



Evaluation of potential evapotranspiration assessment methods for hydrological modelling with SWAT in the Densu river basin in Ghana

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Abstract

Accurate estimation of evapotranspiration (ET) is required for a good estimation of available water for use in any catchment as ET constitutes major means by which water is lost in any catchment. SWAT model uses climate data in estimating potential evapotranspiration (PET). The PET together with other parameters is then used in estimating actual evapotranspiration (AET). SWAT model provides three different methods in estimating PET which are Penman–Monteith (PM), Hargreaves (H) and Priestly–Taylor (PT). These three PET methods were evaluated in a limited available spatial and temporal data Densu river basin to assess their impact on the resulted model water balance. The missing data in the 8 climate stations that were used in this study were estimated using a WXGEN weather generator. The results showed that the accuracy of the water balance from the SWAT model was defined by how well the PET method selected for the SWAT was able to estimate an accurate spatial and temporal distributed PET in the basin. A discharge at Nsawam, a town within the basin, was used for the model calibration and validation. Hargreaves PET method had the best Nash–Sutcliffe model efficiency coefficient (NSE) values of 0.70 for the calibration and 0.74 for validation period, while the PM PET method had the worse NSE value of 0.66 for calibration and 0.62 for validation. These results were attributed to the limited available data within the basin. The discrepancies in the resultant water balance model could be attributed to the three different PET methods used in relation to the climate data that were available for the calibration and validation of the SWAT model.

Keywords Densu River Basin · Potential Evapotranspiration · Actual Evapotranspiration · SWAT Model · Weather Generator

Introduction

A number of hydrological models of different temporal and spatial scales have been developed over the years in estimating the water balance for different watershed, and

the accuracy of the predicted hydrological model results is defined by how well the model inputs and the model itself can represent the hydrological process in the watershed (Xu, 2021; Aliye et al., 2020). Some of the hydrological processes in a watershed that are mostly modelled by the hydrological models are groundwater discharge, stream discharge, infiltration and evapotranspiration (Khoi, 2016). Evapotranspiration (ET) is a very important water balance component obtained in hydrological models used in effective water resource planning and management (Samadi, 2017; Wu, 1997). This is because ET in most cases is the major means by which water is taken away from a basin, and hence, accurate estimation of the ET is essential in determining the accuracy of estimated available water available for use in any hydrological model (Irmak et al., 2005). The accuracy of the AET is defined by the accuracy of the estimated PET used in estimating the AET (Amatya et al. 2014). About 50 different empirical formulas requiring different assumptions

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have been developed in estimation of PET (Wang et al. 2006; Grismer et al., 2002). These different equations also require different climate parameters and mostly result in different levels of accuracy in the estimated PET. Bai et al., 2016 concluded that different empirical equations in estimating PET have resulted in different accuracies for the estimated AET in different regions and hence the choice of empirical equation for PET must be selected based on the region.

Different researches have also analysed the impact of estimated PET on the accuracy of the resulted AET in hydrological models. Bai et al., 2016 investigated the influence of four different PET methods on two hydrological model results and concluded that parameter calibration was enough to eliminate the impact of the PET method on the resultant runoff in both non-humid and humid regions. Seiller and Anctil, 2016 investigated the influence of 24 methods of PET estimates on a hydrological model and concluded that the different estimated PET only slightly affected the results of the hydrological model. In Ouémé watershed at Bonou in Benin, the influence of Penman–Monteith and Oudin PET methods only slightly affected the results of the GR4J hydrological model (Kodja et al., 2020). Schneider et al., 2007 and Wang et al. (2006) also evaluated the influence of different PET methods on the results from SWAT model and concluded that different PET methods resulted in similar discharges. Most of these evaluation of PET methods on the results from hydrological model, were, however, done on basin with enough spatial and temporal data. There is, however, the need to evaluate the impact of different PET methods in basins where there are limited spatial and temporal data.

The Soil and Water Assessment Tool (SWAT) is a river basin or watershed scale hydrological model developed for Agricultural Research Service of the United States Department of Agriculture (USDA) by Dr. Jeff Arnold (Neitsch et al., 2009). The meteorological input data required by SWAT are daily precipitation, maximum/minimum air temperature, solar radiation, wind speed and relative humidity. Accurate and good distribution of meteorological data within a basin that is used in the SWAT model determines the accuracy of the results obtained. However, in most developing countries like Ghana, meteorological data either not available or when available are limited with a lot of missing gaps. This mostly restricts the use of most hydrological models or results in the unreliable model predictions (Polanco et al., 2017; Stehr et al., 2008). In SWAT model, the missing daily meteorological data are estimated from monthly known meteorological data statistics using WXGEN weather generator (Neitsch et al., 2009; Schuol and Abbaspour, 2007). However, there are limitations to the use of WXGEN weather generator in estimating the missing data. In five first-order stations in Texas in the USA, the use of WXGEN weather generator resulted in 15% unrealistic weather

parameters which were likely to negatively affect the model results when used (Wallis and Griffiths, 1995). In a study by Hayhoe, 1998 in five selected climate stations in Canada, WXGEN weather generator could not mimic the established difference in relationships between regional and seasonal weather parameters. There is therefore the need to evaluate weather generators especially when they are applied in areas where climate characteristics are different from where the generators were developed (Gitau et al. 2017).

