Global Journal of HUMAN-SOCIAL SCIENCE: B
Geography, Geo-Sciences, Environmental Science & Disaster Management
Volume 15 Issue 1 Version 1.0 Year 2015
Type: Double Blind Peer Reviewed International Research Journal
Publisher: Global Journals Inc. (USA)
Online ISSN: 2249-460X & Print ISSN: 0975-587X

Comparative Study of Methods for Estimating Evapotranspiration Reference in Paranaíba City, Brazil

By Fernando França da Cunha, Thiago Ramos da Silva, Arthur Ribeiro Ximenes & Rafael Oliveira Batista

Universidade Federal dos Vales do Jequitinhonha e Mucuri, Brazil

Abstract- This study aimed to was evaluating the performance of 30 methods to estimate reference evapotranspiration (ET0) to the city of Paranaíba, Brazil. The meteorological data was removed from National Institute of Meteorology, on the period of six year (March 2008 to February 2014). The method taken as standard was Penman-Monteith-FAO56 and the comparison of results was by the coefficients of determination (r^2), coefficients "a" and "b" of the linear regressions, estimate of standard-error, Willmott's index of agreement (d), Pearson correlation coefficient (r), and reliable coefficient (c). The better methods to ET0 estimate was: Penman-Original, Stephens-Stewart, Priestley-Taylor, Hicks-Hess, Turc, Liquid-Radiation, Thornthwaite-Modified, Temperature-Radiation, Penman-FAO24, Abtew and Camargo. The Camargo method should be preferred when only air temperatures data have. The methods Blaney-Criddle-FAO24 and Hamon should receive calibration for be utilized on the estimate of ET0 in Paranaíba city.

Keywords: *agrometeorology. ET0. evapotranspiration. penman-monteith-FAO56.*

GJHSS-B Classification : *FOR Code: 960301*

Comparative Study of Methods for Estimating Evapotranspiration Reference in Paranaíba City, Brazil

Fernando França da Cunha [α], Thiago Ramos da Silva [σ], Arthur Ribeiro Ximenes [ρ] & Rafael Oliveira Batista [ω]

Abstract- This study aimed to was evaluating the performance of 30 methods to estimate reference evapotranspiration (ET0) to the city of Paranaíba, Brazil. The meteorological data was removed from National Institute of Meteorology, on the period of six year (March 2008 to February 2014). The method taken as standard was Penman-Monteith-FAO56 and the comparison of results was by the coefficients of determination (r^2), coefficients "a" and "b" of the linear regressions, estimate of standard-error, Willmott's index of agreement (d), Pearson correlation coefficient (r), and reliable coefficient (c). The better methods to ET0 estimate was: Penman-Original, Stephens-Stewart, Priestley-Taylor, Hicks-Hess, Turc, Liquid-Radiation, Thornthwaite-Modified, Temperature-Radiation, Penman-FAO24, Abtew and Camargo. The Camargo method should be preferred when only air temperatures data have. The methods Blaney-Criddle-FAO24 and Hamon should receive calibration for be utilized on the estimate of ET0 in Paranaíba city.

Keywords: agrometeorology. ET0. evapotranspiration. penman-monteith-FAO56.

I. Introduction

The evapotranspiration is the term used to define the loss of water vapor to the atmosphere by the effect combined of the process of evaporation of water of superficies of soil and the plant and, of transpiration of water by the plant (OLIVEIRA et al., 2011). The study of evapotranspiration is important to the agricultural planning, being increasingly higher the requirement of information about the water requirement of crop to the regional planning and preliminary project. This study becomes more important in regions characterized by the spatial and temporal irregularity of rainfall (MOURA et al., 2013).

There are many methods to the determination of evapotranspiration, whether direct or indirect. The Penman-Monteith method (ALLEN et al., 1998) was recommended by FAO as standard to calculate the reference evapotranspiration (ET0) and has been utilized in all world. This method requires many input parameters like air temperature, relative humidity, solar radiation and wind speed. However, there are a limited number of meteorological stations to the monitoring of this variable of time. This lack of meteorological data leads to the development of simpler approaches to estimate ET0 that requiring only a few input parameters. In this context, various methods have been reported in the literature for this purpose.

Although there a lot models to estimate of ET0, these, however, are utilized in climate and agronomics conditions very different from those that were originally designed and, therefore, is utmost importance evaluate the degree of accuracy of these models before using them to new condition. Several of work comparing the various models of ET0 estimate are found on literature to different regions (BARROS et al., 2009; KISI, 2009; CAVALCANTE Jr. et al., 2011; OLIVEIRA et al., 2011; KISI et al., 2012; SAHOO et al., 2012; CUNHA et al., 2013; MOURA et al., 2013).

Given the above, the aim of this work was to evaluate the performance of 30 methods for ET0 estimate, comparing them with the standard method of Penman-Monteith-FAO56, for the Paranaíba city, Brazil.

