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ESTIMATION OF EVAPOTRANSPIRATION RATE BY DIFFERENT METHODS FOR PADDY CROP IN SOUTH KODAGU, CENTRAL WESTERN GHATS

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ABSTRACT

The evapotranspiration process consists in conversion of water to vapour from liquid phase. The source of energy for this process is the radiation received from the sun. Solar radiation reaches the outer surface of the earth's atmosphere measured perpendicularly to the beam. Eight evapotranspiration estimation methods viz., Penman, Penman-Monteith, Pan Evaporation, Kimberly-Penman, Priestley-Taylor, Hargreaves, Samani-Hargreaves and Blaney-Criddle were tested with meteorological data of year 2009, Agricultural Research Station, Ponnampet, South Kodagu. The evapotranspiration estimates by all methods shows the same trend throughout the year. Samani-Hargreaves gave the highest estimates followed by the Priestley-Taylor and Hargreaves methods. The lowest estimates were by Penman-Monteith and followed by the Blaney-Criddle and Pan methods. The Penman-Monteith, Blaney-Criddle and Pan methods estimate lower values of evapotranspiration with no significant difference among them. Penman method, though is different from the three methods, estimates reference evapotranspiration close to these three methods. The Penman-Monteith, Blaney-Criddle and Pan are the best methods to estimate evapotranspiration in the study area. The Penman method can be used to get somewhat reasonable estimates though it overestimates the evapotranspiration a little.

1. INTRODUCTION

Crops need water in particular quantities for their optimum growth. Excessive or deficit amounts of water could retard crop growth and ultimately lower the crop yields. Conditions influencing the rate of water use by crops include the type of the crop, stage of its growth, climatic parameters like temperature, wind velocity, humidity etc., available water supply and soil characteristics [1]. The evapotranspiration process consists in conversion of water to vapour from liquid phase. The source of energy for this process is the radiation received from the sun. Solar radiation reaches the outer surface of the earth's atmosphere measured perpendicularly to the beam. Estimates of rice crop evapotranspiration are important in irrigation planning, irrigation scheduling, and overall crop and irrigation system management in large scale paddy producing areas. Traditionally, reference evapotranspiration is defined as the rate of evapotranspiration from an extensive surface of 8 to 15 cm tall green grass cover of uniform height, actively growing, completely shading the ground and not short of water. The reference evapotranspiration (ETr) is the rate of evapotranspiration from a hypothetic crop with an assumed crop height (12 cm) and a fixed canopy resistance which would closely resemble evapotranspiration from an extensive surface of green grass cover of uniform height, actively growing, completely shading the ground and not short of water [2]. Evapotranspiration can be obtained by many estimation methods. Some of these methods need many weather parameters as inputs while others need fewer. Numerous methods have been developed for evapotranspiration estimation out of which some techniques have been developed partly in response to the availability of data. Factors such as data availability, the intended use, and the time scale required by the problem must be considered when choosing the evapotranspiration calculation technique [3].

The Penman equation or the later Penman-Monteith equation requires numerous meteorological data parameters and is also complicated. The Penman equations were also limited by the lack of availability of net radiation or solar radiation data. The Penman method requires a variety of climatological data, such as maximum and minimum air temperatures, relative humidity, solar radiation, and wind speed. If some of these data are not available, alternative methods must be used for evapotranspiration estimation. Furthermore, rapid and reliable methods are needed for estimating evapotranspiration for areas in which weather data are not available. The reference evapotranspiration as determined by the Penman-Monteith approach considers an imaginative crop with fixed parameters and resistance coefficients. Penman-Monteith energy balance equation has become more popular as a method to estimate evapotranspiration as it estimates the flux of energy and moisture between the atmosphere, the land and water surfaces. As it is an energy conservation equation, it is universally accepted. The Penman and Penman-Monteith methods are assumed to be the most reliable because these methods are based on physical principles and because they consider all the climatic factors, which affect reference evapotranspiration. Open pans provide a more satisfactory means of estimating potential evapotranspiration and hence evapotranspiration of rice under flooded conditions than any other available technique. A simpler and economic method like pan-evaporation involving one or two weather parameters with ease in installation, recording and processing and also with reasonable accuracy is comparable to the modified Penman method. The reliable assumption that temperature is an indicator of the evaporative power of the atmosphere is the basis of temperature-based methods. Although temperature based methods are useful when data on other meteorological parameters are unavailable, the estimates produced are generally less reliable than those, which take other climatic factors into account. Blaney-Criddle and, to a lesser extent, Hargreaves are most sensitive to temperature change while their relative sensitivity varies with location and time of year.

