Calibration of Blaney-Morin-Nigeria Evapotranspiration model for Asaba and Uyo, South-south Nigeria

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Abstract: The study was designed to re-examine and calibrate the Blaney-Morin-Nigeria (BMN) evapotranspiration (*ET*) model for two specific locations, Asaba and Uyo in South-south of Nigeria. This was achieved using a non-linear iterative technique based on Levenberg-Marquardt algorithm, making use of climatic variables. The newly developed model constants were H = 288.0, m = 0.96; H = 285.8, m = 0.91 and H = 287.0, m = 1.00 for South-south Nigeria, Asaba and Uyo respectively compared to the H = 520.0, m = 1.31 for the original BMN ET model. Data were analysed using different statistical indices (*RMSE*, *MAE*, S^2d, *MBE* and r). The three newly developed BMN models when compared with FAO-56 PM model gave a more satisfactory reference evapotranspiration ET_o estimates than the original BMN ET model when compared with FAO-56 PM model. In Asaba, result showed that the original BMN, the BMN for Asaba and the BMN for South-south underestimated FAO-56 PM ET by 9.87%, 2.70% and 7.14% respectively, while in Uyo, the original BMN model and South-south model overestimated FAO-56 PM ET by 4.19% and 3.99% respectively, whereas that for Asaba was underestimated by 1.83%. The comparative analysis using statistical indices showed that the new BMN models gave a better prediction of ET_o with s, c, S^2d, *MAE*, *RMSE* and r values as 0.90, 0.54, 0.15 mm^2 day^{-2}, 0.32, 0.41 mm day^{-1} and 0.85 respectively as against 0.46, 2.42, 0.70 mm^2 day^{-2}, 0.80, 0.91 mm day^{-1} and 0.81, which were obtained from the original BMN model. The location specific models for Asaba and Uyo predicted ET_o best among the evapotranspiration models followed by the South-south model and the original BMN model gave the worst prediction.

Keywords: climate change, modelling, FAO-56 PM, Levenberg-Marquardt algorithm.

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1 Introduction

Water is among the most crucial limited natural resources. It is virtually used in every aspect of economic activity including agriculture, industry, energy sector and public use. Over the years, it is widely believed that any change in climate will have a significant impact on the availability of water. Decrease in water resources and quality problems have given rise to increasing need for water conserving policies on a field, watershed and regional scale and this makes efficient use of water resources a responsibility of each consumer. As water becomes increasingly scarce and the need becomes more pressing and adjuring, newer and more complete methods of measuring and

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evaluating techniques of handling water resources becomes very necessary (Irmak, 2011). The scarcity of water has been linked with evapotranspiration and climate change.

Evapotranspiration (*ET*) is a combination of two different processes namely evaporation and transpiration. The former is the process in which liquid water is converted to water vapour and removed from an evaporating surface which includes lakes, rivers, wet soils or vegetation. The latter is the process in which water is respired to the atmosphere predominantly from small openings on the leaf surface called stomata. In practice, these two processes occur simultaneously so there is no easy way of distinguishing between them. Reference evapotranspiration (ET_o) is a concept for measuring evaporation demand from the atmosphere, independent of crop type, crop development, and management practices (Isikwue et al., 2015). The ET_o is important because it is used to determine the evaporative demand of the atmosphere. A better understanding of basic reference evapotranspiration trends is essential for the scientific management of water resources (Yassen et al., 2020). Projecting the demand for water for human and ecological reasons requires continuous research to determine the relative evaporation in different locations and its relationship with different climatic parameters (Abarikwu et al., 2019).

ET_o is a critical factor in irrigation management, watershed water balance, water resource planning, ecosystem health, and watershed operations. It is also considered one of the most important factors in hydrological and climatic studies (Roudier et al., 2014; Pour et al., 2020). Understanding changes in evapotranspiration is essential to manage water resources and develop adaptation strategies to climate change (Wang et al., 2016). Contradictory changes in the thermal, radiative, and aerodynamic components of ET_o have caused an inhomogeneity in the ET_o trend across the globe. Thus, despite the sharp rise in temperature, ET_o was found to have decreased over most of the world over the past fifty years (Pan et al., 2019). In the context of climate change, changes in all climate parameters, including temperature, wind speed, precipitation, solar radiation, and other factors, lead to a change in ET_o, which affects water demand crop management and economics of rural water use planning (Luo et al., 2018). The ET_o estimation is one of the important first steps in calculating the water needs of crops in an agricultural field under current and future climatic conditions. It also provides decision makers with the necessary information to reduce water consumption and ensure sustainable mining (Dinpashoh et al., 2019). Understanding the changing trend of ET_o is important for improving crop growth and irrigation water management, and changing ET_o is an essential step in understanding how climate change affects hydrological processes (Nam et al., 2015). Reports indicate that food security faces a number of challenges as a result of climate change, including deficiencies in agricultural and food practices (Matemilola and Alabi, 2021a), climate change, and global warming are outcomes of increase in earth's average temperature, also known as greenhouse effect (Matemilola and Alabi, 2021b).

