A COMPARATIVE STUDYFOR ESTIMATING REFERENCE EVAPOTRANSPIRATION MODELS OVER KANO, NIGERIA

ABSTRACT

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, mostly results to irrigation. This present study estimates and compares six various universally accepted models for estimating reference evapotranspiration (ET_0) for Kano situated in the Sahelian climatic zone of Nigeria using measured meteorological parameters of monthly average 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 value of ET_o was found in the month of April with 10.0256 mm/day for Kano and low values was found to be in August with 5.0804 mm/day for Kano. The Blaney – Morin Nigeria model was found more accurate for Kano with RMSE, MBE, MAE and R values as 1.5078 mm/day, -1.4634 mm/day, 1.4634 mm/day and 0.9790 respectively.

Keywords: Evapotranspiration, Kano, lysimeter, models, NIMET, statistical indicator

1. INTRODUCTION

Evapotranspiration is a combination of evaporation and transpiration; these two processes leads to the loss of water content in plant. It covers both water evaporation (movement of water to the air directly from soil, canopies and water bodies) and transpiration (movement of water from the soil, through roots and bodies of vegetation, on leaves and then into the air). Evapotranspiration is measured in order to ascertained the amount of water require for irrigation. The rate of evapotranspiration is measured in millimeters per a set unit of time (usually per day) [1]

The total crop water needed is directly proportional to ET, since ET is usually known as crop water needed. These two processes i.e., Evaporation and Transpiration leads to water loss from the crops. The significance of this study is to improve the control of water for irrigation purpose between residential, industrial and agricultural use. This study also helps irrigation managers to know the amount/quantity of water to be applied for irrigation purpose through the help of the most suitable ET model recommended for Kano. Conforming toAllen et al. [2], ET_o is a major agro – meteorological parameter for climatological and hydrological studies, as well as for irrigation scheme and management.
ET is measured with the aid of lysimeter, this lysimeter is not readily available for an individual to obtain because of high cost acquisition and handling of the device leads to the development of several ET models used in the estimation of the ET_o. The major driver that

speed up the rate of ET are solar radiation, weed speed, relative humidity and air temperature [3].

Numerous researches have been carried out on this present study that involves the estimation of evapotranspiration with different ET models across different climatic zones of Nigeria. These includes the study by Yusuf et al. [4] where they conducted a research on the estimation of evapotranspiration in the Sahelian region of Nigeria using generalized regression neural network and feed forward neural method. Onwuegbunam el al. [5] carried out a research on estimation and comparison of reference evapotranspiration within Kaduna central district Nigeria using four different methods. There results show that the values obtained from PM, BC and PiEr were 6.43mm/day, 7.58mm/day and 8.63mm/day, respectively and these occurred in February except for HGRV which estimated its highest ET. (3.78mm/day) In march the lowest ET. Values were obtained in August for all the methods the results showed that BC, HGRV and PiEr gave c-values of 0.88, 0.48 and 0.67 respectively. Other studies include Zarie et al. [6], Akpootu and Ilyasu [7], Adekunle et al. [8] to mention but few.

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

2. 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 Kano situated in Sahelian region of Nigeria was obtained from the Nigerian Meteorological Agency (NIMET), Oshodi, Lagos, Nigeria.

2.1FAO-56 Penman- Monteith Method (FAO56 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. [2], and standardized by the American society of the civil Engineer-ASCE [9] and is expressed as

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

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 (^0C), 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^0C^{-1}). According to

Łabędzki et al. [10], 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 as reported by Allen et al. [2]. The mean saturated vapour pressure derived from air temperature is given by [2].

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

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

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

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:

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

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

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

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

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

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

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

$$\gamma = 6.65 \times 10^{-4}P \qquad (8)$$

The net radiation R_n was estimated using the expression

$$R_n = R_{ns} - R_{nl} \qquad (9)$$

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

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

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})

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

where σ is the Stefan Boltzmann constant (4.903 x 10^{-9} MJm^{-4}m^{-2}day^{-1})

T_{max}, k is the maximum absolute temperature during the 24hour period (k=^{o}C+273.16) T_{min}, k is the minimum absolute temperature during the 24-hour period (k=^{o}C+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

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

$a_s + b_s$ 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

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

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. [2].