II. Material and Methods

The meteorological data required for execution of this study were taken from the National Institute of Meteorology (INMET) for the automatic meteorological station in the Paranaíba city, of Mato Grosso do Sul state, Brazil (Latitude 19º 24' 51"S, Longitude 51º 06' 19" W, Altitude 424 m) for six years, from March 2008 to February 2014. The meteorological data used in the research were: average temperature, maximum and minimum (ºC); average relative humidity, maximum and minimum (%); average dew point temperature, maximum and minimum (ºC); average pressure, maximum and minimum (hPa) wind speed at 10 m height (m s^{-1}) and global radiation (kJ m^{-2}). Data were obtained from a meteorological station that consists of the equipment WAWS 301 (Automatic Weather Station) of the Brand VAISALA, whose composition is described as follows: (1) Pyranometer CM6B; (2) Pressure Sensor PMT16A; (3) Thermometer QMH102; (4) Hygrometer

Author α: Professor Adjunto, Doutor, Universidade Federal dos Vales do Jequitinhonha e Mucuri - UFVJM, Instituto de Ciências Agrárias - ICA, Unaí, MG, Brasil. e-mail: fernando.cunha@ufvjm.edu.br
Author σ ρ: Graduando em Agronomia, Universidade Federal de Mato Grosso do Sul - UFMS, Campus de Chapadão do Sul - CPCS, Chapadão do Sul, MS, Brasil.
Author ω: Professor Adjunto, Doutor, Universidade Federal Rural do Semi-Árido - UFERSA, Departamento de Ciências Ambientaise Tecnológicas, Mossoró, RN, Brasil.

QMH102; (5) Pluviometer QMR102 and (6) Anemometer WAA151. The hourly meteorological data were converted to daily data. In order to make the meteorological variables data more homogeneous, verification was made and, subsequently, the information considered discrepant or inconsistent was eliminated, aiming to obtain more representative data groupings. The methodologies used in this research to estimate the daily reference evapotranspiration (ET0) are presented in Table 1.

Table 1 : Methodologies and their respective equations to estimate the daily reference evapotranspiration (ET0) used in the research

Methodology	Equation
Penman-Monteith-FAO56	$ET0 = \dfrac{0.408\,\Delta\,(Rn - G) + \gamma\,\dfrac{900}{t+273}\,U_2\,\dfrac{(e_s - e)}{10}}{\Delta + \gamma\,(1 + 0.34\,U_2)}$
Penman-Original	$ET0 = \dfrac{\Delta}{\Delta+\gamma}\,0.408\,(Rn - G) + \dfrac{\gamma}{\Delta+\gamma}\,0.26\left(1 + \dfrac{U_2}{160}\right)(e_s - e)$
Penman-FAO24	$ET\,0 = c\left[\dfrac{\Delta}{\Delta+\gamma}\,0.408\,Rn + \dfrac{\gamma}{\Delta+\gamma}\,0.27\,(1 + 0.864\,U_2)(e_s - e)\right]$
Blaney-Criddle-FAO24	$ET\,0 = k\;p\;(0.457\;t + 8.13)$
Radiation-FAO24	$ET\,0 = -0.3 + k\left(\dfrac{\Delta}{\Delta+\gamma}\,R_{SE}\right)$
Makkink	$ET\,0 = R_{SE}\left(\dfrac{\Delta}{\Delta+\gamma}\right) + 0.12$
Hargreaves-Samani	$ET0 = 0.0023\;\;Ra_E\;(t_{max} - t_{min})^{0.5}\;(t + 17.8)$
Hargreaves-Original	$ET0 = 0.135\;\dfrac{R_S}{\lambda}\;(t + 17.8)$
Priestley-Taylor	$ET\,0 = 0.5143\;\dfrac{\Delta}{\Delta+\gamma}\;(Rn - G)$
Jensen-Haise	$ET\,0 = R_{SE}\;(0.025\;t + 0.08)$
Camargo	$ET\,0 = 0.01\;Ra_E\;t$
Linacre	$ET\,0 = \dfrac{500\;(t + 0.006\,z)}{100 - \phi} + 15\;(t - t_d) \Big/ (80 - t)$
Hamon	$ET\,0 = 0.55\left(\dfrac{N}{12}\right)^2\left(\dfrac{4.95\;\exp^{0.062\;t}}{100}\right)25.4$
Ivanov	$ET\,0 = 0.006\;(25 + t)^2\;\left(1 - \dfrac{RH}{100}\right)$
Kharrufa	$ET\,0 = 0.34\;\;p\;t^{1.3}$
Garcia-Lopez	$ET\,0 = 1.21\;\;10^{\left(\frac{7.45\,t}{243.7+t}\right)}\;(1 - 0.01\;RH) + 0.21\;t - 2.30$
Blaney-Morin	$ET\,0 = p\;(0.457\;\;t + 8.13)(1.14 - 0.01\;RH)$
Turc	$ET\,0 = \dfrac{0.013\;t}{t + 15}(23.9\;R_S + 50)$
McCloud	$ET\,0 = 0.254\;\;1.07^{(1.8\,t)}$
McGuiness-Bordne	$ET\,0 = \dfrac{Ra}{\lambda}\;\dfrac{t + 5}{68}$
Romanenko	$ET\,0 = 4.5\left(1 + \dfrac{t}{25}\right)^2\left(1 - \dfrac{e}{e_s}\right)$
Lungeon	$ET\,0 = 0.2985\;(e_s - e)\left(\dfrac{273 + t}{273}\right)\left(\dfrac{760}{P - e_s}\right)$
Abtew	$ET\,0 = \dfrac{0.53}{\lambda}\;R_S\;(1 - \alpha)$

