REFERENCE EVAPOTRANSPIRATION ESTIMATION METHODS FOR TWO LOCATIONS IN BAHIA

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ABSTRACT: In the present study, three methods were used to estimate the reference evapotranspiration (ETo) with the Penman-Monteith method, in dry and wet seasons of 2018 in two locations in the state of Bahia, in the Recôncavo (Cruz das Almas) and in the South (Ilhéus). The values of the coefficients of determination (R^2) and correlation (r), the Standard Error of the Estimation (SEE), the Standard Error of the Adjusted Estimate (SEEa), the Standard Error of the Adjusted Estimate by the origin (SEEao) were used for the methods which presented better evaluation, and the indices of agreement (d) and performance (c). The methods of Hargreaves & Samani and Priestley-Taylor were those that obtained better evaluation, for both periods in Cruz das Almas. For Ilheus the best methods for the dry period were those of Hargreaves & Samani and Priestley-Taylor, however, the Camargo and Priestley-Taylor methods revealed the best performances for the wet period. The Priestley-Taylor method demonstrated the best performance to estimate ETo for both the sites and the periods evaluated in relation to the other methods studied.

KEYWORDS: climatic variables, Penman-Monteith, water management

MÉTODOS DE ESTIMATIVA DA EVAPOTRANSPIRAÇÃO DE REFERÊNCIA PARA DUAS LOCALIDADES DA BAHIA

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RESUMO: No presente estudo, comparou-se três métodos para estimar a evapotranspiração de referência (ETo) com o método de Penman-Monteith, em estações seca e úmida do ano de 2018 em duas localidades do estado da Bahia, no Recôncavo (Cruz das Almas) e no Sul (Ilhéus). Utilizou-se os valores dos coeficientes de determinação (R^2) e de correlação (r), do Erro Padrão da Estimativa (EPE), Erro Padrão da Estimativa Ajustado (EPEa), Erro Padrão da Estimativa Ajustado pela origem (EPEao) para os métodos que apresentaram melhor avaliação, e os índices de concordância (d) e desempenho (c). Os métodos de Hargreaves & Samani e Priestley-Taylor foram os que obtiveram melhor avaliação, para ambos os períodos em Cruz das Almas. Para Ilhéus os melhores métodos para o período seco foram os de Hargreaves & Samani e Priestley-Taylor, contudo, os métodos de Camargo e Priestley-Taylor revelaram as melhores performances para o período úmido. O método de Priestley-Taylor demonstrou o melhor desempenho para estimar ETo, tanto para os locais quanto para os períodos avaliados em relação aos outros métodos estudados.
PALAVRAS-CHAVE: variáveis climáticas, Penman-Monteith, manejo hídrico

INTRODUCTION

The estimate of reference evapotranspiration (ETo) is of great importance to determine the optimal supply of water to a culture (Souza et al., 2014). The method of Penman-Monteith (FAO) was chosen as the standard method to estimate the ETo, since it addresses the evapotranspiration of the grass pattern in the evaluated sites and presents superiority in relation to the other methods (Xing et al., 2008). According to Allen et al. (1998), the estimation of evapotranspiration is fundamental, both from the point of view of the factors of production and for the purposes of planning, granting water, designing and managing irrigation systems.

Thus, the objective of this study was to compare three methods for estimating the ETo with the Penman-Monteith method, dry and humid seasons of the year of 2018 at two localities in the state of Bahia, in the Recôncavo (Cruz das Almas) and in the south (Ilhéus).

MATERIAL AND METHODS

The work was carried out in two sites of the state of Bahia, in Cruz das Almas, coordinates 12º 48 'S and 39º 06' W and average altitude of 225 m. According to the

classification of Köppen, the climate is of type Af, with average annual temperature of 24.2ºC and annual average precipitation of 1200 mm. The city economy is focused on agriculture, with emphasis on tobacco, fruit and cassava plantations. Already the city of Ilhéus, south of the state with geographic coordinates of 14º 47' 20" S and 39º 02' 58" W and average altitude of 80 m. The climate is of type Af, according to the classification of Köppen.

