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ESTUDO COMPARATIVO ENTRE METODOLOGIAS DE ESTIMATIVA DA EVAPOTRANSPIRAÇÃO DE REFERÊNCIA PARA LOCALIDADES DO NORTE DE MINAS GERAIS

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1 RESUMO

A determinação da evapotranspiração é imprescindível para a prática racional da irrigação, o que tem conduzido à formulação de diversas equações para estimativa desta importante variável meteorológica. Nesse sentido, faz-se necessário estudos comparativos com estas equações de modo a avaliar, localmente, sua aplicabilidade. Em linha com o exposto, objetivou-se comparar, para as condições climáticas de Salinas e Januária (ambos situados no Norte de Minas Gerais, Brasil), métodos empíricos de estimativa da evapotranspiração com o método padrão de Penman-Monteith (FAO56). Para tanto, utilizou-se dados meteorológicos de cinco anos (2016 a 2020) obtidos do Instituto Nacional de Meteorologia (INMET). Para a análise comparativa foram utilizados os seguintes indicadores estatísticos: coeficientes de determinação (R^2) e correlação (r), erro absoluto médio (EAM), raiz do erro quadrado médio (REQM), índice de concordância (d) e índice de desempenho (c). Os resultados obtidos demonstram que, para as duas localidades avaliadas, o método de Blaney-Criddle apresenta o melhor desempenho para a estimativa da evapotranspiração, por outro lado, as equações de Hargreaves-Samani e Priestley-Taylor exibiram performance insatisfatória.

Palavras-chave: métodos empíricos, demanda hídrica de cultivos, manejo da irrigação.

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COMPARATIVE STUDY BETWEEN REFERENCE EVAPOTRANSPIRATION ESTIMATION METHODOLOGIES FOR NORTHERN MINAS GERAIS LOCATIONS

2 ABSTRACT

The determination of evapotranspiration is essential for the rational practice of irrigation, which has led to the formulation of several equations to estimate this important meteorological variable. In line with the above objective was to compare, for the climatic conditions of Salinas and Januária (both located in the North of Minas Gerais, Brazil), empirical methods for estimating evapotranspiration with the standard method of Penman-

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Monteith (FAO56). For this purpose, meteorological data for five years (2016 to 2020) obtained from the National Institute of Meteorology (INMET) were used. For the comparative analysis, the following statistical indicators were used: coefficients of determination (R^2) and correlation (r), mean absolute error (EAM), root mean square error (REQM), agreement index (d) and performance index (c). The results obtained demonstrate that, for the two locations evaluated, the Blaney-Criddle method presents the best performance for estimating evapotranspiration, on the other hand, the Hargreaves-Samani and Priestley-Taylor equations showed unsatisfactory performance.

Keywords: crop water demand, empirical methods, irrigation management.

3 INTRODUCTION

Water is an essential element for food production, given that agriculture, through its irrigated form, uses approximately 70% of all freshwater withdrawn from springs (CHRISTOFIDIS, 2013). Given this fact, it is imperative that this important natural resource be used rationally.

For irrigation to be carried out optimally, it is necessary to know the crop's water demand by determining crop evapotranspiration (ETc), the main parameter for sizing and managing irrigation systems. ETc can be obtained through reference evapotranspiration (ETo) corrected by the crop coefficient, where ETo is defined as the combination of two distinct processes: evaporation of water directly from the soil surface and transpiration through plant stomata (ALLEN et al., 1998).

According to Cruz et al. (2017), determining evapotranspiration is difficult and costly because its estimation considers factors related to crops and soil, in addition to meteorological variables. Therefore, the use of mathematical models for its estimation is common, and among them, the Penman–Monteith model (FAO/56) stands out because of its robustness and has been recommended as the standard for estimating evapotranspiration.

Despite the reliability of the Penman–Monteith method (FAO56), this method requires several climatological elements for its estimation, which makes its use difficult in many locations in Brazil. Therefore, simpler approaches for estimating ETo have been developed to address locations with limited meteorological data (ALENCAR et al., 2011).

In this sense, particularly in Brazil, several studies have been carried out with models to estimate ETo to verify their performance for most different climate typologies. As an example, we can mention locations in the states of Alagoas (Macêdo et al., 2017), Goiás (Cruz et al., 2017), Espírito Santo and Rio de Janeiro (Coutinho et al., 2020), Amazonas (Ferreira et al., 2020), São Paulo (Sarnighausen et al., 2021), and Rio Grande do Sul (Ongaratto & Bortolin, 2021).

