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MODELOS PARA ESTIMATIVA DA EVAPOTRANSPIRAÇÃO DE REFERÊNCIA

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1 RESUMO

A estimativa da evapotranspiração de referência pode ocorrer pelo método de Penman-Monteith recomendado pelo Boletim 56 da FAO. Entretanto, esse modelo matemático demanda variáveis meteorológicas completas que não estão disponíveis em muitas regiões. O presente trabalho teve como objetivo verificar a performance dos modelos de estimativa de ETo: Hargreaves-Samani (HS), Thornthwaite (TH), Thornthwaite e Camargo (TC), Camargo (CO), Priestley-Taylor (PT), Blaney-Criddle (BC), Makink (MK), Linacre (LN), Radiação Solar (RS) e Jensen-Haise (JH) para o cálculo da evapotranspiração de referência nas regiões de Buritis-MG e São Desidério-BA. Foram avaliados os coeficientes de determinação (R^2), correlação (r), exatidão (d) e desempenho (c), bem como os Erros médio aleatório (EMA), máximo (EM), aleatório (Ea) e sistêmico (Es) para análise das performances dos métodos utilizados. Para as duas regiões, a metodologia de Priestley-Taylor apresentou o melhor desempenho, bem como uma superestimativa de ETo média anual de 6 e 7% para as cidades de Buritis – MG e São Desidério – BA, respectivamente.

Palavras-chave: modelos de estimativa, irrigação, Penman-Monteith

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MODELS FOR ESTIMATING REFERENCE EVAPOTRANSPIRATION

2 ABSTRACT

The Penman–Monteith methodology is presented in the FAO Bulletin 56 as the standard equation because it requires a range of information related to the climate to determine the reference evapotranspiration (ETo); however, for regions with a lack of information, other methods can be applied, present as alternatives to estimate ETo. The present work aimed to verify the performance of the ETo estimation models Hargreaves-Samani (HS), Thornthwaite (TH), Thornthwaite and Camargo (TC), Camargo (CO), Priestley-Taylor (PT), Blaney-Criddle (BC), Makink (MK), Linacre (LN), Solar Radiation (RS) and Jensen-Haise (JH) for the calculation of reference evapotranspiration in the regions of Buritis-MG and São Desidério-BA. The index of determination (R^2), correlation (r), accuracy (d) and performance (c) were

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evaluated, as were the mean random (EMA), maximum (EM), random (Ea) and systemic (Es) errors for performance analysis of the methods used. For both regions, the Priestley–Taylor methodology showed the best performance, as well as an overestimation of the average annual ETo of 6 and 7% for the cities of Buritis - MG and São Desidério - BA, respectively.

Keywords: Estimation models, irrigation, Penman-Monteith.

3 INTRODUCTION

When properly managed, irrigation is a beneficial practice for agriculture, leading to high crop productivity (Campos et al., 2014). Therefore, analyzing the daily evapotranspiration of a crop is of paramount importance for verifying the system's water demand and adopting sustainable management practices.

According to Fanaya Júnior et al. (2012), the application of the FAO standard method for determining evapotranspiration may not be verified in some situations because meteorological stations lack the necessary equipment for measuring climate data, as well as data recording failures or sensor malfunctions. The authors also report that stations with greater technological resources are more difficult to acquire because of their market value, making the investment in this equipment unfeasible, especially for small producers.

Doria et al. (2015) emphasize that evapotranspiration is of paramount importance for verifying the water demand of a crop and is a crucial element for the rational use of water in an irrigated production system.

Methodologies for verifying evapotranspiration in a given region can be evaluated directly or indirectly. Direct methods involve the use of lysimeters and methodologies for controlling soil moisture and inputs/outputs, which stand out for their applicability; however, they present a high investment cost. For indirect models, evaporimeters (class A pan, atmometers) and equations developed to operate in a general context and others calibrated for specific regions stand out (Bernardo et al., 2019).

With respect to the use of indirect methods for calculating reference evapotranspiration, the Food and Agriculture Organization (FAO - UN) points to the methodology applied by Penman–Monteith as the standard equation for calculating reference evapotranspiration in various regions because of the use of a large amount of data, demonstrating superiority, in most cases, compared with other empirical equations (Alencar; Sediyama; Mantovani, 2015).

The aim of this study was to verify the performance of methodologies for calculating evapotranspiration in two regions of the Brazilian Cerrado (Buritis-MG and São Desidério-BA).

4. MATERIALS AND METHODS

The data were collected from the database of the automatic weather station located in the municipality of Buritis-MG and another in São Desidério-BA.

