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Research Article

A Comparative Analysis of Estimating Reference Evapotranspiration Models in Nguru, Nigeria

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Abstract

This present study estimates and compares six various universally accepted models for estimating reference evapotranspiration (ET_0) for Nguru situated in the Sahelian climatic zone of Nigeria using measured meteorological parameters of monthly mean daily global solar radiation, sunshine hour, wind speed, minimum and maximum temperatures and relative humidity covering a period of thirty one years (1988 – 2018). Four different statistical validation indices of Root Mean Square Error (RMSE), Mean Bias Error (MBE), Mean Absolute Error (MAE) and coefficient of correlation (R) were carried out to test the accuracy of the evaluated models. The result indicated that high values of ET_0 were found in the month of April with 7.9670 mm/day for Nguru, and low values were found to be in August with 4.973 mm/day for Nguru. The Blaney – Morin Nigeria model was found more accurate for estimating evapotranspiration for Nguru with RMSE, MBE, MAE and R values as 0.8561 mm/day, -0.2927 mm/day, 0.2927 mm/day and 0.9162 respectively.

KEYWORDS: meteorological parameters, Nguru, NIMET, reference evapotranspiration, statistical indication

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Introduction

The major factor faced by Agricultural activities is water scarcity. Water is very essential in Agricultural activities (plantation), crop acquires water naturally by precipitation and subsurface moisture. When the supply of water is inadequate for crop use, farming mostly results to irrigation (Adeboye *et al*., 2009). Availability of water is also important in economic activities like industries, the energy sector (hydropower) and public use. Recently, a careful control of water used for irrigation has been major factor to be considered in order for use to enable a necessary distribution or spreading of the available resources among residential, industrial and agricultural use (Maeda, 2011).

Evapotranspiration is the combination of two processes (Evaporation and Transpiration) which involves the loss of water on one hand from the soil surface by evaporation, E, and on the other hand from plant by transpiration, T, which becomes ET by combination (Allen *et al*., 1998). Estimation of ET is very important to identify temporal variations on irrigation requirements, implore water resources allocation and also to determine the effect of land use and management on the water balance (Ortega-Farias *et al*., 2009). Due to regular supervision of irrigation through knowledge and understanding of ET as a major tool in preserving water resources both qualitatively and quantitatively is paramount (Ali *et al*., 2011). Water is a peak factor on crop growth through one of the major concerns in wielding. ET is an accurate stimulation of the soil water balance (Ali *et al*., 2011).

Recently, approximately 70% of fresh water with drains is used for agriculture (FAO, 2005). In most sub-Saharan African countries', agriculture is the main economic activity, representing about 40% of the gross domestic product (Barrios *et al*., 2008) and it is evaluated that between the years 1975 and 2000. The Agricultural areas increased by 57% in the sub-Saharan Africa (Brink and Eva 2009). Therefore, all terms influencing the soil, lack of water balance has to be calculated accurately for water pressure effects to be simulated accordingly (Ali *et al*., 2011). Nguru has three distinct seasons, the rainy season, the cool dry (harmattan) season and the hot dry season (Akpootu *et al.,* 2019a). In this regard, irrigation is required and hence the need to estimate ET models to ascertain the most appropriate. The direct measurement of evapotranspiration (ET) which involve the use of lysimeter is usually not feasible in many field situations because lysimter is very expensive, difficult to maintain and time consuming. The required instrumentation can also be lacking. The fact is that direct measurement of ET is a very difficult task, hence the development of hydro meteorological methods to estimate reference evapotranspiration (ETo) was employed in this study using the United Nation Food and Agricultural Organization Penman- monteith (FAO-56 PM) method as a benchmark for the evaluation of the Evapotranspiration models.

Many researchers have been conducted on studies that involved the estimation and comparison of various models for estimating evapotranspiration in different climatic zone within and outside Nigeria these include the study of Isikwue et al. (2014) where they evaluated evapotranspiration using FAO – 56 PM model in Kano, Nigeria. In another study, Zarie et al. (2015) where they compared several models to estimate reference evapotranspiration in Garebayegan research station at far province. Akpootu and Iliyasu (2017) compared various universal accepted models for estimating ET_o, they consider in their study six models for estimating ET_o for Sokoto, Nigeria.

This present study, evaluates and compares six evapotranspiration models for estimating reference evapotranspiration in Nguru, Nigeria, using FAO – 56 PM method as standard. The main reason for the comparison is to ascertain which of the six models is most appropriate to be considered as an alternative to FAO – 56 PM model for estimating ET_o in the study area based on the four adopted statistical indicators.

Methodology

Over forty (40) weather observatories are located in Nigeria at different stations which are controlled by the Nigerian Meteorological Agency. None of these stations measure evapotranspiration. The climatic data of measured monthly average daily global solar radiation, sunshine hour, wind speed, maximum and minimum temperatures and relative humidity covering a period of thirty-one years (1988-2018) for Nguru situated in Sahelian region of Nigeria was obtained from the Nigerian Meteorological Agency (NIMET), Oshodi, Lagos, Nigeria.

