COMPARATIVE STUDY OF EVALUATION OF EVAPOTRANSPIRATION METHODS AND CALCULATION OF CROP WATER REQUIREMENTS AT CHASKAMAN COMMAND AREA IN PUNE REGION, INDIA

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Abstract

Accurate estimation of evapotranspiration is necessary step in water resources management. Evapotranspiration varies spatially and temporally. Recently, the Food and Agricultural Organisation has suggested FAO-56 PM method (modified PM method) as a standard method for calculating reference evapotranspiration (ET_0), because this method is applicable to all types of season and different climates and gives more accurate result when compared with the physical methods like Lysimeter and Class A Pan. FAO-56 PM method cannot be debated by any other old methods which require less data for calculating ET_0. But FAO-56 PM requires very large amount of meteorological data, which is not available at full climate stations. So there is need to find out the next best suitable method after FAO-56 PM method, which will give ETo results nearer to FAO-56 PM method. Here seven different methods are considered for present study, which are radiation based, temperature based and combine parameters based (FAO-56 modified Penman Monteith, FAO-24 Penman Monteith, FAO-56 Hargreaves, Turc, Thornthwaite, Blaney-Criddle, Priestley Taylor are the methods). Chaskaman dam and its left bank canal is selected for this project. The objective of the project work is to calculate daily, monthly and yearly reference ET_0 using modified PM equations for 'left bank canal of Chaskaman dam and its command area'. Further ET_c (crop evapotranspiration/crop water requirement) will be calculated for that command area.

***Keywords** - Penman Monteith, Hargreaves, Turc, Thornthwaite, Blaney- Criddle, Priestley Taylor, evapotranspiration, crop water requirements.*

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1. INTRODUCTION

Evaporation is the process in which water is lost from soil surface and wet vegetation. It is denoted as E. In this process liquid water is get converted to water vapours and removed from the surface. Evaporation is affected by climatic factors such as solar radiations, air temperature, air humidity and wind speed. **Transpiration** is the second process of water loss, in this process water vaporizes into the atmosphere through small openings in plant leaf (stomata) and it is denoted as T. Transpiration is dependent on the energy supply, vapour pressure gradient, and wind. Environmental aspects, cultivation practice and crop characteristics also influence transpiration.

Now, **evapotranspiration** is the combine process of both evaporation and transpiration. In this process water vaporizes from soil surface on one hand by evaporation and on other hand by transpiration from plant leaf and it is denoted as ET. When height of crop is small, main process is evaporation and when crop is fully grown then dominant process is transpiration. There is no easy way to distinguish between evaporation and transpiration, because both the process occurs simultaneously. **Reference crop evapotranspiration** is an evapotranspiration calculated on reference crop which is not short of water and denoted by ET_o. Reference surface is a hypothetical grass having specific characteristics. Evapotranspiration of reference crop is calculated and then the value is related to other surfaces. So there is no need to calculate separate evapotranspiration for each crop and stage of growth. It is independent of crop type crop development stage and management practices. When ET_o multiplied by particular crop factor (K) it will give ET for that crop.

Crop water requirement (CWR) is the amount of water that is used by the crop for evapotranspiration. FAO (1984) defined crop water as 'the depth of water needed to meet the water loss through evapotranspiration of a crop, being disease free, growing in large fields under non restricting conditions and achieving full production under given growing environment'. The value of CWR is equal to ET_c.

2. 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.

Catchment area of Palleru (K-11) basin in state of Andhra Pradesh, India is considered for this study. The main objective of this study is to calculate daily, monthly and yearly RET using radiation based methods and also performance evaluation with the standard FAO-56 PM method. It is found that monthly RET values found to be increasing as the temperature increases in the month of January to May, and decreasing in the month of June to December as temperature decreases. Three radiation based methods Hargreaves method, Turc method, FAO-24 radiation based method were compared with standard FAO-56 PM method and their positive percentage deviations are taken. The values resulted as 26.68%, 10.63%, 42.69% for Hargreaves method, Turc method, and FAO-24 radiation based method respectively. Where Turc method gave the least value of deviation among all the equation when compared.

For both daily and monthly RET values Turc method showed good correlation with R^2= 0.82 and gave least deviation value as 10.63% when compared with standard FAO-56 PM method. Hence the paper concluded that, for Palleru basin Turc method is the best suitable among all radiation methods.

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. Performances of all method were evaluated by regression and error analysis. Turc method on monthly basis performed best with lowest RMSE (0.562), ARE (0.137) and AAD (0.448). On seasonal basis Priestley-Taylor method was best for Rabi season, at that time Turc holds second. In Kharif season Turc method performed well as compared to all other methods. In summer season Hargreaves method performed better than other methods.
Paper concluded that the performance of all other methods based on climatic conditions perform differently according to the available data but the performance and accuracy of FAO-56 PM method cannot be debated. But in case of non availability of data and for selection of alternative and less data dependent method the comparative evaluation performed in this paper is used as a guideline.