Numerous methods can be used to estimate *ET*. These methods are categorised into direct and indirect measurements. The direct measurement includes the use of lysimeters (Jia et al., 2006; Obioma et al., 2015), atmometer (Diop et al., 2015), pan evaporimeters (Van’t Woudt, 1963; Bloemen, 1978) and the eddy-covariance method (Burba and Anderson, 2007). These direct measurements are not usually feasible because they are time consuming, expensive and complex which is brought about by their dependence on soil condition and plant physiology (Ejieji, 2011). Thus, the estimation of evapotranspiration is usually done using the indirect measurement which no longer depends so gravely on soil and plant factors but primarily on climatic factors. It includes the use of water balance method, micrometeorological method and the use of empirical models which were developed to estimate evapotranspiration using meteorological data. These models range from simple expressions which relate *ET* to temperature or radiation to models having extensive data requirement. The model universally acceptable which has been standardised by the Food and Agriculture Organisation (FAO) is the indirect method, FAO-56 Penman Monteith model that estimates ET_o. It is considered the best because it compasses the physical parameters that govern the exchange of aerodynamic, energy and physiological aspects of nature (Obioma et al., 2015). In Nigeria, the Blaney-Morin-Nigeria (BMN) model developed by Duru (1984) is currently the only *ET* model specifically developed for the Nigerian condition and as would be expected, is enjoying wide use in the country. However, there are some perceived shortcomings (e.g., the use of meteorological data of one State as a representation of the whole country) which are believed to affect its reliability. These shortcomings have already been exhaustively discussed by Dike (2005); Idike and Anekwe (2002) and Ilesanmi et al. (2012).

Considering the situation in Nigeria, as in most developing countries, where the meteorological data needed for the calculation of *ET* using models such as the FAO-56 Penman-Monteith (Umego et al., 2020) are most of the time not readily available, the use of simpler *ET* models whose data requirements are less vigorous to generate than that of FAO 56 PM becomes important (Ahaneku, 2011). It is therefore necessary to test the BMN *ET* model which was developed using data from only one location (Samaru-Zaria) from Northern Guinea Savannah with a tropical savanna climate that has a warm weather year-round, a wet season lasting from April to September, and a drier season from October to March amidst the seven agro-ecological zones in Nigeria to see if it can reliably estimate *ET* in specific locations. With regards to the aforementioned, this study seeks to re-examine and calibrate the BMN *ET* model with a view to calibrate it using standardized procedures and develop location specific model constants for Asaba, Uyo and other locations within the South-south part of Nigeria.

2 Materials and methods

2.1 Study area

The study was carried out in South-south part of Nigeria which is strategically located at the point where the Y tail of the river Niger joins the Atlantic Ocean through the Gulf of Guinea. South-south part of Nigeria as shown in Figure 1 is located within the oil rich Niger Delta with coordinates as latitude 5° 19' 20.40" N and longitude 6° 28' 8.99" E, having a population of 28,829,269 according to Nigeria Bureau of Statistics (NBS, 2016).

This region is characterized by Tropical Monsoon climate, designated by the Köppen climate classification as "Am". The climate is influenced by the monsoons originating from the south Atlantic Ocean, which is brought into the country by the Maritime Tropical (MT) air mass, a warm moist sea to land seasonal wind. Its warmth and high humidity give it a strong tendency to ascend and yield ample rainfall, which is a consequence of the condensation of water vapour in the rapidly rising air. The South-south part of Nigeria experiences heavy and abundant rainfall, which is usually convectional in nature due to the region’s proximity to the equatorial belt. The annual rainfall received in this part of the country is usually between 2,000 and 4,000 mm.

2.2.1 Asaba (6°11′52.23″N, 6°43′42.48″E)

Asaba is situated on a terrace of the western (lower) edge of the Niger River, across the Niger Bridge. It is the capital of Nigeria's Delta State with population of 149,603 as at the 2006 census. Asaba forms a connector between western, eastern and northern Nigeria through the Niger River from the north and via the Asaba Niger Bridge, an east-west link and a Nigerian landmark.

Asaba lies approximately 60° north of the equator and about the same distance east of the meridian; about 160 km north of where the river Niger flows into the Atlantic Ocean. The greater Asaba occupies an area of about 300 km^2. It maintains an average tropical temperature of 32°C during the dry season and an average rainfall of 2,700 mm during the rainy season.

