# Evaluation of Evapotranspiration Methods to Replace Penman-MonteithMethod in the Absence of Required Climatic Data in order to have a better Irrigation Scheduling

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***Abstract**: Evapotranspiration (ET) can be identified as a key function of vegetation which develops interaction in between climatologic, hydrological and terrestrial environments. Though there are number of climatologic methods are available to calculate ET such as Penman-MonteithMethod(PMM), Blany-Criddle Method(BCM), Radiation Method (RM), Hargreaves- Samani Method(HSM), Linacre Method(LM), Makkink Method(MM) and Turc Method(TM),in practice Penman-Monteith Method is used since it is likely to provide the most satisfactory result. But, it is not easier to obtain all types of climatic data since malfunctioning ofweather stations.However, the method selected to estimate ET should produce reasonable result with minimum number of climatic data. Thus, this attempt was taken in order to identify the most suitable method to utilize in various months to calculate ET considering the quality of result and input data requirement.According to the obtained results both Hargreves- Samani and Linacre Methods have shown reasonable values to replace PMM. Therefore Irrigation demand can be predicted and will be able to plan fairly successful irrigation scheduling in the field.*

***Key words:** Evapotranspiration, Penman-Monteith Method, Climatic data, Mean Absolute Error*

## 1. INTRODUCTION (CASE STUDY FOR WALAWE BASIN)

The ET is a combination of two separate processes namely evaporation and transpiration. Evaporation is a process in which water is evaporated or lost to the atmosphere from the wet soil. Transpiration is a process in which water is respired or lost to the atmosphere from small openings on the leaf surface. In practice there is no easy way to distinguish those two processes separately. Normally in the initial stage of the cultivation larger fraction of ET represent by the evaporation. But when the crop canopy shaded more and more area with the time, more than 90% of ET comes from transpiration (Allen *et al*. 1998)

Thus in irrigation schemes mainly water losses occur due to ET. Therefore total crop water requirement is directly proportional to ET. Hence ET is typically known as the term of Crop Water Requirement. Therefore in designing and maintaining irrigation schemes, knowledge about ET becomes more important. For an example if the extent is known, required amount of water can be calculated. Then it will be easy to predict whether there would be any deficit or excess in demand via that early precautions can be taken. The Evapotranspiration from a reference surface (a hypothetical grass reference crop with specific characteristics), not short of water, is called the Reference Evapotranspiration and is denoted as $ET_0$(Allen *et al.*1998).

Recently Food & Agriculture Organization (FAO) has introduced software known as “$ET_0$ calculator” which calculates $ET_0$ once required climatic data are fed, in this programme $ET_0$ is being calculated using Penman-Monteith Method (PMM). But for this methods number of climatic data required is comparatively high. In practice it is not easy to obtain all the parameters from one weather station as most of those stations are not either fully equipped or not function well. On the other hand climatic data are not available free of charge any more.

Therefore it is not easy to strict to a one method. Hence this study was conducted to find out which method is the most appropriate to replace with PMM in each month.

## 2. METHODOLOGY

### 2.1. Selection of Study Area

As the study area, considering the cultivation extent it was decided to select Walawe basin (Cultivation extent nearly298 $km^2$) as it is one of the major basins where cultivation extent is high. There are two Agro-meteorological centers which are maintained by Meteorological Department in Angunakolapelessa and Weerawila close to Walawe basin. Since there is no any other observation center with in the Walawe basin it was decided to use climatic data which were obtained from Angunakolapelessa observation station. A detailed lay out of the basin is shown in Figure1.

