INFLUENCE OF DIFFERENT METHODS OF POTENTIAL EVAPOTRANSPIRATION ESTIMATION IN THE CATOLÉ GRANDE RIVER FLOW USING THE SWAT MODEL

Lorena Lima Ferraz[1], Lucas Farias de Sousa[2], Lorena Júlio Gonçalves[3], Rodrigo Lacerda Brito Neto[4], Carlos Amilton Silva Santos[5], Felizardo Adenilson Rocha[6]

ABSTRACT: The evapotranspiration is an important element in the hydrological simulation for flow estimation, infiltration calculations, and drought forecasting models. Several equations vary in the amount of input data and can be used to estimate annual, monthly and daily evapotranspiration in different regions around the world. In the present study, the potential evapotranspiration of the Catolé Grande river basin was estimated by three SWAT methods: Penman-Monteith, Hargreaves-Samani, and Priestley Taylor. The influence of the use of these methods was evaluated in the simulated Catolé river flow using the coefficient of determination (R^2), Nash-Sutcliffe and the Pbias index. The results of the statistical coefficients showed that the change in the estimation method of potential evapotranspiration affected the simulated flow. Statistical analysis using the Mann-Whitney test indicated that the Penman-Monteith and Hargreaves-Samani models did not show significant differences in flow response, while Priesley-Taylor influenced considerably the estimation result, overestimating all flow values, not being relevant to minimize damages caused by possible large floods, as well as to assist in the development of studies associated with hydrographic rise periods. Thus, the Hargreaves-Samani and Penman-Monteih methods proved adequate for hydrological modeling of the Catolé Grande river basin.

KEYWORDS: ETo Estimation Method, Hydrological Modeling, Simulation.

[1]Mestranda do Programa de Pós-Graduação em Desenvolvimento Regional e Meio Ambiente, Universidade Estadual de Santa Cruz. Fone: (77)99994-0677, e-mail: lorenalferraz@gmail.com.
[2]Doutorando do Programa de Pós-Graduação em Desenvolvimento e Meio Ambiente, Universidade Estadual de Santa Cruz.
[3]Mestranda do Programa de Pós-Graduação em Agronomia, Universidade Estadual do Sudoeste da Bahia.
[4]Mestre em Ciências Florestais, Universidade Estadual do Sudoeste da Bahia.
[5]Professor Doutor do Instituto Federal da Bahia, Campus Vitória da Conquista.
[6]Professor Doutor do Instituto Federal da Bahia, Campus Vitória da Conquista.

INFLUÊNCIA DE DIFERENTES MÉTODOS DE ESTIMATIVA DE EVAPOTRANSPIRAÇÃO POTENCIAL NA VAZÃO DO RIO CATOLÉ GRANDE USANDO O MODELO SWAT

RESUMO: A evapotranspiração é um importante elemento na simulação hidrológica para estimativa da vazão, cálculos de infiltração e modelos de previsão de seca. Várias equações variam na quantidade de variáveis e podem ser usadas para estimar a evapotranspiração anual, mensal e diária em diferentes regiões em todo o mundo. Dessa forma, o presente trabalho teve como objetivo avaliar a influência de três diferentes métodos de estimativa da evapotranspiração potencial na resposta da vazão do rio Catolé Grande usando o modelo de simulação hidrológica SWAT. A evapotranspiração potencial da bacia hidrográfica do rio Catolé Grande foi estimada por três métodos inseridos no modelo SWAT: Penman-Monteith, Hargreaves-Samani e Priestley Taylor. A influência da utilização destes métodos foi avaliada na vazão simulada do rio Catolé utilizando coeficiente de determinação (R^2), Nash-Sutcliffe e o índice Pbias. Os resultados dos coeficientes estatísticos mostraram que a alteração no método de estimativa da evapotranspiração potencial afetou o escoamento simulado. A análise estatística utilizando o teste de Mann-Whitney indicou que os modelos de Penman-Monteith e Hargreaves-Samani não apresentaram diferenças significativas na resposta da vazão, enquanto Priesley-Taylor influencia consideravelmente o resultado da estimativa, superestimando todos os valores de vazão. Assim sendo, os métodos de Hargreaves-Samani e Penman-Monteih se mostraram adequados para modelagem hidrológica da bacia do rio Catolé Grande.

