evapotranspiration is more in the month of March,April, May, June.

It is also seen that From Table [2] the ETo values obtained from THM method are maximum and from RDM Method are minimum. Modified Penman Method and HGM methods give values, which are closer to each other.

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