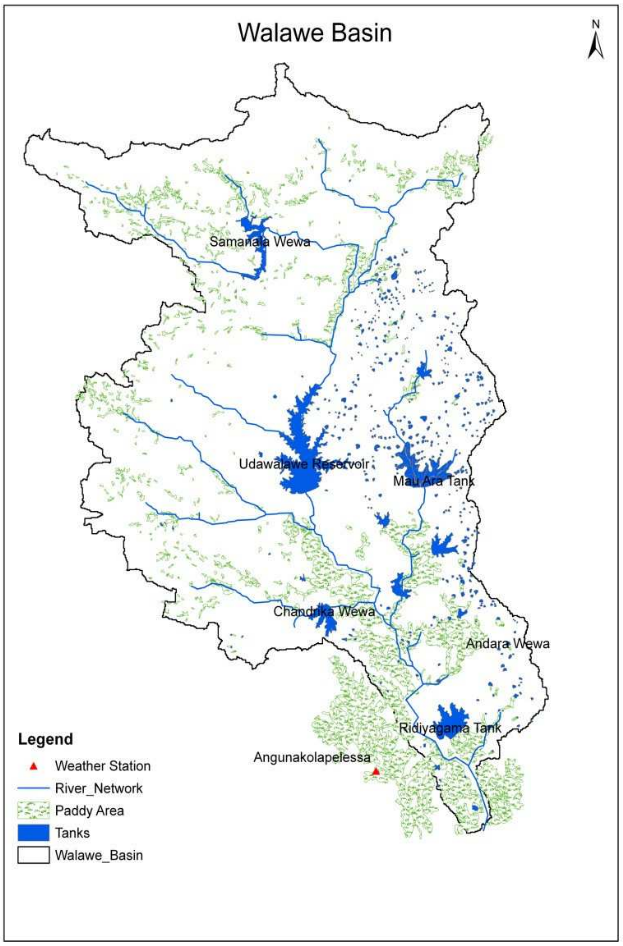



**Figure 1 General Lay Out of Walawe Basin**

### 2.2. Climatic Data Collection

For the $ET_0$ analysis climatic data such as maximum and minimum temperature, maximum and minimum relative humidity, sunshine hour, wind velocity from 2001 to 2005 were collected. Extra-terrestrial radiation was calculated according to the FAO Irrigation & Drainage paper No 56 (Allen *et al.* 1998). In Table 1 it is shown averaged monthly figures of aforesaid climatic data.

**Table 1 Averaged Monthly Climatic Data (From 2001 to 2005) from Angunakolapelessa, Sri Lanka**

| Month | $Temp_{Max}$($^0$C) | $Temp_{Min}$($^0$C) | Sunshine Hrs | Wind Speed (km/h) | $RH_{max}$ (%) | $RH_{min}$ (%) |
|---|---|---|---|---|---|---|
| January | 32 | 23 | 6.6 | 4.73 | 85.21 | 71.11 |
| February | 32 | 22 | 8.5 | 5.04 | 82.46 | 68.34 |
| March | 33 | 23 | 8.3 | 4.36 | 81.27 | 68.51 |
| April | 33 | 24 | 7.0 | 3.39 | 83.61 | 74.78 |
| May | 33 | 25 | 7.3 | 6.36 | 82.95 | 73.58 |
| June | 33 | 25 | 7.7 | 6.98 | 81.52 | 71.74 |
| July | 33 | 25 | 7.4 | 7.52 | 78.23 | 66.99 |
| August | 33 | 25 | 8.5 | 7.62 | 76.89 | 64.46 |
| September | 33 | 24 | 7.4 | 6.57 | 77.81 | 68.02 |
| October | 32 | 24 | 6.9 | 5.05 | 80.81 | 71.94 |
| November | 31 | 24 | 4.9 | 3.37 | 86.08 | 79.20 |
| December | 31 | 23 | 6.2 | 4.19 | 84.83 | 74.99 |

## 2.3. Estimation of Evapotranspiration

The choice of $ET_0$ estimation method depends on its suitability in the particular region and the availability of data. Following mentioned are the widely used methods to calculate$ET_0$ (Race *et al.*2009*,* Hargreves *et al.2003)*.

i. Penman-Monteith Method (MPM)
ii. Blaney- Criddle Method (BCM)
iii. Radiation Method (RM)
iv. Hargreaves- SamaniMethod (HSM)
v. Linacre Method (LM)
vi. Makkink Method (MM)
vii. Turc Method (TM)

The meteorological data required for each method is different to each other. In Table 2 it is shown the data requirement for each climatologic method (Kassan et al. 2001 and Raes et al .2009).

