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REFERENCE EVAPOTRANSPIRATION THROUGH HARGREAVES METHOD USING THE SOLAR RADIATION ESTIMATION FOR GOIÁS STATE, BRAZIL

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ABSTRACT

This study evaluated the Hargreaves model (HG) with seasonal adjustments of the calibration coefficient (K_{rs}) of the radiation equation to estimate the reference evapotranspiration (ET_o) in 23 weather stations in Goiás State, Brazil, in comparison to the Penman-Monteith FAO (PM-FAO) standard method. The models were evaluated using Pearson's correlation coefficient, Willmott's agreement index, relative error, absolute mean error and root mean square error. The Krs values ranged from 0.146 to 0.189 ° $C^{-0.5}$, while ETo PM-FAO ranged from 3.68 to 4.79 mm d^{-1}; ETo HG from 3.99 to 5.16 mm d^{-1} and ETo HG-Krs from 4.15 to 5.02 mm d^{-1} in the annual period. Seasonal adjustments resulted in values of 0.144 to 0.205 ° $C^{-0.5}$ for the dry period, from April to September, and 0.144 to 0.146 ° $C^{-0.5}$ for the rainy period, from October to March. The first quarter (summer), presented Krs values from 0.150 to 0.175 ° $C^{-0.5}$; the second quarter (autumn), from 0.154 to 0.218 ° $C^{-0.5}$; the third quarter (winter), from 0.139 to 0.206 ° $C^{-0.5}$; and, finally, the fourth quarter (spring) of 0.141 to 0.166 ° $C^{-0.5}$. Thus, the use of the seasonally adjusted model proved to be viable for the estimation of ETo, in view of the simplicity and its good adherence to the standard method.

Palavras-chave:
Calibração
Demanda hídrica
Sazonalidade
Temperatura do ar
Uso consuntivo

EVAPOTRANSPIRAÇÃO DE REFERÊNCIA PELO MÉTODO DE HARGREAVES USANDO A ESTIMATIVA DE RADIAÇÃO SOLAR GLOBAL PARA O ESTADO DE GOIÁS

RESUMO

Este trabalho avaliou o modelo de Hargreaves (HG) com ajustes sazonais do coeficiente de calibração (K_{rs}) da equação de radiação para a estimativa da evapotranspiração de referência (ET_o) em 23 estações meteorológicas no estado de Goiás, em comparação ao método padrão de Penman-Monteith FAO (PM-FAO). A avaliação dos modelos foi feita por meio do coeficiente de correlação de Pearson, do índice de Concordância de Willmott, do erro relativo, do erro médio absoluto e da raiz do erro quadrado médio. Os valores de K_{rs} variaram de 0,146 a 0,189 °$C^{-0,5}$, enquanto a ET_o PM-FAO variou de 3,68 a 4,79 mm d^{-1}; a ET_o HG de 3,99 a 5,16 mm d^{-1} e a ET_o HG-K_{rs} de 4,15 a 5,02 mm d^{-1} no período anual. Os ajustes sazonais resultaram em valores de 0,144 a 0,205 °$C^{-0,5}$ para o período seco, de abril a setembro, e de 0,144 a 0,146 °$C^{-0,5}$ para o período chuvoso, de outubro a março. O 1º trimestre (verão), apresentou valores de K_{rs} de 0,150 a 0,175 °$C^{-0,5}$; o 2º trimestre (outono), de 0,154 a 0,218 °$C^{-0,5}$; o 3º trimestre (inverno), de 0,139 a 0,206 °$C^{-0,5}$; e, por fim, o 4º trimestre (primavera) de 0,141 a 0,166 °$C^{-0,5}$. Assim, o uso do modelo ajustado sazonalmente se mostrou viável para a estimativa da ET_o, tendo em vista a simplicidade e sua boa aderência ao método padrão.

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INTRODUCTION

Reference evapotranspiration (ETo) represents the water demand of a reference crop according to the weather elements of a given location. In addition, it is an extremely important parameter for the definition of the water needs of the crops. The empirical and physical models for the estimation of ETo based on the monitoring of weather elements has greatly evolved from the original works of Thornthwaite (1948) and Penman (1948) to the Penman-Monteith equation parameterized by FAO, with a hypothetical crop as a reference surface very similar to grass. Allen *et al*. (1998) recommend the Penman-Monteith FAO method as a method for ETo determination with weather parameters due to its consistent solid formulation, requiring data on global solar radiation, wind speed, temperature and relative air humidity.

The availability of weather information for the ETo estimate is still reduced, considering the number of stations in the Brazilian network, which currently has 573 automatic weather stations and 213 conventional surface stations (INMET, 2018), which implies in an automatic station density for almost 15,000 km². The state of Goiás has 26 automatic weather stations and nine conventional surface stations as part of the national network, which results to an automatic station density of almost 12,600 km². These stations are not evenly distributed across the Brazilian territory. Grego *et al*. (2017) evaluated that the sample density of weather stations in the northern region of Minas Gerais influenced the spatial variability of evapotranspiration from a distance of 80 km.

Considering the difficulty in obtaining meteorological data due to the lack of measurement or failures in the data series, it is necessary to use empirical models, such as the Hargreaves model, which estimates ETo from data of maximum and minimum air temperatures, only (HARGREAVES; SAMANI, 1985, HARGREAVES; ALLEN, 2003). Fernandes *et al*. (2012), Conceição (2013), Vicente *et al*. (2014) and Lima Junior *et al*. (2016) pointed out the viability of the Hargreaves model for different regions in Brazil due to its simplicity. Given the above, the objective of this work was to evaluate the performance of the Hargreaves model in determining ETo for the state of Goiás, making local and seasonal adjustments to estimate global solar radiation.

MATERIAL AND METHODS

The Penman-Monteith FAO (PM-FAO) and Hargreaves (HG) methods were used to estimate the ETo for the state of Goiás. The 23 automatic meteorological stations in the network of the National Institute of Meteorology (Figure 1) were used based on in their complete daily data as shown in Table 1.

Daily reference evapotranspiration (ET_o, mm d^{-1}) was obtained using the standard PM-FAO method, according to Allen *et al*. (1998) (Equation 1).

$$ET_o = \frac{0.408 \times \Delta \times (R_n - G) + \gamma \times \frac{900}{T_m + 273} \times u_2 \times (e_s - e_a)}{\gamma + \Delta \times (1 + 0.34 \times u_2)} \quad (1)$$

Where, Δ - slope of the vapor pressure curve, kPa °C^{-1}; R_n -; R_n - radiation balance, MJ m^{-2} d^{-1}; G- heat flow in the soil, MJ m^{-2} d^{-1}; γ - psychrometric constant, 0.063 kPa°C^{-1}; T_m - average air temperature, °C; u_2 - wind speed at a 2-m height from the surface, m s^{-1}; e_s - saturation vapor pressure, kPa; e_a - current vapor pressure, kPa.

The equation proposed by Hargreaves and Samani (1985) (Equation 2) was tested for the climatic conditions in the State of Goiás.

$$ET_o = 0.0135 \times R_s \times (T_m + 17.8) \quad (2)$$

Where R_s - global solar radiation, mm d^{-1}. The radiation values can also be given in MJ m^{-2} d^{-1}, as it is more common.

The R_s is estimated from extraterrestrial solar radiation (R_a) and thermal amplitude (HARGREAVES; SAMANI, 1982), according to Equation (3), as it follows.

$$R_s = K_{rs} \times \sqrt{T_x - T_n} \times R_a \quad (3)$$

Where, K_{rs} - calibration coefficient, °C$^{-0.5}$; T_x - maximum air temperature, °C; T_n - minimum air temperature, °C. The difference between T_x and T_n indirectly accounts for the cloudiness effects (HARGREAVES; ALLEN, 2003).