2.1.2 Uyo (5°2′N, 7°55′E)

Uyo, the capital of Akwa-Ibom State of Nigeria with population of 427,873 as at 2006 census is located within the equatorial region. It is located about 60 km from the coast of Atlantic Ocean. The rainfall is of the double maxima regime with a break occurring in August. Mean annual rainfall stands at about 2400 mm. Uyo is characterised by a uniform temperature all through the year with a mean high of about 28°C recorded between March/April and a mean low of about 25°C is recorded around August. Relative humidity is equally high with a seasonal variation component. The lowest relative humidity of about 54% is recorded in January and it keeps increasing to about 84% in July. The high relative humidity in the area can be attributed to its proximity to the Atlantic Ocean.

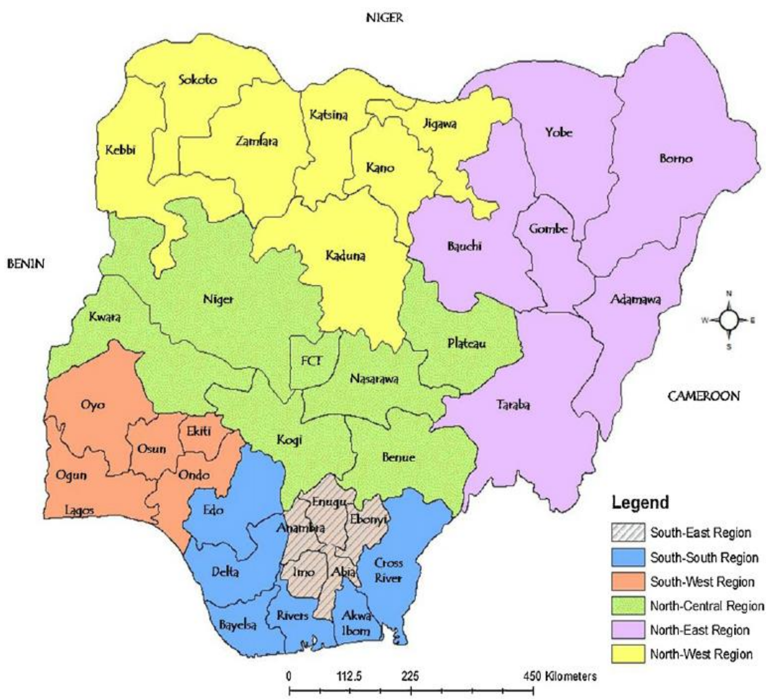

Figure 1 Map of Nigeria showing the two study areas

Two areas from South-south part of Nigeria were considered in this study, Asaba and Uyo.

2.2 Data collection

Records of climatic variables were collected from Nigeria Meteorological Agency (NIMET), Abuja. For Asaba station with elevation of about 97.6 m above mean sea level, 41-years (1975 – 2015) record was obtained with statistically significant increasing evapotranspiration ET_o trend and for Uyo with elevation 38.0 m above mean sea level, 35-years (1981 - 2008) record was obtained with decreased trend in ET_o (Umego et al., 2020). The climatic variables obtained from NIMET include solar radiation, maximum and minimum temperature, relative humidity, sunshine hours and wind speed; all in monthly average.

2.3 Calibration of Blaney-Morin-Nigeria ET Model

Calibration of the BMN *ET* model as given in Equation 1 was carried out and new location model constants (*H* and *m*) were obtained.

BMN ET model:

$$ETo= r_f \frac{(0.45t+8)(H-R^m)}{100} \quad (1)$$

where: ET_o is the reference evapotranspiration (mm day^{-1}), r_f is the ratio of monthly radiation to annual radiation, t is the average monthly temperature (℃), R is the relative humidity (%) and H, m is the Duru's model constants of 520 and 1.31 respectively.

The calibration was done using two-third of the data and the remaining one-third was used to validate the model in order to generate a model that is specific and accurate for the estimation of evapotranspiration at Asaba, Uyo and other locations within the South-south part of Nigeria; since they have similar climatic conditions. This was done to correct some shortcomings observed from the procedure applied by Duru (1984) in creating the model; one of which is the use of a 10-year data obtained from only one station (Samaru-Zaria) which is in the Northern part of the country, a Sudan savannah region.

The procedure used for the generation of model constants is as described in Duru (1984), but the ET_o estimates used for the re-examination was obtained using the FAO56-PM model. Afterwards, a non-linear regression model based on the Levenberg-Marquardt algorithm also known as the damped least-squares used to solve the non-linear least squares problem (given in Sigma-Plot software) was used to generate new model constants for Asaba and Uyo. Also, combined meteorological data from the two locations were used to generate a set of constants for the South-south region. This algorithm was applied to give more accurate values of the parameters H and m, thereby minimising errors.