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

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

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

2.2 Blaney- Morin- Nigeria Model

The Blaney- Morin- Nigeria (BMN) model was developed for the estimation of reference evapotranspiration in Nigeria by [11]. This method was applied following the procedures laid down by Duru [11]. The model equation is equation is given by

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

where, rf is the ratio of monthly radiation to annual radiation, T_{mean} is the mean monthly temperature in ^{o}C and R is the mean monthly relative humidity, 520 and 1.31 are the model constants given by Duru [11]. ET_o is as previously defined.

2.3 Priestley and Taylor model

Priestley and Taylor [12] 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:

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

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^{o}C), $\Delta, \gamma, R_n, ET_o and G$are as previously defined.

2.4 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 [9,13]. Recently, Mankkink is popular in West Europe and has been used successfully in the US Amatya et al*.* [14]. [9] gives the operational form of the Mankkink model as

$$ET_0 = 0.61\left(\frac{\Delta}{\Delta+Y}\right)\left(\frac{R_s}{2.45}-0.12\right) \qquad (17)$$

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.

2.5Hangreaves s and Samani Model (H&M)

This model was developed by Hargreaves and Samani, [15] 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 [16]. 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 [15].

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

where T_{mean} and R_a is extraterrestrial radiation, and the mean air temperature given as [17,18]

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

2.6 Abstew Model (1996)

Abstew [19] make used of simple empirical model which shows reference evapotranspiration ET_oas a function of solar radiation only. The model is given by:

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

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 [19] 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.

2.7 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 [20]. From their study, Jensen-Haise Model developed the following relationship of evapotranspiration model used in computing reference evapotranspiration (ET_O) as reported by James [21]. 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.

2.8 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).

2.8.1 Root Mean Square Error (RMSE)

This measures the average difference. RMSE involves the square of difference and therefore becomes sensitive to extreme values [22]. 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 overestimation by individual model [23]. The peak value for RMSE is zero or 0.0≤ RMSE [24] is given by the equation:

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

2.8.2 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 [22]. 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 -∞ to +∞ ($-\infty <$ bias $\leq +\infty$) [25 – 33]. The MBE is given by:

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

2.8.3 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:

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

2.8.4 Correlation Coefficient (R)

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

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

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 [7].

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, ∑ is the summation sign. In this study, coefficient of correlation (R) was verified using scatter diagram as well.