The SWAT model also uses three different methods of estimating PET, namely Penman–Monteith (PM), Hargreaves and Priestly–Taylor. The error arising from the use of three different PET methods in SWAT on the resulting AET and other water balance components has not been fully analysed especially in basins where there are limited data (Wang et al. 2006). The PET method selected is mostly defined by the level of climate data available, and it also affects the accuracy of the model prediction (Aouissi et al., 2016). When all the climate data are available, the PM method which requires most data is used, and when there are limited temperature data available, the Hargreaves method is used. The data requirement of Priestly–Taylor is between that of PM and Hargreaves. Allen et al., (1998) proposed the use of PM for estimating PET because of its accuracy in different parts of the world when compared with other methods. Licciardello et al., (2012) also concluded in his research in Flascio River basin that PM was more accurate in predicting the basin water balance than the other methods. The level of accuracy of the water balance from SWAT model is therefore defined by the PET method used. The objective of this study is therefore to assess the impact of the extent of data generated with WXGEN weather generator on the SWAT hydrological model results in a limited spatial and temporal climate data Densu basin in Ghana using the three different methods of estimating PET in the model.

Data and study area

Study area: Densu river basin

The Densu basin is part of the Coastal River System group in Ghana with an estimated total area of about 2600 km². The basin is located between latitude 5°30' N–6°17' N and longitude 0°10' W–0°37' W. The river covers a distance of about 116 kms from the Atiwa Mountains where it takes its source to the Weija Dam and then it enters the sea through the Densu Delta Ramsar site also known as Sakumo I Lagoon at Bortianor in the Ga Municipality. High population density within the catchment has resulted in the over exploitation of the Densu river (WRC, 2007).

Most of the communities within the Densu river basin and even some communities outside the basin depend on



the Densu river for their drinking water supply. The Densu Basin has eight drinking supply schemes that supply water to the communities within and outside the basin. Five of the water supply schemes rely directly on the Densu river, while three of the schemes are supplied with groundwater.