**Table 2 Climatic Data Requirement**

| Climatologic Method | Temperature | Humidity | Wind Speed | Radiation | Sunshine Hrs |
|---|---|---|---|---|---|
| Penman-Monteith Method (PMM) | √ | √ | √ | √ | √ |
| Blaney- Criddle Method (BCM) | √ | √ | √ | | √ |
| Radiation Method (RM) | √ | √ | √ | √ | |
| Hargreaves-Samani Method (HSM) | √ | | | √ | |
| Linacre Method (LM) | √ | √ | | | |
| Makkink Method (MM) | √ | | | √ | |
| Turc Method (TM) | √ | √ | | √ | |

## 2.4. Result Analysis Procedures

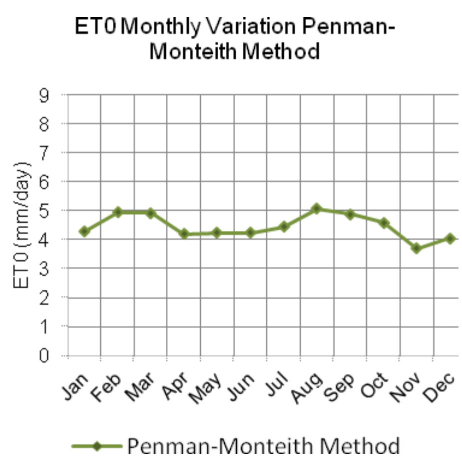
There are several statistical routines are available for this type of result analysis. In this study the criteria onwhich mainly considered was the amount of deviation from the PMM. Therefore Mean Absolute Error (MAE) method was used for analysis (Willmott, 1982).

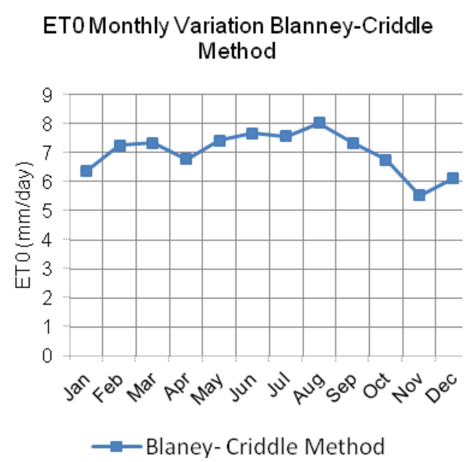
Mean Absolute Error (MAE) = $N^{-1}\sum_{i-1}^{N}(|Pi - Oi|)$

Where N is the number of valid data points (in this case from N=1, since it is considered individual months), P is the test climatologic method $ET_0$ value and O is the value obtained from PMM.

## 3. RESULTS AND DISCUSSION

The calculated $ET_0$ values for each month using various climatologic methods are plotted in Figure 2.