3. RESULTS AND DISCUSSION

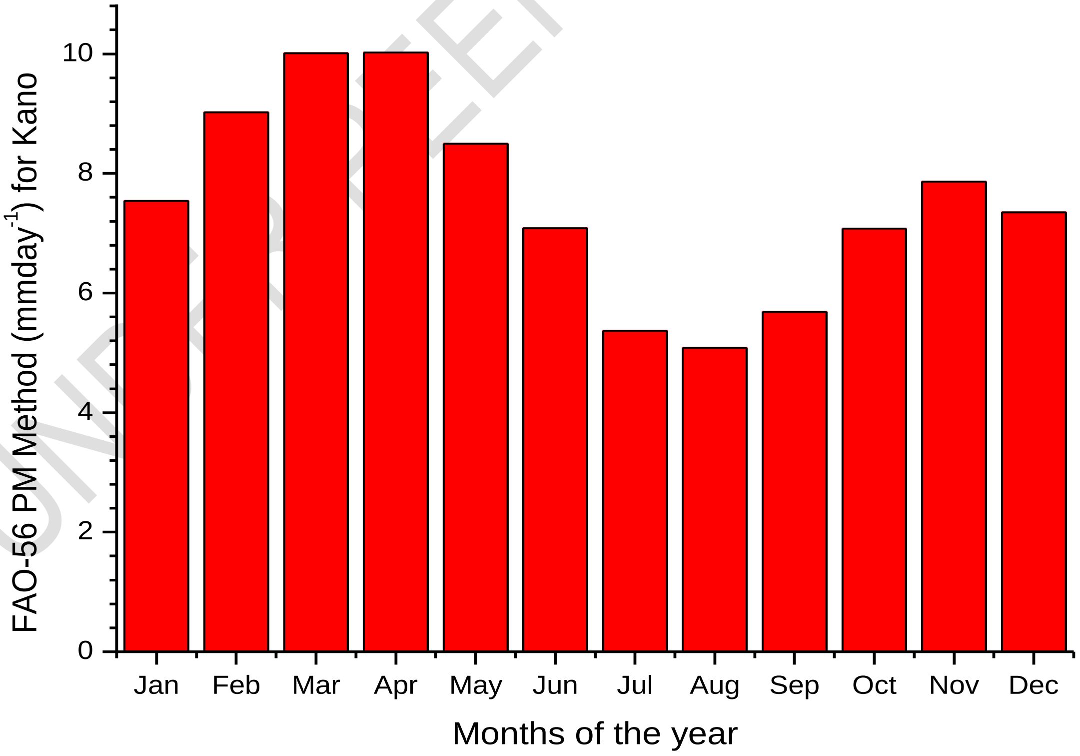

Fig. 1. Monthly values of ET_0 for FAO – 56 PM method in Kano during the period (1988 - 2018)

Fig. 1 shows the variation of evapotranspiration with month for the study area during the study period. Its showed that the highest value of the evapotranspiration was obtained during the hot dry season in the month of April and the lowest value is in the month of August which is rainy (wet) season. This shows that during the hot dry season the amount rate of evapotranspiration is usually maximum and minimum during the rainy season. During the hot dry season, the amount of water required for irrigation is more than during the rainy (wet) season. For this study area, the highest value of ET was found in the month of April with 10.0256 mm/day and the lowest value of 5.0804 mm/day in the month of August. This result is closely related to that of Isikwueet al. [34], they found out that the lowest value was in the month of August with 60.406 mm/day, and the highest value in the month of February with 125.08 mm/day, however, the both results indicate that during the dry season the value of ET_0 is high and is low during the rainy season. The high 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. Solar radiation is one of the weather parameters which contributes to the rate of evapotranspiration. Wind speed also serves as a catalyst during this period, which speedup evaporation that enhance fast 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 an important role in the rate of ET.