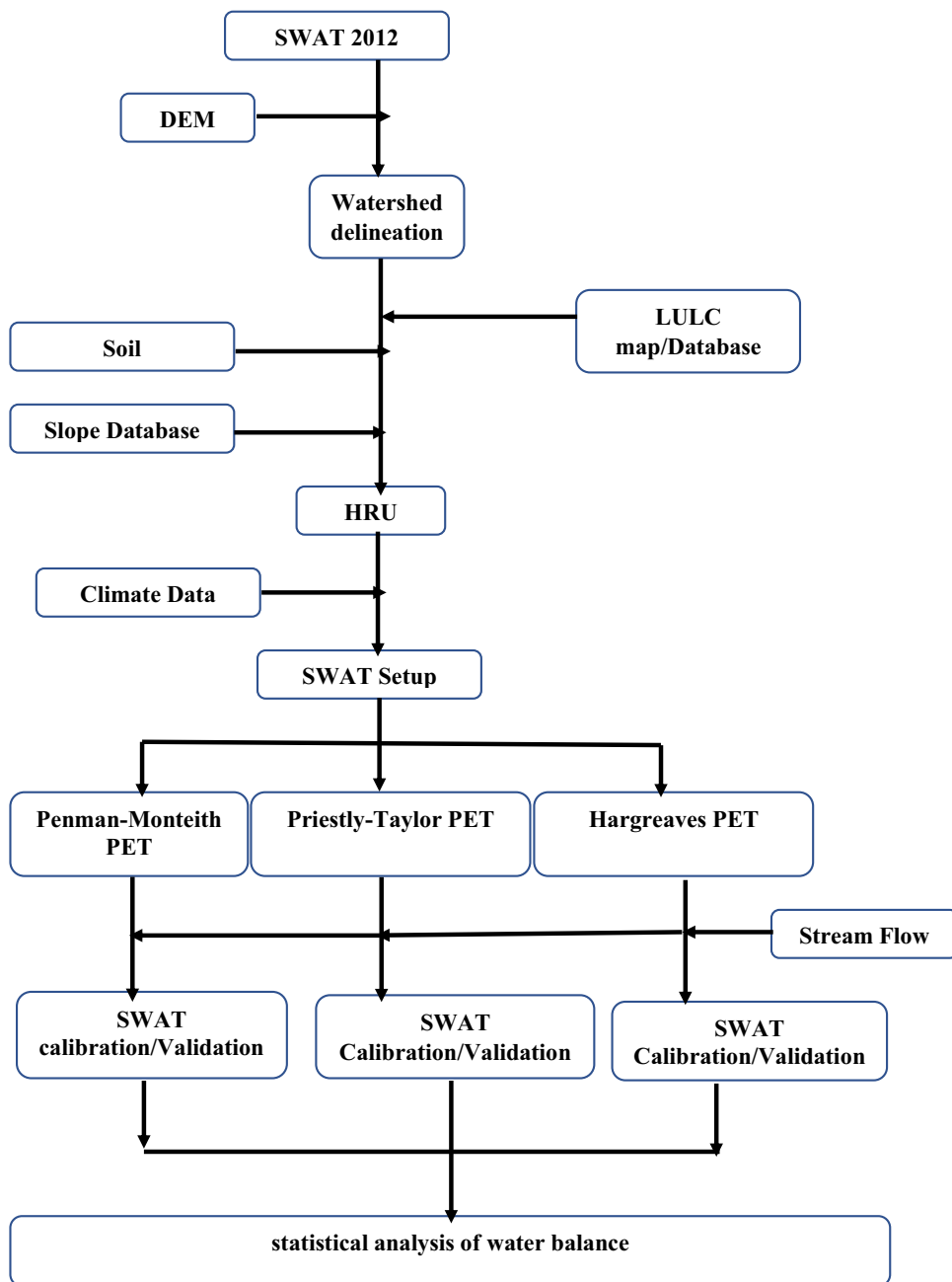
Materials and methods

The SWAT model is a semi-distributed, continuous time model, which requires numerous spatial attribute inputs data such as weather, hydrology, soil properties, plant growth,

nutrients, pesticides, bacteria and pathogens and land management. The model results include water balance components and chemical and sediment yield at different locations within the basin. ARCSWAT is SWAT which is integrated in Geographic Information System (GIS).

The flowchart in Fig. 1 indicates the processes in SWAT hydrological model used in this research work. SWAT model uses DEM together with the location of the basin outlet to delineate the watershed. The Densu basin DEM was therefore loaded together with the map of the Densu river channel into the SWAT model which was used in the watershed delineation. The Densu basin watershed was divided into

Fig. 1 Schematic of GIS integrated SWAT model



sixty-one sub-basins, and each sub-basin had unique identity. A map of sub-basins created in SWAT for the Densu river basin is shown in Fig. 2. SWAT then combines the basin topography from the DEM with the LULC map and soil map to sub-divide the sub-basins into hydraulic response units (HRUs). Simulations in SWAT are done at the hydraulic response units after which they are routed to obtain the simulation for the entire basin. The basin topography, LULC and soil map were combined in SWAT to sub-divide the sub-basins into 335 HRUs.

Observed daily climate data of minimum and maximum temperature, wind speed, relative humidity, rainfall and solar radiation at gauging stations in the Densu basin were input into the model for the final model setup. Eight climate stations distributed within the Densu basin were used. The location of the climate stations is also shown in Fig. 2.

The daily maximum and minimum temperature and precipitation data were collected for all the eight climate stations. Daily wind speed, maximum and minimum humidity and solar radiation data were also obtained for one of the eight stations (Koforidua) for the model. All the climate data were obtained from the Ghana Meteorological Agency (GMet) for a period spanning from 1985 to 2014.

The streamflow data used for calibration and validation of the model were from Nsawam, a station within the Densu Basin. Monthly streamflow data were used for the model calibration and validation. The streamflow data were obtained from the Hydrological Services Department (HSD) in Ghana.

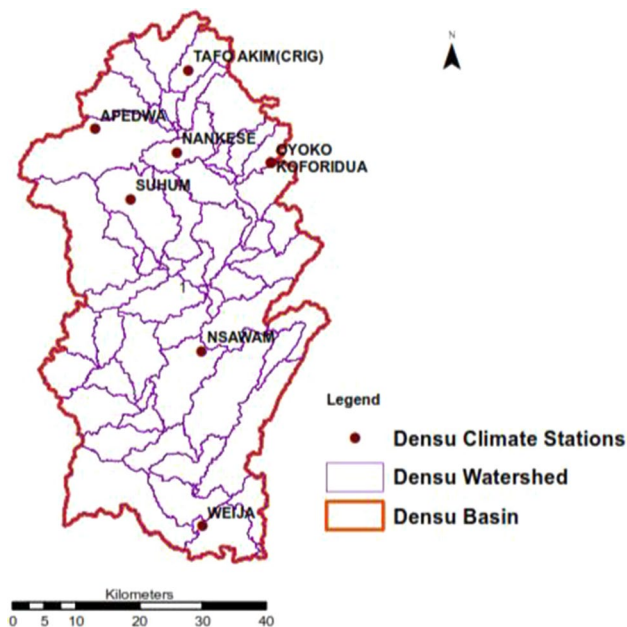


Fig. 2 The map of the Densu sub-basin produced by SWAT and location of climate stations