2.4 Statistical analysis

Quantitative approaches to the evaluation of model performance were applied. Fox (1981); Alexandris et al. (2008) observed that commonly used correlation measures, such as correlation coefficient (r, dimensionless) and regression (R^2, dimensionless), are often unsuitable or misrepresentative when used to compare model predicted variables and observed variables. Model efficiency (EF) according to Greenwood et al. (1985) should be calculated on the basis of the relationship between predicted and observed mean deviations. In essence, the comparison was done using regression analysis (Equation 2, dimensionless), S^2d (Equation 3, mm^2 day^{-2}), MAE (Equation 5, mm day^{-1}), $RMSE$ (Equation 6, mm day^{-1}) and correlation coefficient (r) (Equation 7, dimensionless). Five statistical indices were used to validate and test the efficiency of the modified BMN model used for evapotranspiration estimation. They are;

Regressions analysis:

$$Oi = sPi + c \tag{2}$$

Measurement of the variability of the difference between the predicted and observed values:

$$S^2d = (N-1)^{-1}\sum_{i=1}^{N}(Pi - Oi - MBE)^2 \tag{3}$$

$$MBE = N^{-1}\sum_{i=1}^{N}(Pi - Oi) \tag{4}$$

The Mean Absolute Error:

$$MAE = N^{-1}\sum_{i=1}^{N}|Pi - Oi| \tag{5}$$

The Root Mean Square Error:

$$RMSE = [N^{-1}\sum_{i=1}^{N}(Pi - Oi)^2]^{0.5} \tag{6}$$

The Coefficient of Correlation:

$$r = \frac{\sum PO - \frac{\sum P \sum O}{N}}{\sqrt{(\sum P^2 - \frac{(\sum P)^2}{N})(\sum O^2 - \frac{(\sum O)^2}{N})}} \tag{7}$$

Where: Oi is the observed value which refer to ET_o values estimated using the FAO56-PM model (mm day^{-1}), s is the slope, Pi is the predicted value which refer to ET_o values estimated using the modified BMN model (mm day^{-1}), c is the intercept and N is the number of observations.

The closer to zero the values of S^2d, MAE, RMSE and c, the better performed the respective model, whereas the closer to unity (1.0) the value of r and s, the better the model.

3 Results and discussion

New model constants were generated for Asaba, Uyo and all other locations that fall within the South-south part of Nigeria. These newly generated model constants and the original BMN model constants are presented in Table 1.

The modified BMN equations are in the form:

$BMN_{Original}$:

$$ET_o = (r_f(0.45T + 8)(520 - R^{1.31}))/100 \quad (8)$$

BMN_{Asaba}:

$$ET_o = (r_f(0.45T + 8)(285.8 - R^{0.91}))/100 \quad (9)$$

BMN_{Uyo}:

$$ET_o = (r_f(0.45T + 8)(287 - R^{1.00}))/100 \quad (10)$$

$BMN_{South\text{-}south}$:

$$ET_o = (r_f(0.45T + 8)(288 - R^{0.96}))/100 \quad (11)$$

where: T is the average monthly temperature(℃).

Table 1 Original and newly generated BMN model constants

Station	*N*	*H*	*m*	*SEE*		*p*	
				H	*m*	*H*	*M*
Original BMN	120	520.0	1.31				
Asaba	336	285.8	0.91	8.1105	0.0353	<0.0001	<0.0001
Uyo	288	287.0	1.00	7.8484	0.0023	<0.0001	<0.0001
South-south	576	288.0	0.96	6.4909	0.0227	<0.0001	<0.0001

Note: *N* –Number of months used for the generation of the model, *H* and *m* – BMN ET model constants (dimensionless), *SEE* – Standard error of estimate, and *p* – Probability level.

The validation of the models was made by comparing the ET_o calculated using the new models with that calculated using the FAO-56 PM method. The ET_o estimates from both the new BMN models and the original BMN model were also compared with the standard FAO-56 PM model. This was done to ascertain if the newly generated models gave more satisfactory and better ET_o estimates than the original BMN model.

In Asaba, the mean monthly ET_o estimates obtained by averaging the monthly ET_o values for Asaba for the period of record is summarized in Table 2. The estimations were done using the original BMN model, the new model for Asaba and the South-south model.

Table 2 Mean Monthly ET_o Estimated by Different Models for Asaba

Months	FAO-56 PM mm day^{-1}	Original BMN mm day^{-1}	Asaba BMN mm day^{-1}	South-south mm day^{-1}
Jan	4.56	5.57	4.81	4.64
Feb	4.86	5.27	4.97	4.76
Mar	4.90	4.87	4.87	4.65
Apr	4.86	4.08	4.40	4.19
May	4.40	3.30	3.79	3.60
Jun	3.79	2.68	3.33	3.15
Jul	3.29	2.35	3.07	2.90
Aug	3.16	2.32	3.12	2.94
Sep	3.41	2.73	3.55	3.36
Oct	3.79	3.19	3.83	3.63
Nov	4.30	3.85	4.19	3.99
Dec	4.46	4.66	4.48	4.29
Total	49.78	44.87	48.44	46.09

To ensure an extensive comparison of the models, an extended analysis was performed using different statistical indices for the estimated values. The comparison was done using regression analysis, S^2d, *MAE*, *RMSE* and correlation coefficient (r) as presented in Tables 3 and 4 for Asaba and Uyo respectively.