PALAVRAS-CHAVE: Métodos de estimativa de ETo, Modelagem hidrológica, simulação.

INTRODUCTION

The understanding of the water cycle is essential to reach a desirable level of water resource preservation. It is necessary to develop studies aimed at monitoring and analyzing the main variables of the hydrological cycle (BALBINOT et al., 2008). Thus, one of the scientific ways to obtain answers to the real effects of changes in the basin is through the modeling of environmental systems. This tool enables the representation of climatic, hydrological, hydraulic, water quality, environmental conditions, operational and economic aspects.

In the modeling of environmental systems, it is worth mentioning the use of hydrological models, which allow the study and evaluation of water balance at a spatial and temporal scale, and can be widely used in decision-making to control environmental problems in watersheds (TUCCI, 2005). Thus, these models have been gaining ground by presenting themselves as an instrument for assessing the hydrological behavior of watersheds, and Soil Water Assessment Tools (SWAT) is one of the most widely used and internationally known for showing itself as a robust interdisciplinary tool with respect to to the modeling of hydrological processes (GASSMAN et al., 2007).

One of the variables of the water balance and key element in the hydrological simulation is the evapotranspiration (ET) whose estimation models are based on the use of climatic data. The evapotranspiration estimation methodologies associated with SWAT are: the standard Penman-Monteith method FAO 56, which is based on physical principles and demands the greatest demand for climatic variables such as temperature, radiation, humidity and wind speed; Hargreaves-Samani, which requires maximum and minimum temperatures, as well as radiation; and Priestley-Taylor, in which only the radiative terms are considered.

According to Schneider et al. (2007), evapotranspiration may play a significantly larger role in the water balance of the semi-arid basins because it represents the largest water withdrawal in the system. Santos et al. (2018) reinforce the statement by showing that evapotranspiration is responsible for the loss of up to 86% of the water system, after applying the SWAT model to a semi-arid region of Northeast Brazil. Thus, the use of different methodologies in the calculation of potential evapotranspiration (ETo) may represent influences on the calculated amount of available water in the river basin.

Thus, the present work had as objective to evaluate the influence of different methods of estimation of potential evapotranspiration in hydrological modeling at the Catolé Grande river basin using the SWAT model.

MATERIAL AND METHODS

The Catolé Grande River Basin is an important regional basin located in the southwest region of Bahia, occupying an area of 3,128.81 km² and a perimeter of 343.95 km (Figure 1). The Catolé Grande River has its source located in the city of Vitória da Conquista and drains the Rio Pardo channel, with its control section downstream from the city of Itapetinga. According to the Köppen classification, the climate in the region is classified as semi-arid

Bswh, subtropical tropical (Aw) and tropical altitude (Cwb), characterized by a hot and dry climate, with annual average rainfall less than 900 mm, very short rainy season and severe drought (SEI, 1998).