SWAT Model calibration and validation

The SWAT model was calibrated for the three different methods of PET available in SWAT. The resultant water balances were then analysed to determine the effect of selecting each of the three PET methods available on the accuracy of the resultant water balance. Four statistical parameters were used for the calibration and validation of the model. These statistical parameters are the coefficient of determination (R^2), Nash–Sutcliffe model efficiency coefficient (NSE), percent bias (PBIAS) and root-mean-square error (RSR). The parameters are defined as.

$$R^2 = \left[\frac{\sum_i^N (O_i - \bar{O})(P_i - \bar{P})}{\left[\sum_i^N (O_i - \bar{O})^2 \right]^{0.5} \left[\sum_i^N (P_i - \bar{P})^2 \right]^{0.5}} \right]^2 \quad (1)$$

$$NSE = 1 - \frac{\sum_i^N (O_i - P_i)^2}{\sum_i^N (O_i - \bar{O})^2} \quad (2)$$

$$PBIAS = \frac{\sum_i^N (O_i - P_i)}{\sum_i^N (O_i)} \quad (3)$$

$$RSR = \sqrt{\frac{\sum_{i=1}^N (P_i - O_i)^2}{N}} \quad (4)$$

where O_i is the measured data; P_i is the simulated data; \bar{O} is the mean of the measured data; \bar{P} is the mean of the simulated data; and N is the number of compared values.

The process of calibration and validation was to determine whether the model simulated results suitably represent the observed data (Dile et al., 2016). Calibration and validation were therefore done by comparing the simulated results to the observed data using the four statistical parameters. The performance rating range is given in Table 1

Results and discussion

SWAT model sensitivity analysis

The model calibrated parameters were selected based on their sensitivity analysis. The sensitivity analysis was conducted to determine which of the SWAT parameters influence the prediction of the streamflow that was used for the model calibration and validation most. The initial parameters

Table 1 Performance ratings for a monthly time step statistic (Moriassi et al., 2007)

Performance Rating	RSR	NSE	PBIAS (%)
Very good	$0.00 \leq \text{RSR} \leq 0.50$	$0.75 < \text{NSE} \leq 1.00$	$\text{PBIAS} < \pm 10$
Good	$0.50 < \text{RSR} \leq 0.60$	$0.65 < \text{NSE} \leq 0.75$	$\pm 10 \leq \text{PBIAS} < \pm 15$
Satisfactory	$0.60 < \text{RSR} \leq 0.70$	$0.50 < \text{NSE} \leq 0.65$	$\pm 15 \leq \text{PBIAS} < \pm 25$
Unsatisfactory	$\text{RSR} > 0.70$	$\text{NSE} \leq 0.50$	$\text{PBIAS} \geq \pm 25$

In all cases, Santhi et al., (2001) recommended that $\text{RSR} < 0.70$, $\text{NSE} > 0.50$, PBIAS for Streamflow $< \pm 25$ and $R^2 > 0.60$ give a satisfactory result

were selected for the sensitivity analysis by reviewing documentation from SWAT manuals and based on the initial plot of the model streamflow and the measured streamflow data. The t test and the p value were used in evaluating the sensitivity of the parameters. The larger in absolute terms the values of the t-stat, and the smaller the p-values, the more sensitive the parameter was (Abbaspour, 2015). The selected parameters for the calibration and validation of the SWAT model and their arrangement in terms of decreasing order of sensitivity are shown in Table 2.

The most sensitive parameters were those that affect runoff (CN2.mgt), ground water recharge and flow (GWQMN.gw, GW_DELAY.gw, FFCB.bsn and RCHRG_DP.gw) and evapotranspiration (ESCO.hru). This sensitivity result is in agreement with most of the SWAT studies

that have been conducted in Ghana and this models had CN2.mgt, GWQMN.gw, GW_DELAY.gw and RCHRG_DP.gw as part of its list of most sensitive parameters (Arthur et al., 2020; Guug et al., 2020; Osei et al., 2018). Runoff curve number (CN2) is the most sensitive parameter when SWAT-CUP is used in the calibration and validation of most SWAT model (Osei et al., 2018). In these studies, the most sensitive parameter was also the runoff curve number. The runoff curve number defined how much of rainfall goes into the runoff and is a function of land use and land cover, initial soil water condition and soil permeability. The least sensitive parameters were SLSUBBSN.hru, REVAPMN.gw and SURLAG.bsn. This sensitivity analysis played a very important role in selecting the parameters that were used in the SWAT model calibration and validation with streamflow data.