2. MATERIALS AND METHODOLOGY

The study area, Agricultural Research Station (ARS), Ponnampet is located at $12^0 8'$ N and $75^0 56'$ E and lies, 60 kilometers from the district headquarters, Madikeri. The gross area of paddy field is about 6 hectares. ARS, Ponnampet has a tropical climate characterized by slight to medium humidity due to proximity to coast (about 50 km). It is known to be quite pleasant and healthy, characterized by high humidity, heavy rainfall and cool summer. A major part of the year consists of rainy season as the monsoon period starting in June lasts till the end of September. Even during post monsoon months of October and November study area receives significant amount of rainfall. The day temperature begins to rise sharply during March and marks the commencement of the summer season, which lasts till the end of May. Average temperature in the area is little bit above 21.4^0c. Maximum temperature of the area is about 29.9^0c and the minimum is about 15^0c which are more or less uniform throughout the year. Sunshine duration is about 7 hours or more from January to May while it decreases gradually to 5 hours from June to December. Total evaporation in the month, starts to increase from January to April reaching maximum (>110 mm). The monthly minimum is recorded in October, which is 90 mm.

The climate data for this study were collected from the ARS meteorological station of the University of Agricultural Sciences, Bengaluru. Daily values of data of the year 2009 were used for this study. The data collected are temperature (Maximum, Minimum), relative humidity (Maximum, Minimum), wind speed, solar radiation, sunshine duration, and atmospheric pressure and pan evaporation. Eight methods (Table 1 and Table 2) that are commonly used were selected for this study. Table 1 shows the data needed for these methods while table 2 shows the model being used. Three (Blaney-Criddle, Hargreaves and Samani-Hargreaves) out of 8 methods used are temperature based methods. The Blaney-Criddle and Hargreaves equation are only recommended for the purpose of evapotranspiration estimation based on temperature [1]. These methods use the mean-monthly climatic values, which were calculated using the daily values. The penman [1], Penman-Monteith[2], Kimberly-penman[2] and Priestley-Taylor[2] equations are all known as 'combination methods' because they combine the effects of both radiation and mass transfer on reference evapotranspiration. The penman method uses vapour pressure deficit that in a function of temperature and actual vapour pressure and an empirical wind speed function. Penman-Monteith includes both climatic and vegetation characteristics in quantifying mass transfer effects. It is also the most data demanding requiring information on temperature, radiation, humidity and wind speed, as well as on various characteristics of the vegetation [2]. The daily values for the year 2009 were used to calculate the monthly averages. In case of pan evaporation, the pan co-efficient k_p values were calculated based on FAO irrigation and drainage paper 56 [3].

Table 1. Data requirements of selected formulae.

Method	T	Rs	RH	U	n	P	D	Temporal data period
Pan method			X*	X*			x	Daily
Penman	x	x	x	x		x		Daily
Penman-Monteith	x	x	x	x		x		Daily
Kimberly-Penman	x	x		x		x		Daily
Priestley-Taylor	x	x						Daily
Hargreaves	x							Monthly
Samani-Hargreaves	x							Monthly
Blanney-Criddle	x		x	x	x			Monthly

Legend: * needed to calculate Pan co efficient, D – Pan evaporation, n – sunshine hours, P – atmospheric pressure, RH – relative humidity, R_s- solar radiation, T-temperature, U-wind speed\

3. RESULTS

Table (3) shows the monthly average reference evapotranspiration values by different methods for the study area. Most of these methods showed the same trend throughout the year. The Samani-Hargreaves estimated the highest reference evapotranspiration for all the months and Priestly-Taylor method followed next. The reference evapotranspiration estimates for the month of November was less compare to other months. Figure (1) shows the mean reference evapotranspiration and annual evapotranspiration values estimated by different methods for the study area. Reference evapotranspiration and annual evapotranspiration values showed the same pattern. The Samani-Hargreaves gave the highest estimate while Penman-Monteith the lowest value.