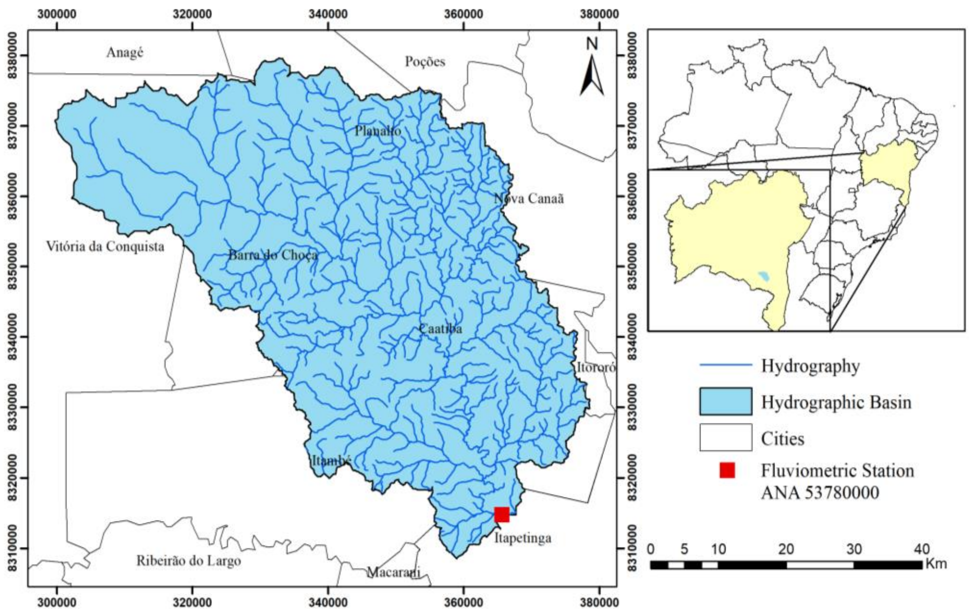

Figure 1. Location map of the Catolé Grande River basin.

In the processing, the software ArcSWAT (Version 2012) associated with ArcGIS (ESRI - Version 10.1) was used. The calibration period was defined between the years 1987 and 1996 and the validation between the years of 1997 and 2011. For the estimation of surface runoff and evapotranspiration, the Curve Number and Penman-Monteith methods were used, respectively. The ETo estimate was made with daily weather data from 1987 to 2011, obtained from the conventional weather station of the Southwest Bahia State University located in Vitória da Conquista - BA, at geographic coordinates 14°53'24” S and 40°48 ' W.

For flow calculation, the SWAT model uses the following water balance equation:

$$SW_t = SW_0 + \sum_{i=1}^{t} (R_{day} - Q_{surf} - E_a - W_{seep} - Q_{gw}) \quad (1)$$

Where,

SW_t - Final soil water content (mm);

SW_0 - Initial soil water content on day *i* (mm);

t - Simulation period (days);

R_{day} - Precipitation on day *i* (mm);

Q_{surf} - Surface runoff on day *i* (mm);

E_a - Evapotranspiration on day *i* (mm);

W_{seep} - Amount of water entering the vadose zone from the soil profile on day *i* (mm);

Q_{gw} - Return flow on day *i* (mm).

Some of the most widely used models for calculating ETo, according to Jensen et al. (1990) are the Hargreaves-Samani equations (HARGREAVES et al., 1985), Penman-Monteith (MONTEITH, 1965) and Priestley-Taylor (PRIESTLEY AND TAYLOR, 1972), which are also the three methods present in the SWAT model to perform the estimation of variable E_a of Equation 1.

Currently considered the standard method for estimating ETo is the Penman-Monteith FAO 56 (PM). This model is based on physical principles and has a higher demand for climate data as well as various vegetation characteristics (ALLEN et al., 1998; MCKENNEY and ROSEMBERG, 1993). Equation 2 describes the PM model:

$$ET_O = \frac{0,408.\Delta.R_n + \gamma.\frac{900}{T+273}.u_2.\Delta_e}{\Delta + \gamma.(1 + 0,34.u_2)} \quad (2)$$

Where,

R_n - Net radiation (MJ m^{-2} d^{-1});

T - Mean daily air temperature at a height of 2 m (ºC);

u_2 - Wind speed at a height of 2 m (m s^{-1});

Δ - Slope of the vapor pressure curve (kPa ºC^{-1});

Δe - Vapor saturation pressure deficit (kPa);

γ - Psychrometric constant (kPa ºC^{-1}).

Hargreaves and Samani (1985) proposed the following equation (Equation 3) to estimate daily ETo using data obtained from the Davis lysimeter (California City) which has a semi-arid climate (PEREIRA et al., 1997):

$$ET_O = 0,0023.Q_O.(T_{máx} - T_{min})^{0,5}.(T + 17,8) \quad (3)$$

Em que,

Q_o - Extraterrestrial radiation (mm dia^{-1});

$T_{máx}$ - Maximum temperature (ºC);

T_{min} - Minimum temperature (ºC);

T - Average temperature (ºC).