Table 2 SWAT Parameters used in the calibration and validation processes arranged in a decreasing order of sensitivity to the model

Parameter name	Description
CN2.mgt	SCS runoff curve number f
GWQMN.gw	for return flow to occur (mm)
GW_DELAY.gw	Groundwater delay (days)
FFCB.bsn	Initial soil water storage expressed as a fraction of field capacity water content
RCHRG_DP.gw	Deep aquifer percolation fraction
ESCO.hru	Soil evaporation compensation factor
CH_K2.rte	Effective hydraulic conductivity in main channel alluvium
ALPHA_BNK.rte	Baseflow alpha factor for bank storage
SOL_K.sol	Saturated hydraulic conductivity
SOL_ALB.sol	Moist soil albedo
ALPHA_BF.gw	Baseflow alpha factor (days)
GW_REVAP.gw	Groundwater "revap" coefficient
CH_ERODMO.rte	Jan. channel erodability factor
SOL_AWC.sol	Available water capacity of the soil layer
EPCO.bsn	Plant uptake compensation factor
OV_N.hru	Manning's "n" value for overland flow
HRU_SLP.hru	Average slope steepness
CH_N2.rte	Manning's "n" value for the main channel
SLSUBBSN.hru	Average slope length
REVAPMN.gw	for "revap" to occur (mm)
SURLAG.bsn	Surface runoff lag time



SWAT calibration and validation

The three PET methods available in SWAT were run with climate data from 1985 to 2014. Data from the first five years (1985–1989) were used as a warm up to the SWAT model. Manual calibration was first done followed by automatic calibration using SUFI-2 in SWAT-CUP. The model was calibrated with data from January 1991 to December 1995. Validation was also done with data from January 1996 to December 2000. Monthly streamflow data for the station in Nsawam were used for the calibration and validation of the SWAT model in the Densu basin. Twenty-one SWAT parameters were carefully selected for the calibration and validation of the model based on the parameter sensitivity to the set-up SWAT model.

Plots of the simulated and observed streamflow data for the calibrated and validated period for the three different PET methods in SWAT are shown in Figs. 3, 4 and 5. Their corresponding summary statistics for the calibrated and

validated period are given in Table 3. For the monthly calibration and validation plot, data from 1 to 60 represent the calibration period, while data from 61 to 102 represent the validation period.

The statistical test performed between the simulated and observed streamflow (discharge) shows a good agreement for both the calibrated and validated periods for all the three PET different methods. This confirmed the results from Schneider et al., (2007) and Wang et al. (2006) who concluded that the PET method selected has only little influence in the accuracy of the modelled streamflow. Hargreaves PET had the best NSE values of 0.70 for the calibration and NSE of 0.74 for validation period, while the PM PET method had the worse NSE value of 0.66 for calibration and 0.62 for validation. This may be due to the limitation of the available data within the basin. Most of the stations have only temperature data, and hence, Hargreaves PET better represents the basin PET than the other methods. Densu basin has only one station with enough data to calculate the PM PET.

Fig. 3 Monthly observed and simulated discharge at Nsawam during calibration and validation from 1991 to 2000 for Hargreaves Potential ET Method

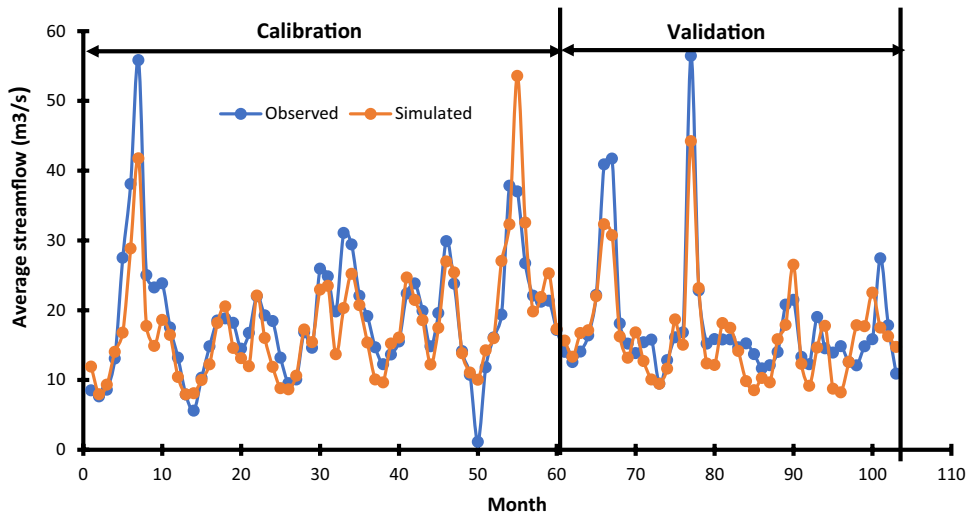


Fig. 4 Monthly observed and simulated discharge at Nsawam during calibration and validation from 1991 to 2000 for Priestly-Taylor Potential ET Method