The average maximum temperature is 28°C and the minimum temperature is 21°C and mean annual precipitation of 2200 mm. The economic base is mainly agricultural, linked to the cacao plantations. The data referring to the climatic variables were obtained through an INMET automatic station of INMET, located in the municipalities of Cruz das Almas and Ilhéus-BA. Estimations of ETo estimation were performed using the Penman-Montheith methods (Allen et al., 1998) (1), Hargreaves and Samani (1985), Camargo (1971), Makkink (1957) and Priestley-Taylor (1972).

$$ETo = \frac{0.408\,\Delta(\mathrm{Rn} - \mathrm{G}) + \gamma \frac{900}{\mathrm{T} + 275} u_2 (e_s - e_d)}{\Delta + \gamma(1 + 0.34u_2)} \quad (1)$$

wherein:

ETo - reference evapotranspiration ($mm.d^{-1}$); Rn- net radiation at the surface ($MJ.m^{-2}.d^{-1}$); G - soil heat flux ($MJ.m^{-2}.d^{-1}$); T - air temperature (°C); u_2 - wind speed at 2.0 m height ($m\ s^{-1}$); (e_s-e_d) - vapor pressure deficit (kPa); Δ - the slope of the curve saturation vapor pressure ($kPa.\ C^{-1}$); γ - psychrometric constant ($kPa.\ C^{-1}$).

To compare the values of ETo between Penman-Montheith with the others methods, it was used the criteria proposed by Jensen et al. (1990), which are the standard error of estimate (SEE) (2) and the standard error of estimate adjusted (SEEa) (3), coefficients of determination (R^2) and standard error of estimate adjusted by origin (SEEao) to the methods that showed better assessment.

$$SEE = \left(\frac{\sum (Y_i - Y_m)^2}{n - 1} \right)^{0.5} \quad (2)$$

$$SEEa = \left(\frac{\sum (Y_{ic} - Y_m)^2}{n - 1} \right)^{0.5} \quad (3)$$

wherein:

Y_i - evapotranspiration estimated by the method ($mm.d^{-1}$); Y_m - evapotranspiration estimated by the standard method ($mm.d^{-1}$); Y_{ic} – estimate using evapotranspiration, adjusted by coefficients of linear regression ($mm.d^{-1}$); and n- total number of observations.

It was also tested in the correlation of the estimated values of the ETo parameters related to precision, correlation coefficient (r) (4), accuracy (Willmott "d" index) (5) described by Willmott et al. (1985) and performance (index "c") (6), described in Camargo and Sentelhas (1997).

$$r = \sqrt{R^2} (4)$$

wherein:

r - correlation coefficient, R^2- coefficient of determination.

$$d = 1 - \left[\frac{\sum(P_i - O_i)^2}{\sum(|P_i - O| + |O_i - O|)^2}\right] (5)$$

wherein:

P_i - Estimated value; O_i - observed value, and O - average of the observed values.

$$c = r.d\ (6)$$

wherein:

r - correlation coefficient, d - index Willmott.

For interpretation of the methods of estimate of ETo using the performance index “c”, it was used the criteria proposed by Camargo & Sentelhas (1997), which are in Table 1.

Table 1. Values of "c" interpretive criteria for the performance of estimating ETo.

Values de “c”	Performance
> 0.85	Excellent
0.76 – 0.85	Very good
0.66 – 0.75	Good
0.61 – 0.65	Median
0.51 – 0.60	Tolerable
0.40 – 0.50	Poor
≤ 0.40	Very poor

RESULTS AND DISCUSSION

It is observed in Table 2 that the Hargreaves & Samani and Priestley-Taylor methods were those with the best precision parameters, also the best coefficient of determination (R^2) and standard error of estimation (SEE) and the standard error of the adjusted estimate (SEEa) near zero, a more significant result for the Priestley-Taylor method, for both sites. However, the Camargo method presented better performances for the humid periods when compared to Hargreaves & Samani.

Borges Junior et al. (2012) reported that during the wettest period of the year the values of "c" for the Camargo method presented higher values, considering that the performance of this model tends to be better under more hazy conditions, a fact observed for both sites. Silva et al. (2011) working under climatic conditions of Uberlândia found that the Priestley-Taylor method was more accurate and reliable compared to other methods.

When it only has data for air temperature, the method of Thornthwaite or Hargreaves & Samani can be used with good reliability, showing that irrigation management requires, in addition to appropriate methods and technology, studies of specific water consumption for each crop in different times, places and stages of development (Souza et al., 2014). However, Oliveira et al. (2010) found in the northern region of Bahia that the methods of Hargreaves & Samani and Makkink, which use as an input variable the air temperature and global solar radiation, showed good performance, both with coefficient "c" = 0.76, diverging from the data found in this research.

Table 2. Parameters of coefficient of determination (R^2), standard error of estimation (SEE), standard error of adjusted estimate (SEEa), correlation coefficient (r), agreement index (d), confidence index performance, during the dry and humid period in Cruz das Almas and Ilhéus-Bahia.