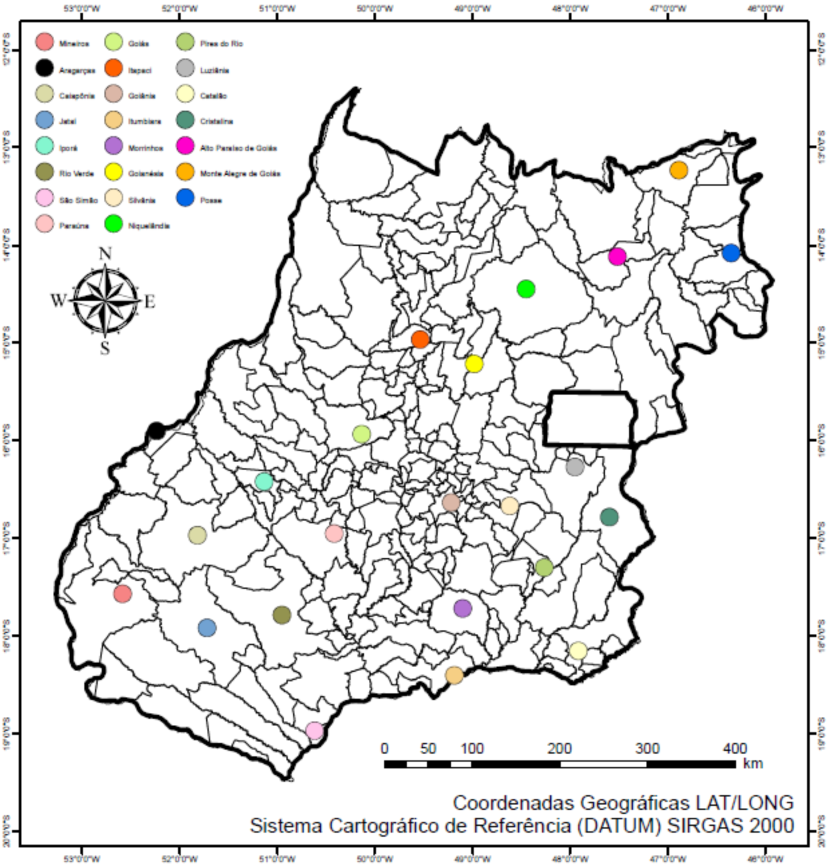

Figure 1. Automatic weather station in the State of Goiás

Table 1. Characteristics of the automatic weather stations in the study

Station	INMET Code	Latitude	Longitude	Altitude (m)	Start	End	Samples
Alto Paraíso de Goiás	A024	-14.117	-47.517	1.260	06/04/07	09/30/15	2.889
Aragarças	A013	-15.900	-52.233	347	07/13/07	09/29/15	2.500
Caiapônia	A023	-16.967	-51.817	737	05/2207	09/30/15	2.481
Catalão	A034	-18.150	-47.917	890	02/0108	09/30/15	2.550
Cristalina	A036	-16.783	-47.600	1.202	12/17/07	09/30/15	2.819
Goianésia	A022	-15.217	-48.983	667	06/03/07	09/30/15	2.685
Goiânia	A002	-16.633	-49.217	770	05/31/01	09/30/15	4.667
Goiás	A014	-15.933	-50.133	512	07/19/07	09/30/15	2.896
Iporá	A028	-16.417	-51.133	625	06/28/13	09/30/15	524
Itapaci	A015	-14.967	-49.533	522	02/04/07	09/30/15	2.692
Itumbiara	A035	-18.400	-49.183	488	11/02/07	09/29/15	2.697
Jataí	A016	-17.917	-51.717	582	06/01/07	09/30/15	2.647
Luziânia	A012	-16.267	-47.950	958	10/22/06	09/29/15	3.131
Mineiros	A026	-17.567	-52.583	706	11/25/07	09/30/15	2.176
Monte Alegre de Goiás	A032	-13.233	-46.883	1.253	06/12/07	09/30/15	2.834
Morrinhos	A003	-17.717	-49.100	771	05/31/01	09/30/15	3.473
Niquelândia	A004	-14.450	-48.450	583	02/06/01	09/30/15	2.971
Paraúna	A027	-16.950	-50.417	678	29/03/08	08/26/15	2.329
Pires do Rio	A033	-17.300	-48.267	752	13/10/07	09/30/15	2.829
Posse	A017	-14.083	-46.350	834	21/04/07	09/30/15	2.751
Rio Verde	A025	-17.783	-50.950	782	18/05/07	09/30/15	2.367
São Simão	A011	-18.967	-50.617	489	30/07/06	09/30/15	2.764
Silvânia	A037	-16.667	-48.617	949	12/10/10	09/30/15	1.736

Source: INMET, 2018

The K_{rs} adjustment coefficient of Equation (3) was estimated at each location for different periods of time, using non-linear regressions with the Microsoft Excel® Solver® tool. This adjustment has been used for different regions in Brazil (CONCEIÇÃO, 2013; LIMA JUNIOR *et al.*, 2016; BARROS *et al.*, 2017; PAZ; THEBALDI, 2018). The tool was used in this study in order to minimize the error between the estimated values of R_s and that measured at the weather station.

In order to guarantee the data integrity and to allow the comparison between the models, the evaluations were made only for situations where it was possible to obtain complete daily data from the weather station. The results obtained were compared with the ET_o from the application of the standard PM-FAO method. The comparisons had their performance evaluated using simple linear regression, by means of Pearson's correlation coefficient (r), according to Equation (5).

$$r = \frac{\sum_{i=1}^{n}(x_i - \bar{x}) \times (y_i - \bar{y})}{\sqrt{\sum_{i=1}^{n}(x_i - \bar{x})^2 \times \sum_{i=1}^{n}(y_i - \bar{y})^2}} \quad (5)$$

Where, *r* - Pearson's correlation coefficient; *x* – estimate determined by the standard method, mm d^{-1}; *y* - estimate by the evaluated model, mm d^{-1}.

The Willmott's agreement index (*d*) (Willmott, 1984) is given by Equation (6).

$$d = 1 - \frac{\sum_{i=1}^{n}(x_i - y_i)^2}{\sum_{i=1}^{n}\left(|y_i - \bar{x}| + |x_i - \bar{x}|\right)^2} \quad (6)$$

The performance index (*c*), as stipulated by Camargo and Sentelhas (1997) is obtained by the product between Pearson's correlation coefficient (r) and Willmott's Agreement index (d). The estimation of the error between the models was given by three measures, namely: the relative error (*RE*); the mean absolute error (*MAE*); and the root of the mean square error (RMSE); given by Equation (9), (10) and (11), respectively.

$$RE = \frac{\bar{y} - \bar{x}}{\bar{x}} \quad (7)$$

$$MAE = \frac{\sum_{i=1}^{n}|y_i - x_i|}{n} \quad (8)$$

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n}(y_i - x_i)^2}{n}} \quad (9)$$

RESULTS AND DISCUSSION

Table 2 shows the variation of the average monthly air temperature for the locations under study. The Goiás station had the highest average temperature, 29.3°C, which occurred in September, while the Cristalina station had the lowest average temperature in July, 19.3°C. The temporal variation of temperature occurred in a similar way for all locations, with higher values from September to April and lower between May and August. Similarly, the global average monthly solar radiation is shown in Table 3. It is observed that the Niquelândia station, in June, had the highest monthly average value, 24.84 MJ m^{-2} d^{-1}, and São Simão, in July, presented the lowest value, 13.77 MJ m^{-2} d^{-1}.

The K_{rs} values of the Hargreaves radiation equation are shown in Table 4.

Table 2. Variation of the average monthly air temperature in °C

Station	Average monthly average temperature (°C)											
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC
Alto Paraíso de Goiás	21.5	21.8	21.9	21.5	20.2	19,4	19.4	20.3	23.0	23.0	21.6	21.5
Aragarças	26.8	27.1	27.3	27.2	25.7	25,0	24.5	26.0	29.0	29.1	27.5	27.0
Caiapônia	24.5	24.7	24.8	24.1	22.7	22,1	21.9	23.7	26.1	25.9	24.9	24.6
Catalão	24.6	24.8	24.3	23.5	21.7	21,1	21.3	22.7	25.0	25.0	24.3	24.5
Cristalina	22.3	22.6	22.4	21.8	20.2	19,4	19.3	20.5	22.9	22.9	22.1	22.1
Goianésia	24.9	25.2	25.3	25.2	24.2	23,4	23.6	24.9	27.1	26.6	25.0	24.8
Goiânia	25.3	25.2	25.2	24.7	22.7	21,7	21.7	23.2	25.9	26.2	25.4	25.4
Goiás	26.1	26.4	26.5	26.5	25.7	25,1	25.4	27.1	29.3	28.4	26.5	25.9
Iporá	25.9	25.2	25.1	25.5	23.7	23,4	22.9	24.2	27.3	26.3	25.1	25.0
Itapaci	25.6	25.7	25.9	25.5	23.9	22,5	22.3	23.1	26.2	26.8	25.9	25.6
Itumbiara	26.1	26.2	25.8	24.8	22.5	21,9	21.8	23.5	26.3	26.7	26.2	26.2
Jataí	25.0	25.1	25.1	23.9	21.4	21,2	20.9	22.2	25.1	25.7	25.2	25.1
Luziânia	25.3	25.2	25.2	24.7	22.7	21,7	21.7	23.2	25.9	26.2	25.4	25.4
Mineiros	24.8	24.5	24.9	24.2	21.4	20,6	20.6	21.8	24.9	25.5	24.8	25.0

Monte Alegre de Goiás	25.8	26.0	26.0	25.9	25.0	24,5	24.5	25.9	28.3	28.3	26.3	25.7
Morrinhos	24.6	24.5	24.4	23.5	21.0	20,2	20.1	21.7	24.2	25.3	24.7	24.6
Niquelândia	24.9	25.0	25.0	25.2	24.4	23,6	23.7	25.3	27.2	26.5	25.2	24.7
Paraúna	25.5	25.5	25.4	24.9	23.2	22,8	23.2	24.6	26.8	26.4	25.6	25.2
Pires do Rio	24.8	24.9	24.8	24.0	21.8	20,9	20.8	22.3	25.3	25.6	25.1	24.9
Posse	24.9	25.1	24.9	24.9	24.2	23,8	23.7	24.6	26.8	26.7	24.8	24.6
Rio Verde	24.3	24.5	24.6	23.7	21.7	20,7	21.4	23.0	25.4	25.6	24.7	24.6
São Simão	26.3	26.2	26.0	25.3	22.8	21,9	21.5	23.9	26.3	26.8	26.1	26.2
Silvânia	23.4	23.6	23.7	23.2	21.0	20,6	20.4	21.8	24.6	24.3	23.6	23.7

Source: INMET, 2018.

Table 3. Monthly variation of the average global solar radiation in MJ m^{-2} d^{-1}

Station	Global solar radiation (MJ m^{-2} d^{-1})											
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Alto Paraíso de Goiás	18.17	18.76	17.28	17.24	16.96	17.56	19.08	21.36	21.62	18.95	15.96	17.25
Aragarças	19.52	20.49	19.20	19.00	17.92	17.33	18.05	20.52	20.35	20.37	19.72	19.46
Caiapônia	19.71	19.96	18.67	18.52	17.92	16.71	17.77	20.39	20.42	19.98	19.59	19.25
Catalão	20.04	21.27	18.45	17.75	16.13	15.51	16.41	18.93	20.30	20.46	19.68	19.21
Cristalina	20.35	21.09	18.75	18.30	17.28	16.49	17.65	20.41	21.22	20.76	18.87	18.93
Goianésia	19.87	20.56	19.58	18.73	17.41	16.60	17.42	19.15	19.77	19.29	18.13	18.29
Goiânia	19.13	19.01	18.36	18.05	16.77	16.16	16.60	19.04	19.67	19.27	18.67	18.62
Goiás	19.53	19.96	19.55	19.43	18.56	17.78	18.91	21.05	21.29	20.71	19.68	18.71
Iporá	22.76	20.42	18.90	17.51	16.99	17.23	18.78	20.86	20.66	20.43	19.45	18.97
Itapaci	19.43	19.74	18.89	17.36	15.88	15.72	16.35	18.35	19.45	18.23	17.93	17.84
Itumbiara	21.15	21.68	18.81	18.49	17.14	16.03	16.87	19.86	20.22	21.13	21.39	20.27
Jataí	21.10	19.60	19.09	18.43	16.98	15.71	17.22	19.79	20.01	20.10	21.17	21.14
Luziânia	19.13	19.01	18.36	18.05	16.77	16.16	16.60	19.04	19.67	19.27	18.67	18.62
Mineiros	21.11	19.36	19.33	18.64	17.26	13.66	17.52	19.64	19.65	20.19	21.24	21.13
Monte Alegre de Goiás	21.60	21.53	19.91	19.59	18.50	18.20	19.15	21.24	22.43	21.18	19.20	20.27
Morrinhos	20.75	20.56	19.47	18.92	17.27	16.56	17.18	19.66	20.28	20.53	20.03	19.87
Niquelândia	21.01	20.71	20.33	21.36	23.59	24.84	23.38	21.71	21.99	20.53	20.92	20.74
Paraúna	20.70	20.70	19.29	18.21	16.12	15.16	16.58	18.69	20.13	19.76	19.85	18.96
Pires do Rio	20.69	21.83	19.44	19.11	17.60	16.47	17.28	20.10	20.69	20.27	20.17	19.84
Posse	20.98	21.16	19.67	19.10	18.48	18.57	20.03	22.52	23.41	21.23	18.23	20.27
Rio Verde	20.29	19.34	18.08	18.09	17.05	14.84	17.19	19.80	19.86	19.77	19.70	20.19
São Simão	20.53	20.75	19.21	17.77	15.68	13.97	13.77	18.28	18.62	20.39	21.10	20.36
Silvânia	19.91	20.07	17.88	17.96	15.76	14.40	15.61	19.64	20.26	19.80	18.10	18.34