Hicks-Hess	$ET0 = \frac{1}{\lambda}\left(\frac{\Delta}{0.90\ \Delta + 0.63\ \gamma}\right) Rn$
Global-Radiation	$ET0 = 0.9 + 0.115\ R_S$
Liquid-Radiation	$ET0 = 0.86\ \frac{Rn}{\lambda}$
Temperature-Radiation	$ET0 = \frac{1}{\lambda}\left(\frac{R_S\ t_{max}}{56}\right)$
Stephens-Stewart	$ET0 = 0.4047\ R_S\ \left[(0.01476\ t) + 0.0724\right]$
Tanner-Pelton	$ET0 = 0.457\ Rn - 0.11$
Thornthwaite-Modified	$ET0 = \frac{16}{30}\left(10\ \frac{0.36\ (3\ t_{max} - t_{min})}{I}\right)^a \frac{N}{12}$
Thornthwaite	$ET0 = \frac{16}{30}\left(10\ \frac{t_i}{I}\right)^a \frac{N}{12}$

ET0 = reference evapotranspiration (mm day); Δ = slope vapour pressure curve (kPa °C^{-1}); Rn = net radiation at the crop surface (MJ m^{-2} day^{-1}); G = soil heat flux (MJ m^{-2} day^{-1}); γ = psychrometric constant (kPa °C^{-1}); t = mean daily air temperature at 2 m height (°C); U_2 = wind speed at 2 m height (m s^{-1}); e_s = saturation vapor pressure (hPa); e = actual vapour pressure (hPa); c = adjustment coefficient (adm); k = local coefficient (adm); p = annual percentage of light (%); RH = relative humidity (%), R_{SE} = solar or shortwave radiation (mm day^{-1}); Ra_E = extraterrestrial radiation (mm day^{-1}); t_{max} = maximum temperature (°C); t_{min} = minimum temperature (°C); λ = latent heat of vaporization (MJ kg^{-1}); z = local altitude (m); φ = local latitude (degrees); t_d = dew point temperature (°C); N = photoperiod (h); R_S = solar or shortwave radiation (MJ m^{-2} day^{-1}); Ra = extraterrestrial radiation (MJ m^{-2} day^{-1}); P = atmospheric pressure (hPa); α = albedo or canopy reflection coefficient (dimensionless); a = local constant (adm); I = annual heat index (adm); and t_i = monthly temperature (°C).

The wind speed was corrected to a height of 2 m (Equation 1).

$$U_2 = \frac{4.868}{\ln\ (67.75\ z - 5.42)}\ U_z \quad (1)$$

where: U_2 = wind speed at 2 m height (m s^{-1}); U_z = wind speed at "z" m above ground surface (m s^{-1}); and z = height of wind measurements (m).
The net radiation was estimated according to the following equations:

$$Rn = Rns + Rnl \quad (2)$$

$$Rns = R_S\ (1 - \alpha) \quad (3)$$

$$Rnl = 4.8989\ 10^{-9}\ T^4\ \left(0.09\ \sqrt{0.75\ e} - 0.56\right)\left(1.35\ \frac{R_S}{(a+b)\ Ra} - 0.35\right) \quad (4)$$

where: Rn = net radiation at the crop surface (MJ m^{-2} day^{-1}); Rns = net solar or shortwave radiation (MJ m^{-2} day^{-1}); Rnl = net longwave radiation (MJ m^{-2} day^{-1}); R_S = solar or shortwave radiation (MJ m^{-2} day^{-1}); α = albedo or canopy reflection coefficient (dimensionless); T = average daily temperature of the air (K [K = °C + 273.16]); e = actual vapour pressure (kPa); a e b = fraction of extraterrestrial radiation reaching the earth on clear days (dimensionless); and Ra = extraterrestrial radiation (MJ m^{-2} day^{-1}).