The automatic weather station is located in the municipality of Buritis, MG, at coordinates 15°49'21.43"S and 46°30'55.39"W and an altitude of 935 m above sea level. This equipment has instruments for collecting daily data on maximum, average and minimum temperatures (°C), average relative humidity (%), wind speed (ms^{-1}), solar radiation (Wm^2), and precipitation (mm).

The data processed for the São Desidério region were collected using the climate history of the automatic weather station located at coordinates 12°45'15"S and 45°15'07"W and an altitude of 750 m above sea level. The station has instruments for collecting daily data on maximum, average, and minimum temperatures (°C), average relative humidity (%), wind speed (ms^{-1}), solar radiation (Wm^2), and precipitation (mm).

The data come from the company Irriger, and the selected time series period is from 2010 to 2019.

The methods used to obtain evapotranspiration (mm day^{-1}) were Penman–Monteith (PM), Hargreaves–Samani (HS), Blaney–Criddle (BC), Thornthwaite (TH), Thornthwaite–Camargo (TC), Camargo (CO), Priestley–Taylor (PT), Linacre (LN), Makink (MK), Jensen–Haise (JH) and Solar Radiation (RS), as shown in Table 1.

Table 1 Proposed methodologies for estimating reference evapotranspiration for the municipalities of Burits, MG, and São Desidério, BA.

Methodology	**Equation**
Penman–Monteith (PM)	$ET_0PM = \frac{0{,}408\Delta \times (R_n - G) + y \times \left(\frac{900}{T+273}\right) \times \mu_2 \times (e_s - e_a)}{\Delta + y(1 + 0{,}34\mu_2)}$
Hargreaves-Samani (HS)	$ET_0HS = 0{,}0023 \times R_a \times (T_{máx} - T_{min})^{0{,}5} \times (T_{méd} + 17{,}8)$
Blaney-Criddle (BC)	$ET_0BC = a + b \times [f \times (0{,}46 \times T_{méd} + 8{,}13)]$
Thornthwaite (TH)	$ET_0TH = \left(\frac{ET_p}{30}\right) \times \left(\frac{N}{12}\right)$
Thornthwaite-Camargo (TC)	$ET_0TC = 16 \times \left(10 \times \left(\frac{T_{ef}}{I}\right)^{\alpha} \times \left(\frac{N}{12}\right) \times \left(\frac{1}{30}\right)\right)$
Camargo (CO)	$ET_0CO = 0{,}01 \times R_a \times T_{méd} \times K$
Priestley-Taylor (PT)	$ET_0PT = \frac{\alpha \times W \times (R_n - G)}{\lambda}$
Linacre (LN)	$ET_0LN = \frac{\frac{J\,(T_m + 0.006h)}{100 - \lvert\varphi\rvert} + 15 \times (T_m + T_0)}{80 - T_m}$
Makkink (MK)	$ET_0MK = 0{,}61 \times WS_r - 0.12$
Solar Radiation (RS)	$ET_0RS = c_0 + c_1 \times W\, x\, S_r$
Jensen-Haise (JH)	$ET_0JH = Sr \times (0{,}0252 \times T_m + 0{,}078)$

Where ET0 = reference evapotranspiration (mm day^{-1}); Rn = net radiation at the crop surface (MJ m^{-2} day^{-1}); G = soil heat flux density (MJ m^{-2} day^{-1}); T = air temperature at 2 m height (°C); μ2 = wind speed at 2 m height (ms^{-1}); es = saturation vapor pressure (kPa); ea = actual vapor pressure (kPa); es – ea = saturation vapor pressure deficit (kPa); Δ = slope of the saturation vapor pressure vs. temperature curve (kPa°C^{-1}); and Γ = psychrometric constant (kPa°C^{-1}).R_a = Radiation at the top of the atmosphere (MJ m^{-2}); T_{max} = maximum temperature (°C); T_{med} = average temperature (°C); T_{min} = minimum temperature (°C); aeb = adjustment factors according to Doorenbos and Pruitt (1975); f = percentage of hours of sunlight, as described by Doorenbos and Pruitt (1975); ETo TH = reference evapotranspiration (mm day^{-1}); ETp = potential evapotranspiration for a 30-day month; N = photoperiod (h); T ef = effective temperature (°C); T_{max} = maximum temperature (°C); T_{min} = minimum temperature (°C); EToCO = reference evapotranspiration (mm day^{-1}); K = adjustment factor as a function of temperature; J = 500 (constant of the formula considering albedo = 0.25); $|\varphi|$= latitude in degrees (°); To = average monthly temperature (°C); R = difference between the warmest and coldest temperatures of the month (°C); h = altitude (m); EToPT = reference evapotranspiration (mm day^{-1}); λ= latent heat of vaporization (2.45 MJ).

