Applicability of Estimating Evapo-Transpiration using Different Methods for Badulla Region

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Introduction

Potential evapo-transpiration (PET) is an essential tool widely used in hydrological studies. The magnitude and the variation of PET are required for water resources planning and management, proper irrigation scheduling, assessment of irrigation efficiency in different irrigation methods and estimation of water supply requirements of irrigation projects.

Owing to the wide ranging inconsistency in meteorological data collection procedures and standards, two types of PET equations have been used by different authors; empirical equations with lower data requirement and physically-based equations that require more data. The International Commission for Irrigation and Drainage (ICID), the Food and Agriculture Organization (FAO) and the American Society of Civil Engineers (ASCE) have adopted the Penman-Monteith (PM) method as the standard way to compute PETfrom climate data. PM is widely used as it is predominantly a physically-based approach that can be used globally and that has been widely tested using Lysimeter data from a wide range of climatic conditions (Itenfisu *et al.*, 2000).

When the data are limited, PET is calculated by estimating the absent parameters indirectly from the available data to use in PM equation (Allen *et al.*, 1998) or by the use of less data intensive empirical equations some of which are based on temperature (e.g. Thornthwaite, 1948; Blaney and Criddle, 1950; Romanenko, 1961; Hargreaves, 1975 and Kharrufa, 1985). It is generally accepted that empirical formulae may be reliable in the areas and over the periods for which they were developed, but large errors can be expected when they are extrapolated to other climatic areas without recalibrating the constants involved in the formulae (Hounam, 1971).

There is a scarcity of accurate meteorological data in *Uva* Province of Sri Lanka for estimating PET using standard PM method. Therefore, this research was conducted to analyze and compare temperature-based methods with the standard Modified Penman-Monteith (MPM) method and to select the best equation/s which can be applied to estimate the PET of the region.

Materials and Methods

Two agro-meteorological stations located at either sides of *Badulla* region of *Uva* Province were selected for this study. They were *Kahagolla* station [longitude of $80^0\ 59'$, latitude of $6^0\ 49'$ and elevation of 1219 m from mean sea level (MSL)] and *Pelgahathenna* station (longitude of $81^0\ 07'$, latitude of $6^0\ 59'$ and elevation of 1120 m from MSL). Monthly average values of the maximum temperature (^{0}C), minimum temperature (^{0}C), relative humidity (%), wind speed (km/day) and the total bright sun shine hours (hrs/day) obtained from the two stations during the last twelve years (2000-2011) were used for the study.

Temperature-based five empirical equations were used to estimate the PET values:Thornthwaite (TH), Blaney and Criddle (BC), Hargreaves (HG), Kharrufa (KF) and Romanenko (RM). Those values were then evaluated against the PET values calculated using the Modified Penman-Monteith (MPM) method by determining the percentage error [100*(Estimated PET from temperature-based method – PET estimate from MPM method)/PET estimate from MPM method] and the correlation co-efficient (R^2).

Results and Discussion

The estimated monthly PET values using different temperature-based methods together with the standard Modified Penman-Monteith (MPM) method are shown in Table 1 and Table 2 for *Kahagolla* and *Pelgahathenna* stations, respectively.

Table 1: Monthly averages of PET estimates from different methods at *Kahagolla* station

Month	PET estimates (mm/day)					
	MPM	TH	HG	BC	KF	RM
Jan	3.08	2.14	3.11	3.95	4.44	1.81
Feb	3.75	2.41	3.75	4.05	4.7	2.72
Mar	4.13	2.87	4.16	4.19	5.12	3.34
Apr	3.67	3.16	3.97	4.42	5.53	2.71
May	3.68	3.41	4.09	4.48	5.7	2.77
Jun	3.7	3.32	4	4.45	5.61	3.34
Jul	3.72	3.18	4.15	4.42	5.5	2.99
Aug	3.69	3.19	4.15	4.43	5.53	3.08
Sep	3.61	3.01	4.05	4.39	5.42	3.18
Oct	3.37	2.76	3.8	4.16	5.04	2.58
Nov	2.79	2.4	3.23	4.05	4.72	1.83
Dec	2.8	2.19	2.98	3.98	4.5	1.76

Table 2: Monthly averages of PET estimates from different methods at *Pelgahathenna* station

Month	PET estimates (mm/day)					
	MPM	TH	HG	BC	KF	RM
JAN	3.13	2.05	3.41	3.88	4.25	2.14
FEB	3.92	2.26	4.19	3.96	4.46	3.28
MAR	4.36	2.57	4.7	4.07	4.76	3.59
APR	4.13	2.88	4.58	4.31	5.2	2.96
MAY	4.36	3.08	4.68	4.36	5.34	3.54
JUN	4.62	3.00	4.45	4.33	5.24	4.34
JUL	4.79	2.94	4.49	4.32	5.21	4.5
AUG	4.72	2.91	4.64	4.31	5.21	4.34
SEP	4.58	3.45	3.74	4.51	5.78	4.23
OCT	3.62	2.62	4.16	4.09	4.83	2.71
NOV	3.05	2.5	3.61	4.06	4.75	2.03
DEC	2.85	2.14	3.23	3.92	4.36	1.88

The Table 3 shows the obtained percentage and the results of the linear regression in each temperature-based method against the MPM method at the two stations. It reveals that the lowest percentage errors resulted only in the HG method at both stations compared to other four methods which underestimated the PET values entailing higher percentage errors.

When the monthly PET values were computed using the different methods (X) these were analyzed to check the correlation with the PET calculated with MPM method (Y) using a linear regression equation:

$$Y = mX + c$$

only RM estimates were correlated well with MPM estimates showing the highest R^2 values 0.95 and 0.84 at both stations. The second highest R^2 values were shown in HG and BC (0.64) at *Kahagolla* station and HG (0.83) at *Pelgahathenna* station. Although the R^2 values of the TH and KF methods did not differ much at *Kahagolla* station, they did so at *Pelgahathenna* station. Many researchers (Xu and Singh, 2001; Droogers and Allen, 2002) have reported the empirical HG equation as a better alternative for estimating PET, when the available data are not enough to use the standard MPM method.

Table 3: Percentage Errors and Regression relationships between the estimated PET values with Modified PM Method and the PET estimates of the selected five methods

Method	*Kahagolla* Station				*Pelgahathenna* Station			
	Error	Regression Analysis			Error	Regression Analysis		
	%	Slope	Intercept	R^2	%	Slope	Intercept	R^2
TH	-32.05	1.32	0.45	0.63	-18.92	0.63	1.72	0.48
HG	4.89	1.04	-0.35	0.64	8.34	0.86	0.24	0.83
BC	6.71	2.75	-7.46	0.64	22.56	1.26	-1.87	0.40
KF	25.4	1.19	-1.87	0.61	48.08	0.59	0.45	0.44
RM	-19.4	0.71	1.69	0.95	-24.33	0.65	1.77	0.84

When slopes and intercepts were compared, large biases exist for most of the cases, revealing either the slopes (m) were significantly different from 1 or the intercepts (c) are significantly different from 0 or both, except the HG method at both stations. This reveals that HG is the closest representation for MPM method that represents the widely - adopted method for estimating PET.

Conclusion

The Hargreaves (HG) method can be selected as the most appropriate method for the estimation of PET. Therefore, Hargreaves method can be generalized to estimate the PET in Badulla region where only the temperature data are available.

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