Penman-Montheith	Cruz das Almas - Period Dry						
	R^2	SEE	SEEa	r	d	c	Performance
Hargreaves & Samani	0.8906	1.70	1.70	0.94	0.58	0.55	Tolerable
Camargo	0.7788	4.55	4.54	0.88	0.27	0.24	Very poor
Makkink	0.6967	8.43	8.41	0.83	0.34	0.28	Very poor
Priestley-Taylor	0.9997	0.13	0.13	1.00	0.98	0.98	Excellent
Penman-Montheith	Cruz das Almas - Period Humid						
	R^2	SEE	SEEa	r	d	c	Performance
Hargreaves & Samani	0.8887	1.81	1.80	0.94	0.77	0.73	Good
Camargo	0.7903	4.84	4.82	0.89	0.96	0.85	Very good
Makkink	0.5838	9.23	9.21	0.76	0.22	0.17	Very poor
Priestley-Taylor	0.9997	0.16	0.16	0.94	0.92	0.87	Excellent
Penman-Montheith	Ilhéus - Period Dry						

	R²	SEE	SEEa	r	d	c	Performance
Hargreaves & Samani	0.8918	0.77	0.76	0.94	0.58	0.55	Tolerable
Camargo	0.8896	3.86	3.85	0.94	0.43	0.40	Very poor
Makkink	0.8644	7.59	7.57	0.93	0.32	0.30	Very poor
Priestley-Taylor	1	0.42	0.42	1.00	0.86	0.86	Excellent
Penman-Montheith	Ilhéus - Period Humid						
	R²	SEE	SEEa	r	d	c	Performance
Hargreaves & Samani	0.7218	0.85	0.83	0.85	0.57	0.48	Poor
Camargo	0.7834	3.52	3.50	0.89	0.83	0.74	Good
Makkink	0.7285	7.13	7.10	0.85	0.24	0.20	Very poor
Priestley-Taylor	0.9999	0.43	0.43	1.00	0.88	0.88	Excellent

We verified in figure 1 the forced regression through the origin and SEEao of the methods that presented the best performance, and that the Priestley-Taylor method overestimated ETo in relation to Penman-Montheith for both sites, thus obtaining values of R². Corroborating with the results of Souza et al. (2014), when comparing ETo methods in two sites in Espírito Santo-ES.

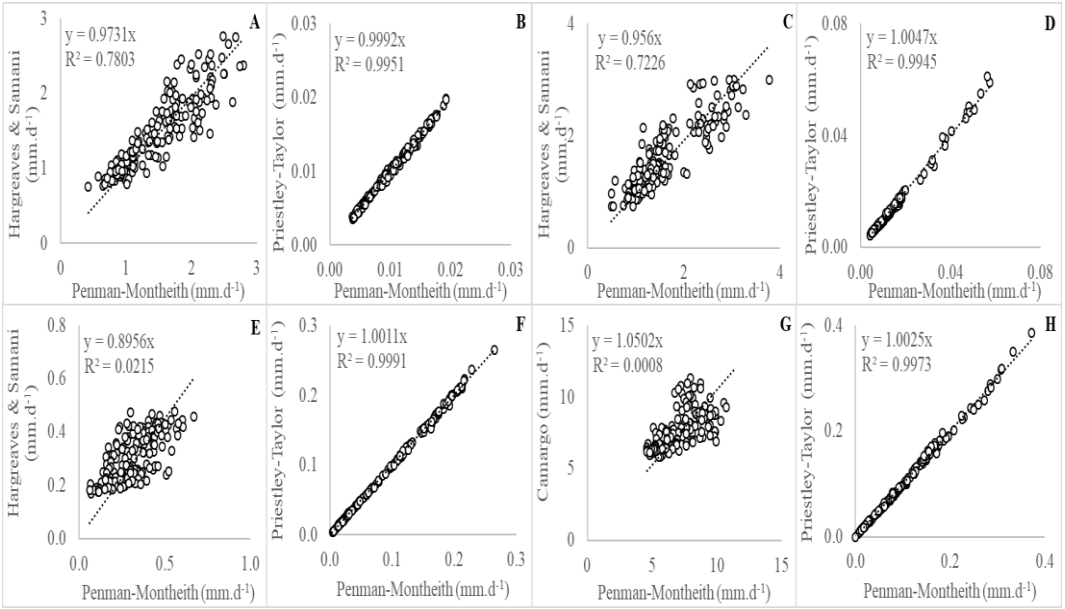

Figure 1. Linear regression between daily values of reference evapotranspiration (ETo) for the dry period (A and B) and humid (C and D) for Cruz das Almas-BA and dry period (E and F) and humid (G and H) to Ilhéus-BA, forced by origin, estimated by the Penman-Montheith method in relation to Hargreaves & Samani, Camargo and Priestley-Taylor.

CONCLUSIONS

The Priestley-Taylor method showed the best performance to estimate ETo for both the sites and the periods evaluated in relation to the other methods studied.

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