To verify the performance of the methodologies compared to the standard equation, evaluations of the adjustment coefficients of the linear equations were carried out to verify the precision of the estimates, using the coefficient of determination R^2, the correlation index "r", the accuracy index "d" applied by Willmont, Ackleson and Davis (1985), where the values whose variation is between 0 (no agreement) and 1 (perfect agreement), and the performance index "c" described in Camargo and Sentelhas (1997).

Table 2. Rating scale for the performance coefficient (c).

Performance coefficient	Performance
> 0.85	Great
0.76 - 0.85	Very good (MB)
0.66 - 0.75	Good (B)
0.61 - 0.65	Median (Me)
0.51 - 0.60	Tolerable (T)
0.41 - 0.50	Bad (M)
≤ 0.40	Terrible (P)

For error quantification, the mean absolute error (MAE), maximum error (ME), random error (Ea), and systematic error (Es) were verified, as presented in equations 1 to 5, respectively.

$$EMA = \left(\frac{1}{N}\right) \times \sum_i^n (P_i - O_i)^2 \quad (1)$$

$$EM = max(|O_i - P_i|)_1^n \quad (2)$$

$$Ea = \left(\frac{1}{N}\right) \times \sum_i^n (P_i - P^*)^2 \quad (3)$$

$$Es = \left(\frac{1}{N}\right) \times \sum_i^n (P^* - O_i)^2 \quad (4)$$

In what way:
N = Number of estimates

$$P^* = a + bO_i \quad (5)$$

" a" and "b" are estimated by the least squares method.

5. RESULTS AND DISCUSSION

For the city of Buritis, the Prestley–Taylor equation demonstrated the best coefficient of determination, with a value of 0.9368, followed by the Camargo (R^2 = 0.9262), Solar Radiation (R^2 = 0.9213), and Makink (R^2 = 0.9100) methodologies (Figure 1). The Thornthwaite and Linacre equations, however, did not present good coefficients, with R^2 values of 0.2974 and 0.4685, respectively. Notably, for both regions, the accuracy, correlation, and performance coefficients should be evaluated on the basis of the daily analysis of reference evapotranspiration values obtained during the period from 2010 to 2019 using the empirical equations employed, as presented in Tables 3 and 4. It is observed from the values obtained for the coefficients r and dec that for both regions, the Thornthwaite (TH), Camargo (CO), and Linacre (LN) methodologies classified performance as poor or very poor. This analysis differs from the observation made by Syperreck et al. (2008), who verified good performance for the Camargo and Thornthwaite methodologies in a study analyzing empirical equations for calculating ETo in the city of Palotina, PR. The same was verified by Borges and Mediondo (2007), who concluded that the Thornthwaite (TH) and Camargo (CO) methods present high reliability indices for regions with positive temperatures.

Silva et al. (2005) reported that in the absence of wind speed and insolation data, the Hargreaves and Samani (HS) equation can be used for warmer regions. Notably, this methodology presents good accuracy and correlation index, indicating good performance for Buritis; however, for the municipality of São Desidério, the values of "d" and "r" were lower, as was its performance, indicating that it was tolerable.

Table 3. Values of the accuracy (d), correlation (r) and performance (c) indices obtained by the empirical equations for the Buritis–MG regions.

Methodology	Buritis - MG			
	d	r	w	Performance
PM	1	1	1	THE
HS	0.84	0.85	0.72	B
TH	0.59	0.55	0.32	P
TC	0.87	0.78	0.67	B
CO	0.54	0.96	0.52	T
PT	0.96	0.94	0.91	THE
BC	0.57	0.65	0.37	P
MK	0.94	0.95	0.89	THE
LN	0.65	0.68	0.44	M
RS	0.91	0.96	0.87	THE
JH	0.82	0.97	0.79	MB

Table 4. Values of the accuracy (d), correlation (r) and performance (c) indices obtained by the empirical equations for the regions of São Desidério–BA.

Methodology	São Desidério - BA			
	d	r	w	Performance
PM	1	1	1	THE
HS	0.71	0.75	0.53	T
TH	0.6	0.51	0.3	P
TC	0.75	0.72	0.53	T
CO	0.49	0.94	0.46	M
PT	0.95	0.93	0.88	THE
BC	0.52	0.6	0.31	P
MK	0.92	0.92	0.84	THE
LN	0.62	0.67	0.42	M
RS	0.79	0.91	0.72	B
JH	0.67	0.94	0.63	Me

Table 5. Annual reference evapotranspiration (mm) obtained through ETo estimation models for the period 2010 to 2019 for the Buritis region, MG.