FAO-56 Penman- Monteith Method (FAO 56 PM)

This approach has been implemented and recommended as the general overall method for the determinant of ET_O by the United Nation Food and Agricultural Organizations (FAO) and was used worldwide because it put both the physical and aerodynamic parameters into consideration. PM equation is considered the best methods so far for the estimation of ET_O in all climatic conditions. The FAO- 56 PM method is often recommended as a standard procedure for accurate estimation of ET_O where there is no measured lysimeter data on reference evapotranspiration. The evapotranspiration ET values obtained from the derived equations are usually compared against this method. The ET_O was calculated using the PM model for the ET_O estimation recommended by the FAO-56 paper (Allen *et al.*, 1998), and standardized by the American society of the civil Engineer-ASCE (Allen *et al.*, 2005) and is expressed as;

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$$ET_0 = \frac{0.408\Delta(R_n - G) + \frac{900}{T+273}U_2(e_s - e_a)}{\Delta + \gamma(1 + 0.34U_2)} \quad (1)$$

where ET_0 is the reference evapotranspiration (mmday^{-1}), R_n is the net radiation at the crop surface (MJm^{-2}day^{-1}), G is the solar heat flux (MJm^{-2}day^{-1}), T is the mean daily air temperature (^{0}C), U_2 is the wind speed at 2m height (ms^{-1}), e_s is the saturated vapour pressure (KPa), e_a is the actual vapour pressure (KPa), e_s-e_a is the saturated vapour pressure difference (KPa) and γ is the psychometric constant (KPa^{0}C^{-1}). According to Łabędzki et al. (2011), the soil heat flux can be ignored and assumed to be zero, since it is small compared to the value R_n.

In this study, R_n, Δ, U_2, e_s, e_a and γ was be calculated as proposed by FAO (Allen *et al*., 1998). The mean saturated vapour pressure derived from air temperature is given by (Allen *et al*., 1998).

$$e_s = \frac{e_{(Tmax)} + e_{(T_{min})}}{2} \quad (2)$$

$$e_{(T_{max})} = 0.6108\, exp\left(\frac{17.27T_{max}}{T_{max}+273}\right) \quad (3)$$

$$e_{(T_{min})} = 0.6108\, \exp\left(\frac{17.27T_{min}}{T_{min}+273}\right) \quad (4)$$

T_{max} is the maximum daily air temperature in ^{0}C, T_{min} is the minimum daily temperature in ^{0}C.

The actual vapour pressure derived from relative humidity was computed using the expression:

$$e_a = \frac{RH_{max}}{100}\left[\frac{e_{(Tmax)} + e_{(T_{min})}}{2}\right] \quad (5)$$

The slope of the saturated vapour pressure curve was obtained using the following expression:

$$\Delta = 4098\left[\frac{0.6108exp\left(\frac{17.27T}{T+273.3}\right)}{(T+273.3)^2}\right] \quad (6)$$

The atmospheric pressure P is related to z as shown in the expression below

$$P = 101.3\left(\frac{293 - 0.0056Z}{293}\right)^{5.26} \quad (7)$$

where, Z is the station elevation above sea level in meters.

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The psychrometric constant, is related to P by the expression given below:

$$\gamma = 6.65 \times 10^{-4} P \tag{8}$$

The net radiation R_n will be estimated using the expression

$$R_n = R_{ns} - R_{nl} \tag{9}$$

where R_{ns} and R_{nl} is a shortwave and longwave radiation in ($MJm^{-2}day^{-1}$) was calculated according to the FAO irrigation and drainage paper No. 56 as

$$R_{ns} = (1 - a)R_s \tag{10}$$

where a is the albedo or canopy reflection coefficient which is 0.23 for the hypothetical grass references crop (dimensionless) Rs is the incoming solar radiation ($MJm^{-2}day^{-1}$)

$$R_{nl} = \sigma \left[\frac{T_{max,k^4} + T_{min,k^4}}{2}\right]\left(0.34 - 0.14\sqrt{e_a}\right)\left\{1.35\frac{R_s}{R_{so}} - 0.35\right\} \tag{11}$$

where σ is the Stefan Boltzmann constant (4.903×10^{-9} $MJm^{-4}m^{-2}day^{-1}$)
T_{max}, k is the maximum absolute temperature during the 24 hour period (k = ^oC+273.16)
T_{min}, k is the minimum absolute temperature during the 24-hour period (k = ^oC+273.16)

R_s/R_{so} is the relative shortwave radiation (limited to ≤1.0) and R_{so} is the calculated clear sky radiation ($MJm^{-2}day^{-1}$). R_{so} was obtained using the following expression

$$R_{so} = (a_s + b_s)R_a \tag{12}$$

$a_s + b_s$ is the fraction of extraterrestrial radiation reaching the earth no clear sky day and Ra is the extraterrestrial radiation ($MJm^{-2}day^{-1}$). The fraction of extraterrestrial radiation reaching the earth on clear sky day was obtained using regression analysis with Minitab 16.0 software based on the following expression

$$R_s = \left[a_s + b_s\left(\frac{s}{s_0}\right)R_a\right] \tag{13}$$

where s/s_0 is the relative sunshine duration R_a was calculated according to the FAO irrigation and drainage paper No. 56 (Allen *et al.*, 1998).

The wind speed data obtained from the meteorological station was converted to 2 m as required for agrometeorological according to the following expression:

$$U_2 = U_z \frac{4.87}{\ln(678z - 5.42)} \tag{14}$$

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where U_z is the measured wind speed at Z m above the ground surface (m/s).Six ET models are utilized in this study.

Blaney- Morin- Nigeria Model

The Blaney- Morin- Nigeria (BMN) model was developed for the estimation of reference evapotranspiration in Nigeria by Duru (1984). This method was applied following the procedures laid down by Duru (1984). The model equation is equation is given by

$$ET_o = \frac{rf(0.45T_{mean}+8)(520-R^{1.31})}{100} \quad (15)$$

where, rf is the ratio of monthly radiation to annual radiation, T_{mean} is the mean monthly temperature in ^oC and R is the mean monthly relative humidity, 520 and 1.31 are the model constants given by Duru (1984). ET_o is as previously defined.