Source: INMET, 2018

Table 4. K_{rs} estimate for each station in different periods

Station	K_{rs} (°C$^{-0.5}$)						
	Annual	Rainy	Dry	1st quarter	2nd quarter	3rd quarter	4th quarter
Alto Paraíso de Goiás	0.171	0.146	0.1845	0.150	0.182	0.186	0.141
Aragarças	0.152	0.161	0.1566	0.164	0.175	0.155	0.157
Caiapônia	0.169	0.163	0.1740	0.166	0.181	0.169	0.159
Catalão	0.175	0.161	0.1840	0.165	0.187	0.183	0.155
Cristalina	0.185	0.169	0.1967	0.175	0.198	0.195	0.162
Goianésia	0.164	0.157	0.1701	0.165	0.178	0.163	0.149
Goiânia	0.152	0.149	0.1546	0.151	0.161	0.150	0.147
Goiás	0.168	0.155	0.1780	0.157	0.184	0.173	0.153
Iporá	0.167	0.166	0.1673	0.169	0.177	0.165	0.161
Itapaci	0.146	0.148	0.1442	0.155	0.154	0.139	0.141
Itumbiara	0.164	0.162	0.1662	0.165	0.175	0.160	0.159
Jataí	0.155	0.152	0.1553	0.156	0.168	0.149	0.152
Luziânia	0.178	0.163	0.1906	0.168	0.193	0.189	0.157
Mineiros	0.154	0.156	0.1521	0.157	0.166	0.148	0.155
Monte Alegre de Goiás	0.174	0.166	0.1784	0.171	0.181	0.176	0.163
Morrinhos	0.152	0.159	0.1622	0.170	0.169	0.157	0.154
Niquelândia	0.181	0.164	0.2020	0.165	0.218	0.188	0.164
Paraúna	0.165	0.163	0.1651	0.169	0.171	0.164	0.157
Pires do Rio	0.164	0.161	0.1653	0.165	0.174	0.160	0.156
Posse	0.189	0.169	0.2054	0.173	0.204	0.206	0.166
Rio Verde	0.160	0.154	0.1686	0.156	0.177	0.165	0.152
São Simão	0.152	0.160	0.1605	0.163	0.170	0.152	0.158
Silvânia	0.158	0.150	0.1616	0.158	0.164	0.160	0.145

Source: INMET, 2018

Figure 2 shows the spatialization of K_{rs} values in each period.

Although the amplitude of this coefficient is not high, it was possible to demarcate four very different regions for the annual period (Figure 2a) and for the dry period (Figure 2b), with a very similar pattern with continuous and well-defined regions. For the rainy season (Figure 2c), a defined pattern was not found, showing a more erratic variation of the K_{rs} coefficient, which may occur due to a greater daily variation of cloudiness in the rainy season, as pointed out by Baratto *et al*. (2017) when analyzing the variability of this coefficient at different temporal scales for different stations in the country.

As expected, the second and third quarters (Figures 2e and 2f) showed a K_{rs} coefficient pattern with continuous and delimited regions similar to the dry semester, as it covers the same time period. For the first and fourth quarters (Figures 2d and 2g), the variation in the coefficient also followed a distribution close to that of the rainy season.

For the annual period, the highest K_{rs} value was found in Posse, 0.189 $°C^{-0.5}$, and the lowest value, 0.146 $°C^{-0.5}$, was found in Itapaci. Allen (1997) proposed K_{rs} equal to 0.17$°C^{-0.5}$for inland regions and 0.20$°C^{-0.5}$ for coastal regions, including an adjustment according to the altitude. Allen *et al*.

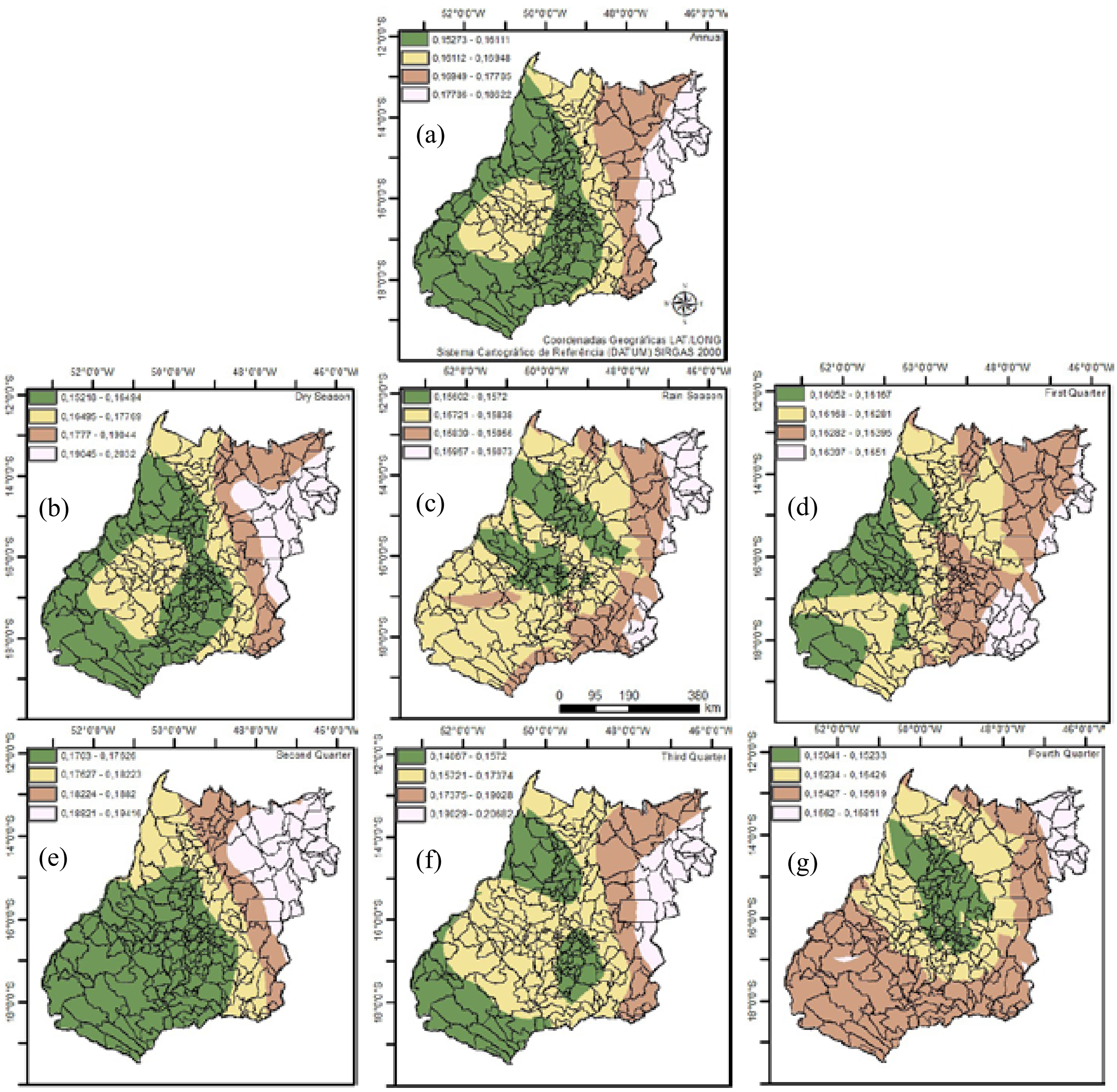

Figure 2. K_{rs} coefficient for the state of Goiás for the annual period (a), dry semester (b), rainy semester (c), 1st quarter (d), 2nd quarter (e), 3rd quarter (f) and 4th quarter (g)

(1998) proposes values of 0.19°C$^{-0.5}$ for coastal regions and 0.16 °C$^{-0.5}$for inland regions. But Todorovic *et al.* (2013) argues on the value of K_{rs} to be adopted, considering that its variation may be lower in temperate climates, and large where the climate is tropical and subtropical, as in Brazil.

Table 5 shows the analysis of the adjustments based on ET_o, using the Penman-Monteith FAO method (PM-FAO) as a reference for comparison with the Hargreaves method (HG) and the application of K_{rs} coefficients (HG- K*rs*).

Table 5. Evaluation of the models for ET_o estimate for the annual period.