The Priestley-Taylor Method (Equation 4) is a simplification of the PM equation. It has a lower requirement on the number of climatic variables, where only the diabetic (thermodynamic) terms corrected by a coefficient are considered (SILVA et al., 2015).

$$ET_O = \alpha . W . (R_n - G) \quad (4)$$

Em que,

α - Adjustment factor: Priestley-Taylor parameter;

W - Weighting factor dependent on temperature, relative humidity and psychometric coefficient;

Rn - Liquid solar radiation available (MJ m^{-2} d^{-1});

G - Soil heat flow (MJ m^{-2} d^{-1}).

To evaluate the model performance, three precision statistics were used: the Nash-Sutcliffe coefficient (NASH and SUTCLIFFE, 1970), the bias percentage and the determination coefficient (R^2), using the criterion proposed by Moriasi et al. (2015), described in Table 1.

Table 1. Hydrological model performance evaluation criteria and range of values

Coefficient	**Performance Evaluation Criteria**				
	Very good	**Good**	**Satisfactory**	**Unsatisfactory**	**Range**
R^2	$R^2 > 0.85$	$0.75 < R^2 \leq 0.85$	$0.60 < R^2 \leq 0.75$	$R^2 \leq 0.60$	-1 a 1
NSE	NSE > 0.80	0.70 < NSE ≤ 0.80	0.50 < NSE ≤ 0.70	NSE ≤ 0.50	-∞ a 1.0
PBIAS (%)	PBIAS <±5	±5 ≤ PBIAS <±10	±10 ≤ PBIAS <±15	PBIAS ≥±15	-∞ a ∞

The observed and simulated flow data considering the different ETo estimation methods were submitted to the Kolmogorov-Smirnov test, using the software SPSS version 21, in order to evaluate whether or not the data follow a normal distribution. After verifying the hypothesis of data normality, the homogeneity hypothesis test was applied to evaluate the stationarity of the series, ie to detect trends and abrupt changes. Considering that the flow data had no normal distribution, the Mann-Whitney nonparametric test was applied to compare the observed flows with those simulated by the SWAT, with a significance level of 1%.

RESULTS AND DISCUSSION

The statistical coefficients obtained on the monthly time scale for flow estimation efficiency analysis considering each ETo calculation method are presented in Table 2. In the scenario using the reference method, the value obtained for NSE was classified as “satisfactory” and the Pbias as “very good” for studying monthly flow rates.

Several authors used the SWAT model to simulate monthly flows considering the Penman-Monteith method, obtaining good values of statistical coefficients. Andrade et al. (2013), performing the hydrological simulation in a watershed in the Alto Rio Grande-MG region, found Nash-Sutcliffe coefficient values of 0.66. Santos et al. (2018), calibrating the SWAT model in three sub-basins of the semi-arid Northeast of Brazil, obtained the NSE coefficient of 0.76 for monthly flows in the Andaraí River sub-basin.

Considering the Hargreaves-Samani model, the value of Pbias was rated "good". As positive, the Pbias value indicates that the simulated flow data were underestimated, resulting in a decrease in the NSE compared to the reference method.

Table 2. Values of the statistical coefficients referring to the observed and calculated flow considering each ETo estimation method.

Eto estimation methods	Coefficients		
	R^2	NSE	Pbias (%)
Penman-Monteith	0.73 (satisfactory)	0.7 (satisfactory)	3.61 (very good)
Hargreaves-Samani	0.65 (good)	0.6 (satisfactory)	8.83 (satisfactory)
Priestley-Taylor	0.64 (good)	0.18 (unsatisfactory)	-37.92 (unsatisfactory)

According to Pereira et al. (1997), Hargreaves-Samani is indicated for semiarid regions due to climatic similarities related to the development site and initial calibration of the model, which explains its good performance in the present study. Aouissi et al. (2016) concluded that hydrologic simulations in a rural Tunisian basin of the same climatic characteristics were close to those observed using the Hargreaves-Samani method, with a Nash-Sutcliffe efficiency of 0.90 and an R^2 value of 0.92, considered “very good” according to Moriasi et al. (2015).