After obtaining the daily ET0 through different methodologies it was conducted a regression analysis that correlated the ET0 values estimated by empirical equations with the Penman-Monteith-FAO56 method (ALLEN et al., 1998). It was considered the coefficients "a" and "b" of the respective linear regressions and the coefficient of determination (r^2). The best alternative was the one that showed regression coefficient "a" near to zero, coefficient "b" near the unity and higher coefficient of determination, more than 0.60. The precision was measured through the coefficient of determination, which indicates the degree to which the regression explains the sum of the total squared.

The models performance analysis was performed by comparing the daily ET0 values obtained by empirical methods such as the Penman-Monteith-FAO56 (ALLEN et al., 1998). The methodology adopted for comparison of results was proposed by Allen et al. (1989), and is based on the estimate of standard-error (ESE), calculated by Equation 5. The best method to estimate ET0 was the one that presented the lowest ESE.

$$ESE = \left[\frac{\sum_{i=1}^{n}(X_i - Y_i)^2}{n-1}\right]^{1/2} \quad (5)$$

where: ESE = estimate of standard-error (mm day^{-1}); X_i = reference evapotranspiration estimated by the standard method (mm day^{-1}); Y_i = reference evapotranspiration obtained through the tested method (mm day^{-1}); and n = number of observations.

The approximation of ET0 values estimated by the method studied, in relation to the values obtained using the standard method, was obtained by an index called concordance, represented by the letter "d" where its values range from zero, where there is no concordance, to 1, for the perfect concordance. The concordance index (d) was calculated using the Equation 6. To validate the model, it was also obtained the Pearson's correlation coefficient (r) through Equation 7 and the reliable coefficient or performance (c) through Equation 8.

$$d = 1 - \frac{\sum_{i=1}^{n}(X_i - Y_i)^2}{\sum_{i=1}^{n}\left[\left(\left|X_i - \overline{X}\right|\right) + \left(\left|Y_i - \overline{X}\right|\right)\right]^2} \quad (6)$$

$$r = \frac{\sum_{i=1}^{n}\left[\left(\left|X_i - \overline{X}\right|\right)\left(\left|Y_i - \overline{Y}\right|\right)\right]}{\sqrt{\sum_{i=1}^{n}\left(X_i - \overline{X}\right)^2}\sqrt{\sum_{i=1}^{n}\left(Y_i - \overline{Y}\right)^2}} \quad (7)$$

$$c = r\, d \quad (8)$$

where: d = Willmott's concordance index; X_i = reference evapotranspiration estimated through the standard method (mm day^{-1}); Y_i = reference evapotranspiration obtained through the method tested (mm day^{-1}); $\overline{Y}$ = average values of reference evapotranspiration obtained through the method tested (mm day^{-1}); $\overline{X}$ = average values of reference evapotranspiration obtained through standard method (mm day^{-1}); n = number of observations; r = Pearson's correlation coefficient; and c = reliable coefficient or performance.

According to Cohen (1988), the correlation coefficient (r) can be classified as: "very low" ($r < 0.1$), "low" ($0.1 < r < 0.3$), "moderate" ($0.3 < r < 0.5$); "high" ($0.5 < r < 0.7$); "very high" ($0.7 < r < 0.9$); and "almost perfect" ($r > 0.9$).

The reliable coefficient or performance, proposed by Camargoe Sentelhas (1997), is interpreted in accordance with authors such as: "great" ($c > 0.85$); "very good" ($0.76 < c < 0.85$); "good" ($0.66 < c < 0.75$), "average" ($0.61 < c < 0.65$), "badly" ($0.51 < c < 0.60$), "not good" ($0.41 < c < 0.50$) and "terrible" ($c < 0.40$).

III. Results and Discussion

On Figures 1 and 2 are shown the graphs and the resulting linear regression models considering the methods to estimates of reference evapotranspiration (ET0) utilized on the analysis having the Penman-Monteith method standardized by FAO as standard. It is observed, based on regression straight, that Blaney-Criddle-FAO24 method underestimated the ET0 values only when the Penman-Monteith-FAO56 method was accused estimates exceeding 4.5 mm day^{-1}. The Camargo, Hamon, Abtew and Global-Radiation methods underestimated ET0 when the values of Penman-Monteith-FAO56 were accused estimates above 3.0 mm day^{-1} and Blaney-Morin above 1.5 mm dia^{-1}. The methods of Penman-Original, Priestley-Taylor, Hicks-Hess, Lungeon, Turc, Liquid-Radiation, Stephens-Stewart e Thornthwaite-Modified accused good estimate of ET0, presenting curves of regression near relation of 1:1. Of these, the first four methods deserve spotlight, because presented the regression coefficients "a" next to zero and the coefficient "b" near to unit. Have other methods, independent of evapotranspirometrical demand, presenting higher regressions coefficients and overestimated the values of ET0 in relation to standard method.