Station	Model	Mean	σ	RE	MAE	RMSE	r	D	c
Alto Paraíso de Goiás	PM-FAO	3.87	1.14	-	-	-	-	-	-
	HG	4.15	0.81	0.0728	0.743	0.930	0.6321	0.7563	0.4780
	HG - K_{rs}	4.15	0.81	0.0744	0.745	0.932	0.6321	0.7560	0.4778
Aragarças	PM-FAO	4.23	1.05	-	-	-	-	-	-
	HG	5.16	0.94	0.2181	0.944	1.079	0.8467	0.7613	0.6446
	HG - K_{rs}	4.61	0.84	0.0895	0.542	0.675	0.8467	0.8713	0.7378
Caiapônia	PM-FAO	4.15	1.03	-	-	-	-	-	-
	HG	4.69	0.88	0.1321	0.640	0.799	0.8272	0.8343	0.6902
	HG - K_{rs}	4.65	0.87	0.1212	0.611	0.768	0.8272	0.8428	0.6972
Catalão	PM-FAO	4.14	1.22	-	-	-	-	-	-
	HG	4.30	1.00	0.0392	0.680	0.851	0.7327	0.8406	0.6159
	HG - K_{rs}	4.42	1.03	0.0677	0.708	0.886	0.7327	0.8348	0.6117
Cristalina	PM-FAO	4.04	1.18	-	-	-	-	-	-
	HG	3.99	0.85	-0.0127	0.606	0.747	0.7785	0.8532	0.6642
	HG - K_{rs}	4.33	0.92	0.0712	0.628	0.796	0.7785	0.8506	0.6621
Goianésia	PM-FAO	3.93	1.01	-	-	-	-	-	-
	HG	4.70	0.91	0.1965	0.816	0.945	0,8430	0.7917	0.6674
	HG - K_{rs}	4.51	0.87	0.1489	0.664	0.798	0.8430	0.8325	0.7018
Goiânia	PM-FAO	3.92	1.00	-	-	-	-	-	-
	HG	4.82	0.92	0.2286	0.966	1.104	0.7765	0.7302	0.5670
	HG - K_{rs}	4.31	0.82	0.0989	0.600	0.740	0.7765	0.8314	0.6456
Goiás	PM-FAO	4.30	1,.15	-	-	-	-	-	-
	HG	5.03	0.97	0.1688	0.930	1.105	0.7022	0.7435	0.5221
	HG - K_{rs}	4.97	0.95	0.1550	0.888	1.065	0.7022	0.7533	0.5290
Iporá	PM-FAO	4.39	1.12	-	-	-	-	-	-
	HG	4.91	0.91	0.1176	0.668	0.803	0.8354	0.8471	0.7076
	HG - K_{rs}	4.80	0.89	0.0925	0.601	0.738	0.8354	0.8641	0.7219
Itapaci	PM-FAO	3.86	1.00	-	-	-	-	-	-
	HG	5.07	0.89	0.3143	1.217	1.334	0.8347	0.6811	0.5685
	HG - K_{rs}	4.34	0.77	0.1249	0.599	0.736	0.8347	0.8357	0.6975
Itumbiara	PM-FAO	4.31	1.32	-	-	-	-	-	-
	HG	4.80	1.07	0.1149	0.771	0.940	0.7949	0.8431	0.6702
	HG - K_{rs}	4.63	1.04	0.0746	0.681	0.861	0.7949	0.8592	0.6830
Jataí	PM-FAO	4.11	1.15	-	-	-	-	-	-
	HG	5.00	1.01	0.2155	0.960	1.105	0.8200	0.7754	0.6358
	HG - K_{rs}	4.55	0.92	0.1050	0.627	0.786	0.8200	0.8544	0.7006
Luziânia	PM-FAO	4.41	1.24	-	-	-	-	-	-
	HG	4.37	0.88	-0.0088	0.710	0.868	0.7127	0.8154	0.5812
	HG - K_{rs}	4.56	0.92	0.0348	0.712	0.882	0.7127	0.8186	0.5834
Mineiros	PM-FAO	3.96	1.00	-	-	-	-	-	-
	HG	5.08	0.96	0.2804	1.128	1.276	0.7946	0.6929	0.5505
	HG - K_{rs}	4.57	0.86	0.1536	0.707	0.861	0.7946	0.8020	0.6372

Monte Alegre de Goiás	PM-FAO	4.63	1.22	-	-	-	-	-	-
	HG	4.92	0.89	0.0613	0.692	0.861	0.7465	0.8231	0.6144
	HG - K_{rs}	5.02	0.91	0.0827	0.735	0.898	0.7465	0.8147	0.6082
Morrinhos	PM-FAO	4.06	1.09	-	-	-	-	-	-
	HG	4.71	0.98	0.1598	0.756	0.887	0.8342	0.8283	0.6909
	HG - K_{rs}	4.22	0.88	0.0374	0.480	0.620	0.8342	0.8953	0.7469
Niquelândia	PM-FAO	4.71	1.04	-	-	-	-	-	-
	HG	4.71	0.88	-0.0010	0.866	1.104	0.3478	0.6209	0.2160
	HG - k_{rs}	5.01	0.94	0.0624	0.931	1.169	0.3478	0.6064	0.2109
Paraúna	PM-FAO	3.93	1.03	-	-	-	-	-	-
	HG	4.64	0.92	0.1803	0.751	0.892	0.8523	0.8159	0.6954
	HG - K_{rs}	4.48	0.89	0.1397	0.627	0.770	0.8523	0.8491	0.7237
Pires do Rio	PM-FAO	3.92	1.07	-	-	-	-	-	-
	HG	4,76	0.98	0.2136	0.870	1.001	0.8606	0.7979	0.6866
	HG - K_{rs}	4.57	0.94	0.1652	0.711	0.847	0.8606	0.8376	0.7208
Posse	PM-FAO	4.79	1.34	-	-	-	-	-	-
	HG	4.49	0.87	-0.0627	0.866	1.045	0.6624	0.7539	0.4994
	HG - K_{rs}	4.99	0.96	0.0399	0.844	1.022	0.6624	0.7819	0.5179
Rio Verde	PM-FAO	4.20	1.17	-	-	-	-	-	-
	HG	4.81	0.95	0,1472	0,786	0,955	0,7825	0,8068	0,6314
	HG - K_{rs}	4.53	0.89	0.0798	0.637	0.801	0.7825	0.8440	0.6605
São Simão	PM-FAO	4.53	1.39	-	-	-	-	-	-
	HG	4.96	1.03	0.0939	0.793	0.966	0.7843	0.8365	0.6561
	HG - K_{rs}	4.44	0.92	-0.0216	0.674	0.887	0.7843	0.8423	0.6606
Silvânia	PM-FAO	3,68	1,02	-	-	-	-	-	-
	HG	4.54	0.96	0.2359	0.879	1.003	0.8711	0.7885	0.6869
	HG - K_{rs}	4.21	0.88	0.1441	0.593	0.728	0.8711	0.8623	0.7511

Source: The authors

It is underlined that only five stations did not present a better adjustment to the HG - K_{rs} model to estimate ET_o in relation to the standard model PM-FAO, namely: Alto Paraíso de Goiás, Cristalina, Goiânia, Monte Alegre de Goiás and Niquelândia. However, these stations are not grouped in any specific region neither are close to each other. All the other 18 stations showed a better adjustment for the model with the K_{rs} coefficient, evaluated mainly by means of the lowest error value (*RE*, *MAE* and *RMSE*) and by the highest values of the Willmott agreement (*d*) and performance indexes (c).

Afterwards, the seasonality analysis of this coefficient was carried out, estimating its values for semiannual periods. This division is justified as an approach of the dry (April to September) and rainy (October to March) periods. Considering the dry period, the highest K_{rs} value was found in Posse, 0.205°C$^{-0.5}$, and the lowest value, 0.144°C$^{-0.5}$, in Itapaci. In relation to the rainy season, the values of this coefficient varied from 0.146°C$^{-0.5}$ in Alto Paraíso de Goiás up to a maximum of 0.169°C$^{-0.5}$ in Posse.

Tables 6 and 7 show the analysis of the HG and HG - K_{rs} models compared to the PM-FAO method, in order to assess the quality of these adjustments.

Four stations did not show improvement in the model with the seasonal adjustment for K_{rs} for the dry period, namely: Caiapônia, Goiás, Monte Alegre de Goiás and São Simão, as it can be seen from the values of the *d* and *c* indexes. Nevertheless, all stations showed better results for the *d* and *c* indices for the rainy season, in addition to a less error (*RE*, *MAE* and *RMSE*) for the HG - K_{rs} model, when compared to the standard PM-FAO method.

Table 6. Evaluation of the models for ET_o estimate for the dry season.

Station	Model	Mean	σ	RE	MAE	RMSE	r	d	c
Alto Paraíso de Goiás	PM-FAO	3.93	1.02	-	-	-	-	-	-
	HG	3.82	0.69	-0.028	0.580	0.760	0.677	0.782	0.529
	HG - K_{rs}	4.13	0.75	0.052	0.614	0.782	0.677	0.787	0.533
Aragarças	PM-FAO	4.02	0.84	-	-	-	-	-	-
	HG	4.92	0.93	0.224	0.914	1.032	0.841	0.733	0.617
	HG - K_{rs}	4.52	0.86	0.125	0.573	0.692	0.841	0.840	0.707
Caiapônia	PM-FAO	4.02	0.87	-	-	-	-	-	-
	HG	4.39	0.82	0.09	0.485	0.611	0,831	0,867	0,721
	HG - K_{rs}	4.48	0.83	0.113	0.547	0.672	0.831	0.848	0.704
Catalão	PM-FAO	3.88	1.08	-	-	-	-	-	-
	HG	3.71	0.77	-0.045	0.533	0.677	0.8	0.858	0.686
	HG - K_{rs}	4.01	0.83	0.032	0.535	0.659	0.8	0.872	0.697
Cristalina	PM-FAO	3.84	1.03	-	-	-	-	-	-
	HG	3.52	0.69	-0.085	0.518	0.661	0.846	0.851	0.719
	HG - K_{rs}	4.06	0.8	0.057	0.463	0.594	0.846	0.89	0.752
Goianésia	PM-FAO	3.71	0.83	-	-	-	-	-	-
	HG	4.33	0.77	0.169	0.697	0.818	0.787	0.771	0.606
	HG - K_{rs}	4.32	0.77	0.167	0.691	0.812	0.787	0.773	0.608
Goiânia	PM-FAO	3.74	0.89	-	-	-	-	-	-
	HG	4.44	0.79	0.188	0.821	0.949	0.721	0.728	0.525
	HG - K_{rs}	4.03	0.72	0.078	0.56	0.688	0.721	0.806	0.581
Goiás	PM-FAO	4.27	1.06	-	-	-	-	-	-
	HG	4.66	0.82	0.091	0.745	0.899	0.656	0.755	0.495
	HG - K_{rs}	4.87	0.86	0.14	0.865	1.013	0.656	0.726	0.476
Iporá	PM-FAO	4.35	1.02	-	-	-	-	-	-
	HG	4.67	0.93	0.075	0.594	0.71	0.792	0.859	0.68
	HG - K_{rs}	4.59	0.91	0.055	0.551	0.673	0.792	0.869	0.688
Itapaci	PM-FAO	3.59	0.8	-	-	-	-	-	-
	HG	4.8	0.79	0.337	1.214	1.312	0.793	0.621	0.493
	HG - K_{rs}	4.06	0.66	0.131	0.553	0.677	0.793	0.804	0.638
Itumbiara	PM-FAO	3.98	1.26	-	-	-	-	-	-
	HG	4.23	0.9	0.062	0.665	0.827	0.781	0.843	0.658
	HG - K_{rs}	4.13	0.88	0.036	0.628	0.805	0.781	0,846	0.661
Jataí	PM-FAO	3.8	1.11	-	-	-	-	-	-
	HG	4.56	0.98	0.2	0.878	1.007	0.805	0.79	0.636
	HG - K_{rs}	4.16	0.89	0.093	0.589	0.746	0.805	0.856	0.689
Luziânia	PM-FAO	4.36	1.11	-	-	-	-	-	-
	HG	3.89	0.71	-0.109	0.657	0.824	0.812	0.802	0.652
	HG - K_{rs}	4.35	0.8	-0.003	0.507	0.656	0.812	0.873	0.709
Mineiros	PM-FAO	3.59	0.84	-	-	-	-	-	-
	HG	4.69	0.95	0.308	1.118	1.237	0.813	0.666	0.541
	HG - K_{rs}	4.19	0.85	0.167	0.664	0.792	0.813	0.798	0.649