In view of the above, the objective of this study was to evaluate empirical methods for estimating reference evapotranspiration: the modified Penman (FAO24) method, radiation method, the Blaney-Criddle method, the Hargreaves-Samani method, the Priestley-Taylor method and the Turc method, in two municipalities in the northern region of Minas Gerais (Salinas and Januária), in which the standard Penman–Monteith method (FAO/56) was adopted as a parameter for comparison.

4 MATERIALS AND METHODS

The study area covers the municipalities of Salinas (latitude 16° 16' S, longitude 42° 30' W, altitude 471 m) and Januária (latitude 15° 29' S, longitude 44° 21' W, altitude 473 m), both of which are located in the northern region of Minas Gerais, where the semiarid region of Minas Gerais predominates. In Salinas, the average temperature and annual rainfall are 23.6 °C and 716 mm, respectively; in Januária, the average temperature and annual rainfall are 24.5 °C and 926 mm, respectively.

Daily data on air temperature (°C), humidity (%), sunshine (hours), wind speed (ms-1), and atmospheric pressure (kPa) from both locations were used for the study, with data evaluated over a five-year period (2016--2020). Meteorological data were obtained from the database of the National Institute of Meteorology (INMET; available at https://portal.inmet.gov.br/).

Evapotranspiration estimates were calculated via REF-ET software (ALLEN, 2000) via the Penman–Monteith (FAO56), modified Penman (FAO24), radiation, Blaney–Criddle, Hargreaves–Samani, Priestley–Taylor and Turc methods on a daily scale. The Penman–Monteith (FAO56) method was adopted as the standard and used to evaluate the performance of the other methods.

For the data, statistical analysis was performed to evaluate the performance of the empirical methods compared with that of the standard method. In this sense, the following statistical indicators were used: coefficient of determination (R^2), correlation coefficient (r), mean absolute error (MAE), root mean square error (RMSE), concordance index (d) of Willmott et al. (1985), and performance index (c, CAMARGO & SENTELHAS, 1997), in addition to the linear and angular coefficients of the simple regressions.

Specifically, regarding the performance index, the criterion adopted to interpret the performance of the methods through the “c” index is presented in Table 1.

Table 1. Criteria for interpreting the performance of ETo estimation methods via the “c” index proposed by Camargo & Sentelhas (1997) – ICS.

Interpretation of the Method by Index “c”	
Performance	**Value of “c”**
Excellent	> 0.85
Very good	0.76 to 0.85
Good	0.66 to 0.75
Median	0.61 to 0.65
Terrible	0.51 to 0.60
Bad	0.41 to 0.50
Terrible	<0.40

ICS – Performance Index Interpretation

5 RESULTS AND DISCUSSION

Table 2 presents the statistical performance indices for the comparative analysis of the empirical methods for estimating evapotranspiration compared with the standard Penman–Monteith method (FAO56), which is applied to the municipalities of Salinas and Januária. The average reference evapotranspiration (METo), obtained from the Penman–Monteith method (FAO56) for the studied locations, was 4.24 mm.day $^{-1}$ for Salinas and 5.14 mm.day $^{-1}$ for Januária.

Table 2. Statistical indicators for estimated values of reference evapotranspiration calculated at the daily scale in the municipalities of Salinas/MG and Januária/MG.

Mod	a	b	R²	r	E	RE	d	c	ICS	METo
					Salinas					
PM	-	-	-	-	-	-	-	-	-	4,24
PMod	-0,27	1,31	0,98	0,99	1,11	1,23	0,89	0,88	Ótimo	5,32
R	-0,72	1,26	0,92	0,96	0,66	0,79	0,94	0,90	Ótimo	4,75
BC	0,07	1,02	0,92	0,96	0,36	0,47	0,97	0,93	Ótimo	4,51
HS	1,72	0,73	0,72	0,85	0,75	0,91	0,89	0,76	MB	4,92
PT	0,59	0,84	0,73	0,86	0,61	0,77	0,92	0,79	MB	4,15
T	0,55	0,80	0,85	0,92	0,47	0,65	0,94	0,86	Ótimo	4,07
					Januária					
PM	-	-	-	-	-	-	-	-	-	5,14
PMod	0,23	1,20	0,95	0,98	1,29	1,39	0,87	0,85	MB	6,44
R	0,05	1,09	0,87	0,93	0,72	0,87	0,94	0,87	Ótimo	5,60
BC	0,53	0,95	0,89	0,94	0,45	0,60	0,96	0,91	Ótimo	5,56
HS	2,67	0,50	0,55	0,74	0,84	1,07	0,82	0,61	Med	5,22
PT	1,67	0,55	0,47	0,69	1,03	1,36	0,76	0,53	S	4,38
T	1,18	0,65	0,77	0,88	0,76	1,02	0,86	0,76	MB	4,49