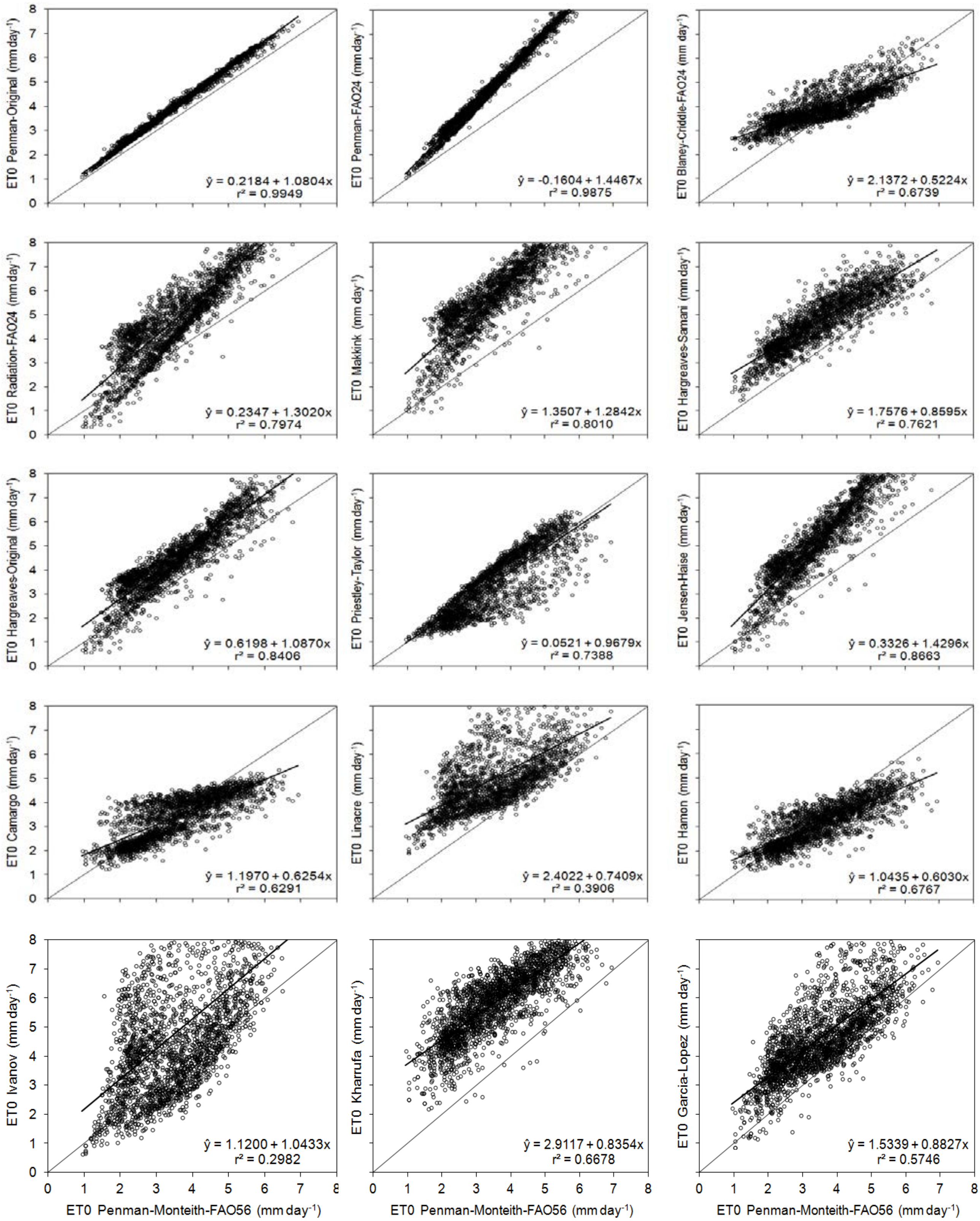

Figure 1 : Values of reference evapotranspiration (ET0) obtained through Penman-Monteith-FAO56 compared with ET0 values obtained through the methods studied.