Monte Alegre de Goiás	PM-FAO	4.58	1.12	-	-	-	-	-	-
	HG	4.61	0.77	0.006	0.652	0.819	0.684	0.79	0.54
	HG - K_{rs}	4.82	0.8	0.053	0.708	0.855	0.684	0.784	0.536
Morrinhos	PM-FAO	3.75	0.96	-	-	-	-	-	-
	HG	4.28	0.83	0.139	0.685	0.794	0.786	0.809	0.635
	HG - K_{rs}	4.07	0.79	0.084	0.559	0.674	0.786	0.845	0.664
Niquelândia	PM-FAO	5.01	1.05	-	-	-	-	-	-
	HG	4.33	0.72	-0.135	0.952	1.235	0.368	0.586	0.216
	HG - K_{rs}	5.14	0.86	0.025	0.882	1.09	0.368	0.615	0.227
Paraúna	PM-FAO	3.63	0.87	-	-	-	-	-	-
	HG	4.24	0.8	0.171	0.663	0.763	0.861	0.816	0.702
	HG - K_{rs}	4.11	0.78	0.134	0.559	0.659	0.861	0.849	0.731
Pires do Rio	PM-FAO	3.53	0.83	-	-	-	-	-	-
	HG	4.28	0.84	0.214	0.796	0.914	0.812	0,.755	0.613
	HG - K_{rs}	4.16	0.81	0.179	0.691	0.808	0.812	0.788	0.640
Posse	PM-FAO	4.88	1.16	-	-	-	-	-	-
	HG	4.09	0.70	-0.163	0.921	1.099	0.776	0.709	0.55
	HG - K_{rs}	4.92	0.85	0.009	0.583	0.733	0.776	0.855	0.663
Rio Verde	PM-FAO	4.03	1.14	-	-	-	-	-	-
	HG	4.36	0.86	0.081	0.626	0.778	0.787	0.844	0.664
	HG - K_{rs}	4.31	0.85	0.07	0.608	0.761	0.787	0.848	0.667
São Simão	PM-FAO	4.29	1.52	-	-	-	-	-	-
	HG	4.36	0.96	0.015	0.752	0.933	0.81	0.847	0.686
	HG - K_{rs}	4.1	0.9	-0.044	0.739	0.967	0.81	0.83	0.672
Silvânia	PM-FAO	3.37	0.83	-	-	-	-	-	-
	HG	4.06	0.84	0.205	0.706	0.789	0.897	0.812	0.729
	HG - K_{rs}	3.85	0.8	0.144	0.526	0.61	0.897	0.869	0.779

Source: The authors

Table 7. Evaluation of the models for ET_o estimate for the rainy season

Station	Model	Mean	σ	RE	MAE	RMSE	r	d	c
Alto Paraíso de Goiás	PM-FAO	3.79	1.26	-	-	-	-	-	-
	HG	4.54	0.76	0.198	0.938	1.100	0.792	0.752	0.596
	HG - K_{rs}	3.89	0.65	0.026	0.693	0.848	0.792	0.790	0.626
Aragarças	PM-FAO	4.42	1.15	-	-	-	-	-	-
	HG	5.39	0.87	0.218	0.994	1.144	0.852	0.749	0.639
	HG - K_{rs}	5.08	0.82	0.148	0.748	0.905	0.852	0.809	0.690
Caiapônia	PM-FAO	4.25	1.14	-	-	-	-	-	-
	HG	4.95	0.84	0.166	0.770	0.927	0.858	0.808	0.693
	HG - K_{rs}	4.73	0.80	0.113	0.632	0.778	0.858	0.846	0.726
Catalão	PM-FAO	4.46	1.30	-	-	-	-	-	-
	HG	5.03	0.74	0.128	0.860	1.025	0.789	0.763	0.602
	HG - K_{rs}	4.74	0.70	0.064	0.758	0.911	0.789	0.784	0.619
Cristalina	PM-FAO	4.25	1.30	-	-	-	-	-	-
	HG	4.49	0.70	0.057	0.698	0.829	0,849	0.824	0.699
	HG - K_{rs}	4.44	0.70	0.045	0.689	0.820	0.849	0.825	0.700

Goianésia	PM-FAO	4.15	1.11	-	-	-	-	-	-
	HG	5.07	0.89	0.221	0.936	1.057	0.886	0.778	0.689
	HG - K_{rs}	4.67	0.82	0.125	0.617	0.750	0.886	0.858	0.760
Goiânia	PM-FAO	4.12	1.06	-	-	-	-	-	-
	HG	5.22	0.87	0.267	1.121	1.248	0.834	0.705	0.588
	HG - K_{rs}	4,58	0.76	0.110	0.613	0.753	0.834	0.835	0.696
Goiás	PM-FAO	4.34	1.23	-	-	-	-	-	-
	HG	5.43	0.95	0.252	1.131	1.292	0.833	0.732	0.610
	HG - K_{rs}	4.93	0.86	0.136	0.750	0.919	0.833	0.819	0.682
Iporá	PM-FAO	4.43	1.19	-	-	-	-	-	-
	HG	5.09	0.86	0.150	0.725	0.868	0.901	0.838	0.755
	HG - K_{rs}	4.96	0.84	0.121	0.636	0.779	0.901	0.861	0.776
Itapaci	PM-FAO	4.07	1.09	-	-	-	-	-	-
	HG	5.29	0.92	0.298	1.219	1.351	0.843	0.695	0.585
	HG - K_{rs}	4.59	0.80	0.126	0.640	0.791	0.843	0.834	0.703
Itumbiara	PM-FAO	4.65	1.29	-	-	-	-	-	-
	HG	5.41	0.90	0.164	0.884	1.047	0.843	0.796	0.671
	HG - K_{rs}	5.13	0.85	0.103	0.709	0.877	0.843	0.835	0.704
Jataí	PM-FAO	4.39	1.11	-	-	-	-	-	-
	HG	5.39	0.86	0.228	1.033	1.186	0.821	0.727	0.597
	HG - K_{rs}	4.82	0.77	0.098	0.626	0.780	0.821	0.831	0.682
Luziânia	PM-FAO	4.46	1.35	-	-	-	-	-	-
	HG	4.87	0.76	0.092	0.766	0.912	0.849	0.817	0.694
	HG - K_{rs}	4.65	0.73	0.044	0.709	0.853	0.849	0.826	0.701
Mineiros	PM-FAO	4.26	1.01	-	-	-	-	-	-
	HG	5.38	0.84	0.262	1.136	1.307	0.748	0.660	0.494
	HG - K_{rs}	4.92	0.77	0.154	0.760	0.938	0.748	0.754	0.564
Monte Alegre de Goiás	PM-FAO	4.69	1.32	-	-	-	-	-	-
	HG	5.27	0.89	0.122	0.737	0.905	0.869	0.841	0.730
	HG - K_{rs}	5.14	0.87	0.095	0.671	0.838	0.869	0.855	0.743
Morrinhos	PM-FAO	4.43	1.12	-	-	-	-	-	-
	HG	5.23	0.89	0.181	0.839	0.987	0.859	0.794	0.682
	HG - K_{rs}	4.87	0.83	0.099	0.582	0.732	0.859	0.861	0.740
Niquelândia	PM-FAO	4.49	0.97	-	-	-	-	-	-
	HG	4.98	0.89	0.110	0.803	0.995	0.571	0.712	0.407
	HG - K_{rs}	4.81	0.86	0.072	0.736	0.911	0.571	0.734	0.419
Paraúna	PM-FAO	4.29	1.09	-	-	-	-	-	-
	HG	5.10	0.83	0.190	0.853	1.020	0.826	0.768	0.634
	HG - K_{rs}	4.87	0.80	0.136	0.683	0.851	0.826	0.812	0.671
Pires do Rio	PM-FAO	4.33	1.13	-	-	-	-	-	-
	HG	5.25	0.86	0.213	0.947	1.084	0.870	0.767	0.668
	HG - K_{rs}	4.95	0.81	0.143	0.698	0.850	0.870	0.827	0.719
Posse	PM-FAO	4.70	1.50	-	-	-	-	-	-
	HG	4.94	0.80	0.051	0.807	0.983	0.825	0.811	0.668
	HG - K_{rs}	4.91	0.80	0.046	0.801	0.979	0.825	0.811	0.669
Rio Verde	PM-FAO	4.34	1.17	-	-	-	-	-	-
	HG	5.22	0.83	0.201	0.927	1.087	0.845	0.762	0.644
	HG - K_{rs}	4.71	0.75	0.086	0.621	0.766	0.845	0.842	0.711
São Simão	PM-FAO	4.71	1.26	-	-	-	-	-	-
	HG	5.40	0.84	0.147	0.823	0.989	0.850	0.802	0.682
	HG - K_{rs}	5.09	0.79	0.079	0.656	0.816	0.850	0.842	0.716
Silvânia	PM-FAO	4.00	1.10	-	-	-	-	-	-
	HG	5.06	0.79	0.263	1.064	1.191	0.877	0.722	0.633
	HG - K_{rs}	4.46	0.70	0.113	0.609	0.743	0.877	0.837	0.734

Source: The authors

Finally, the K_{rs} coefficient was analyzed for quarterly periods, which is a reasonable approach of the summer (January to March), autumn (April to June), winter (July to September) and spring (October to December) seasons.