Priestley and Taylor model

Priestley and Taylor (1972) method is a simplified method requiring only solar radiation and temperature weather parameters for the computation of evapotranspiration. This is based on the fact that radiation is the major source of energy and thus a potential factor as compared to other weather parameters for evapotranspiration computation. According to them about two-third radiation components contributes to the evaluation of evapotranspiration. The model estimation is done using the equation:

$$ET_o = \alpha \frac{\Delta}{\Delta+\gamma}(R_n - G)\frac{1}{\lambda} \quad (16)$$

where, α is an empirically determined dimensionless correction given as α = 1.26 and λ is the latent heat of vaporization (2.45 MJg^{-1} @ 20^oC), $\Delta, \gamma, R_n, ET_o$ *and* $G$are as previously defined.

Mankkink (Makik) Model

The Mankink model was proposed in 1957 in the Netherlands as a modification of Penman after comparing the Penman model to lysimetric data (Mankkink, 1975; Allen, 2005). Recently, Mankkink is popular in West Europe and has been used successfully in the US (Amatya *et al.*, 1995). Allen (2005) gives the operational form of the Mankkink model as

$$ET_0 = 0.61\left(\frac{\Delta}{\Delta+\Upsilon}\right)\left(\frac{R_s}{2{,}45} - 0.12\right) \quad (17)$$

where ET_o is the reference Evapotranspiration (mmday^{-1}), R_s is the solar radiation (MJm^{-2}day^{-1}) and Δ and $\gamma$are as already defined.

Hangreaves and Samani Model (H&M)

This model was developed by (Hargreaves and Samani, 1985) using 8 years of daily lysimeter data from Daris California and the model was tested in different locations such as Australia, Haiti, and Bangladesh. Since the development of the model, it has been successfully implemented and recommended worldwide (Gavilán *et al*., 2006). The Hangreaves equation requires only daily mean, maximum and minimum air temperature and extraterrestrial radiation. This simply means that any condition where solar radiation, wind speed and relative humidity data are not measured, ET_O can be determined using temperature data according to the model equation stated by Hangreaves and Samani (1985).

$$ET_0 = 0.0023(T_{mean} + 17.8)(T_{max} - T_{min})^{0.5} R_a \quad (18)$$

where T_{mean} and R_a is extraterrestrial radiation, and the mean air temperature given as (Akpootu *et al*., 2019b; Akpootu *et al*., 2022a)

$$T_{mean} = \frac{T_{max} + T_{min}}{2} \quad (19)$$

Abstew Model (1996)

Abstew (1996) make used of simple empirical model which shows reference evapotranspiration ET_oas a function of solar radiation only. The model is given by:

$$ET_0 = \frac{0.53 R_s}{\lambda} \quad (20)$$

where λ is the latent heat flux and $R_s$is the shortwave solar radiation (MJm^{-2}day^{-1}) Abstew approach was cross validated by comparing the estimates to four years of Bowen ratio ET_o measurement at nine site (area) Everglade of South Florida (Abstew, 1996) and the results revealed a very good correlation of ET_o estimated by Abstew method and that obtained by Bowen-Ratio over a wet land.

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Jensen Haise Model (JHM)

This model was estimated over 3000 observation of evapotranspiration (ET) as calculated by soil sampling steps over the period of 35 years in western USA (Jensen and Haise, 1963). From their study, Jensen-Haise Model developed the following relationship of evapotranspiration model used in computing reference evapotranspiration (ET_O) as reported by James (1988). The equation of the model is given by

$$ET_0 = C_T(T_{mean} - T_x)R_s \qquad (21)$$

C_T and T_x are constants expressed as;

$$C_T = \frac{1}{\left[\left(45 - \frac{L}{137}\right) + \left(\frac{365}{e_{(Tmax)} - e_{(Tmin)}}\right)\right]} \qquad (22)$$

$$T_x = -2.5 - 0.14\left[e_{(Tmax)} - e_{(Tmin)}\right] - \frac{h}{500} \qquad (23)$$

where h is the attitude of the location $e_{(Tmax)}$, $e_{(Tmax)}$, T_{mean} and R_s are define previously.

Statistical Analysis

The models that are used in this study in computing the reference evapotranspiration (ET_o) for the location under study were statistically tested using the Mean Bias Error (MBE), Root Mean Square Error (RMSE), Mean Absolute Error (MAE) and Correlation Coefficient (R).

Root Mean Square Error (RMSE)

This measures the average difference. RMSE involves the square of difference and therefore becomes sensitive to extreme values (Wilmott, 1983). The smaller the value of the RMSE the better is the model Performance. The magnitudes of RMSE values are useful to identify model performance but not of under or over estimation by individual model (Jacovides and Kontoyianis, 1995). The peak value for RMSE is zero or 0.0 ≤ RMSE is given by the equation which is a modified form as reported by Gana and Akpootu (2013a, b), Akpootu and Gana (2014), Akpootu and Sanusi (2015), Olomiyesan et al., (2021), Akpootu and Iliyasu (2015a, b):

$$RMSE = \left[\frac{1}{n}\sum_{i=1}^{n}(ET_{oest} - ET_{OFAO})^2\right]^{\frac{1}{2}} \qquad (24)$$

Mean Bias Error (MBE)

The mean bias error is a very good measure of model bias and simplifies the average of all differences in the set. It provides general business but not of the average error that could be expected. The positive MBE value indicates overestimation and the negative value indicates underestimation. The absolute value is indicator of model performance. The peak value for MBE is zero like RMSE and the biasness lies between the range of -∞

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to +∞ (-∞ < bias ≤ +∞) (Ram and Anju, 2012). The MBE which is modification of as reported in the work of Akpootu and Momoh (2014), Akpootu and Sulu (2015), Akpootu et al. (2019c, d, e, f), Akpootu and Abdullahi (2022), Akpootu et al. (2022b), Akpootu et al. (2023).

$$MBE = \frac{1}{n}\sum_{i=1}^{n}(ET_{oest} - ET_{OFAO}) \quad (25)$$

Mean Absolute Error (MAE)