The results obtained by Kavian et al. (2017), comparing potential evapotranspiration estimation methods in the hydrological modeling of the Taleghan Basin using the SWAT model corroborate with the statement that the Hargreaves-Samani method provided better flow simulation results than the Penman-Monteith and Priestley-Taylor because it is a locality of arid and semi-arid climates.

In the hydrological simulation using the scenario where the Priestley-Taylor method is used to estimate evapotranspiration, the values of the NSE and Pbias coefficients were classified as "unsatisfactory". The negative Pbias value indicates the overestimation of the model, generating higher flow values than the observed actual data and other methods studied for both maximum values (peak flow) and minimum values (drought periods).

Schneider et al. (2007), evaluating which evapotranspiration method is most suitable for a basin located in a semi-arid climate in northern China, also sought to investigate whether the performance of the SWAT model can be improved by using the most appropriate evapotranspiration method. They concluded that the Hargreaves-Samani equation was more efficient than the other methods tested and the Priestley-Taylor method overestimated the flow values by almost 38%, superior to the other methodologies evaluated.

Wang et al. (2006), testing the three ETo estimation methods available within the SWAT framework in the Wild Rice River basin in northwest Minnesota, concluded that the Priestley-Taylor model overestimated the observed Q_{mean} by 30%, while Penman-Monteith and Hargreaves-Samani presented simulated mean flow values 23 and 16.4% above the observed levels.

Figure 2 shows the results of the regression analysis between simulated and observed monthly flow data. Regression coefficients showed that there were differences between observations and simulations with the Hargreaves-Samani and Priestley-Taylor methods compared to the reference method (Penman-Monteith), which presents higher reliability for flow estimation.

The value obtained for the R^2 statistic for the reference method was 0.73, so the model can be classified as “satisfactory”, showing a good correlation trend. Considering the Hargreaves-Samani method, the values found for R^2 were classified as a good correlation of observed and simulated data. Analysis using the R^2 coefficient showed that the Priestley-Taylor model tended to overestimate the flow values, exposing the lowest correlation value, with R^2 in the range of 0.644.