Table 3 Summary Statistics of mean monthly ET_o estimated for Asaba

Asaba	Regression	S^2d	*MAE*	*RMSE*	*r*	*N*
Original BMN	$Oi = 0.46\ Pi + 2.42$	0.70	0.80	0.91	0.81	156
BMN Asaba	$Oi = 0.90\ Pi + 0.54$	0.15	0.32	0.41	0.85	156
South-south	$Oi = 0.89\ Pi + 0.97$	0.15	0.39	0.50	0.84	156

Note: S^2d- Measurement of the variability of the difference between the predicted and observed values (mm^2 day^{-2})*; MAE* - Mean absolute error*; RMSE* - Root mean square error (mm day^{-1})*; r* - Correlation coefficient (dimensionless)*;* and *N* – Number of months used for the validation of the model.

Table 4 Summary Statistics of mean monthly ET_o estimated for Uyo

Uyo	Regression	S^2d	*MAE*	*RMSE*	*R*	*N*
Original BMN	$Oi = 0.47\ Pi + 1.86$	0.72	0.70	0.79	0.85	132
BMN Uyo	$Oi = 1.00\ Pi + 0.06$	0.16	0.30	0.37	0.86	132
South-south	$Oi = 0.99\ Pi + 0.13$	0.17	0.35	0.44	0.84	132

Note: S^2d- Measurement of the variability of the difference between the predicted and observed values (mm^2 day^{-2})*; MAE* - Mean absolute error*; RMSE* - Root mean square error (mm day^{-1})*; r* - Correlation coefficient (dimensionless)*; and N* – Number of months used for the validation of the model.

In Asaba, all the three models underestimated the FAO-56 PM *ET*. The original BMN model underestimated by 9.87%; BMN model for Asaba underestimated by 2.70% while the BMN for South-south underestimated by 7.14%. This makes the BMN model for Asaba the best ET_o predictor for the location and that for south-south the second best.

These comparisons were also shown graphically in Figures 2 and 3 where the points are more closely distributed along the FAO-56 PM series for the modified BMN model for Asaba and South-south than the original BMN model.

Statistically, the estimated values of ET_o from the new models compared favourably with the ET_o values estimated from the FAO-56 PM model (Table 3). As stated in the methodology, the best method for ET_o estimation compared with FAO-56 PM is the one with smallest S^2d, *MAE* and *RMSE* values, *c* value closet to zero and *s* and *r* value closet to 1.0.

The ET_o estimates from the BMN model for Asaba when compared to the original BMN gave reliable and more satisfactory ET_o estimates with *s*, *c*, S^2d, *MAE*, *RMSE,* and *r* values as 0.90, 0.54, 0.15 mm^2 day^{-2}, 0.32, 0.41 mm day^{-1} and 0.85 respectively as against 0.46, 2.42, 0.70 mm^2 day^{-2}, 0.80, 0.91 mm day^{-1} and 0.81 which was obtained from the original BMN model. In addition, the South-south model when applied in Asaba also gave a better estimate with *s*, *c*, S^2d, *MAE*, *RMSE*, and *r* as 0.89, 0.97, 0.15 mm^2 day^{-2}, 0.39, 0.50 mm day^{-1} and 0.84 than the original BMN model as represented in Figure 4.

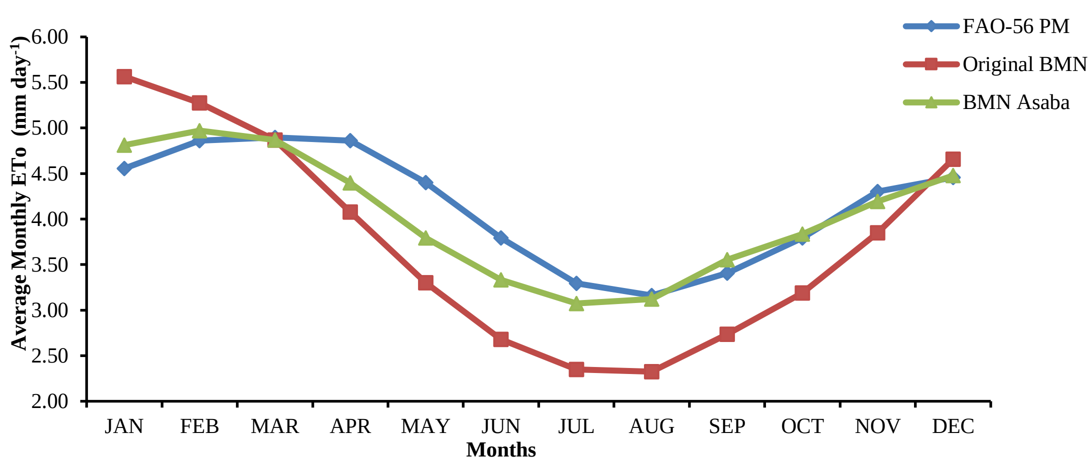

Figure 2 Average monthly ET_o values of the original BMN model, BMN for Asaba and FAO-56 PM model