The MAE is an absolute value of the MBE. Thus, in this case, all the value of MBE becomes positive. The MAE is given by the equation:

$$MAE = \frac{1}{n}\sum_{i=1}^{n}|ET_{oest} - ET_{OFAO}| \quad (26)$$

Correlation Coefficient (R)

The quantity (R) called the coefficient of correlation and is given by the equation:

$$R = \frac{\sum ET_{oest}ET_{OFAO} - \frac{1}{n}\sum ET_{oest}\sum ET_{OFAO}}{\sqrt{\left(\sum ET_{oest}{}^{2} - \frac{(\sum ET_{oest})^{2}}{n}\right)\left(\sum ET_{OFAO} - \frac{(\sum ET_{OFAO})^{2}}{n}\right)}} \quad (27)$$

The value of R varies between -1 and +1. The + and – signs signifies positive linear correlation and negative correlation respectively. The R is a dimensionless quantity. The estimated value of R measures the degree of the agreement relative to the type of equation that is actually assumed. Thus, the R measures the goodness of fit between the equation actually assumed and the data. High correlation coefficient R, implies (near 1 and -1). In general values close to unity as desired or required (Akpootu and Ilyasu, 2017).

From the equations above the variable ET_{oFAO} represents the observed or measured reference evapotranspiration (ET_o) values (the FAO-56 PM model); ET_{oest} is the estimated/ predicted values of the reference evapotranspiration (ET_o) obtained from the other models, n is the number of observations, $\sum$ is the summation sign. In this study, coefficient of correlation (R) was verified using scatter diagram as well.

Results and Discussion

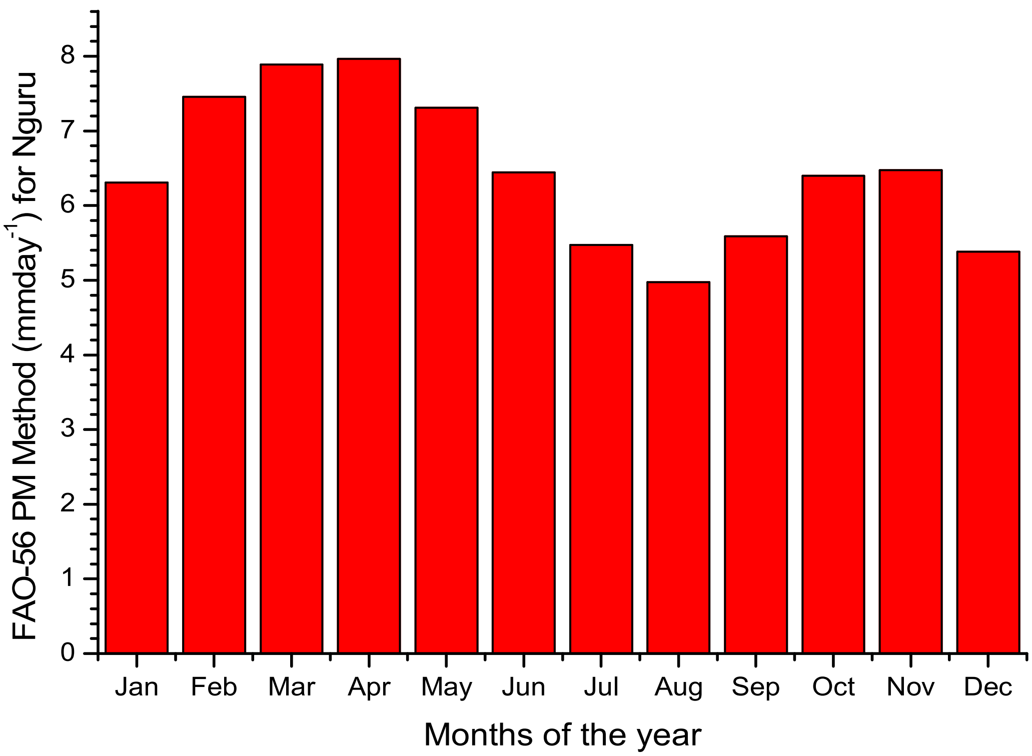

Figure 1: Monthly values of ET_0 for FAO – 56 PM method in Nguru during the period (1988 - 2018)

Figure 1 shows the variation of evapotranspiration with month for the study area during the study period. It was indicated that the peak value of the evapotranspiration was obtained during the onset of rainy season in the month of April and the least value is in the month of August which is the rainy season. This shows that during the dry season the rate of evapotranspiration is usually high and very low during the rainy season. During the dry season, the amount of water required for irrigation is more than during the rainy season. For this study area, the peak value of ET in the month of April is 7.9670 mm/day and the lowest of 4.9731 mm/day in the month of August which is the raining season. The peak value is due to the fact that ET is high during the hot dry weather or clear sky condition as a result of dryness of air and the amount of heat energy available for evaporation. One of the weather parameters is the solar radiation which contributes to the rate of evapotranspiration. Wind speed also serves as an accelerator during this period, which accelerates evaporation that enhances turbulent transport of water vapour from moist vegetation of the dry atmosphere. The constant replacement of the moist air located within and just above the plant canopy with dry air from above is done by the wind. Solar radiation and wind speed play a vital role in the rate of ET. This result is congruence to that of Akpootu and Ilyasu, (2017) in Sokoto using Blaney - morin – Nigeria Model. This results also indicates that in figure 2, ET_0 decreases during the month of July, August and September which comprised the peak Mansoon season with high relative humidity, low wind speed and low temperature; this is similar to the observation carried out by Akpootu and Iliyasu (2017).