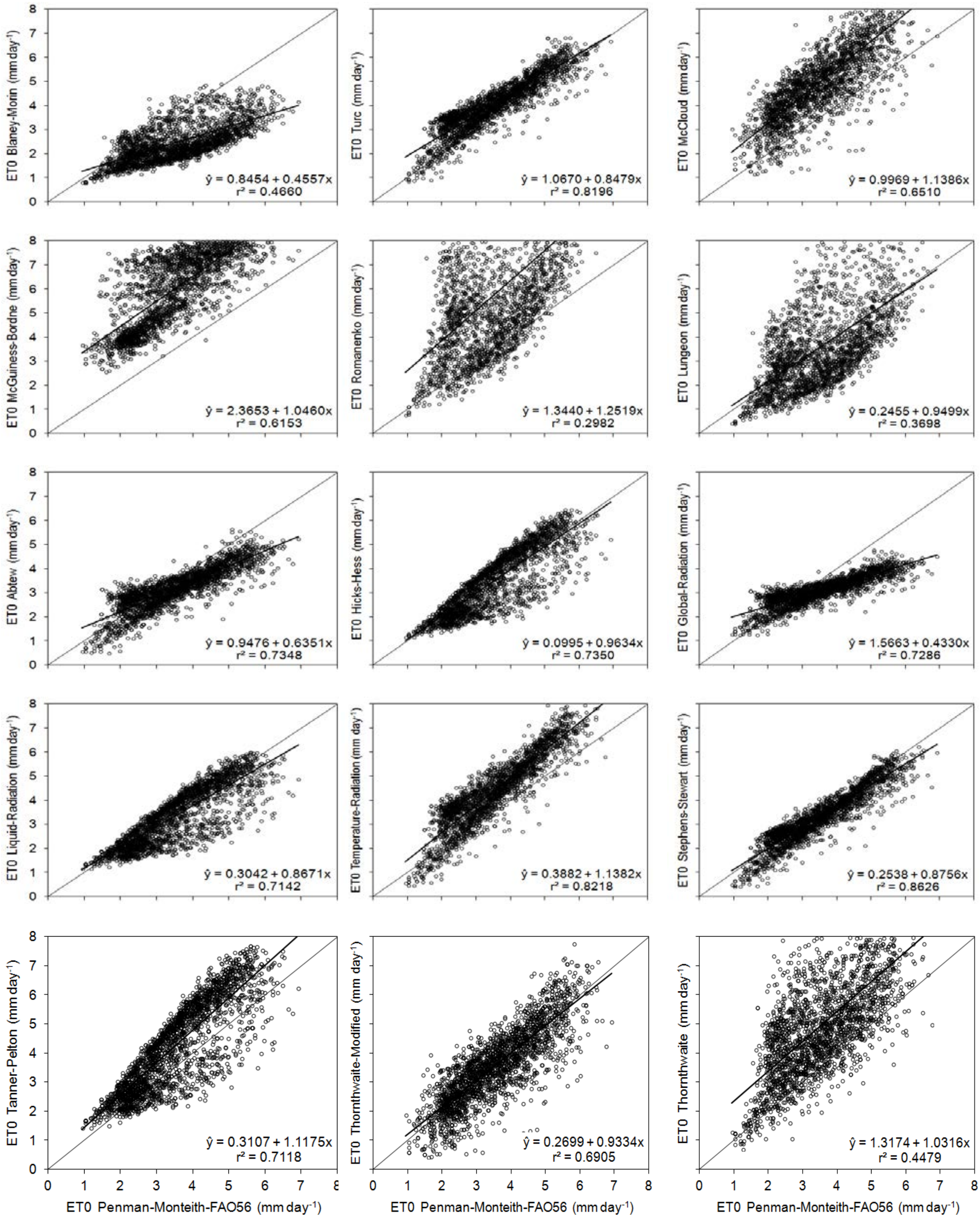

Figure 2 : Values of reference evapotranspiration (ET0) obtained through Penman-Monteith-FAO56 compared with ET0 values obtained through the methods studied.

It is observed also on the Figures 1 and 2 that the methods that presented the better adjustment, according with the determination coefficient (r^2), were the methods of Penman-Original (r^2 = 0.9949) and Penman-FAO24 (r^2 = 0.9875), that utilize the same input parameters that standard method. However, it is observed that the Penman-FAO24 overestimated the ET0 (Figure 1), corroborating with Barros et al. (2009). These authors affirmed that the simple adoption of r^2 as the only criterion of definition of quality of methods is not appropriate, once that this method does not establish the type and the magnitude of the differences between a standard value and a provided value by estimate models.

On the Table 2 are presented the estimate of standard-error (ESE), Willmot's concordance, Pearson's correlation (r), reliable coefficient (c) and performance of Camargo e Sentelhas (1997), obtained of correlation between the values of ET0 by the method of Penam-Monteith-FAO56 with the obtained by the methods available. It is observed that the better model to estimate of ET0 to Paranaíba city, according with the ESE and the performance of Camargo e Sentelhas (1997), was the method of Penman-Original corroboring with Cavalcante Jr. et al. (2011) in semi-arid Northeast, Brazil, Kisi et al. (2012) in United State of America and Cunha et al. (2013) in Chapadão do Sul city, Brazil. The Stephens-Stewart method presented performance "great" by having conciliated high values of Willmot's concordance of and Pearson's correlation. Furthermore, these methods showed the lower value of ESE confirming its satisfactory performance. However, this method need, beyond the temperature, global radiation or actual duration of sunshine in a day as input parameters, difficulting the utilization in relation to methods that need only datas of extraterrestrial radiation, temperature and relative humidity. It is worth mentioning that the extraterrestrial radiation can be obtained only with the date and latitude of the place, therefore not requiring devices to your measurement. Some authors also found satisfactory estimates of ET0 using the Stephens-Stewart method (KISI, 2009; KISI et al., 2012; SAHOO et al., 2012; CUNHA et al., 2013).