For the first quarter, the highest K_{rs} was found in Cristalina, 0.175 ºC$^{-0.5}$, and the lowest in Alto Paraíso de Goiás, 0.150 ºC$^{-0.5}$. For the second quarter, the maximum and the minimum values of the coefficient was 0.218 ºC$^{-0.5}$ for Niquelândia and 0.154 ºC$^{-0.5}$ for Itapaci, respectively. As for the third quarter, the coefficient ranged from 0.206 ºC$^{-0.5}$ in Posse to 0.139 ºC$^{-0.5}$ in Itapaci. In the fourth and last quarter, the highest and the lowest K_{rs} values was 0.166 ºC$^{-0.5}$ for Posse and 0.141ºC$^{-0.5}$ for Itapaci.

Tables 8, 9 10 and 11 show the analyses of the Hargreaves model (HG) without and with K_{rs} coefficient (HG - K_{rs}) compared to the standard method (PM-FAO) for assessing the adjustment quality.

Table 8. Evaluation of the models for ET_o estimate for the first quarter

Station	Model	Mean	σ	RE	MAE	RMSE	r	d	c
Alto Paraíso de Goiás	PM-FAO	3.699	1.086	-	-	-	-	-	-
	HG	4.491	0.680	0.2142	0.884	1.053	0.7854	0.7298	0.5732
	HG - K_{rs}	3.964	0.600	0.0716	0.639	0.765	0.7854	0.7928	0.6226
Aragarças	PM-FAO	4.272	1.128	-	-	-	-	-	-
	HG	5.158	0.803	0.2075	0.907	1.056	0.8764	0.7649	0.6704
	HG - K_{rs}	4.972	0.774	0.1639	0.755	0.912	0.8764	0.8019	0.7028
Caiapônia	PM-FAO	4.105	1.117	-	-	-	-	-	-
	HG	4.776	0.830	0.1634	0.727	0.873	0.8759	0.8223	0.7202
	HG - K_{rs}	4.665	0.811	0.1364	0.652	0.795	0.8759	0.8427	0.7381
Catalão	PM-FAO	4.361	1.245	-	-	-	-	-	-
	HG	4.898	0.679	0.1233	0.822	0.989	0.7813	0.7542	0.5892
	HG - K_{rs}	4.756	0.660	0.0908	0.772	0.926	0.7813	0.7665	0.5989
Cristalina	PM-FAO	4.208	1.223	-	-	-	-	-	-
	HG	4.404	0.651	0.0465	0.658	0.779	0.8473	0.8215	0.6961
	HG - K_{rs}	4.533	0.670	0.0773	0.684	0.813	0.8473	0.8160	0.6914
Goianésia	PM-FAO	4.176	1.047	-	-	-	-	-	-
	HG	5.007	0.826	0.1990	0.844	0.959	0.8957	0.7884	0.7061
	HG - K_{rs}	4.858	0.801	0.1631	0.711	0.836	0.8957	0.8224	0.7367
Goiânia	PM-FAO	4.026	0.984	-	-	-	-	-	-
	HG	5.103	0.780	0.2674	1.082	1.196	0.8499	0.6943	0.5900
	HG - K_{rs}	4.529	0.692	0.1250	0.607	0.737	0.8499	0.8223	0.6988
Goiás	PM-FAO	4.217	1.146	-	-	-	-	-	-
	HG	5.312	0.904	0.2598	1.108	1.264	0.8356	0.7221	0.6034
	HG - K_{rs}	4.893	0.833	0.1604	0.765	0.932	0.8356	0.8032	0.6712
Iporá	PM-FAO	4.461	1.216	-	-	-	-	-	-
	HG	5.118	0.978	0.1473	0.695	0.826	0.9181	0.8691	0.7979
	HG - K_{rs}	5.086	0.972	0.1403	0.670	0.802	0.9181	0.8745	0.8029
Itapaci	PM-FAO	4.089	1.058	-	-	-	-	-	-
	HG	5.208	0.835	0.2734	1.122	1.250	0.8511	0.7048	0.5999
	HG - K_{rs}	4.726	0.758	0.1555	0.706	0.856	0.8511	0.8052	0.6853
Itumbiara	PM-FAO	4.464	1.220	-	-	-	-	-	-
	HG	5.229	0.895	0.1713	0.827	0.983	0.8735	0.8110	0.7084
	HG - K_{rs}	5.055	0.865	0.1324	0.706	0.861	0.8735	0.8406	0.7343

Jataí	PM-FAO	4.204	1.026	-	-	-	-	-	-
	HG	5.211	0.821	0.2397	1.021	1.165	0.8216	0.7123	0.5852
	HG - K_{rs}	4.762	0.750	0.1327	0.656	0.813	0.8216	0.8078	0.6637
Luziânia	PM-FAO	4.410	1.248	-	-	-	-	-	-
	HG	4.797	0.701	0.0878	0.706	0.837	0.8555	0.8190	0.7006
	HG - K_{rs}	4.730	0.692	0.0727	0.688	0.813	0.8555	0.8239	0.7048
Mineiros	PM-FAO	4.102	0.964	-	-	-	-	-	-
	HG	5.171	0.808	0.2604	1.084	1.247	0.7499	0.6631	0.4972
	HG - K_{rs}	4.758	0.743	0.1598	0.741	0.915	0.7499	0.7504	0.5628
Monte Alegre de Goiás	PM-FAO	4.572	1.131	-	-	-	-	-	-
	HG	5.181	0.807	0.1332	0.675	0.832	0.8811	0.8320	0.7331
	HG - K_{rs}	5.207	0.811	0.1388	0.694	0.850	0.8811	0.8273	0.7290
Morrinhos	PM-FAO	4.285	1.010	-	-	-	-	-	-
	HG	5.054	0.804	0.1794	0.789	0.924	0.8637	0.7847	0.6778
	HG - K_{rs}	5.043	0.802	0.1769	0.779	0.915	0.8637	0.7873	0.6800
Niquelândia	PM-FAO	4.342	0.862	-	-	-	-	-	-
	HG	4.878	0.801	0.1234	0.831	1.027	0.4463	0.6277	0.2802
	HG - K_{rs}	4.722	0.775	0.0875	0.766	0.944	0.4463	0.6492	0.2898
Paraúna	PM-FAO	4.264	1.044	-	-	-	-	-	-
	HG	4.974	0.786	0.1665	0.739	0.887	0.8682	0.8016	0.6960
	HG - K_{rs}	4.936	0.780	0.1576	0.708	0.857	0.8682	0.8097	0.7030
Pires do Rio	PM-FAO	4.284	1.084	-	-	-	-	-	-
	HG	5.155	0.819	0.2034	0.884	1.015	0.8866	0.7757	0.6878
	HG - K_{rs}	4.994	0.794	0.1658	0.741	0.885	0.8866	0.8101	0.7183
Posse	PM-FAO	4.603	1.317	-	-	-	-	-	-
	HG	4.864	0.722	0.0567	0.727	0.886	0.8089	0.8049	0.6511
	HG - K_{rs}	4.932	0.732	0.0714	0.743	0.904	0.8089	0.8021	0.6488
Rio Verde	PM-FAO	4.145	1.115	-	-	-	-	-	-
	HG	5.005	0.777	0.2076	0.904	1.058	0.8465	0.7553	0.6394
	HG - K_{rs}	4.579	0.711	0.1047	0.628	0.771	0.8465	0.8285	0.7013
São Simão	PM-FAO	4.473	1.138	-	-	-	-	-	-
	HG	5.217	0.787	0.1663	0.821	0.984	0.8371	0.7798	0.6528
	HG - K_{rs}	4.994	0.754	0.1165	0.675	0.836	0.8371	0.8176	0.6844
Silvânia	PM-FAO	3.981	1.103	-	-	-	-	-	-
	HG	4.956	0.784	0.2449	0.978	1.107	0.8987	0.7503	0.6743
	HG - K_{rs}	4.587	0.726	0.1521	0.664	0.818	0.8987	0.8246	0.7411

Source: The authors

Table 9. Evaluation of the models for ET_o estimate for the second quarter

Station	Model	Mean	σ	RE	MAE	RMSE	r	d	C
Alto Paraíso de Goiás	PM-FAO	3.265	0.594	-	-	-	-	-	-
	HG	3.482	0.469	0.0664	0.462	0.587	0.4920	0.6747	0.3320
	HG - K_{rs}	3.729	0.502	0.1420	0.579	0.725	0.4920	0.6203	0.3052
Aragarças	PM-FAO	3.583	0.650	-	-	-	-	-	-
	HG	4.309	0.545	0.2025	0.735	0.821	0.8057	0.6834	0.5506
	HG - K_{rs}	4.423	0.559	0.2344	0.844	0.925	0.8057	0.6456	0.5201
Caiapônia	PM-FAO	3.464	0.532	-	-	-	-	-	-
	HG	3.817	0.431	0.1019	0.401	0.492	0.7649	0.7670	0.5866
	HG - K_{rs}	4.062	0.459	0.1726	0.611	0.691	0.7649	0.6667	0.5100
Catalão	PM-FAO	3.277	0.618	-	-	-	-	-	-
	HG	3.360	0.500	0.0252	0.369	0.458	0.6934	0.8157	0.5656
	HG - K_{rs}	3.689	0.549	0.1257	0.502	0.618	0.6934	0.7406	0.5135