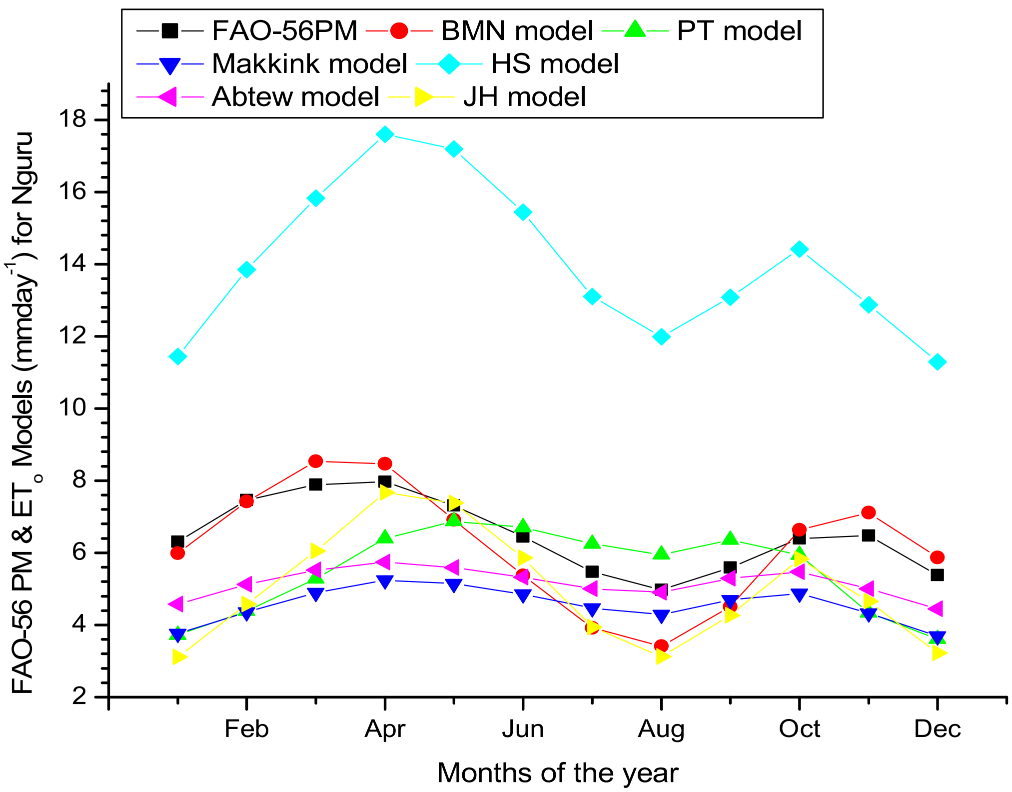

Figure 2. Comparison between estimated ET_0 by FAO – 56 PM and evaluated models in Nguru during the period (1988 - 2018)

Figure 2 shows the monthly averages values of ET_0 estimates, for the period under study (1988 – 2018). An absolute examination of figure 4.1.2 shows the Blaney – Morin Nigeria model overestimates the FAO – 56 PM model including other estimated ET models in the month of March, April and from October to December and Jessen – Haise model underestimates the Blaney – Morin Nigeria model and FAO – 56 PM model including other estimated ET models in the months of January, August, and December, except for Hangreaves and Samani model that overestimates throughout the year. The Blaney –

Morin Nigeria model curve pattern estimates closely follows the pattern obtained by FAO – 56 PM model during the entire year. In relation to this, the pattern obtained in the figure 3 by the other ET models indicates some form of dispersion in comparison with the reference ET model. The figure showed that a large overestimation was observed for the Hangreeve and Samani model in comparison with the other models including the reference FAO – 56 PM model.

Considering the six evaluated ET models, the peak value of the ET was recorded in the month of March with 8.5399 mm/day and the least value in the month of August with 3.4102 mm/day for Blaney – Morin Nigeria model. The peak value of ET was recorded in the month of May with 6.8770 mm/day and the least value in the month of December 3.6096 mm/day for Priestley and Taylor model. The peak value of ET was recorded in the month of April with 5.2470 mm/day and the least in the month of December with 3.6874 mm/day for Makkink model. The peak value of the ET was recorded in the month of April with 17.5979 mm/day and the least in the month of December with 11.2909 mm/day for Hangreeve and Samani model. The peak value of ET was recorded in the month April with 5.7416 mm/day and the least in the month of December with 4.4475 mm/day for Abstew model. The peak value of the ET was recorded in the month of April with 7.6662 mm/day and the least value in the month January with 3.1186 mm/day for Jessen – Haise model.

The ET_0 value computed was observed that Blaney – Morin Nigeria model is in line with FAO – 56 PM model value, as the peak and least values was in the same months of March and August respectively. More so, the Blaney – Morin Nigeria model for estimating ET_0 compares favorably well with the FAO – 56 PM model and therefore can be used as an alternate for estimating ET in Nguru.