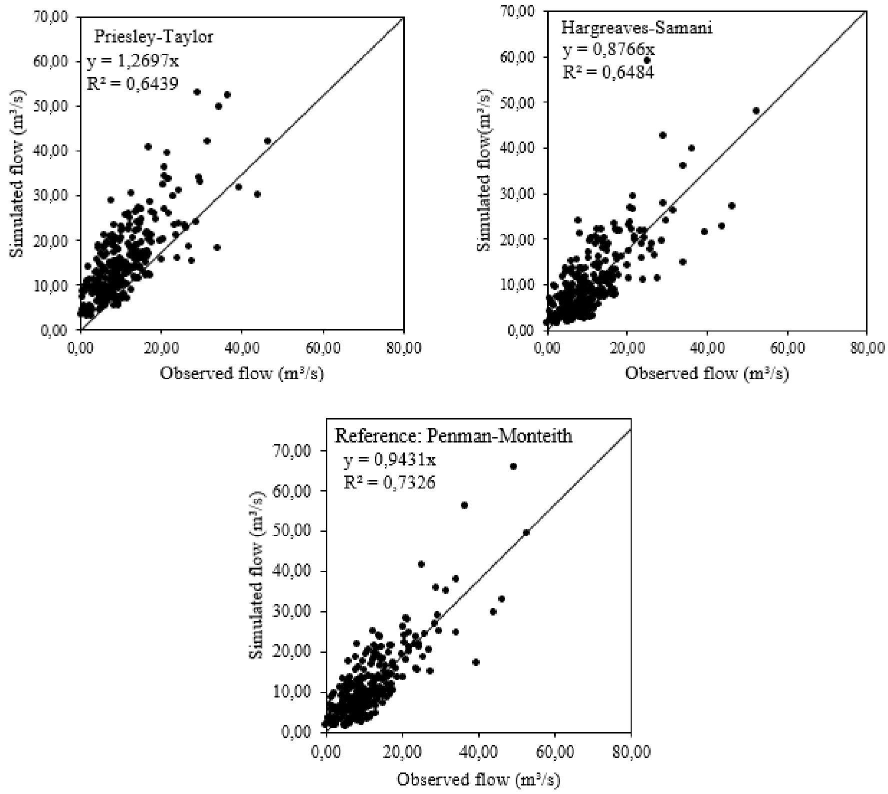

Figure 2. Regression analysis between simulated and observed flow.

Figure 3 presents the flow duration curves for the basin on a logarithmic scale, aiming at a better perception of the adjustment of low, medium and high flow rates. Analyzing the curves, we notice the good fit between observed and simulated data by Penman-Monteith and Hargreaves-Samani, as well as the overestimation of all flows using Priestley-Taylor to estimate potential evapotranspiration.

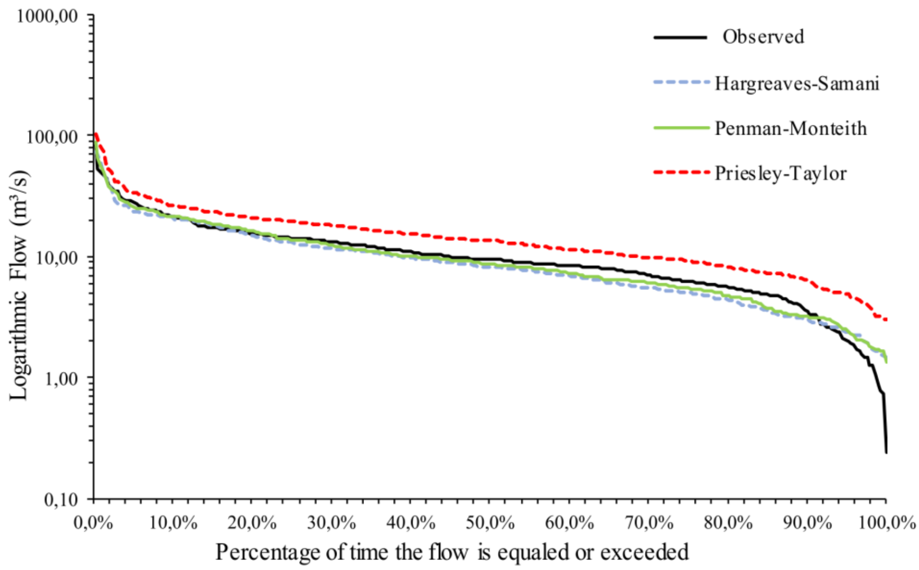

Figure 3. Observed and simulated flow duration curves by each ETo estimation method from 1987 to 2011.

The variations in the maximum, average and minimum flow rates caused by the change in the potential evapotranspiration estimation methodology can be observed in Table 3. The results of the simulations were compared with the observed values of maximum and average flow, as well as the permanence curve for the concessions of water in the state of Bahia.

Table 3. Permanence flows observed and simulated by each ETo estimation method as well as the error associated with the calculations.

Q_{90}[1] obs (m³/s)	Penman-Monteith		Hargreaves-Samani		Priestley-Taylor	
	Q_{90} est. (m³/s)	ER (%)	Q_{90} est. (m³/s)	ER (%)	Q_{90} est. (m³/s)	ER (%)
3.57	3.02	15.4	3.2	10.36	6.35	77.87
Q_{mean}[2] obs (m³/s)	Q_{mean} est (m³/s)	ER (%)	Q_{mean} est (m³/s)	ER (%)	Q_{mean} est (m³/s)	ER (%)
11.60	11.18	3.62	10.58	8.8	16.00	37.93
Q_{10}[3] obs (m³/s)	Q_{10} est (m³/s)	ER (%)	Q_{10} est (m³/s)	ER (%)	Q_{10} est (m³/s)	ER (%)
21.17	21.41	1.13	20.46	3.35	23.60	24.23