Year	PM	HS	TH	TC	CO	PT	BC	MK	LN	RS	JH
2010	1.404	1,573	1.034	1,384	627	1,441	969	1.222	1,721	1,659	1,799
2011	1,340	1,511	983	1.306	585	1.367	953	1.153	1,563	1,556	1,686
2012	1.396	1,572	1.038	1.369	622	1.427	980	1.203	1,674	1,640	1,787
2013	1.269	1,538	1.010	1.343	583	1.365	967	1.138	1,559	1,488	1,679
2014	1.338	1,583	1.010	1.385	621	1,439	965	1.215	1,692	1,617	1,786
2015	1.375	1,647	1.089	1,458	647	1,470	998	1.228	1,802	1,654	1,852
2016	1.331	1,611	1.068	1.459	633	1,443	995	1.210	1,749	1,596	1,812
2017	1.259	1,578	1.032	1.379	584	1.357	975	1.127	1,729	1,492	1,677
2018	1.224	1,547	1.017	1.361	580	1.363	968	1.129	1,613	1.445	1,669
2019	1.285	1,633	1.072	1,460	605	1.402	992	1.151	1,794	1,504	1,734
Average	1.322	1,579	1.035	1,390	609	1.408	976	1.178	1,690	1,565	1,748

PM = Penman–Monteith; HS = Hargreaves and Samani; TH = Thornthwaite; TC = Thornthwaite-Camargo; CO = Camargo; PT = Priestley-Taylor; BC = Blaney-Criddle; MK = Makink; LN = Linacre; RS = Solar Radiation; JH = Jensen-Haise.

Figure 1. Linear regression analysis between daily ETo values estimated by the standard Penman–Monteith (PM) method for the Buritis–MG region during the period from 2010 to 2019.