Table 2. Methods used to estimate reference evapotranspiration.

Method	Formula Applied
Pan method Pan co-efficient	$ET_r = K_p E_{pan}$ $K_p = 0.108 - 0.0286U2 + 0.0422\ln(FET) + 0.1434\ln(RH_m) - 0.000631[\ln(FET)^2]\ln(RH_m)$
Penman [1]	$\mathrm{ETr} = \Delta\frac{R_n - G}{\Delta} + \frac{\gamma 6.43\, \mathrm{f(u)(ea - ed)}}{\gamma}$
Penman Monteith[2]	$\frac{\Delta(R_n - G) + \rho_a C_p (e_a - e_d)/r_a}{\Delta + \gamma(1 + \gamma_c/\gamma_a)}$
Kimberly-Penman[2]	$ET_r = \frac{\Delta(R_n - G)}{\Delta + \gamma} + \frac{\gamma}{\Delta + \gamma} \frac{6.43 W_f D}{\lambda}$
Priestley-Taylor[2]	$ET_r = 1.26 \frac{\Delta(R_n - G)}{\Delta + \gamma}$
Hargreaves[2] Samani-Hargreaves [2]	$ET_r = 0.0038 R_a T(\delta T)^{0.5}$ $ET_t = 0.00094 S_o \delta T_f T_f$
Blanney-Criddle[2]	$ET_r = a_{BC} + b_{BC} f$ f= p(0.46T+8.13) $a_{BC} = 0.0043(RH_{min}) - \left(\frac{n}{N}\right)$ $b_{BC} = 0.82 - 0.0041(RH_{min}) + 1.07\left(\frac{n}{N}\right) + 0.066(U_d)$

Legend: ETr is reference ET (mm/day), Kp is pan co-efficient, U_2 is average daily wind speed at 2 m height (ms^{-1}), RH_m is average daily relative humidity (%), FET is fetch, E_{pan} is pan evaporation (mm), Δ is gradient of saturation vapour pressure temperature function (kPa^0C^{-1}), R_n is the net radiation (MJm^{-2} day), G is soil heat flux ($MJm^{-2}day^{-1}$), γ_a is air density (Kg m^{-3}), C_p is specific heat of the air at constant pressure (KP_a), γ is psychrometric constant (kPa^0C^{-1}), f(u) is an empirical wind speed function, γ_a is aerodynamic resistance to water vapour diffusion into the atmospheric boundary layer (Sm^{-1}), γ_c is the vegetation canopy resistance to water vapour transfer (Sm^{-1}), W_f is a wind function., ʎ is latent heat of vapourization of water ($MJkg^{-1}$), Ra is extra terrestrial radiation expressed in equivalent evaporation ($mmday^{-1}$), T is mean air temperature (^0c), δT is the difference between mean monthly maximum and mean monthly minimum temperature (^0c),So is water equivalent of extra terrestrial radiation ($mmday^{-1}$), δT_F is the difference between mean monthly maximum and mean monthly minimum temperature (^0c),T_F is mean temperature (^0c), a_{BC}, b_{BC} and F are functions, (n/N) is the ratio of actual to possible sunshine hours, RH_{min} is minimum daily relative humidity, P is the ratio of actual daily day time hours to annual mean daily day time hours, V_d is the day time wind at 2 m height (ms^{-1}).

Table 3. Monthly average reference evapotranspiration (ETr) for the study area.