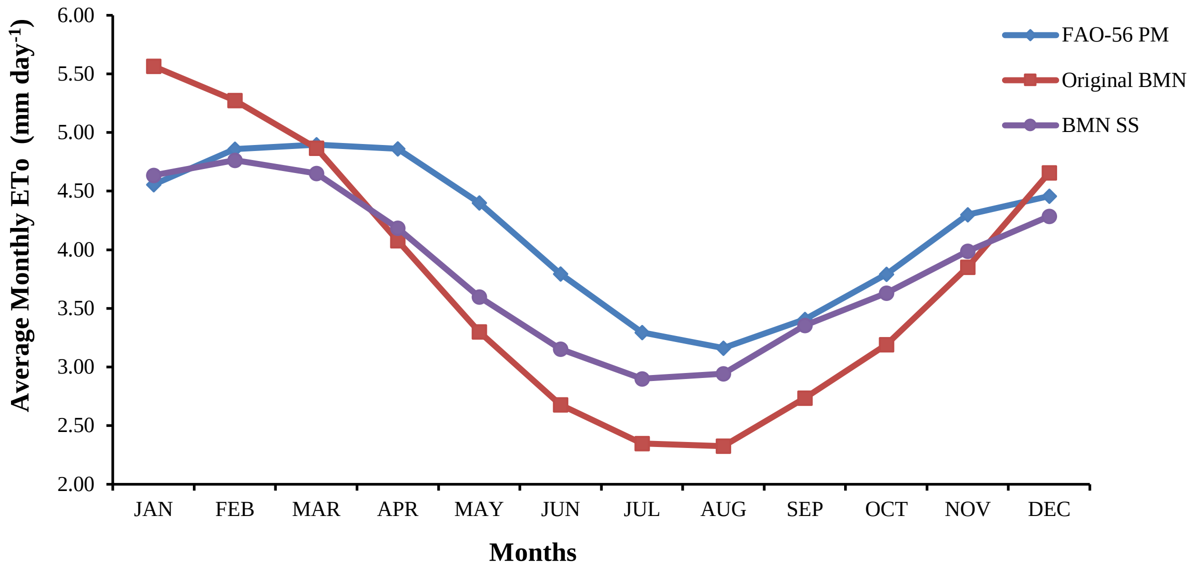

Figure 3 Average monthly ET_o values of the original BMN model, BMN for South-south and FAO-56 PM model for Asaba

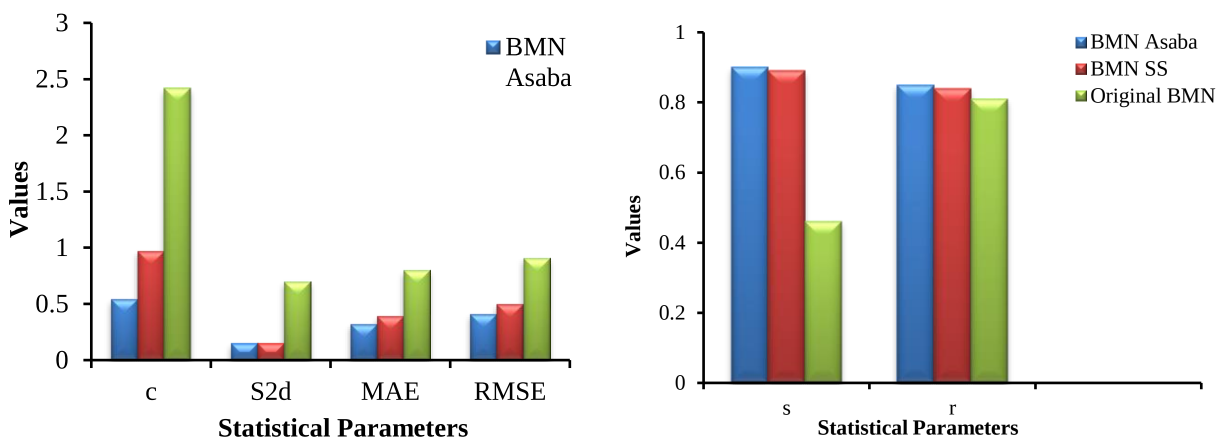

Figure 4 Graphical representation of statistical parameters of the BMN models for Asaba

The closer to zero the values of intercept (c), S^2d (mm^2 day^{-2}), MAE and RMSE (mm day^{-1}) and the closer to unity the values of slope (s) and r (dimensionless), the better performed the respective model.