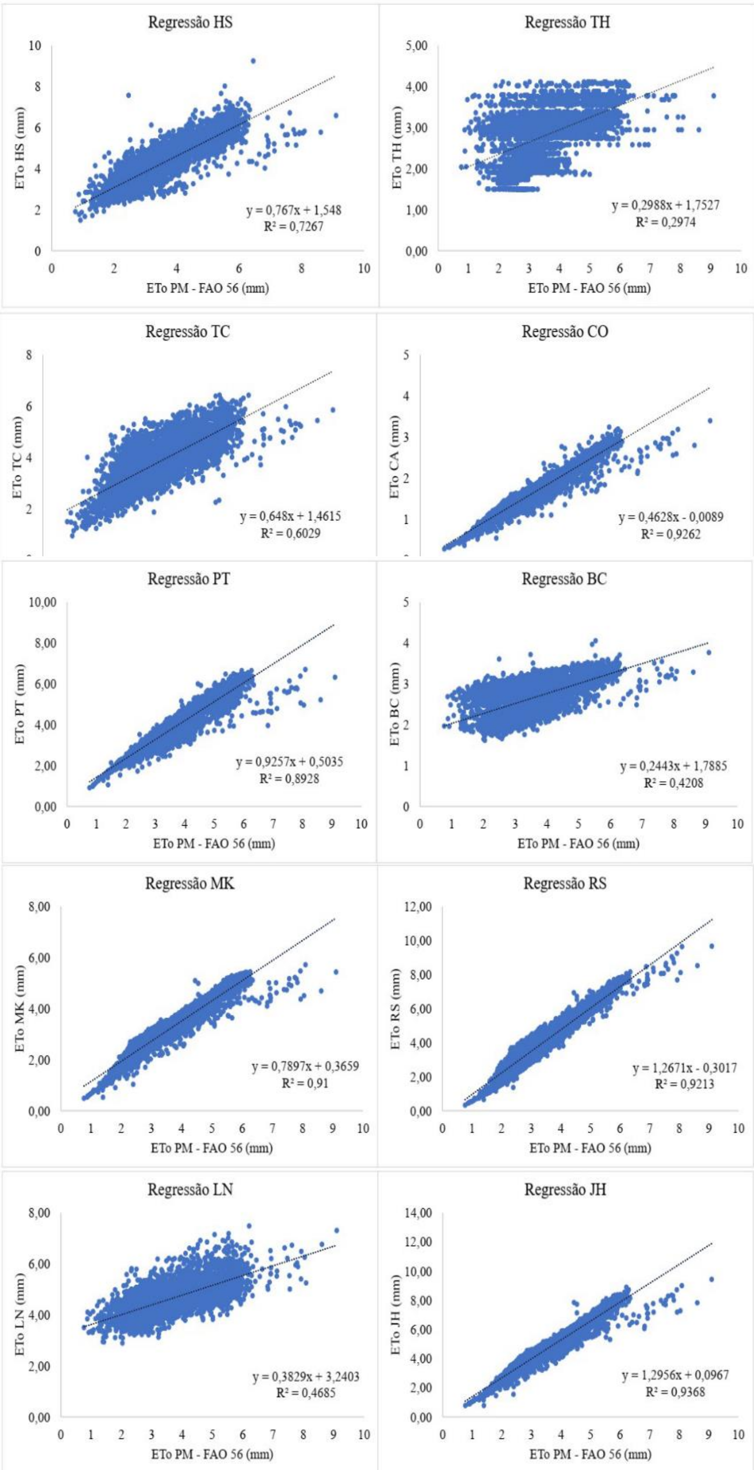
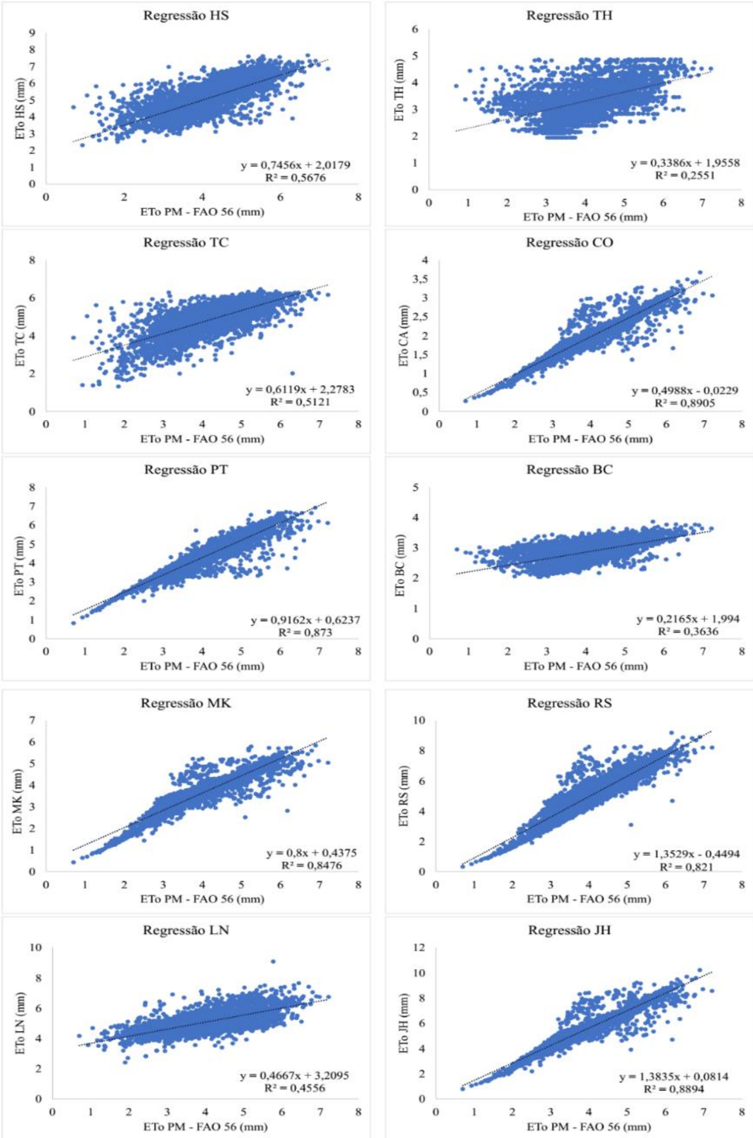


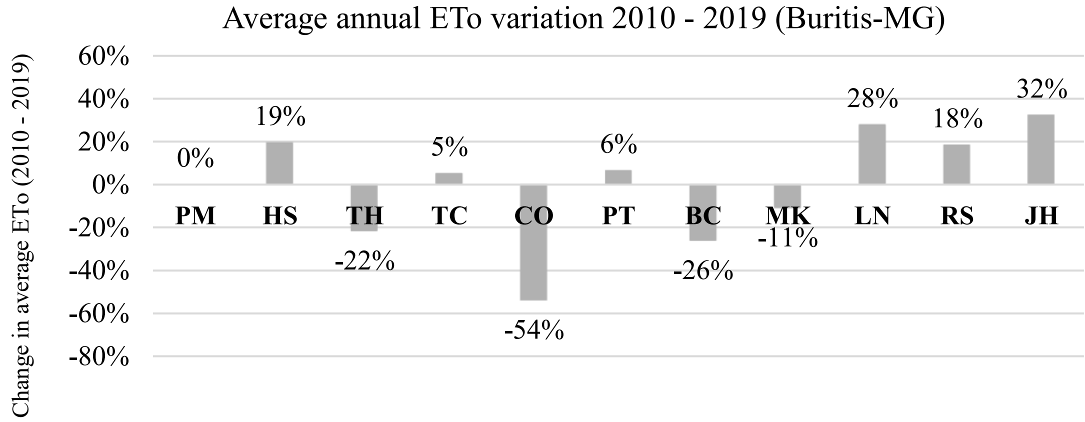
Figure 2. Linear regression analysis between daily ETo values estimated by the standard Penman–Monteith (PM) method for the São Desidério–BA region during the period from 2010 to 2019.