Months	P	Pan	PM	KP	PT	BC	SH	H
January	2.87	2.50	2.09	3.50	2.60	3.30	3.50	3.20
February	3.06	3.06	2.59	2.86	3.50	2.60	3.50	3.50
March	2.69	2.60	2.45	2.85	3.00	2.40	3.20	3.15
April	3.80	3.60	3.50	4.20	4.60	3.40	4.70	4.60
May	3.60	3.30	3.20	4.30	4.50	3.50	4.60	4.40
June	2.00	1.81	1.75	2.53	2.45	2.15	2.63	2.60
July	1.69	1.52	1.46	2.25	2.30	1.69	2.20	2.05
August	2.05	1.92	1.92	2.25	2.43	1.98	2.50	2.41
September	2.03	1.96	1.89	2.25	2.30	1.89	2.20	2.15
October	2.78	2.50	2.42	3.05	3.25	2.45	3.25	3.18
November	2.26	2.08	2.08	2.56	2.98	2.26	3.06	3.05
December	1.11	0.98	1.00	1.26	1.35	0.98	1.50	1.26

4. Discussion

The Pan method needs only the depth of daily evaporation together with wind speed and relative humidity to calculate the pan co-efficient. The Blaney-Criddle method used in this study needs mean monthly temperature, mean, relative humidity, mean day time wind speed at 2 meter height. As this equation needs only few input data and is monthly averages in case of Blaney-Criddle, it is much more convenient to use. If more precise information on evapotranspiration is required, then it is more suitable to use the penman-Monteith equation. The penman method is also suitable for the purpose of estimating the reference evapotranspiration but it is over estimated. This could be because of the empirical wind function used in the equation. The evapotranspiration estimates by all these methods shows the same trend throughout the year. The annual estimated evapotranspiration also shows the same trend for all the methods. Samani-Hargreaves gave the highest estimated followed by Priestly-Taylor and Hargreaves methods. The lowest estimates were by Penman-Monteith and followed by Blaney-Criddle method. The lowest estimates for the month of November were less compare to other months could be due to low radiation and sunshine hours.

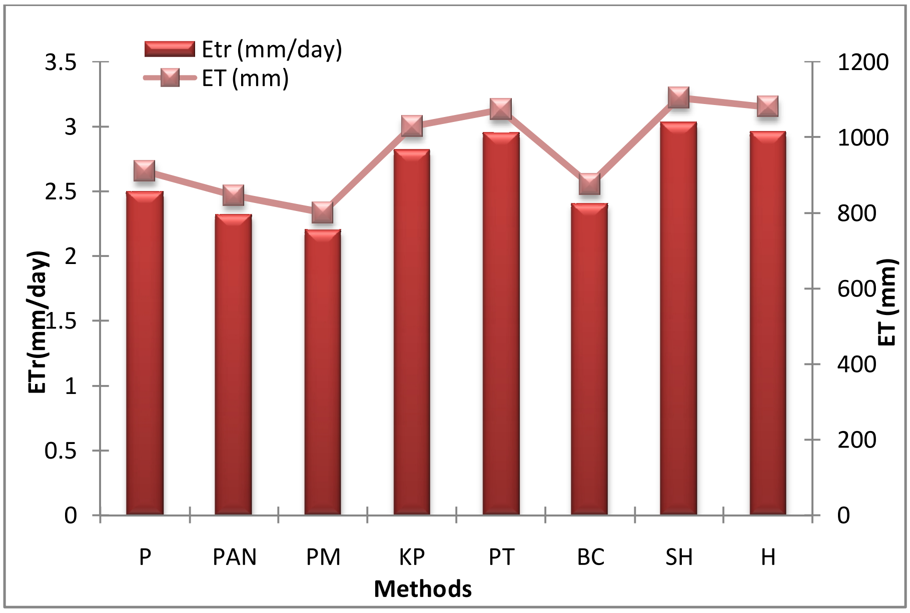

Figure **1.** Mean Reference Evapotranspiration and Annual Evapotranspiration for ARS, Ponnampet.

Abbreviations

P= Pan evaporation method
Pan= Penman Method
PM= Penman- Monteith method
KP= Kimberly-penman method
PT= Priestley Taylor method
BC= Blanney-criddle method
SH= Samani- Hargreaves method
H= Hargreaves metho

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