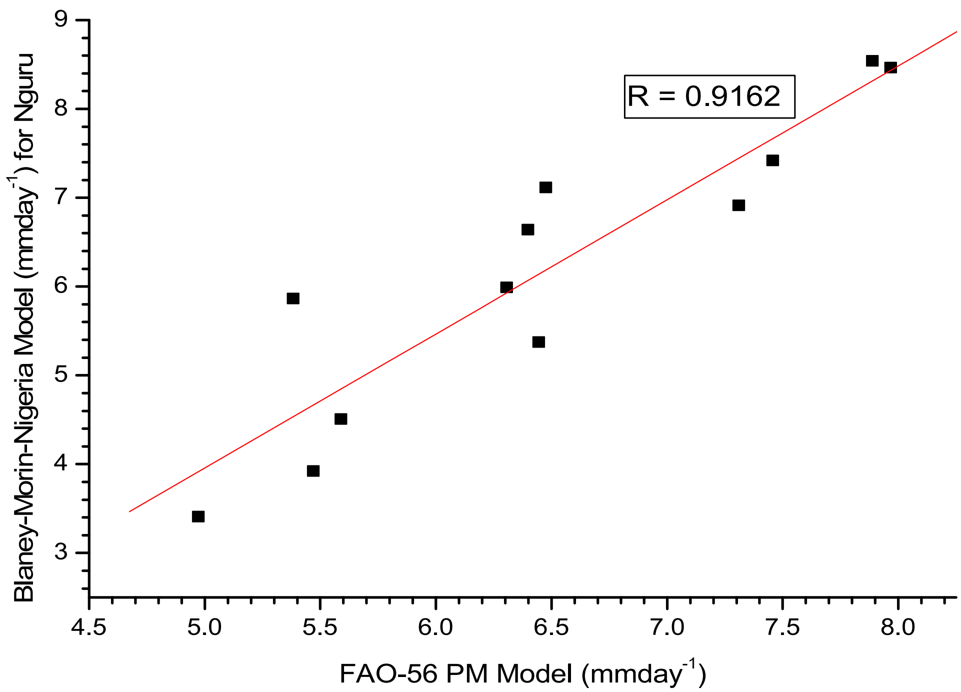

Figure 3: Fitted regression line of BMNM with reference FAO – 56 PM model

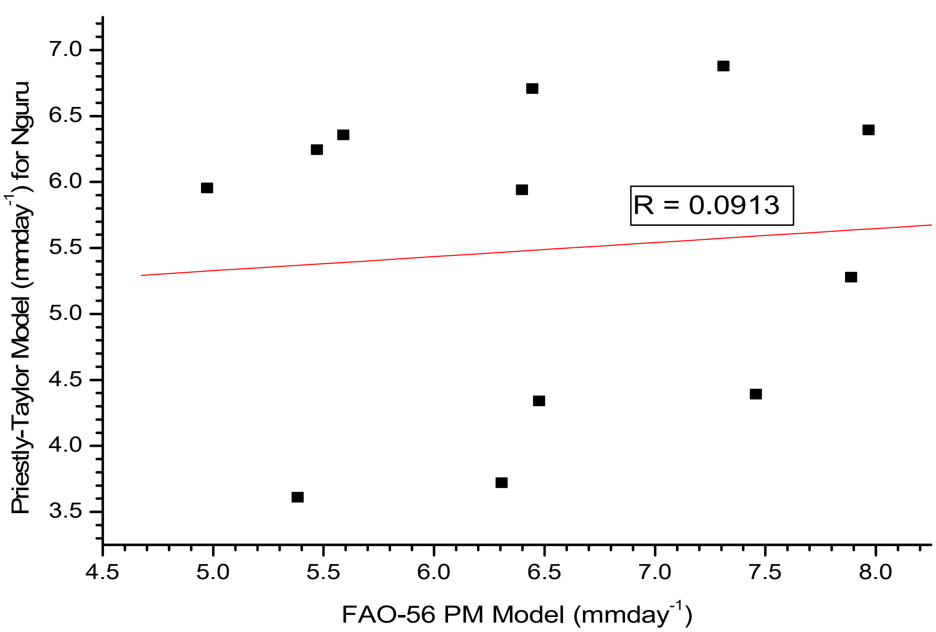

Figure 4: Fitted regression line of priestley and Taylor model with reference FAO – 56 PM model

ISSN: 1597 – 9928. Science and Education Development Inst., Nigeria

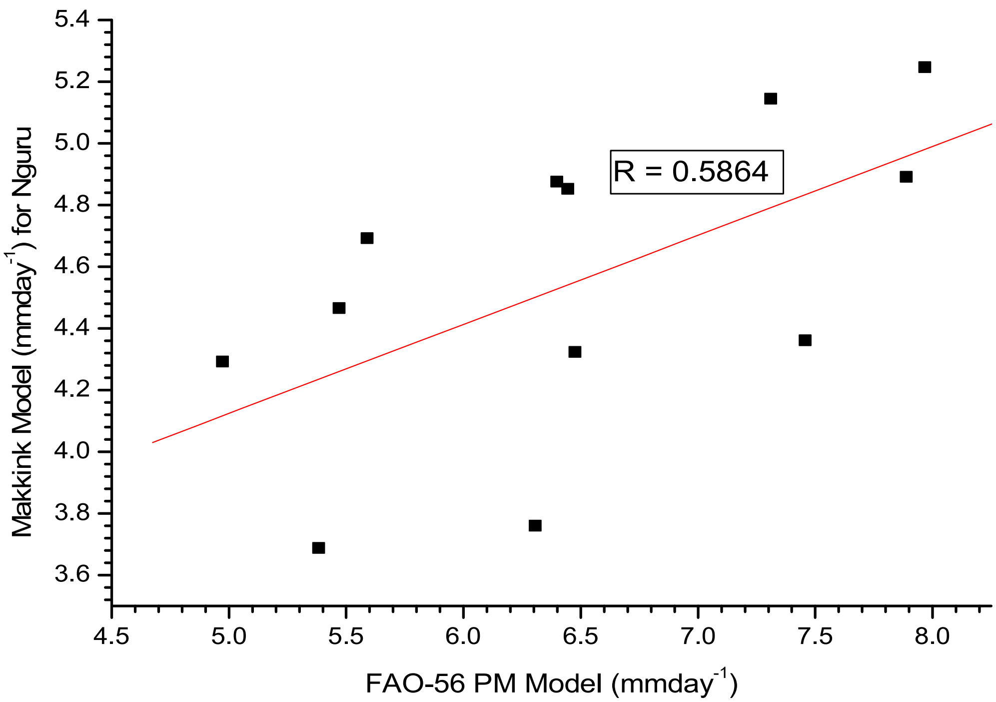

Figure 5: Fitted regression line of Makkink model with reference FAO – 56 PM model