Hari Datta Paudel and Ashish Pandey [3]
During last 50 years of research, large number of empirical methods was developed for calculation of RET. The result from different methods varies with different climatological conditions. Hence minimising the difficulties in direct measurement, several radiation based, temperature based, pan evaporation based and combination based equations was used and compared for this study.

For this study, Sikta irrigation command area situated in western Nepal is considered and five ETo methods (i.e. FAO Penman Monteith; Modified Penman; Hargreaves' methods; Class A Pan Evaporation with FAO Paper-56 Pan coefficient and Orang Pan coefficient) were applied for water balance estimation. The values estimated annually was found to be 1311, 1530.9, 1643.12, 1372.5 and 1344.8 mm , respectively. Except months of may- july and October pan evaporation (with Orang coefficient) method matches closely with FAO- 56 PM method and found suitable for the planning of Sikta irrigation project. Total annual irrigation water requirements, maximum possible utilization of surface water resources and conjunctive use of ground water resources was 512.2, 486.2 and 26.0 MCM, respectively.

Paper concluded that pan evaporation with Orang coefficient method gave values closer to FAO-56 PM method and considered as the most suitable method for the water balance estimation of irrigation project. Selection of ETo methods estimate effects the estimation of conjunctive use of ground water resources and there is no effect on the design discharge of main canal.

Swati Pandey et. Al [4]
Calculation of evapotranspiration plays a vital role in agricultural planning, but because of non availability of data, planning suffers badly. In past few years, many different methods of ETo estimation has developed which are depending upon the meteorological data availability.

Jharkhand state of India is considered for the present case study and it comprises of various methods of ETo which are compared with FAO-56 PM method which is sole standard method for calculation of ETo. Hargreaves method (1985), Christiansen method (1968) along with Pan Evaporation method (1977) are used. To analyse the sensitivity and dependency of all different meteorological parameters on evapotranspiration, they developed transformed model of standard equations using single or multi parametric approach. During estimation of ETo, transformed models indicated that in the morning Relative humidity (RH1) plays dominant role i.e. 99%. And by combining two parameters such as bright sunshine (BSS) with wind speed (WV) plays better role than minimum temperature (T) with wind speed.

Paper concluded that all the four parameters i.e. (RH1, BSS, WV, T) gives high accuracy in ETo calculation when taken in combination with each other rather than to consider single or two parameters in combine. In regression analysis Hargreaves method gave more accurate result after FAO-56 PM method (R^2= 97.2%).

Lakshman Nandagiri, Gicy M. Kovoor [5]
Reference evapotranspiration is the important part for estimation of evapotranspiration rate of agricultural crops. The growing evidences of calculation of evapotranspiration shows that FAO-56 PM method (combine parameters) gives more accurate result across wide range of climates and is declared as sole standard method. Other methods are also continued to remain more popular because of their simple input data requirements for calculations.

In this study ETo is calculated from different areas in India of different climatic conditions. Seven methods are considered which are radiation based, temperature based, evaporation based and combine equation based. These methods are compared with FAO-56 PM method. Historical input data from four stations which are located in arid (Jodhpur), semi-arid (Hyderabad), sub humid (Bangalore) and humid (Pattambi) is collected. For all regions ETo extending over 3-4 years is calculated and comparative study is done. For both daily and monthly time steps FAO-56 Hargreaves method (temperature based) yielded results closest to the FAO-56 PM method, but in humid climate Turc (radiation based) was best amongst all. SEE in daily comparison were 1.35, 0.78, 0.67 and 0.31 mm/day, for arid, semi arid, sub humid and humid respectively. Similarly for monthly comparison values for SEE were 0.95, 0.59, 0.38, and 0.20 mm/day for arid, semi arid, sub humid and humid respectively. For practitioner’s ease of work linear regression equation for FAO-56 PM method estimates in terms of evapotranspiration estimates is developed as a simpler tool for each climate.

Paper concluded that methods which are radiation and temperature based provided good comparison results with FAO-56 PM method, all other methods were given rank on the basis of Standard Deviation, SEE and R^2 analysis. Validation tests showed that ETo results from PM method from regression equation were more accurate than the results obtained from original equations and that served easy practical tool of ETo calculations for practitioners and researchers.