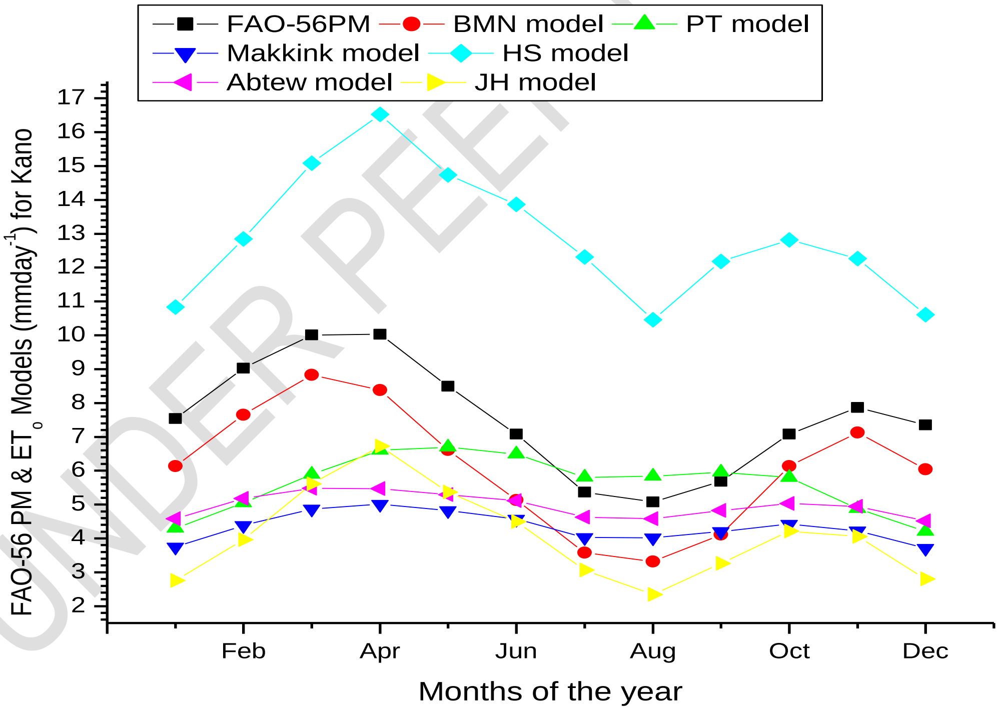

Fig. 2. Comparison between estimated ET_0 by FAO – 56 PM and evaluated models in Kano during the period (1988 - 2018)

Fig. 2 shows the monthly averages values of ET_0 estimates, using as the baseline the period from 1988 – 2018. Obviously from figure 2, its shows FAO – 56 PM model overestimates the Blaney – Morin Nigeria model including other estimated ET_0 models from January to June and from October to December, except for Hangreaves and Samani model that overestimated other estimated ET models including the reference FAO – 56 PM model throughout the year. The Jessen – Haise model underestimates other estimated ET models from July to December. The Blaney – Morin Nigeria model curve pattern estimates closely follows the pattern of the FAO – 56 PM model during the entire year but there is some form of dispersion between them.

In view of the six evaluated ET models, the value of the ET was recorded to be high in the month of March with 8.8326 mm/day and the lowest value in the month of August with 3.3137 mm/day for Blaney – Morin Nigeria model. The highest value of ET was recorded in the month of May with 6.7003 mm/day and the lowest in the month of December with 4.2099 for Priestley and Taylor model. The highest value of ET was recorded in the month of April with 5.0087 mm/day and the lowest in the month of December with 3.7081 mm/day for Makkink model. The highest value of the ET was recorded in the month of April with 16. 5282 mm/day and the lowest in the month of August with 10.4552 mm/day for Hangreaves and Samani model. The highest value of ET was recorded in the month March with 5.4805 mm/day and the lowest in the month of December with 4.5113 mm/day for Abstew model. The highest value of the ET was recorded in the month of April with 6.7256 mm/day and the lowest value in the month August with 2.3394 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 highest and lowest values was in the same months of March and August respectively. Subsequently, 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 alternative method of estimating ET in Kano.