Cristalina	PM-FAO	3.297	0.616	-	-	-	-	-	-
	HG	3.215	0.455	-0.0248	0.333	0.412	0.7554	0.8410	0.6353
	HG - K_{rs}	3.739	0.530	0.1343	0.487	0.602	0.7554	0.7552	0.5705
Goianésia	PM-FAO	3.373	0.593	-	-	-	-	-	-
	HG	3.960	0.471	0.1741	0.613	0.697	0.7748	0.6951	0.5386
	HG - K_{rs}	4.130	0.491	0.2244	0.769	0.845	0.7748	0.6358	0.4926
Goiânia	PM-FAO	3.309	0.559	-	-	-	-	-	-
	HG	4.051	0.506	0.2243	0.759	0.853	0.6927	0.6113	0.4234
	HG - K_{rs}	3.832	0.479	0.1580	0.568	0.666	0.6927	0.6861	0.4753
Goiás	PM-FAO	3.692	0.633	-	-	-	-	-	-
	HG	4.221	0.478	0.1432	0.617	0.722	0.6384	0.6661	0.4252
	HG - K_{rs}	4.551	0.515	0.2325	0.896	0.993	0.6384	0.5713	0.3647
Iporá	PM-FAO	3.376	0.492	-	-	-	-	-	-
	HG	3.861	0.397	0.1437	0.527	0.606	0.6810	0.6525	0.4444
	HG - K_{rs}	4.007	0.412	0.1869	0.656	0.730	0.6810	0.5935	0.4042
Itapaci	PM-FAO	3.281	0.648	-	-	-	-	-	-
	HG	4.380	0.520	0.3348	1.104	1.211	0.6389	0.5238	0.3346
	HG - K_{rs}	3.967	0.471	0.2091	0.714	0.850	0.6389	0.6272	0.4007
Itumbiara	PM-FAO	3.369	0.669	-	-	-	-	-	-
	HG	3.809	0.552	0.1305	0.530	0.629	0.7440	0.7615	0.5666
	HG - K_{rs}	3.917	0.568	0.1627	0.611	0.710	0.7440	0.7271	0.5410
Jataí	PM-FAO	3.177	0.668	-	-	-	-	-	-
	HG	3.946	0.596	0.2421	0.779	0.852	0.8378	0.6887	0.5770
	HG - K_{rs}	3.883	0.586	0.2221	0.719	0.795	0.8378	0.7109	0.5956
Luziânia	PM-FAO	3.700	0.651	-	-	-	-	-	-
	HG	3.551	0.459	-0.0402	0.398	0.482	0.7090	0.7998	0.5671
	HG - K_{rs}	4.016	0.519	0.0853	0.421	0.560	0.7090	0.7739	0.5487
Mineiros	PM-FAO	3.256	0.698	-	-	-	-	-	-
	HG	4.160	0.664	0.2776	0.907	0.981	0.8438	0.6636	0.5600
	HG - K_{rs}	4.041	0.645	0.2413	0.790	0.872	0.8438	0.7023	0.5926
Monte Alegre de Goiás	PM-FAO	3.933	0.681	-	-	-	-	-	-
	HG	4.221	0.543	0.0733	0.480	0.593	0.6612	0.7596	0.5022
	HG - K_{rs}	4.476	0.575	0.1382	0.638	0.756	0.6612	0.6929	0.4581
Morrinhos	PM-FAO	3.229	0.585	-	-	-	-	-	-
	HG	3.855	0.525	0.1939	0.648	0.715	0.8103	0.7079	0.5736
	HG - K_{rs}	3.827	0.522	0.1851	0.622	0.691	0.8103	0.7183	0.5820
Niquelândia	PM-FAO	4.703	0.974	-	-	-	-	-	-
	HG	4.033	0.497	-0.1425	0.924	1.239	0.1127	0.4742	0.0534
	HG - K_{rs}	5.149	0.635	0.0948	0.992	1.187	0.1127	0.4199	0.0473
Paraúna	PM-FAO	3.203	0.593	-	-	-	-	-	-
	HG	3.817	0.502	0.1917	0.620	0.679	0.8722	0.7281	0.6351
	HG - K_{rs}	3.820	0.502	0.1926	0.622	0.682	0.8722	0.7269	0.6340
Pires do Rio	PM-FAO	3.182	0.603	-	-	-	-	-	-
	HG	3.889	0.515	0.2223	0.715	0.790	0.8129	0.6797	0.5525
	HG - K_{rs}	3.967	0.526	0.2469	0.790	0.861	0.8129	0.6528	0.5306
Posse	PM-FAO	4.107	0.716	-	-	-	-	-	-
	HG	3.719	0.451	-0.0945	0.593	0.709	0.5626	0.6639	0.3735
	HG - K_{rs}	4.462	0.541	0.0866	0.548	0.704	0.5626	0.6823	0.3839
Rio Verde	PM-FAO	3.326	0.702	-	-	-	-	-	-
	HG	3.810	0.499	0.1458	0.530	0.633	0.8228	0.7655	0.6299
	HG - K_{rs}	3.959	0.519	0.1903	0.652	0.750	0.8228	0.7164	0.5894
São Simão	PM-FAO	3.459	0.873	-	-	-	-	-	-
	HG	3.843	0.644	0.1110	0.553	0.662	0.7872	0.8147	0.6413
	HG - K_{rs}	3.839	0.643	0.1098	0.551	0.660	0.7872	0.8155	0.6420
Silvânia	PM-FAO	2.971	0.583	-	-	-	-	-	-
	HG	3.642	0.502	0.2260	0.673	0.730	0.8695	0.7041	0.6123
	HG - K_{rs}	3.496	0.481	0.1767	0.535	0.599	0.8695	0.7620	0.6625

Source: The authors

Table 10. Evaluation of the models for ET_o estimate for the third quarter

Station	Model	Mean	σ	RE	MAE	RMSE	r	d	c
Alto Paraíso de Goiás	PM-FAO	4.533	0.954	-	-	-	-	-	-
	HG	4.126	0.717	-0.0899	0.688	0.889	0.5844	0.7129	0.4166
	HG - K_{rs}	4.498	0.781	-0.0077	0.624	0.806	0.5844	0.7543	0.4408
Aragarças	PM-FAO	4.396	0.800	-	-	-	-	-	-
	HG	5.446	0.877	0.2389	1.070	1.186	0.7883	0.6530	0.5148
	HG - K_{rs}	4.971	0.801	0.1307	0.657	0.775	0.7883	0.7852	0.6189
Caiapônia	PM-FAO	4.446	0.837	-	-	-	-	-	-
	HG	4.813	0.777	0.0825	0.549	0.687	0.7431	0.8144	0.6051
	HG - K_{rs}	4.779	0.772	0.0748	0.531	0.668	0.7431	0.8210	0.6101
Catalão	PM-FAO	4.450	1.108	-	-	-	-	-	-
	HG	4.034	0.835	-0.0935	0.686	0.831	0.7606	0.8137	0.6189
	HG - K_{rs}	4.333	0.897	-0.0263	0.602	0.730	0.7606	0.8555	0.6506
Cristalina	PM-FAO	4.383	1.062	-	-	-	-	-	-
	HG	3.817	0.747	-0.1292	0.701	0.837	0.8223	0.7984	0.6566
	HG - K_{rs}	4.371	0.855	-0.0026	0.462	0.604	0.8223	0.8934	0.7347
Goianésia	PM-FAO	4.094	0.903	-	-	-	-	-	-
	HG	4.767	0.817	0.1643	0.795	0.941	0.7112	0.7294	0.5188
	HG - K_{rs}	4.553	0.780	0.1121	0.656	0.795	0.7112	0.7757	0.5517
Goiânia	PM-FAO	4.116	0.959	-	-	-	-	-	-
	HG	4.786	0.838	0.1629	0.874	1.025	0.6341	0.6937	0.4399
	HG - K_{rs}	4.216	0.738	0.0244	0.615	0.759	0.6341	0.7717	0.4893
Goiás	PM-FAO	4.802	1.093	-	-	-	-	-	-
	HG	5.064	0.868	0.0546	0.861	1.034	0.4985	0.6744	0.3362
	HG - K_{rs}	5.149	0.883	0.0722	0.890	1.063	0.4985	0.6671	0.3325
Iporá	PM-FAO	4.832	0.852	-	-	-	-	-	-
	HG	5.078	0.845	0.0509	0.628	0.757	0.6419	0.7789	0.5000
	HG - K_{rs}	4.915	0.818	0.0172	0.572	0.710	0.6419	0.7960	0.5109
Itapaci	PM-FAO	3.892	0.814	-	-	-	-	-	-
	HG	5.209	0.785	0.3384	1.322	1.403	0.8164	0.6031	0.4923
	HG - K_{rs}	4.263	0.642	0.0954	0.497	0.599	0.8164	0.8351	0.6818
Itumbiara	PM-FAO	4.641	1.401	-	-	-	-	-	-
	HG	4.681	0.980	0.0086	0.810	0.997	0.7030	0.8049	0.5658
	HG - K_{rs}	4.393	0.920	-0.0534	0.799	1.028	0.7030	0.7871	0.5534
Jataí	PM-FAO	4.339	1.127	-	-	-	-	-	-
	HG	5.088	0.939	0.1727	0.963	1.124	0.6846	0.7222	0.4944
	HG - K_{rs}	4.440	0.819	0.0233	0.620	0.828	0.6846	0.7977	0.5461
Luziânia	PM-FAO	4.984	1.092	-	-	-	-	-	-
	HG	4.205	0.761	-0.1562	0.899	1.048	0.7698	0.7300	0.5620
	HG - K_{rs}	4.672	0.846	-0.0626	0.619	0.763	0.7698	0.8375	0.6448
Mineiros	PM-FAO	3.828	0.849	-	-	-	-	-	-
	HG	5.076	0.941	0.3260	1.269	1.392	0.7671	0.6144	0.4713
	HG - K_{rs}	4.400	0.816	0.1496	0.683	0.807	0.7671	0.7807	0.5989
Monte Alegre de Goiás	PM-FAO	5.168	1.122	-	-	-	-	-	-
	HG	4.957	0.775	-0.0408	0.809	0.981	0.5405	0.7018	0.3793
	HG - K_{rs}	5.112	0.799	-0.0109	0.805	0.964	0.5405	0.7102	0.3839
Morrinhos	PM-FAO	4.164	0.997	-	-	-	-	-	-
	HG	4.603	0.870	0.1054	0.714	0.850	0.7039	0.7846	0.5523
	HG - K_{rs}	4.231	0.799	0.0159	0.571	0.718	0.7039	0.8227	0.5791
Niquelândia	PM-FAO	5.354	1.023	-	-	-	-	-	-
	HG	4.665	0.785	-0.1287	0.982	1.231	0.3868	0.5897	0.2281
	HG - K_{rs}	5.143	0.865	-0.0394	0.866	1.074	0.3868	0.6357	0.2459
Paraúna	PM-FAO	3.475	0.743	-	-	-	-	-	-
	HG	4.066	0.659	0.1703	0.648	0.735	0.8129	0.7658	0.6225
	HG - K_{rs}	3.905	0.632	0.1239	0.525	0.611	0.8129	0.8131	0.6610
Pires do Rio	PM-FAO	3.873	0.890	-	-	-	-	-	-
	HG	4.679	0.911	0.2080	0.878	1.023	0.7547	0.7258	0.5478
	HG - K_{rs}	4.383	0.854	0.1315	0.669	0.796	0.7547	0.7948	0.5998