Table 2 : Estimate of standard-error (ESE), Willmott's concordance (d), Pearson's correlation (r), reliable coefficient (c) and Camargo and Sentelhas performance, obtained from correlations between the reference evapotranspiration values estimated by the studied methods, with values estimated by Penman-Monteith-FAO56 method in Paranaíba city, Brazil

Method	ET0	ESE	d	r	c	Performance
Penman-Monteith-FAO56	3.5356	-				
Penman-Original	4.0383	0.5193	0.9561	0.9976	0.9537	Great
Penman-FAO24	4.9544	1.5231	0.7771	0.9938	0.7723	Very good
Blaney-Criddle-FAO24	3.9843	0.8298	0.8132	0.8708	0.7082	Good
Radiation-FAO24	4.8380	1.5501	0.7620	0.9090	0.6926	Good
Makkink	5.8910	2.4928	0.5871	0.9074	0.5327	Badly
Hargreaves-Samani	4.7963	1.3888	0.7334	0.8969	0.6578	Average
Hargreaves-Original	4.4629	1.0834	0.8397	0.9270	0.7784	Very good
Priestley-Taylor	3.4741	0.6732	0.9223	0.9023	0.8321	Very good
Jensen-Haise	5.3871	2.0264	0.6775	0.9398	0.6368	Average
Camargo	3.4081	0.7198	0.8726	0.8785	0.7665	Very good
Linacre	5.0218	1.8599	0.6082	0.7441	0.4526	Not good
Hamon	3.1756	0.7601	0.8553	0.8858	0.7576	Good
Ivanov	4.8086	2.2559	0.5808	0.7226	0.4197	Not good
Kharrufa	5.8654	2.4366	0.5397	0.8751	0.4723	Not good
Garcia-Lopez	4.6547	1.4324	0.7279	0.8218	0.5981	Badly
Blaney-Morin	2.4566	1.3738	0.6492	0.7861	0.5104	Badly
Turc	4.0649	0.7250	0.8995	0.9167	0.8245	Very good
McCloud	5.0226	1.7827	0.6883	0.8568	0.5897	Badly
McGuiness-Bordne	6.0635	2.7059	0.5174	0.8759	0.4531	Not good
Romanenko	5.7703	3.1736	0.4755	0.7226	0.3436	Terrible
Lungeon	3.6041	1.4451	0.7318	0.7413	0.5425	Badly
Abtew	3.1932	0.7030	0.8769	0.8783	0.7702	Very good
Hicks-Hess	3.5058	0.6748	0.9216	0.9010	0.8304	Very good
Global-Radiation	3.0972	0.8495	0.7753	0.8760	0.6792	Good
Liquid-Radiation	3.3699	0.6769	0.9138	0.8941	0.8170	Very good
Temperature-Radiation	4.4124	1.0841	0.8455	0.9193	0.7773	Very good
Stephens-Stewart	3.3494	0.4699	0.9558	0.9379	0.8965	Great
Tanner-Pelton	4.2615	1.1090	0.8355	0.8933	0.7463	Good
Thornthwaite-Modified	3.5698	0.7316	0.9064	0.8757	0.7938	Very good
Thornthwaite	4.9645	1.9540	0.6402	0.7773	0.4977	Not good

The methods Penman-FAO24, Hargreaves-Original, Turc, Abtew, Hicks-Hess, Liquid-Radiation, Temperature-Radiation received performance "very good", according Camargo e Sentelhas (1997). This methods can be utilized to estimating of ET0 in Paranaíba city but present the inconvenient dependence of global radiation to your calculate, as reported previously to the method of Stephens-Stewart.

Despite the Penman-FAO24 method have presented r^2 satisfactory, your value of Willmott's concordance not obtained the same success, making with your performance were classified only as "very good". These result can be explained by the fact of the values estimated by Penman-FAO24 have overestimated appreciably the ET0 in relation to standard method in moments of high rate evapotranspirometrical (Figure 1), with this, in comparison between these point values of ET0, there was a reduction in the value of concordance index.

The methods Priestley-Taylor, Camargo e Thornthwaite-Modified also received performance "very good", according Camargo e Sentelhas (1967). The Priestley-Taylor method was development to estimate of evaporation of satured surfaces in a not saturated atmosphere, that is the normal condition of nature (BARROS et al., 2009; CAVALCANTE Jr. et al., 2011) and your performance corroborated with Cunha et al. (2013) in Chapadão do Sul city, Brazil. Oliveira et al. (2011) in Aquidauana city, Brazil and Moura et al. (2013) in the state of Pernambuco state, Brazil also observed good estimates of ET0 by the Camargo method. To be quite simple, requiring only medium temperature data, it is expected that the Camargo methodology to be used by those is producers devoid of complete weather stations. The Thornthwaite-Modified method can be used in the study area. Among all methods studied in this research, the equations Thornthwaite-Modified along with Thornthwaite who received "bad" performance are the only physical equations.