Using the accumulated annual ETo values, the average annual reference evapotranspiration was calculated for the study period, generating analyses of underestimates and overestimates for the two regions on the basis of the difference between the value obtained by the standard methodology (PM) and the other equations evaluated. These estimates are presented in Tables 5 and 6 and Figures 3 and 4.

Evaluating the average of the years for the Buritis region, it is possible to verify that the models proposed by Jensen-Haise (JH) and Linacre (LN) overestimated ETo by 32% and 28%, respectively, whereas the Camargo equation underestimated it by 54%, followed by Blaney-Criddle at 26%. Additionally, in the data referring to the ten-year average, the equations proposed by Thornthwaite-Camargo and Priestley-Taylor present the smallest variation, with ETo overestimating by 5% and 6%, respectively.

Figure 3. Underestimates and overestimates the annual average ETo for the years 2010 to 2019 in the Buritis/MG region.



PM = Penman–Monteith; HS = Hargreaves and Samani; TH = Thornthwaite; TC = Thornthwaite-Camargo; CO = Camargo; PT = Priestley-Taylor; BC = Blaney-Criddle; MK = Makink; LN = Linacre; RS = Solar Radiation; JH = Jensen-Haise.

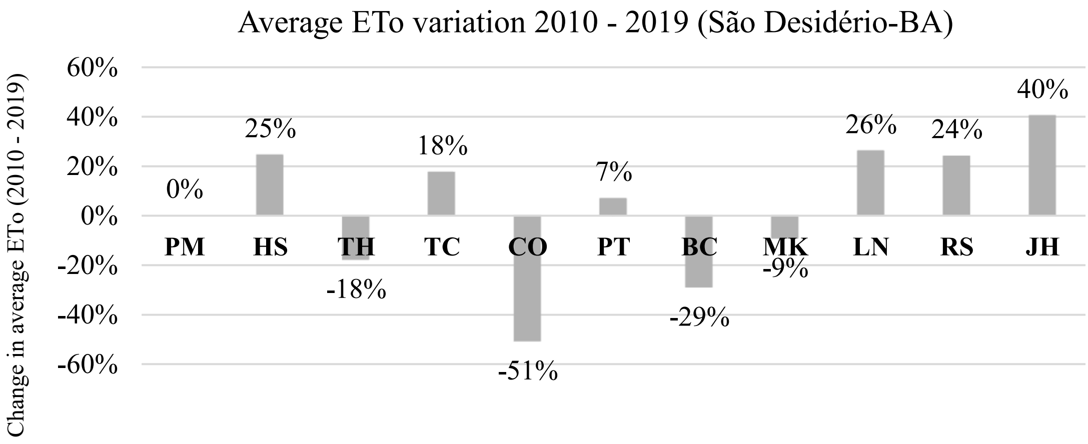
It was found that, as with Buritis, the Jensen–Haise equation overestimated the average ETo value for the municipality of São Desidério to a greater extent than the PM equation did. The Camargo model showed the greatest underestimation of ETo. The Priestley–Taylor equation was the closest to the standard methodology, with an overestimation of 7%, followed by the Makink methodology, which underestimated the average annual accumulated evapotranspiration by -9%.

Table 6. Annual reference evapotranspiration (mm) obtained through ETo estimation models for the period 2010 to 2019 for the São Desidério region, BA.