Formulae of Methods:-

Sr. no	Name of method	Formula
1	FAO-56 Modified Penman Monteith	$ET_0 = \frac{0.408\,\Delta(R_n - G) + \gamma \frac{900}{T+273} u_2 (e_s - e_a)}{\Delta + \gamma(1 + 0.34 u_2)}$
2	FAO-24 Penman Monteith	$\lambda ET = \frac{\Delta(R_n - G) + \rho_a c_a \frac{e_s - e_a}{r_a}}{\Delta + \gamma(1 + \frac{r_s}{r_a})}$
3	FAO- 56 Hargreaves	$ET_O = 0.0135 \frac{R_s}{\lambda}(T + 17.8)$
4	Turc	ET_o = 0.013TM/(TM+15) (23.9 R_s+50)
5	Thornthwaite	$E = 16(\frac{10T}{I})^a * \frac{\mu N}{360}$
6	Blaney-Criddle	ETo = p (0.46 T mean +8)
7	Priestley Taylor	$\mathrm{ETo} = \frac{I * S * (R_n - G)}{\lambda * (S + \gamma)} * \alpha$

3. SUMMARY OF LITERATURE REVIEW

From all above research paper we can summarise that the research study done by scientists declared that FAO-56 Modified Penman Monteith Method (Combined parameters) for calculation of Evapotranspiration is the sole standard method and gives very accurate results. All the other methods which requires less data for their calculations are also very popular because of their traditional use, but they cannot debate FAO-56 PM method. Evapotranspiration varies according to area and their climatic conditions. Comparative study of all methods gives another best suitable method after FAO-56 PM methods. The study of researchers gives the proper idea about Regression Analysis, SEE, RMSE and Absolute Average Deviation.

4. DETAILS OF PRESENT STUDY

In the present study, left bank canal Chaskaman dam which is situated in Rajgurunagar, Pune district, Maharashtra is considered for calculation of evapotranspiration, crop water and irrigation requirements. Its Co-ordinates are 18°57'39"N-73°47'8"E. Meteorological data required for this area is collected from Indian Meteorological Department, Pune. Seven methods to calculate ETo which are FAO-56 modified Penman Monteith, FAO-24 Penman Monteith, FAO-56 Hargreaves, Turc, Thornthwaite, Blaney-Criddle, Priestley Taylor (temperature based, radiation based and standard combination methods) are considered. Their performance based evaluation will be calculated and each method will be compared with FAO-56 PM method which is standard. RMSE, ARE, AAD, and Regression Analysis will be used to find out the next best suitable method after standard FAO-56 PM method. After comparison, crop water and irrigation requirements will be calculated, which will be very useful in forming proper water balance system for that command area.

5. DISCUSSIONS AND FUTURE SCOPE

This study will be beneficial for all farmers as well as people coming under this command area. During non availability of meteorological data, if characteristics of one command area (with calculated ETo) match with other, then we can apply same ETo values to that area where data is missing. After finding out the crop water requirements, water will be applied as per the requirement of that crop and hence water balance system can be developed. Irrigation requirements are calculated with the help of crop water requirement of each crop. That is nothing but the water required for that crop to fulfill their need. Water required for that crop from sowing process to harvesting process.

ACKNOWLEDGEMENTS

I would like to thank my Principal of institute Dr. S. D. Lokhande, HOD Dr. S. S. Shastri, M.E. coordinator Prof. Nishad Patki, my guide Prof. Ravichandra Masuti, M.E. staff and all my dear friends for their support.

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NOTATIONS:-

ρa	= air density in kg m-3,
Cp	= specific heat of dry air [~1.013 x 10-3 MJ kg-1 ºC-1]
es	= mean saturated vapor pressure in kPa computed as the mean eo at the daily minimum and maximum air temperature in ºC
ra	= bulk surface aerodynamic resistance for water vapor in s m-1
ea	= mean daily ambient vapor pressure in kPa
rs	= canopy surface resistance in s m-1
ETo	= Reference evapotranspiration (mm/day)
Rn	= Net radiation at the crop surface (MJ/m2 per day)
G	= Soil heat flux density (MJ/m2 per day)
T	= Mean daily air temperature at 2 m height (°C)
u2	= Wind speed at 2 m height (m/sec)
es - ea	= Saturation vapour pressure deficit(kPa)
Δ	= Slope of saturation vapour pressure curve at temperature T (kPa/°C)
γ	= Psychometric constant (kPa/°C)
λ	=Latent heat of vaporizations, [MJ/kg] [2.45 MJ/kg],
R_s	=Solar radiation, [MJ/m^2 d^{-1}]
T	=Mean air temperature, [ºC]
I	= for each month is derived from mean monthly temperatures according to the formula i_j = 0.09*(Tj) 1.5, where subscript j indicates the specific month under investigation
a	= empirically derived exponent which is a function of I, and is 0.016*I + 0.5
N	= mean number of daylight hours in a particular month
μ	= number of days in the month
R_S	= Daily global solar radiation, [KJ/ m^2 d^{-1}]
α	= Priestley Taylor coefficient (1.26)