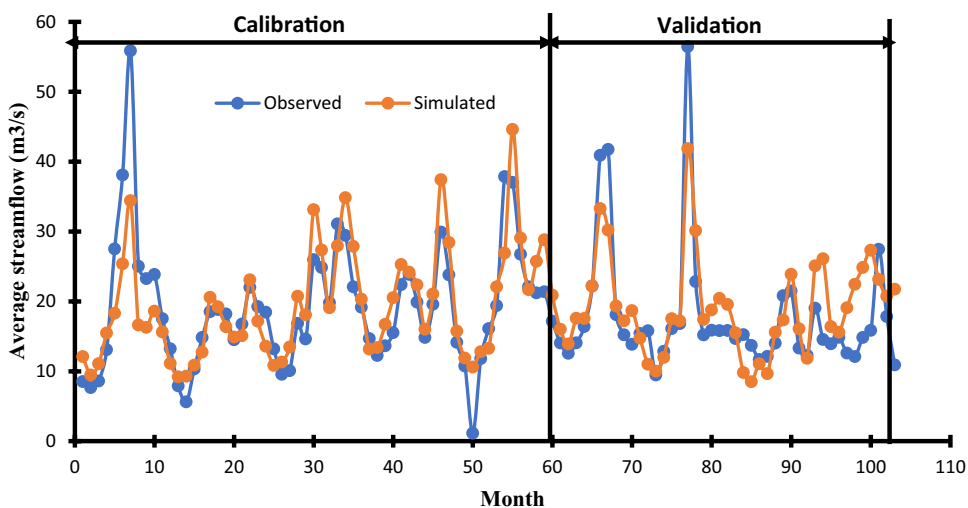


Fig. 5 Monthly observed and simulated discharge at Nsawam during calibration and validation from 1991 to 2000 for PM ET Method

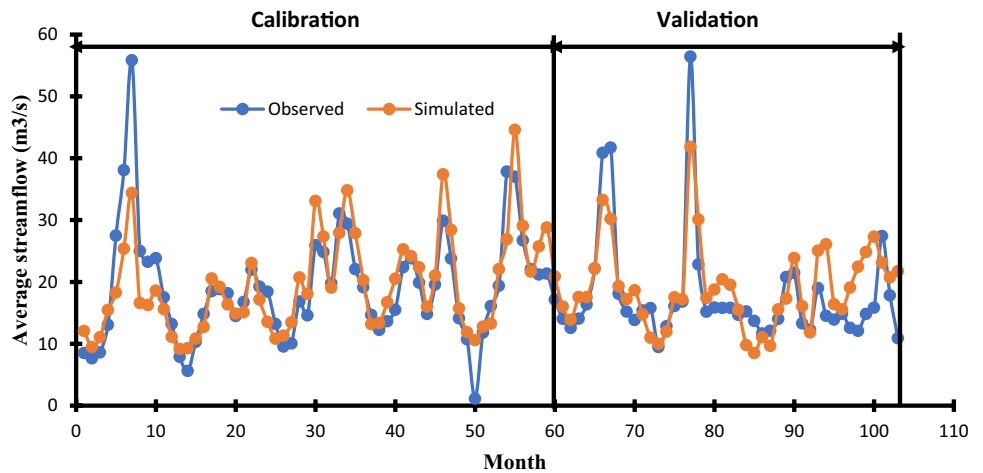


Table 3 Calibration and validation statistics using soil and water assessment tool coupled SUFI-2 in SWAT-CUP for Hargreaves Potential ET Method, Priestly-Taylor ET Method and PM ET Method

Period of time	Statistics indicators			
	R ²	NSE	RSR	PBIAS (%) Stream-flow
Hargreaves PET method				
Calibration (1991–1995)	0.67	0.70	0.55	7.00
Validation (1996–2000)	0.77	0.74	0.51	7.70
Priestly-Taylor PET method				
Calibration (1991–1995)	0.67	0.67	0.58	– 0.47
Validation (1996–2000)	0.63	0.63	0.61	2.70
PM PET method				
Calibration (1991–1995)	0.66	0.66	0.58	– 2.00
Validation (1996–2000)	0.62	0.62	0.62	1.40

Hence, using PM to evaluate the evapotranspiration in the Densu basin will not give a good representation of the real distribution of the evapotranspiration data in the basin. The performance of Priestly–Taylor PET method was between that of Hargreaves and PM method.

Tables 4, 5 and 6 give a summaries of average annual water balance components in the Densu river basin for the three different PET methods from 1990 to 2014. The mean annual rainfall within the Densu river basin was about 1200 mm. The selected PET method affected the calculated model PET than the actual ET, and this confirms the results from Aouissi et al., (2016). The highest PET was observed with the Hargreaves PET method, but the highest actual ET was from the Priestly–Taylor method. The Priestly–Taylor and PM PET methods produced almost the same annual PET values, even though the actual ET from Priestly–Taylor was slightly higher than the value from PM method. This is similar to the results obtained when the station data were used in estimating the reference evapotranspiration in Koforidua.