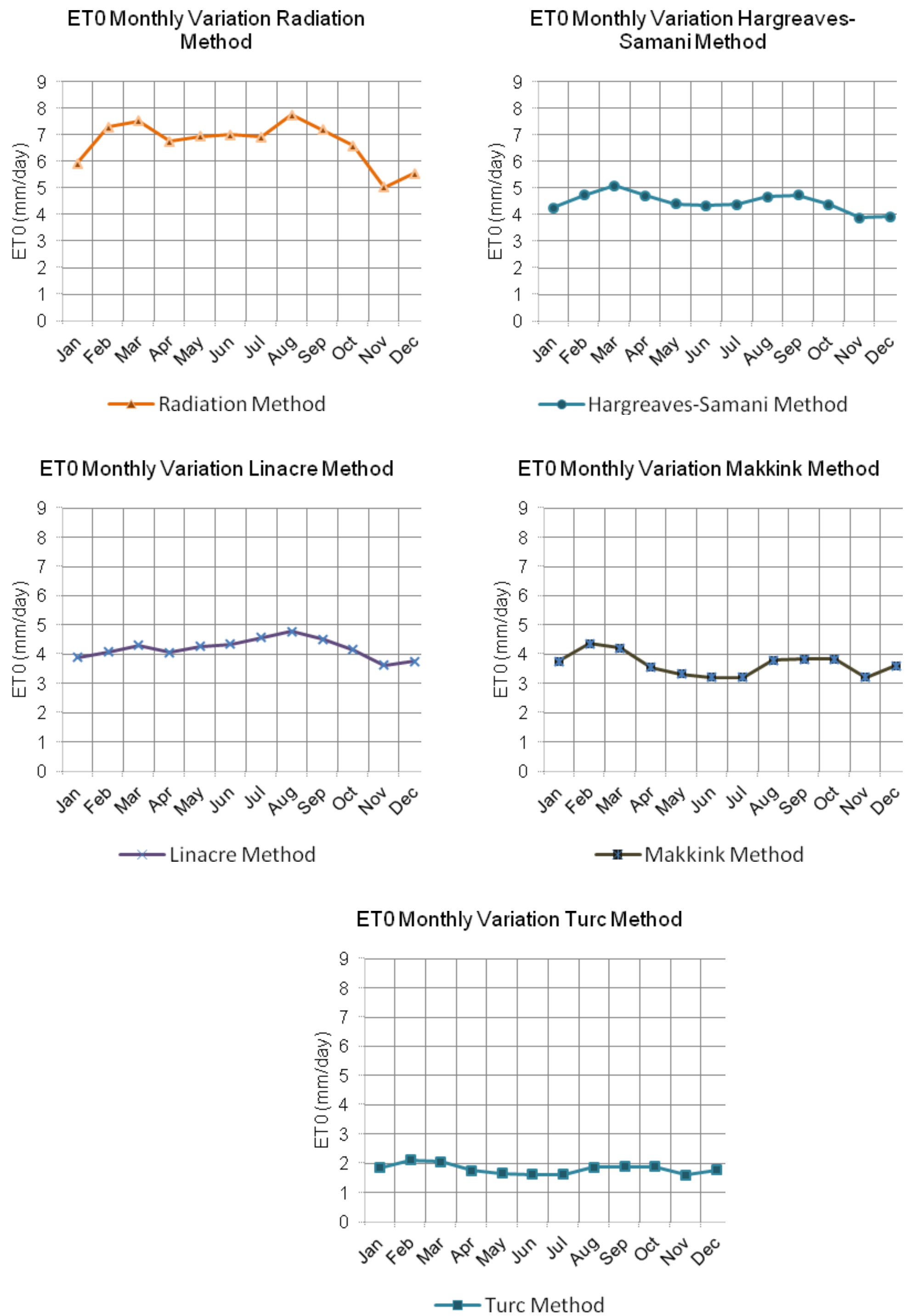



**Figure 2 ET0 Variations in Different Climatologic Methods**

Generally $ET_0$ is more sensitive to relative humidity and it has a negative correlation with $ET_0$ (Yu-Min Wang *et al.*2011). This relationship can be clearly visible from the obtained $ET_0$ results. $ET_0$ is comparatively high in February, March, August and September where relative humidity is less and less $ET_0$ in October, December and January where relative humidity is high.

The calculated MAE for each method in each month is listed out in Table 3.