YEAR	pH	HS	TH	TC	CO	PT	BC	MK	LN	RS	JH
2010	1.413	1,826	1.139	1,734	702	1,561	1.023	1.321	1,838	1,751	2006
2011	1.349	1,787	1.083	1,677	666	1,500	1.002	1,270	1,693	1,660	1,907
2012	1,593	1,855	1.210	1,760	735	1,579	1.051	1.357	1,871	1,941	2.095
2013	1.417	1,783	1.173	1,682	700	1,540	1.035	1.295	1,759	1,760	1,994
2014	1,489	1,830	1.208	1,731	741	1.604	1.047	1.367	1,874	1,859	2.109
2015	1,511	1,924	1.276	1,804	754	1.615	1.066	1.369	1,983	1,891	2,140
2016	1,519	1,902	1.345	1,820	790	1,654	1.091	1.413	1,897	1,966	2,236
2017	1.515	1,808	1,270	1,678	781	1,650	1.066	1.421	1,929	1,975	2.218
2018	1.406	1,756	1.166	1,637	687	1,526	1.032	1,280	1,772	1,700	1,960
2019	1,537	1,895	1.265	1,821	717	1,563	1.063	1.304	1,988	1,810	2.038
Average	1.475	1,837	1.214	1.735	727	1,579	1.048	1,340	1,860	1,831	2.070

PM = Penman–Monteith; HS = Hargreaves and Samani; TH = Thornthwaite; TC = Thornthwaite-Camargo; CO = Camargo; PT = Priestley-Taylor; BC = Blaney-Criddle; MK = Makink; LN = Linacre; RS = Solar Radiation; JH = Jensen-Haise

Figure 4. Underestimates and overestimates the annual average ETo for the years 2010 to 2019 in the São Desidério/BA region.



PM = Penman–Monteith; HS = Hargreaves and Samani; TH = Thornthwaite; TC = Thornthwaite–Camargo; CO = Camargo; PT = Priestley–Taylor; BC = Blaney–Criddle; MK = Makink; LN = Linacre; RS = Solar Radiation; JH = Jensen–Haise.

The Hargreaves and Samani methodology overestimated ETo by 25% for the municipality of São Desidério and 18% for Buritis. Comparing evapotranspiration estimation methodologies, Oliveira et al. (2005) reported that the HS equation overestimated ETo by 24.5% compared with the PM equation for the Cerrado region of Goiás in the municipality of Santo Antônio de Goiás in the state of Goiás.

With respect to the Thornthwaite and Makink methods, both underestimated ETo for the two regions. The same was verified by Barreto, Webdkabdm and Marcuzzo (2009), who evaluated the performance of empirical equations for estimating the annual accumulated reference evapotranspiration for the year 2005 in the municipality of Brotas, São Paulo state. For Passos, Raposo and Mendes (2017), methodologies based on air temperature for calculating ETo estimates tend to present overestimated values in humid climate regions.

On the basis of the analysis of the linear regression equation, the coefficient of determination (R^2) on a daily scale was evaluated during the period from 2010 to 2019 for the methodologies used to estimate reference evapotranspiration in relation to the standard Penman–Monteith equation.

Table 7 shows the error values found in the municipalities for the different models.

Table 7. Evaluation of errors for daily ETo estimation (mm day^{-1}) for the municipalities of Buritis and São Desidério.

Methodology	Buritis - MG				São Desidério - BA			
	EMA	IN	Ea	Es	EMA	IN	Ea	Es
Penman–Monteith	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hargreaves-Samani	-0.70	5.12	0.31	0.57	-0.99	4.55	0.42	1.04
Thornthwaite	0.79	5.66	0.29	1.30	0.72	3.53	0.33	0.94
Tornthwaite-Camargo	-0.19	3.25	0.39	0.21	-0.71	4.33	0.35	0.65
Camargo	1.95	5.82	0.02	4.22	2.05	4.51	0.03	4.44
Prestley-Taylor	-0.23	3.39	0.14	0.06	-0.29	2.46	0.12	0.09
Blaney-Criddle	0.95	5.33	0.11	1.69	1.17	3.59	0.08	1.98
Makink	0.40	5.33	0.09	0.22	0.37	3.59	0.11	0.18
Linacre	-1.01	3.48	0.23	1.54	-1.06	3.93	0.26	1.40
Solar Radiation	-0.67	2.51	0.19	0.54	-0.98	4.25	0.39	1.08
Jensen-Haize	-1.17	3.41	0.16	1.48	-1.63	4.55	0.23	2.80

In addition to presenting the lowest accuracy coefficients and the greatest discrepancy in the underestimation of average annual evapotranspiration compared to the standard method for the two regions evaluated, the Camargo (CO) methodology presented the highest mean absolute and systemic errors for both cities and the highest maximum error for Buritis, MG, as shown in Table 13. Notably, for the São Desidério region, the Hargreaves Samani method presented the highest maximum error and random error, whereas the Thornthwaite and Camargo (TC) equation obtained the greatest random error for the Buritis region.