Table 4 Average annual water balance component in the Densu basin from 1990 to 2014 using Hargreaves Potential ET Method

Water balance component	Amount (mm)	Percentage of rainfall (%)
Rainfall	1229.4	100
Potential Evapotranspiration	1674	136.2
Actual Evapotranspiration	732.8	60
Stream flow	201.02	16
Groundwater recharge	110.20	9
Water Yield	311.35	25.33

Table 5 Average annual water balance component in the Densu basin from 1990 to 2014 using Priestly-Taylor Potential ET Method

Water balance component	Amount (mm)	Percentage of rainfall (%)
Rainfall	1229.4	100
Potential evapotranspiration	1152.5	93.7
Actual evapotranspiration	808.3	66
Stream flow	108.24	9
Groundwater recharge	150.83	12
Water yield	261.20	21.25

Table 6 Average annual water balance component in the Densu basin from 1990 to 2014 using PM ET Method

Water balance component	Amount (mm)	Percentage of rainfall (%)
Rainfall	1229.4	100
Potential evapotranspiration	1196.9	97.4
Actual evapotranspiration	784.3	64
Stream flow	216.47	18
Groundwater recharge	91.42	7
Water yield	316.63	25.75

The highest actual evapotranspiration was, however, from Priestly–Taylor, while the lowest actual evapotranspiration was from Hargreaves PET method, as shown in Tables 4, 5 and 6. The actual evapotranspiration was 60% of rainfall in the Hargreaves PET method, 64% in PM method and 66% in Priestly–Taylor.

Graphs of monthly average PET and actual evapotranspiration values from the SWAT model are shown in Figs. 6 and 7.

The temperature regime within the basin is also almost uniform with the highest temperature occurring in March and April and the lowest temperature occurring in August (WRC, 2007). This trend in temperature influenced the trend in PET shown in Fig. 6. The highest PET values occurred in March and April where the temperature was the highest, while the lowest PET occurs in August because of the lower temperature in August. The model therefore depicts accurately the relationship between temperature and PET.

The Densu basin can be said to have a bi-model rainfall regime with a first raining season which starts from April to July, while the second raining season starts from September to November (WRC, 2007). This explains the pattern of the actual evapotranspiration in Fig. 7 which have two peaks in May and October, and the two peaks represent the two rainfall seasons. The actual evapotranspiration is highest during

the two raining seasons and is lower during the dry season. This is because if water is available, the actual evapotranspiration will reach its maximum value and in days where there is no water, actual evapotranspiration will be zero. This trend in rainfall and actual evapotranspiration indicates a correct relationship between rainfall and actual evapotranspiration.

Hargreaves PET was the highest for all the months, while the PET from Priestly–Taylor and PM was almost the same for all the months. This is because the parameters used in Priestly–Taylor equation are similar to those used in PM equation. Hargreaves equation only uses temperature, and hence, their values are a bit different and higher than the values from Priestly–Taylor and PM equation. This Hargreaves result is similar to the results obtained in Ganjiang River Basin in Southern China, where the Hargreaves PET equation produced a higher PET values than the PM equation in a CREST 3.0 model (Li et al., 2018). Hargreaves equation most of the time overestimates the PET values, while PM equation is the most accurate equation in estimating PET when their values are compared to measure Pan PET values (Duhan et al., 2021; Li et al., 2018; Adeboye et al., 2009).

For the actual evapotranspiration, the highest values were estimated with Priestly–Taylor, while the lowest values were estimated with Hargreaves PET. The actual monthly ET produced by the three ET methods was, however, not

Fig. 6 Average monthly PET for the three PET methods in SWAT from 1990 to 2014 in the Densu Basin

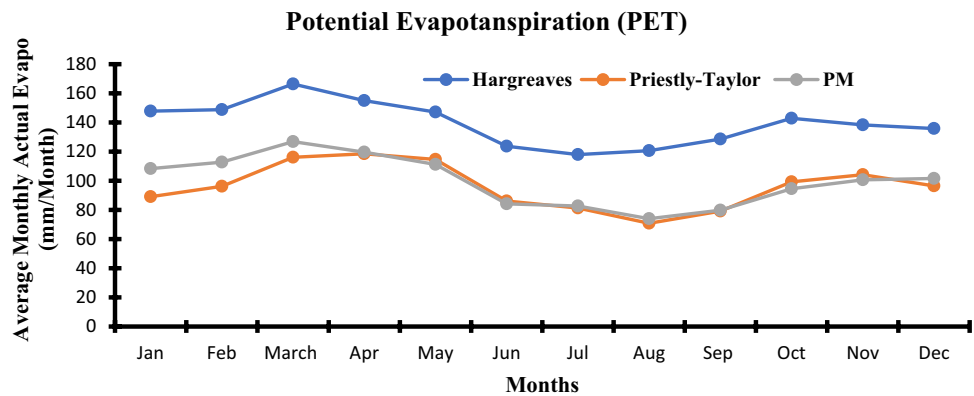
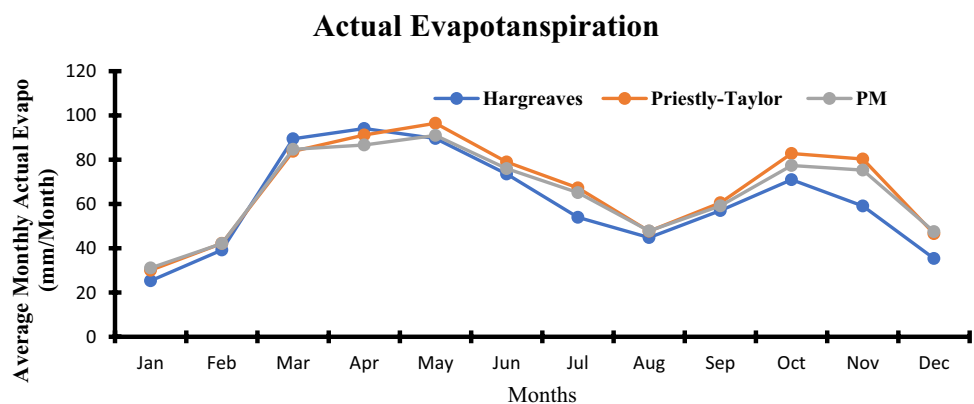