Table 5 Mean Monthly *ET_o* estimated by different models for Uyo

Months	FAO-56 PM mm day^{-1}	Uyo BMN mm day^{-1}	South-south mm day^{-1}
Jan	4.28	4.41	4.61
Feb	4.85	4.66	4.88
Mar	4.51	4.27	4.52
Apr	4.12	3.80	4.04
May	3.62	3.34	3.40
Jun	3.20	2.96	3.17
Jul	2.89	2.69	2.90
Aug	2.96	2.75	2.96
Sep	3.15	3.12	3.35
Oct	3.29	3.40	3.63
Nov	3.27	3.55	3.79
Dec	3.38	3.81	4.04
Annual	43.54	42.76	45.29

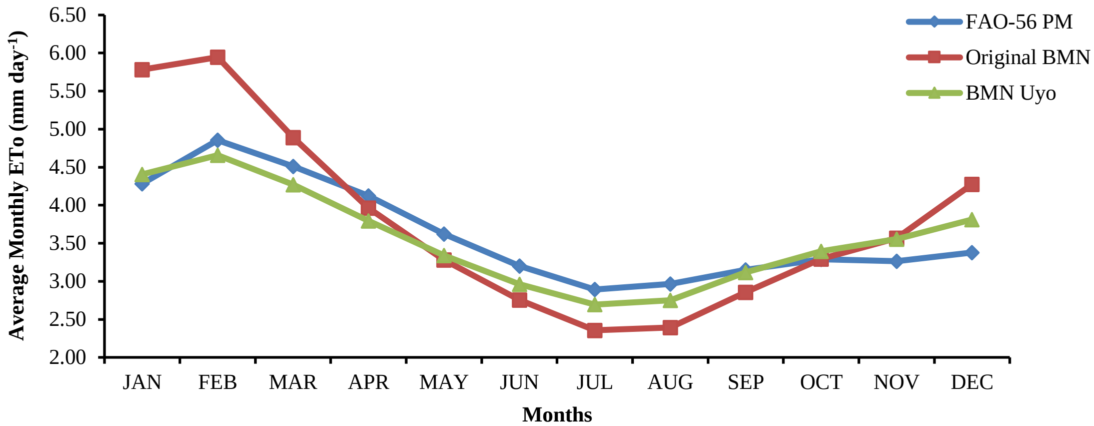

Figure 5 Average monthly ET_o values for values of the original BMN model, BMN for Uyo and FAO-56 PM model

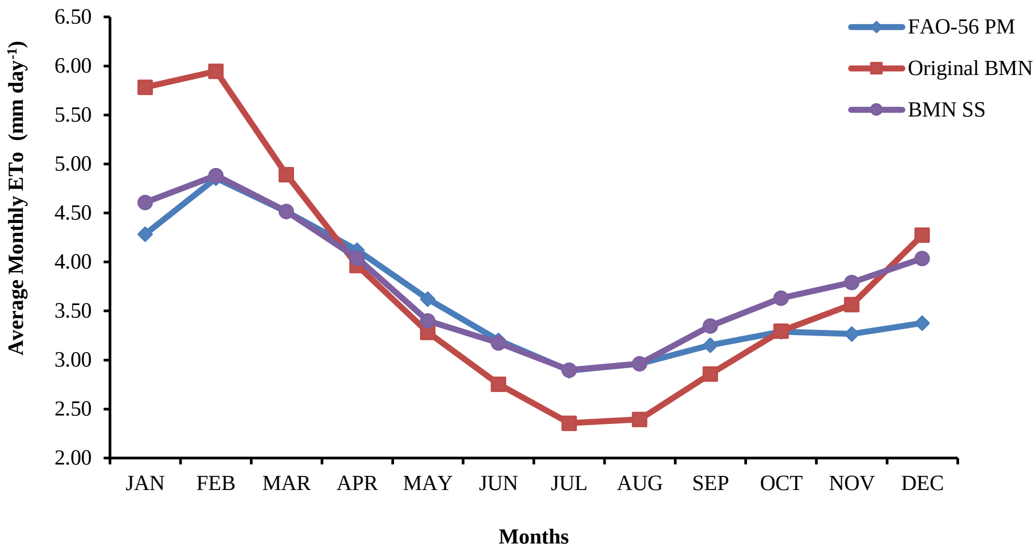

Figure 6 Average monthly ET_o values of the original BMN model, BMN for South-south and FAO-56 PM model for Uyo

In Uyo, the average monthly ET_o estimates obtained by averaging the monthly evapotranspiration values for Uyo for the period of record are summarised in Table 5. As in Asaba, the estimations were done using the original BMN model, the new model for Uyo and the South-south model. The new model for Uyo underestimated the FAO-56 PM *ET* by 1.83% while the original BMN model and that for South-south overestimated FAO-56 PM *ET* by 4.19% and 3.99% respectively. This makes the BMN model for Asaba the best ET_o predictor for the location and that for South-south the second best same as obtained in Asaba. The graphical comparison are shown in Figures 5 and 6.