The methods Blaney-Criddle-FAO24, Radiation-FAO24, Hamon, Global-Radiation e Tanner-Pelton received performance "good" and can be utilized with restriction. The Blaney-Criddle-FAO24 methods and Hamon presented simplicity in your calculate, and only the air temperature as input parameter measured. Thus, it will be able to obtain calibration from this methods for those producers without condition of acquire a meteorological station complete can obtain estimate reliable of ET0 to the proper irrigation management, using only a thermometer.

The other evaluated methods received performance "Not good", "badly" or "terrible" performance and should not be used to estimate ET0 in Paranaíba city.

IV. Conclusions

In order, the best methods for estimating evapotranspiration reference to Paranaíba city, Brazil are: Penman-Original, Stephens-Stewart, Priestley-Taylor, Hicks-Hess, Turc, Liquid-Radiation, Thornthwaite-Modified, Temperature-Radiation, Penman-FAO24, Abtew and Camargo.

When have only temperature data, it is recommended using the method of Camargo to estimate reference evapotranspiration in Paranaíba city.

The Blaney-Criddle-FAO24 and Hamon methods after receiving calibration can be used to estimate reference evapotranspiration in Paranaíba city.

References Références Referencias

1. ALLEN, R.G.; JENSEN, M.E.; WRIGHT, J.; BURMAN, R.D. Operational estimates of reference evapotranspiration. **Agronomy Journal**, Madison, v.81, n.4, p.650-662, 1989.
2. ALLEN, R.G.; PEREIRA, L.S.; RAES, D.; SMITH, M. **Crop evapotranspiration: Guidelines for computing crop water requirements**. Rome: FAO, 1998. 300p. (Irrigation and Drainage Paper, 56).
3. BARROS, V.R.; SOUZA, A.P.; FONSECA, D.C.; SILVA, L.B.D. Avaliação da evapotranspiração de referência na região de Seropédica, Rio de Janeiro, utilizando lisímetro de pesagem e modelos matemáticos. **Revista Brasileira de Ciências Agrárias**, Recife, v.4, n.2, p.198-203, 2009.
4. CAMARGO, A.P.; SENTELHAS, P.C. Avaliação do desempenho de diferentes métodos de estimativa da evapotranspiração potencial no estado de São Paulo. **Revista Brasileira de Agrometeorologia**, Santa Maria, v.5, n.1, p.89-97, 1997.
5. CAVALCANTE JR., E.G.; OLIVEIRA, A.D.; ALMEIDA, B.M.; ESPÍNOLA SOBRINHO, J. Métodos de estimativa da evapotranspiração de referência para as condições do semiárido Nordestino. **Semina: Ciências Agrárias**, Londrina, v.32, n.supl., p.1699-1708, 2011.
6. COHEN, J. **Statistical power analysis for the behavioral sciences**. New Jersey: Lawrence Erlbaum, 1988. 569p.
7. CUNHA, F.F.; MAGALHÃES, F.F.; CASTRO, M.A. Métodos para estimativa da evapotranspiração de referência para Chapadão do Sul-MS. **Engenharia na Agricultura**, Viçosa, v.21, n.2, p.159-172, 2013.
8. KISI, O. Modeling monthly evaporation using two different neural computing techniques. **Irrigation Science**, New York, v.29, n.2, p.417-430, 2009.
9. KISI, O.; ALI BABA, A.P.; SHIRI, J. Generalized neurofuzzy models for estimating daily pan evaporation values from weather data. **Journal of Irrigation and Drainage Engineering**, New York, v.138, n.4, p.349-362, 2012.

10. MOURA, A.R.C; MONTENEGRO, S.M.G.L.; ANTONINO, A.C.D.; AZEVEDO, J.R.G.; SILVA, B.B.; OLIVEIRA, L.M.M. Evapotranspiração de referência baseada em métodos empíricos em bacia experimental no Estado de Pernambuco. **Revista Brasileira de Meteorologia**, São José dos Campos, v.28, n.2, p.181-191, 2013.
11. OLIVEIRA, G.Q.; LOPES, A.S.; JUNG, L.H.; NAGEL, P.L.; BERTOLI, D.M. Desempenho de métodos de estimativa da evapotranspiração de referência baseadas na temperatura do ar, em Aquidauana-MS. **Revista Brasileira de Agricultura Irrigada**, Fortaleza, v.5, n.3, p.224-234, 2011.
12. SAHOO, B.; WALLING, I.; DEKA, B.C.; BHATT, B.P. Standardization of reference evapotranspiration models for a sub-humid Valley Rangeland of Eastern Himalayas. **Journal of Irrigation and Drainage Engineering**, New York, v.138, n.10, p.880-895, 2012.

Global Journal of Human-Social Science (B) Volume XV Issue I Version I Year 2015