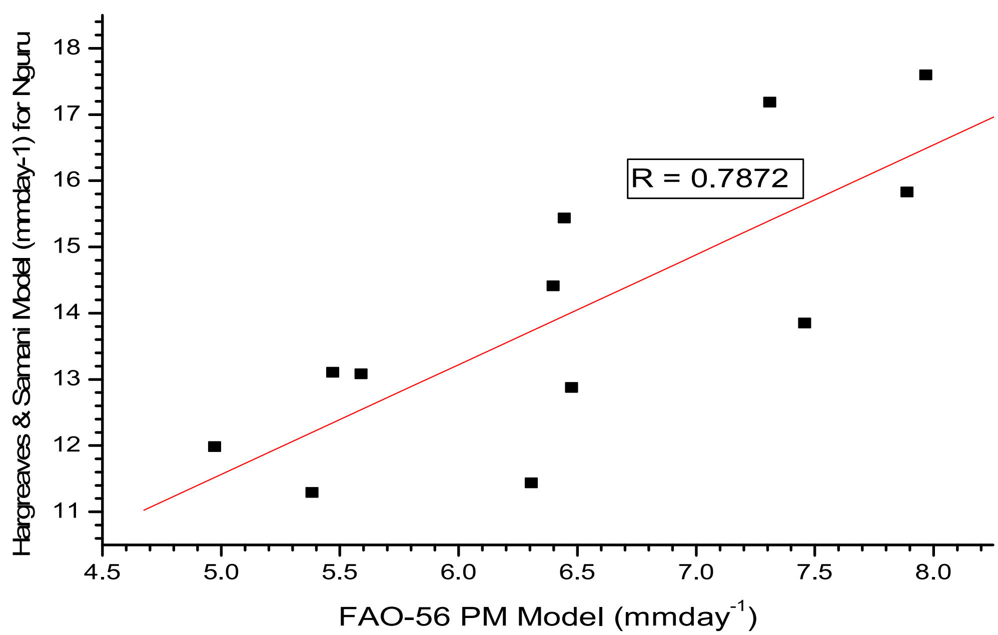

Figure 6: Fitted regression line of Hangreaves and Samani model with reference FAO – 56 PM model

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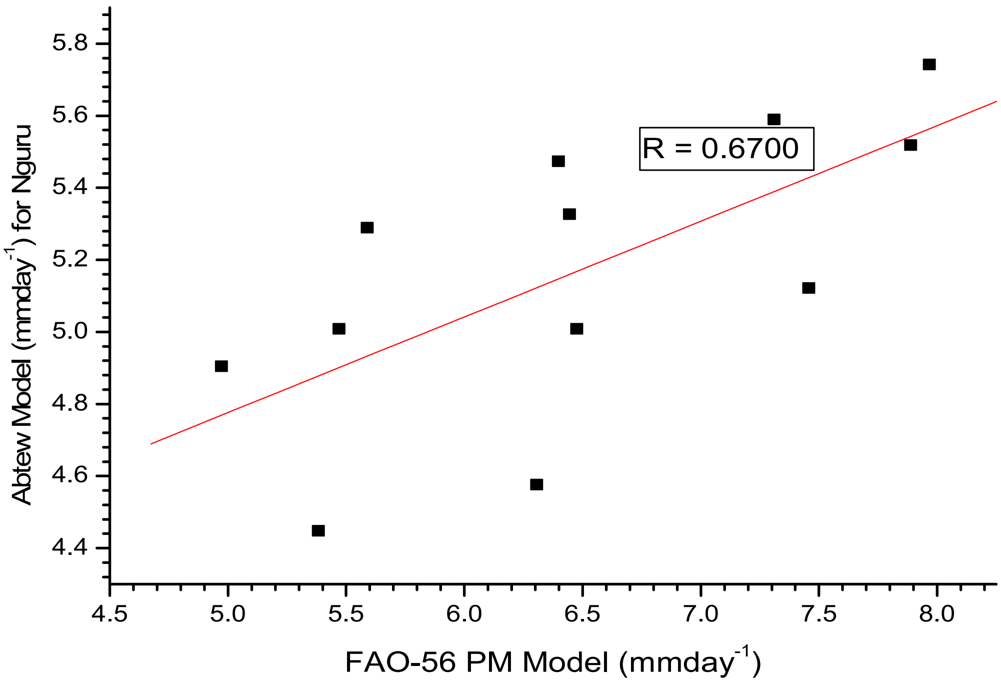

Figure 7: Fitted regression line of Abstew model with reference FAO – 56 PM model