a – linear coefficient of the linear regression equation, b – angular coefficient of the linear regression equation, R² – coefficient of determination, r – correlation coefficient, E – mean absolute error (MEA), RE – root mean square error (RMSE), d – concordance index, c – performance index , ICS – interpretation of the performance index as proposed by Camargo and Sentelhas (1997), METo – mean value of reference evapotranspiration (mm.day $^{-1}$) , Mod – Model, PM - Penman–Monteith, PMod - Modified Penman, R – Radiation, BC - Blaney-Criddle, HS - Hargreaves-Samani, PT - Priestley -Taylor, T – Turc, MB – Very good, Med – Average, S – Poor.

The Blaney-Criddle method performed best in both cities, according to the agreement (d) and performance (c) indices. In both municipalities, the method was classified as having "excellent" performance, according to the criterion proposed by Camargo and Sentelhas (1997). Furthermore, the coefficient of determination (R^2) corroborated these indices, demonstrating that the method presented satisfactory adjustments. The mean absolute error (MAE) of this method demonstrated better results than the other methods did, and following this indicator, the root mean square error (RMSE) also expressed the best results for both cities evaluated.

This condition, in which the empirical Blaney-Criddle model performed best, corroborates the results of studies conducted by Alencar et al. (2011) , also conducted in northern Minas Gerais, in which the authors evaluated different models to estimate ETo in periods of high and low evaporative demand, in addition to analyzing the entire year. In the three situations presented, the Blaney-Criddle model stood out as the most suitable for estimating ETo. Similarly, Costa et al. (2017) , evaluated ETo estimation methods in the state of Alagoas, where the authors also found better performance of the Blaney-Criddle method on the basis of the analyzed indicators, which were similar to those of the present study.

The Blaney-Criddle model's best performance in estimating ETo is explained by its development for a semiarid region (western US), similar to the cities evaluated. Furthermore, the method's formula considers solar radiation, air humidity, and wind speed, variables that significantly influence evapotranspiration. The Blaney–Criddle method's best performance is demonstrated in Figures 1 and 2, where smaller dispersions can be observed than those of the other methods.

Figure 1. Reference evapotranspiration (ETo, in mm.day-1) was estimated via the Penman–Monteith method (FAO56) and via empirical methods evaluated for the climatic conditions of Salinas, MG (2016--2020).