Fig. 7 Average monthly Actual ET for the three PET methods in SWAT from 1990 to 2014 in the Densu Basin



substantially different, and these were similar to the results reported by Earls and Dixon, (2008). This is mainly because the calibration parameters are mostly able to reduce the effect of the difference in the three PET methods on the resultant actual evapotranspiration from the hydrological model (Kodja et al., 2020; Seiller and Anctil, 2016). This situation is not the same in all catchments and also under different climate conditions. In Susquehanna River Basin in the north-eastern USA, the application of different PET methods resulted in the increase in the actual evapotranspiration from 14 to 24% in one scenario, and from 7 to 12% in another scenario (Seong et al., 2018). In Urabá region of Columbia, Hargreaves PET method resulted in a better estimates of streamflow than when the Turc PET method was used. In this study in the Densu basin, even though different PET methods resulted in different PET estimates, the calibrated parameters reduced the effect of the difference in the PET on the actual evapotranspiration estimates. This therefore resulted in similar actual evapotranspiration estimates for the three different PET methods. The difference in the PET values was more pronounced than that the difference in actual evapotranspiration values for the three different PET methods in the SWAT model for the Densu river basin.

The groundwater recharge was highest in Priestly–Taylor PET method and lowest in PM PET method. Groundwater recharge was 9% of rainfall in Hargreaves PET method, 12% in Priestly–Taylor PET method and 7% in PM PET method. Groundwater recharge was estimated to be 14% of rainfall by WRC (2007), 8% by Atia, (2010) and 7% by Adomako et al., (2010).

Streamflow was 16% of rainfall in the Hargreaves PET method, 9% of rainfall in the Priestly–Taylor PET method and 18% of rainfall in the PM PET method. In general, however, all the water balance parameters are similar to what is in most literature from the Densu basin (Adomako et al., 2010; Bob Atia, 2010; WRC, 2007). Atia (2010) analysed the Densu basin water balance and concluded that when daily rainfall time steps are implemented in the model, the overflow constituted 5% of rainfall; however, when hourly time steps were implemented, the overflow was 16% of rainfall. The small discrepancies in the resultant water balance components for the three different PET methods could be attributed to the available climate data for the SWAT model and how they relate to the three different PET methods.

Conclusion

The study was used to evaluate the PET methods available in SWAT in a limited data Densu basin in Ghana. The most available climate data with wide spatial distribution were temperature and rainfall. Solar radiation, humidity and wind speed data were only available at the station in Koforidua.

All eight climate stations were used in the SWAT model calibration and validation. WXGEN weather generator was used to generate the missing climate data for all the stations.

The results show that even though the three PET methods available in SWAT result in a good estimation of the water balance components of basin, the accuracy of the results was not the same and hence care ought to be taken as to which PET method is selected in SWAT for the water balance analysis. The method of PET in SWAT selected must be informed by the available data and the good distribution of the available data. When only temperature data are mostly available, the best method to use is Hargreaves. The PM could be selected when there are enough data which has a good distribution to calculate PET with the PM equation.

All the three methods of estimating PET available in SWAT give fairly accurate result. The small discrepancies in the water balance estimates can be attributed to the effect of different methods of PET in SWAT in relation to the available climate data that were used for the model. In the limited Densu basin, Hargreaves PET method gave the best calibrated and validated result. This could be attributed to the available climate data and the distribution of the available data within the basin. Hargreaves uses air temperature in estimating PET, and in the Densu basin, the data that were mostly available and had a good spatial distributed were air temperature. Data to calculate PET using Priestly–Taylor and PM method were only limited to the station in Koforidua. Hence, the PET in SWAT using Priestly–Taylor and PM method did not have a good spatial distribution resulting in their less accuracy in estimating the basin streamflow.

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Availability of data and material Data are available on request.

Declarations

Conflict of interest No conflict of interest.

Ethics approval Not applicable.

Consent to participate Not applicable.

Consent for publication Not applicable.

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