[1]Minimum flow (Q_{90}); [2]Average flow (Q_{mean}); [3]Maximum flow (Q_{10})

Regarding the lower frequency values (higher flow rates), the optimal adjustment of flow rates with 10% permanence (Q10) is visualized for the Penman-Monteith and Hargreaves-Samani methods, showing an error of 1.13 and 3.35%, respectively, about the observed Q10. Regarding the average flow rates, the Penman-Monteith method offers higher levels of accuracy than the other methods, indicating an average error of 3.62%. The minimum flow rates were better adjusted using Hargreaves-Samani, with an error of 3.2% less.

By analyzing the similar behavior of the flow duration curves (Figure 3) regarding the Hargreaves-Samani and Penman-Monteith methods with the observed data, the results attest to the good performance of the models for hydrological studies, demonstrating the qualities required for flow prediction. for various uses.

The results indicate that the Priestley-Taylor model overestimates the flow to maximum, medium and minimum values, corroborating with the flow duration curve observed in Figure 3, showing an error that reached 77.87% in the estimation of permanence flows Q_{90}.

Pereira et al. (2014) stated that errors up to 30% in simulated flows are considered satisfactory for the concession of water use in irrigated areas of Brazil. Thus, this method is not suitable for hydrological behavior analysis to predict the flow of this basin and it is not relevant to minimize the damage resulting from possible major floods, as well as to assist in the development of studies associated with the periods of hydrographic rise.

After applying the statistical tests, it was observed that the choice of Penman-Monteith and Hargreaves-Samani models do not affect the flow calculation at the 1% level by the Mann Whitney test. On the other hand, comparing the observed flow with the simulated flow from the Priesley-Taylor model, this one presented a statistically significant difference.

CONCLUSIONS

In the change simulations of the potential evapotranspiration estimation method for the calculation of the Catolé Grande river flow, the analysis of the statistical coefficients shows that the Hargreaves-Samani equation provides satisfactory results. The Priestley-Taylor method was not suitable for use in the basin in question.

Regarding the permanence flow rates, the Penman-Monteith and Hargreaves-Samani methods presented similar behavior, and the maximum flow rates presented better estimates by both methods. The choice of the Priestley-Taylor model caused the overestimation of all permanence flow values analyzed.

Statistical analysis using the Mann-Whitney test indicated that the Penman-Monteith and Hargreaves-Samani methods were the most efficient, being statistically similar for the hydrological simulation of the Catolé Grande river basin, being the Priestley-Taylor method not suitable to estimate the flow rate by the SWAT model.

REFERENCES

ALLEN, R. G.; PEREIRA, L.; RAES, D.; SMITH, M. **Crop evapotranspiration: guidelines for computing crop water requirements**. Rome: FAO, 1998. (FAO. Irrigation and Drainage Paper, 56). Disponível em: Acesso em: 19 dez. 2018.

ANDRADE, M. A.; MELLO, C. R.; BESKOW, S. Simulação hidrológica em uma bacia hidrográfica representativa dos Latossolos na região Alto Rio Grande, MG. **Revista Brasileira de Engenharia Agrícola e Ambiental**, v. 17, n. 1, p.69–76, 2013.

AOUISSI, J.; BENABDALLAH, S.; CHABAAÂNE, Z. L.; CUDENNEC, C. Evaluation of potential evapotranspiration assessment methods for hydrological modelling with SWAT—

Application in data-scarce rural Tunisia. **Agricultural Water Management**, n. 174, p. 39-51, 2016.

BALBINOT, R.; OLIVEIRA, N. K.; VANZETTO, S. C.; PEDROSO, K.; VALÉRIO, A. F. O papel da floresta no ciclo hidrológico em bacias hidrográficas. **Ambiência**, vol. 4, n. 1, 2008.

GASSMAN, P. W.; REYES, M. R.; GREEN C. H.; ARNOLD, J. G. The soil and water assessment tool: historical development, applications, and future research directions. **Transaction of the ASABE**, v.50, p.1211-1250, 2007.