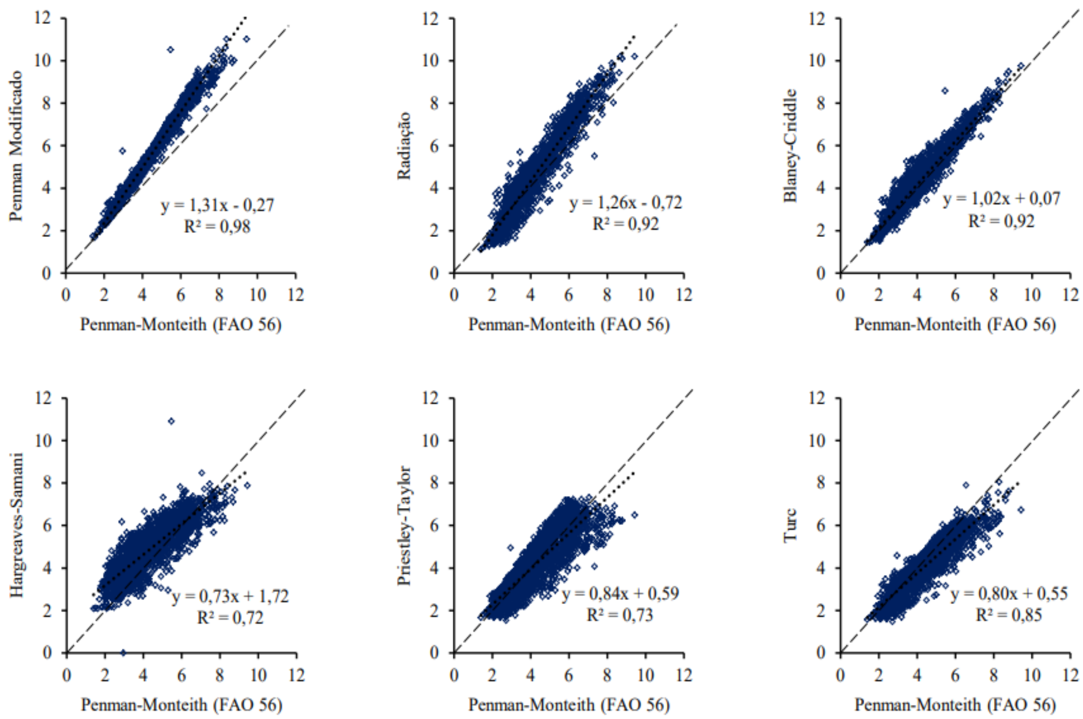
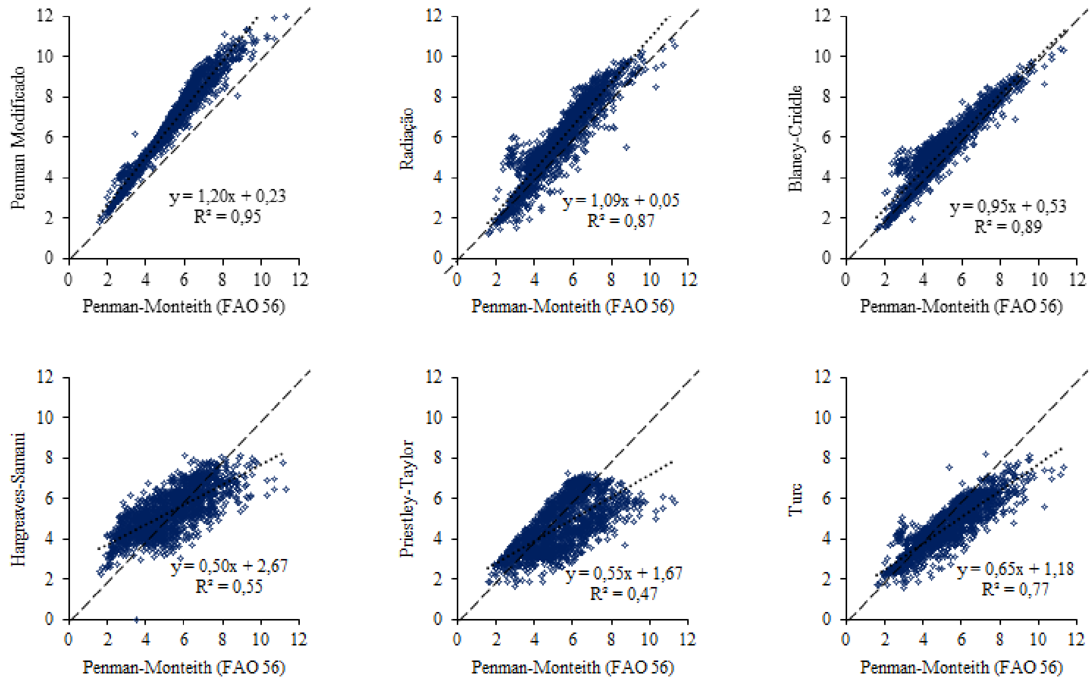


Figure 2. Reference evapotranspiration (ETo, in mm.day-1) estimated by the Penman–Monteith method (FAO56) and by the empirical methods evaluated for the climatic conditions of Januária, MG (2016--2020).



In the Blaney-Criddle method, the Hargreaves-Samani (overestimating by 0.68 mm/day) and Priestley-Taylor (underestimating by 0.76 mm/day) methods presented the worst statistical performance, both in Salinas and Januária. These two methods were classified with performance indices between "very good" and "poor" (Table 1) and should be associated with the high errors obtained and the low coefficients of determination (R2) and correlation (r), which highlights the poor performance of these methods in estimating ETo in the evaluated regions.

This same behavior was observed by Alencar et al. (2011), according to the aforementioned research, in which the authors also reported the worst performance indices for the Hargreaves–Samani method in cities in northern Minas Gerais. Cruz et al. (2017) evaluated different methods for estimating ETo in the city of Rio Verde, in Goiás, and identified the same behavior for the Priestley-Taylor method, as it presented "poor" performance under the conditions analyzed (Table 1).

As shown in Figures 1 and 2, the Hargreaves–Samani and Priestley–Taylor methods present the greatest dispersion in their data, in which they do not follow the trend line, with a greater distance from the 1:1 value line. The high dispersion of the verified points associated with the evaluated parameters highlights the poor fit of these models for the regions under study, which is reflected in their unsatisfactory performance in both locations (Salinas and Januária).

6 CONCLUSION

The Blaney-Monteith model performed best in estimating reference evapotranspiration for the cities studied and is recommended as an alternative to the Penman–Monteith method (FAO56) when meteorological data are limited.

Specifically, for Januária, Minas Gerais, the Hargreaves–Samani and Priestley–Taylor methods performed poorly and are not recommended for this region.

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