Statistically, the ET_o estimates from the BMN model for Uyo when compared to the original BMN gave more satisfactory ET_o estimates with *s*, *c*, S^2d, *MAE RMSE* and *r* values as 1.00, 0.06, 0.16 mm^2 day^{-2}, 0.32 mm day^{-1}, 0.30 and 0.86 respectively as against 0.47, 1.86, 0.72 mm^2 day^{-2}, 0.70, 0.79 mm day^{-1} and 0.85 which was obtained from the original BMN model (see Figure 7).

The original BMN model has a better correlation coefficient (r = 0.85) to FAO-56 PM than the new model for South-south (*r*=0.84) but has other statistical parameters *s*, *c*, S^2d, *MAE* and *RMSE* lower-performed than that obtained South-south BMN model (0.99, 0.13, 0.17 mm^2 day^{-2}, 0.35 and 0.44 mm day^{-1} respectively). As earlier stated, the original BMN overestimated FAO-56 PM by 4.19% whereas the South-south model overestimated by 3.99%. This is in line with the observation made by Fox (1981) and Alexandris et al. (2008) that correlation measures (r) and (R^2), are often unsuitable when used to compare model predicted variables and observed variables. This implies that the calibrated model can be best applied in any location in the South-south parts of the country Nigeria to obtain useful ET_o estimates.

In summary, the newly developed models for Asaba and Uyo and the model developed for use in any location within the South-south Nigeria predicted more reliable and satisfactory reference evapotranspiration estimate than the original BMN model developed for use in any location in Nigeria. This is in line with the observations made by Idike and Anekwe (2002) and Dike (2005) of which one of them was that the BMN *ET* model does not satisfactorily predict ET_o in locations that were not captured in the model development. In addition, Echiegu et al. (2016) developed new BMN model for Enugu and Ilesanmi et al. (2012) developed new BMN models for Ibadan, Kano and Onne; these new models all predicts more reliable ET_o estimates than the original BMN model.

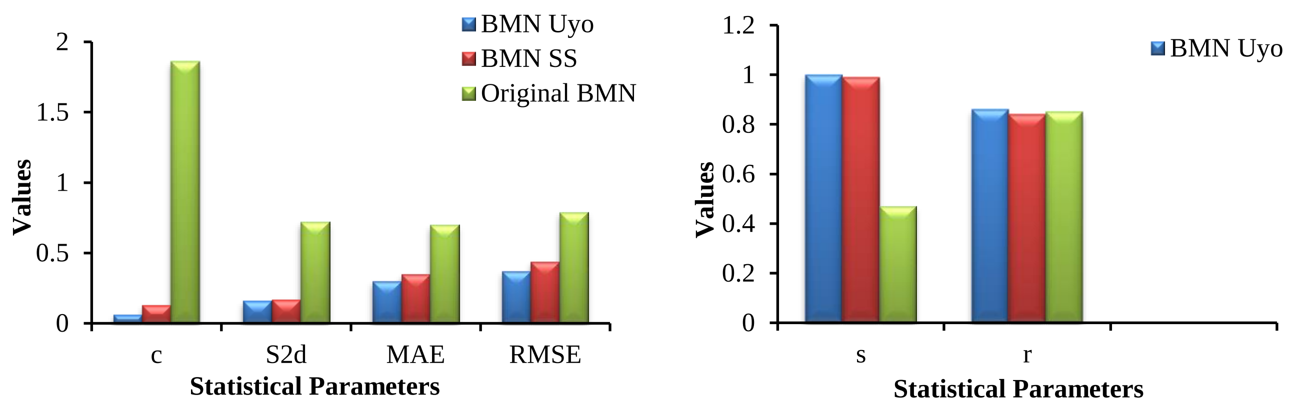

Figure 7 Graphical representation of statistical parameters of the BMN models for Uyo

The closer to zero the values of intercept *(c)*, S^2d (mm^2 day^{-2}), *MAE* and *RMSE* (mmday^{-1}) and the closer to unity the values of slope *(s)* and *r* (dimensionless), the better performed the respective model.

4 Conclusion

This study recalibrated the BMN evapotranspiration model developed by Duru (1984) using the Sigma Plot software (based on Levenberg-Marquardt Algorithm). New BMN *ET* models with new constants were developed for South-south Nigeria and specific model constants were as well developed for Asaba and Uyo. The evaluation and analysis made in this study showed that, the three newly calibrated BMN models when applied in Asaba and Uyo gave a more reliable and accurate reference evapotranspiration (ET_o) estimates than the estimates from the original BMN model when compared with FAO-56 PM model which was used as standard. It also showed that BMN *ET* model which was developed for use in Nigeria cannot predict ET_o satisfactorily in locations that were not captured in its development. This agrees with the fact that it is very important to verify, or even recalibrate models when they are used within a new geographical location or climatic area if account is to be taken of relational changes between meteorological factors such as net radiation, air temperature, elevation advection and relative humidity.

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