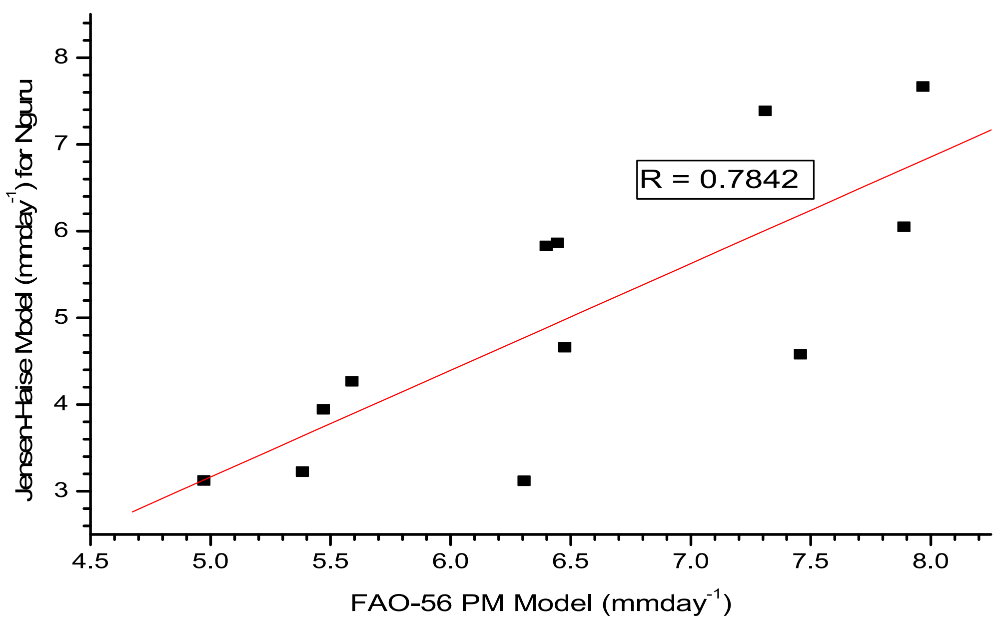

Figure 8: Fitted regression line of Jessen – Haise model with reference FAO – 56 PM model

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The fitted regression lines obtained in the regression analysis using the reference FAO – 56 PM model and the computed models are shown on figures (3 – 8). The Blaney – Morin Nigeria model achieved the best fit resulting in correlation coefficient with 0.9162 (91.62 %) showing a peak positive correlation between the Blaney – Morin Nigeria model and FAO – 56 PM models, followed by Hangreaves and Samani model with correlation coefficient with 0.7872 (78.72 %). The least correlation coefficient is observed for Priestley and Taylor model with 0.0913 (9.13 %).

Table 1. Statistical comparison between ET by FAO – 56 PM and other empirical models for Nguru

Models	MBE	RMSE	MAE	R
BMNM	-0.2927	0.8561	0.2927	0.9162
PTM	-0.9876	1.7245	0.9876	0.0913
Mak	-1.9230	2.0776	1.9230	0.5864
HSM	7.5346	7.6646	7.5346	0.7872
Abstew	-1.3053	1.5121	1.3053	0.6700
JHM	-1.4980	1.7822	1.4980	0.7842

Table 1 shows the different statistical indicators of RMSE, MBE, MAE and R which were carried out to verify the performance of the selected models with the reference FAO – 56 model and the results evaluated were used for ranking to ascertain the best model for the study area. The MBE values ranged from -0.2927 mm/day of the Blaney – Morin Nigeria model to 7.5346 mm/day of the Hangreaves and Samani model. The biasness which was indicated by Mean Bias Error (MBE) represents overestimation when it is positive and the negative sign indicates the underestimation. Based on the MBE, the Blaney – Morin Nigeria model has the lowest value with underestimation of 0.2927 mm/day in its estimated value and was reported the best. The RMSE values ranged from 0.8561 mm/day with the Blaney – Morin Nigeria model to 7.6646 mm/day of Hangreeve and Samani model. Based on the RMSE, the Blaney – Morin Nigeria model has the lowest value with underestimation of 0.8561 mm/day in its estimated value and was reported the best. The MAE values ranged from 0.2927 mm/day of Blaney – Morin Nigeria model to 7.5346 mm/day with the Hangreaves and Samani model. Based on the MAE, the Blaney – Morin Nigeria model has the lowest value with underestimation of 0.2927 mm/day in its estimated value and was reported the best. Due to the high value of the correlation coefficient of the Blaney – Morin Nigeria model performed better with coefficient of 0.9162 followed by the Hangreaves and Samani model with coefficient of 0.7872. The overall results show that the Blaney – Morin Nigeria model performed better in term of MBE, RMSE, MAE and R.

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Table 2. Ranking of evaluated models as per statistical indication for estimating ET_0 for Nguru

Model	MBE	RMSE	MAE	R	Total	Rank
BMNM	1	1	1	1	4	1
PTM	2	3	2	6	13	3
MakM	5	5	5	5	20	5
HSM	6	6	6	2	20	5
Abs M	3	2	3	4	12	2
JH	4	4	4	3	15	4

The ranking of the models used in computing ET_0 tells which of the models serves as an alternate with the FAO – 56 PM model, this ranking of the selected models was done based on the statistical indicators of MBE, RMSE, MAE and R of Table 2. The total ranks acquired by the different models were in the range of 4 to 20. The Blaney – Morin Nigeria model was found to perform better based on the total rank acquired. So, it was found suitable for estimating ET_0 followed by Abstew model that was rank 2nd, Priestley and Taylor model was ranked 3rd, Jessen – Haise model was ranked 4th and Makkink model and Hangreaves and Samani model was ranked 5th. Therefore, the Blaney – Morin Nigeria model was ranked 1st and thus reported as the best model for estimating ET_o in Nguru. The result in this study is in line with that of Akpootu and Iliyasu (2017) where they reported that the Blaney – Morin Nigeria model was found most accurate for estimating reference evapotranspiration in Sokoto.

Conclusion

This study utilized thirty one year monthly data of global solar radiation, sunshine hour, wind speed, maximum and minimum temperature and relative humidity obtained from the Nigerian Meteorological Agency (NIMET) to evaluate and compare six ET models with a view to ascertain the most suitable model capable of estimating ET in Nguru situated in the Sahelian climatic zone of Nigeria, the FAO – 56 PM is used as the standard ET model. The Blaney – Morin Nigeria model was found most appropriate for estimating ET based on the statistical test carried out as compared to other models in Nguru. This study provides information on evapotranspiration, if the information is properly used, can provide correct estimates of daily uses of water and therefore helps the irrigation managers in Nguru and those with similar climatic information with the important decisions of when water is to applied and the quantity of water to apply for the design, operation and management of irrigation systems.

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