6 CONCLUSIONS

With respect to the city of Buritis, the Priestley-Taylor equation performed best among the other methods; however, the Makink, Solar Radiation, Jensen-Haise, Thornthwaite and Camargo, Hargreaves and Samani methodologies are available as alternatives for calculating the ETo estimate, as they demonstrated good results for accuracy, correlation, and performance indices. The Priestley–Taylor methodology showed the best performance for the São Desidério, BA region, followed by the Makink and Solar Radiation equations, indicating that the Priestley–Taylor method is an option for calculating ETo in the region.

7 REFERENCE

ALENCAR, LP; SEDIYAMA, GC; MANTOVANI, EC Estimation of reference evapotranspiration (FAO Standard ETo) for Minas Gerais, in absence of some climate data. **Magazine Engineering Agrícola,** Jaboticabal, v. 35, n. 1, Jan./Feb. 2015.

BARRETO, CEAG; WEBDKABDM, E.; MARCUZZO, FFN. Estimation of evapotranspiration from the variation of static aquifer level. **Agricultural Engineering**, Jaboticabal, v. 29, n. 1, p. 52-61, 2009.

BERNARDO, S.; MANTOVANI, EC; SILVA, DD; SOARES, A. A. Irrigation **Manual**. 9th ed. Viçosa: UFV, 2019.

BORGES, AC; MEDIONDO, EM Comparison between empirical equations for estimating reference evapotranspiration in the Jacupiranga River Basin. **Brazilian**

Journal of Agricultural and Environmental Engineering, Campina Grande, v. 11, n. 3, p. 293-300, 2007.

CAMARGO, AO; SENTELHAS, PC. Evaluation of the performance of different methods for estimating potential evapotranspiration in the State of São Paulo. **Revista Brasileira de Agrometeorologia**, Santa Maria, v. 5, n. 1, p. 89-97, 1997.

CAMPOS, PF; ALVES JÚNIOR, J.; CASAROLI, D.; FONTOURA, PR; EVANGELISTA, AWP. Sugarcane varieties subjected to supplemental irrigation in the Cerrado of Goiás. **Agricultural Engineering**, Jaboticabal, v. 34, n. 6, p. 1139-1149, Nov./Dec. 2014.

DOORENBOS, J.; PRUITT, WO **Crop water Requirements**. Rome: FAO, 1975. (FAO Irrigation and Drainage Paper, n. 24).

DORIA, BRS; TAVARES, LOG de S.; RAMOS, FS de M.; SOUZA, JA; SANTOS, DM; FACCIOLI, GG. Determination of water demand of carrot and beet crops irrigated with wastewater under greenhouse conditions in São Cristóvão. *In* : NATIONAL CONGRESS ON IRRIGATION AND DRAINAGE, 25th, 2015, São Cristóvão. **Proceedings** [...]. São Cristóvão: UFS, 2015. p. 880-886.

FANAYA JÚNIOR, ED; LOPES, AS; OLIVEIRA, GQ de.; JUNG, LH Empirical methods for estimating reference evapotranspiration for Aquadauana, MS. **Irriga**, Botucatu, v. 17, n. 4, p. 418-434, Oct./Dec. 2012.

OLIVEIRA, RZ; OLIVEIRA, LFC; WEHY, TR; BORGES, LB; BONONO, R. Comparison of methodologies for estimating reference evapotranspiration for the Goiânia region, GO. **Bioscience Journal,** Uberlândia, v. 21, n. 3, p. 19-27, 2005.

PASSOS, MLV; RAPOSO, AB; MENDES, TJ. Reference evapotranspiration by different methods for the municipality of Chapadinha-MA. **Agropecuária Científica no Semiárido**, Patos, v. 13, n. 2, p. 146-153, Apr./Jun. 2017.

SILVA, KO da.; MIRADA, JH de.; DUARTE, SN; FOLEGATTI, MVN. Analysis of evapotranspiration estimation methods in the optimization of drainage systems. **Brazilian Journal of Agricultural and Environmental Engineering**, Campina Grande, v. 9, n. 2, Apr./Jun. 2005.

SYPERRECK, VLG; KLOSOWSKI, ES; GRECO, M.; FURLANETTOET, C. Performance evaluation of methods for estimating reference evapotranspiration for the Palotina region, Paraná State. **Acta Scientiarum Agronomy**, Maringá, v. 30, p. 603-609, 2008.

WILLMONT, C.J.; ACKLESON, SG; DAVIS, RE Statistics for the evaluation and comparison of models. **Journal of Geophysical Research**, Ottawa, vol. 90, no. 5, p. 8995-9005, 1985.