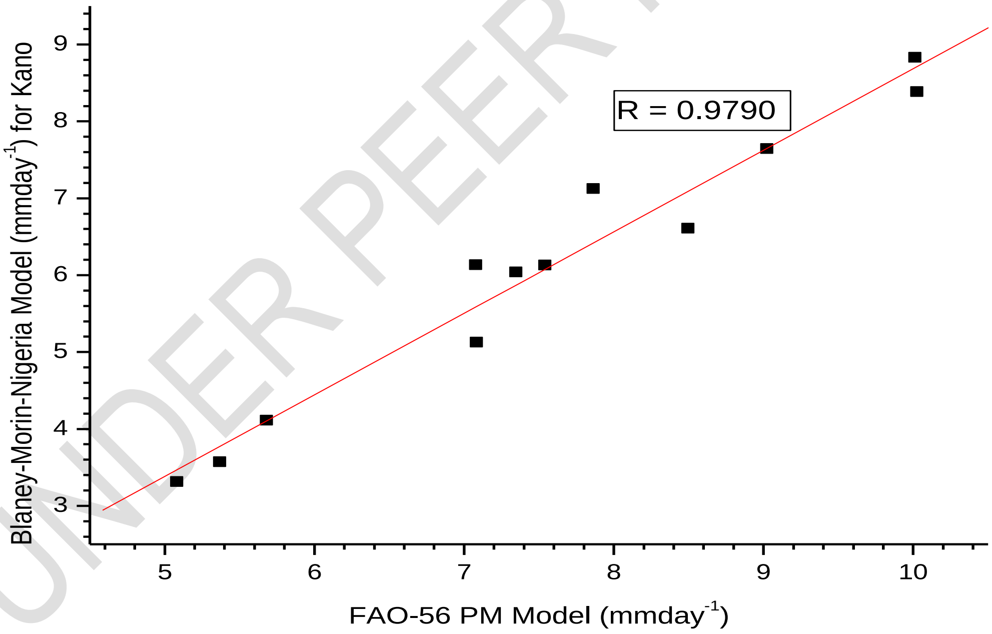

Fig. 3. Fitted regression line of Blaney – Morin Nigeria model with reference FAO – 56 PM model

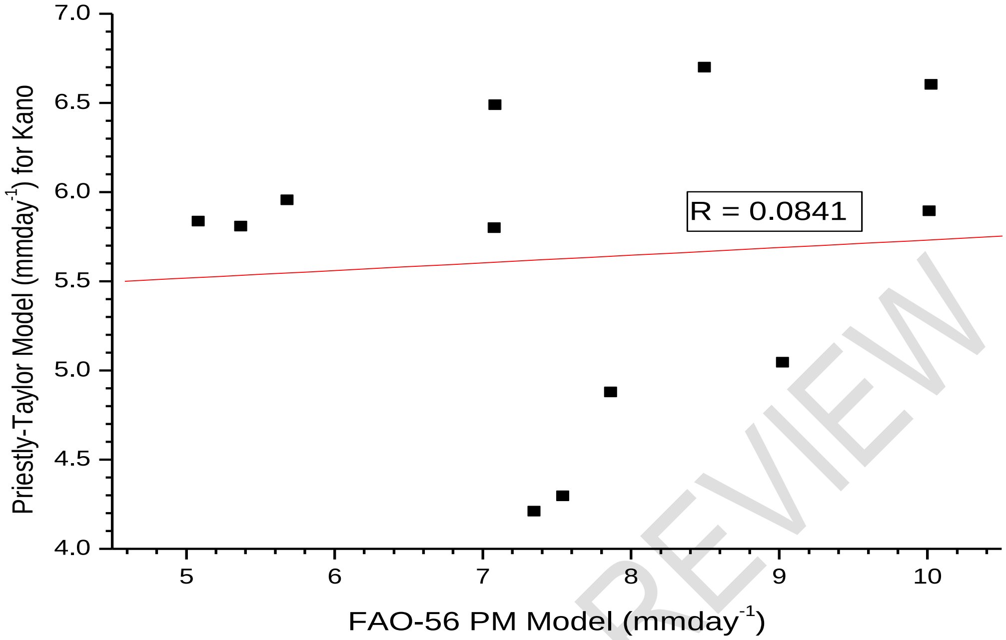

Fig. 4. Fitted regression line of Priestley and Taylor model with reference FAO – 56 PM model