HARGREAVES, G. H.; SAMANI, Z. A. Reference crop evapotranspiration from temperature. **Appl. Eng. Agric.**, vol. 1, p. 96-99, 1985.

JENSEN, M. E.; BURMAN, R. D.; ALLEN, R. G. Evapotranspiration and Irrigation Water Requirements. **ASCE Manuals and Reports on Eng. Practice**, n. 70, 1990.

KAVIAN, A.; BAHRAMI, M.; ROUHANI, H. Comparison of Potential Evapotranspiration Estimation Methods in Stream flow Modeling Using SWAT in Taleghan Watershed. **Desert Ecosystem Engineering Journal**, vol. 6, n. 15, p. 115-125, 2017.

MCKENNEY, M. S.; ROSENBERG, N. J. Sensitivity of some potential evapotranspiration estimation methods to climate change. **Agricultural and Forest Meteorology**, vol. 64, n. 1-2, p. 81–110, 1993.

MONTEITH, J. L. Evaporation and Environment. **Symp. Soc. For Exper. Biol**., vol. 19, p. 205-234, 1965.

MORIASI, D. N.; GITAU, M. W.; PAI, N.; DAGGUPATI, P. Hydrologic and water quality models: Performance measures and evaluation criteria. **Trans. ASABE**, vol. 58, n.6, p. 1763-1785, 2015.

NASH, J.; SUTCLIFFE, J. River flow forecasting through conceptual models: Part I. A discussion of principles. **Jounal of Hydrology**, vol. 10, n. 3, p. 282-290, 1970.

PEREIRA, D. D. R.; MARTINEZ, M. A.; ALMEIDA, A. Q.; PRUSKI, F. F.; SILVA, D. D.; ZONTA, J. H. Hydrological simulation using SWAT model in headwater basin in Southeast Brazil. **Eng. Agríc.**, vol. 34, n.4, p. 789–799, 2014.

PEREIRA, A. R.; VILLA NOVA, N. A.; SEDIYAMA, G. C. **Evapo(transpi)ração**. Piracicaba: FEALQ. 1997. 183p.

PRIESTLEY, C. H. B.; TAYLOR, R. J. On the Assessment of Surface Heat Flux and Evaporation Using Large Scale Parameters. **Mon. Weather Rev.**, vol. 100, p. 81-92, 1972.

SANTOS, C. A. S.; ALMEIDA, C.; RAMOS, T. B.; ROCHA, F. A.; OLIVEIRA, R.; NEVES, R. Using a Hierarchical Approach to Calibrate SWAT and Predict the Semi-Arid Hydrologic Regime of Northeastern Brazil. **Water**, vol. 10, n. 9, p. 1137, 2018.

SEI - Superintendência de Estudos Econômicos e Sociais da Bahia. Tipologia climática de Köppen. Estado da Bahia. 1998. Disponível em: <http://www.sei.ba.gov.br/site/geoambientais/mapas/pdf/tipologia_climatica_segundo_koppen_2014.pdf>. Acesso em: 04 fev. 2019.

SILVA, V. P. R. et al. Methods for estimating the sugarcane evapotranspiration under rainfed conditions. **Revista Brasileira de Engenharia Agrícola e Ambiental**, v. 19, n. 5, p. 411–417, 2015.

SCHNEIDER, K.; KETZER, B.; BREUER, L.; VACHÉ, K. B.; BERNHOFER, C.; FREDE, H. G. Evaluation of evapotranspiration methods for model validation in a semi-arid watershed in northern China. **Advances in Geosciences,** vol. 11, p. 37-42, 2007.

TUCCI, C. E. M. **Modelos hidrológicos**. 2.ed. Porto Alegre: ABRH/Editora da UFRGS, 2005.

WANG, X.; MELESSE, A. M.; YANG, W. Influences of potential evapotranspiration estimation methods on swat's hydrologic simulation in a Northwestern Minnesota watershed. **Transactions of the ASABE**, vol. 49, n. 6, p. 1755-1771, 2006.