**Table 3 Calculated Mean Absolute Error for Each Method**

| Month | Blaney-Criddle Method | Hargreaves-Samani Method | Linacre Method | Makkink Method | Radiation Method | Turc Method |
|---|---|---|---|---|---|---|
| January | 2.07 | 0.03 | 0.40 | 0.53 | 1.64 | 2.44 |
| February | 2.31 | 0.20 | 0.86 | 0.58 | 2.36 | 2.84 |
| March | 2.43 | 0.18 | 0.62 | 0.71 | 2.59 | 2.87 |
| April | 2.59 | 0.52 | 0.12 | 0.65 | 2.56 | 2.43 |
| May | 3.18 | 0.17 | 0.02 | 0.93 | 2.70 | 2.58 |
| June | 3.41 | 0.08 | 0.10 | 1.03 | 2.75 | 2.63 |
| July | 3.13 | 0.05 | 0.14 | 1.23 | 2.49 | 2.82 |
| August | 2.96 | 0.39 | 0.27 | 1.27 | 2.70 | 3.20 |
| September | 2.45 | 0.16 | 0.38 | 1.06 | 2.31 | 3.01 |
| October | 2.16 | 0.19 | 0.43 | 0.74 | 2.01 | 2.70 |
| November | 1.84 | 0.21 | 0.06 | 0.49 | 1.35 | 2.08 |
| December | 2.08 | 0.12 | 0.29 | 0.44 | 1.52 | 2.26 |

Since the objective of the study is to identify the most suitable method to replace with PMM in monthly basis, in Table 4 it is ranked from lowest MAE value to highest (Rank 1 implies the lowest MAE value while Rank 6 implies the highest) for each month.

According to the obtained data, Hargreves- Samani and Linacre methods give closest answers to PMM while Blaney Criddle and Turc methods deviate from PMM. According to the obtained result Hargreves Samani method canbe used for January, February, March, June, July and December months and Linacre method canbe used for April, May, Auguest and November in the absence of required climatic data for PMM .

**Table 4 Ranking According to the MAE value**

| Month | Rank 1 | Rank 2 | Rank 3 | Rank 4 | Rank 5 | Rank 6 |
|---|---|---|---|---|---|---|
| January | HSM | LM | MM | RM | BCM | TM |
| February | HSM | MM | LM | BCM | RM | TM |
| March | HSM | LM | MM | BCM | RM | TM |
| April | LM | HSM | MM | TM | RM | BCM |
| May | LM | HSM | MM | TM | RM | BCM |
| June | HSM | LM | MM | TM | RM | BCM |
| July | HSM | LM | MM | RM | TM | BCM |
| August | LM | HSM | MM | RM | BCM | TM |
| September | HSM | LM | MM | RM | BCM | TM |
| October | HSM | LM | MM | RM | BCM | TM |
| November | LM | HSM | MM | RM | BCM | TM |
| December | HSM | LM | MM | RM | BCM | TM |

In Normal case, results obtained from Blaney Criddle method closly vary with result obtained from PMM. But in this case it does not show such variation. It is because , BCM is not accurate in extrem climatic conditions such as windy, dry and sunny conditions(C Bruwer *et al*). On the Other hand Radiation method shows a significance deviation. It is because, the performance of Radiation method in arid zone is erratic (Allen *et al* 1998). Genarally, Turc method should agree with PMM. But the reliability of this method depends on the wind speed (Trajkovic *et al.*2007). Since the Angunakolapelessa weather station is closer to coastal area this type of variation can be expected due to high wind speed. Therefor in oder to have a reasonable result from Turc method, a wind speed adjustment factor should be applied to the equation (Trajkovic *et al.*2007*).*

In this research it was used only five years of climatic data. The significance of result can be improved with more than five years data. On the other hand result can be improved further more if it is possible to take the daily climatic data for the calculations.

In general , the result presented in this paper provides a basic idea for the agricultural sector which method will give better estimation of $ET_0$ for Walawe basin (as well as the sourthern regions where the same climatic conditions are available) in the absence of climatic data for PMM. The obtained result will help to irrigation sector for irrigation scheduling and there by increasing productivity,profit and reducing public conflicts on irrigation water supply.

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