Posse	PM-FAO	5.596	1.019	-	-	-	-	-	-
	HG	4.424	0.723	-0.2096	1.222	1.362	0.7342	0.6181	0.4538
	HG - K_{rs}	5.342	0.874	-0.0454	0.604	0.747	0.7342	0.8321	0.6110
Rio Verde	PM-FAO	4.501	1.141	-	-	-	-	-	-
	HG	4.723	0.860	0.0493	0.690	0.861	0.6866	0.7983	0.5481
	HG - K_{rs}	4.573	0.833	0.0161	0.666	0.833	0.6866	0.8031	0.5514
São Simão	PM-FAO	5.234	1.545	-	-	-	-	-	-
	HG	4.938	0.923	-0.0566	0.978	1.167	0.6879	0.7614	0.5237
	HG - K_{rs}	4.396	0.821	-0.1602	1.154	1.420	0.6879	0.6884	0.4735
Silvânia	PM-FAO	3.755	0.854	-	-	-	-	-	-
	HG	4.468	0.896	0.1898	0.738	0.842	0.8692	0.7973	0.6930
	HG - K_{rs}	4.196	0.842	0.1174	0.519	0.618	0.8692	0.8695	0.7558

Source: The authors

Table 11. Evaluation of the models for ET_o estimate for the fourth quarter

Station	Model	Mean	σ	RE	MAE	RMSE	r	d	c
Alto Paraíso de Goiás	PM-FAO	3.867	1.388	-	-	-	-	-	-
	HG	4.581	0.824	0.1849	0.984	1.138	0.7956	0.7638	0.6076
	HG - K_{rs}	3.781	0.680	-0.0221	0.748	0.945	0.7956	0.7750	0.6166
Aragarças	PM-FAO	4.565	1.189	-	-	-	-	-	-
	HG	5.562	0.926	0.2185	1.026	1.174	0.8565	0.7531	0.6451
	HG - K_{rs}	5.111	0.851	0.1197	0.685	0.838	0.8565	0.8378	0.7176
Caiapônia	PM-FAO	4.372	1.151	-	-	-	-	-	-
	HG	5.105	0.822	0.1676	0.807	0.971	0.8428	0.7889	0.6648
	HG - K_{rs}	4.768	0.768	0.0904	0.620	0.762	0.8428	0.8432	0.7106
Catalão	PM-FAO	4.549	1.348	-	-	-	-	-	-
	HG	5.154	0.769	0.1330	0.895	1.057	0.7980	0.7666	0.6117
	HG - K_{rs}	4.693	0.700	0.0315	0.742	0.905	0.7980	0.7918	0.6319
Cristalina	PM-FAO	4.292	1.373	-	-	-	-	-	-
	HG	4.581	0.746	0.0676	0.741	0.879	0.8555	0.8245	0.7053
	HG - K_{rs}	4.367	0.711	0.0175	0.702	0.852	0.8555	0.8239	0.7048
Goianésia	PM-FAO	4.131	1.172	-	-	-	-	-	-
	HG	5.133	0.945	0.2426	1.025	1.144	0.8855	0.7700	0.6818
	HG - K_{rs}	4.499	0.828	0.0892	0.559	0.690	0.8855	0.8814	0.7805
Goiânia	PM-FAO	4.213	1.128	-	-	-	-	-	-
	HG	5.339	0.927	0.2673	1.158	1.297	0.8211	0.7080	0.5814
	HG - K_{rs}	4.619	0.802	0.0964	0.621	0.771	0.8211	0.8402	0.6899
Goiás	PM-FAO	4.465	1.308	-	-	-	-	-	-
	HG	5.556	0.973	0.2444	1.153	1.319	0.8281	0.7363	0.6097
	HG - K_{rs}	4.986	0.873	0.1168	0.751	0.924	0.8281	0.8243	0.6826
Iporá	PM-FAO	4.351	1.219	-	-	-	-	-	-
	HG	5.021	0.811	0.1540	0.759	0.916	0.8852	0.8163	0.7226
	HG - K_{rs}	4.757	0.768	0.0934	0.619	0.762	0.8852	0.8555	0.7574
Itapaci	PM-FAO	4.058	1.130	-	-	-	-	-	-
	HG	5.376	0.989	0.3247	1.322	1.449	0.8465	0.6871	0.5816
	HG - K_{rs}	4.445	0.817	0.0953	0.588	0.728	0.8465	0.8606	0.7285
Itumbiara	PM-FAO	4.853	1.337	-	-	-	-	-	-
	HG	5.609	0.857	0.1558	0.946	1.113	0.8084	0.7672	0.6202
	HG - K_{rs}	5.237	0.800	0.0792	0.737	0.919	0.8084	0.8109	0.6555
Jataí	PM-FAO	4.581	1.160	-	-	-	-	-	-
	HG	5.575	0.859	0.2169	1.045	1.206	0.8105	0.7247	0.5873
	HG - K_{rs}	4.987	0.768	0.0885	0.653	0.810	0.8105	0.8234	0.6674
Luziânia	PM-FAO	4.510	1.450	-	-	-	-	-	-
	HG	4.944	0.807	0.0962	0.825	0.980	0.8465	0.8146	0.6896
	HG - K_{rs}	4.554	0.744	0.0097	0.734	0.912	0.8465	0.8175	0.6920
Mineiros	PM-FAO	4.419	1.035	-	-	-	-	-	-
	HG	5.583	0.829	0.2633	1.186	1.361	0.7339	0.6417	0.4709
	HG - K_{rs}	5.073	0.753	0.1480	0.781	0.960	0.7339	0.7414	0.5441

Monte Alegre de Goiás	PM-FAO	4.815	1.476	-	-	-	-	-	-
	HG	5.349	0.962	0.1110	0.799	0.972	0.8606	0.8442	0.7265
	HG - K_{rs}	5.132	0.923	0.0659	0.711	0.886	0.8606	0.8599	0.7401
Morrinhos	PM-FAO	4.559	1.186	-	-	-	-	-	-
	HG	5.391	0.932	0.1825	0.883	1.039	0.8543	0.7932	0.6776
	HG - K_{rs}	4.871	0.842	0.0685	0.559	0.711	0.8543	0.8739	0.7465
Niquelândia	PM-FAO	4.610	1.037	-	-	-	-	-	-
	HG	5.070	0.946	0.0997	0.780	0.968	0.6335	0.7549	0.4782
	HG - K_{rs}	4.870	0.908	0.0563	0.710	0.880	0.6335	0.7779	0.4928
Paraúna	PM-FAO	4.306	1.126	-	-	-	-	-	-
	HG	5.214	0.862	0.2108	0.957	1.129	0.8031	0.7417	0.5957
	HG - K_{rs}	4.796	0.793	0.1137	0.673	0.838	0.8031	0.8153	0.6548
Pires do Rio	PM-FAO	4.380	1.179	-	-	-	-	-	-
	HG	5.354	0.899	0.2223	1.013	1.151	0.8589	0.7579	0.6510
	HG - K_{rs}	4.887	0.820	0.1157	0.661	0.811	0.8589	0.8415	0.7227
Posse	PM-FAO	4.784	1.649	-	-	-	-	-	-
	HG	5.007	0.869	0.0467	0.881	1.065	0.8334	0.8128	0.6774
	HG - K_{rs}	4.868	0.845	0.0175	0.854	1.057	0.8334	0.8093	0.6745
Rio Verde	PM-FAO	4.517	1.192	-	-	-	-	-	-
	HG	5.403	0.833	0.1962	0.948	1.112	0.8374	0.7574	0.6343
	HG - K_{rs}	4.834	0.745	0.0702	0.620	0.767	0.8374	0.8420	0.7051
São Simão	PM-FAO	4.950	1.336	-	-	-	-	-	-
	HG	5.589	0.841	0.1290	0.825	0.993	0.8515	0.8080	0.6880
	HG - K_{rs}	5.191	0.781	0.0486	0.660	0.822	0.8515	0.8447	0.7193
Silvânia	PM-FAO	4.025	1.090	-	-	-	-	-	-
	HG	5.152	0.787	0.2801	1.142	1.262	0.8656	0.6972	0.6035
	HG - K_{rs}	4.395	0.671	0.0920	0.585	0.713	0.8656	0.8386	0.7259

Source: The authors

Only three stations showed no improvement in the model with the seasonal adjustment of K_{rs} for the first quarter, namely: Cristalina, Monte Alegre de Minas and Posse. For the second quarter, only 9 stations showed improvement in the model with the seasonal adjustment of the K_{rs} coefficient; Alto Paraíso de Goiás, Goiânia, Itapaci, Jataí, Mineiros, Morrinhos, Posse, São Simão and Silvânia. In relation to the third quarter, four stations would not show improvement in the model with the adjustment, that is, in the stations of Aragarças, Goiás, Itumbiara and São Simão, it was proved to be better to apply the Hargreaves model in its classic configuration, without adjustments. In the fourth and last quarter, only the Cristalina and Posse stations did not perform better when a seasonal calibration of the K*rs* coefficient was applied.

Martí *et al*. (2015) found better results for the Hargreaves model adjusted on larger time scales. The estimate of this work for K_{rs} was better due to the data on temperature, longitude, altitude and qualitative assessments of wind speed, although they recognize that the introduction of more variables impairs the application of the model.

Carbone *et al*. (2016) found better results for ET_o through the Hargreaves model using measured solar radiation rather than the estimated one as a function of maximum and minimum temperature and extraterrestrial solar radiation (R_a). The authors attributed this fact to the relevance of radiation for estimating ET_o.

Several authors chose not to estimate the K_{rs} adjustment coefficient, proceeding only with the linear regression of ET_o values between the HG and PM-FAO models, as it was done by Bachour et al. (2013), Mendicino and Senatore (2013), Vicente *et al*. (2014), Berti *et al*. (2014). Valiantzas (2018), however, despite using nonlinear regression, makes only statistical adjustments for calibration of a new model of global solar radiation as a function of temperature and air relative humidity, finding good results for this estimate.

CONCLUSIONS

- The use of the Hargreaves model to estimate the reference evapotranspiration for the state of Goiás was shown to be a feasible alternative due to the reduced need for climatic data and its good adherence to the standard Penman-Monteith model parameterized by FAO.

- The local and seasonal calibration of the model based on the estimate of global solar radiation using the Hargreaves equation also improved the quality of the model.
- It is recommended the evaluation of the tests performed in this study for other stations and, preferably, for longer time scales such as quarterly or monthly periods.

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