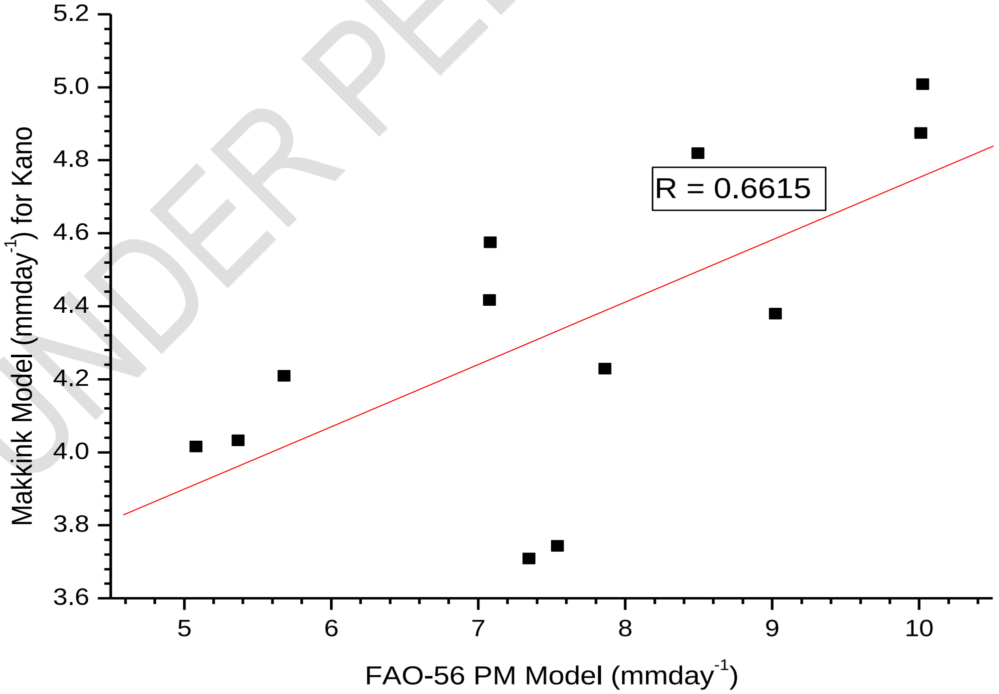

Fig. 5. Fitted regression line of Makkink model with reference FAO – 56 PM model

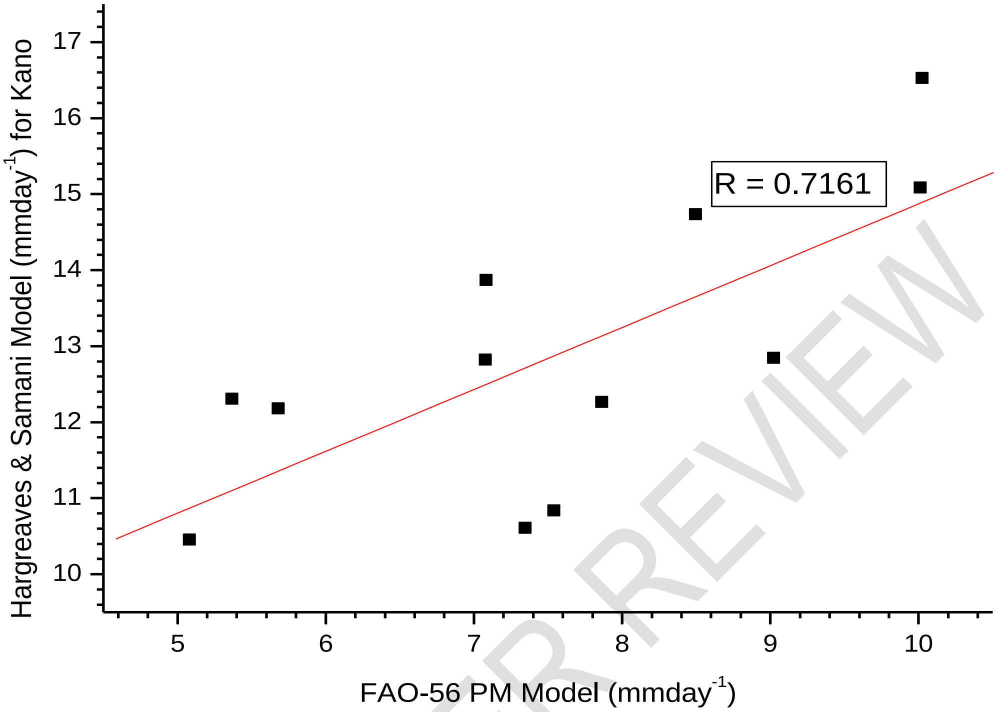

Fig. 6. Fitted regression line of Hangreaves and Samani model with reference FAO – 56 PM model

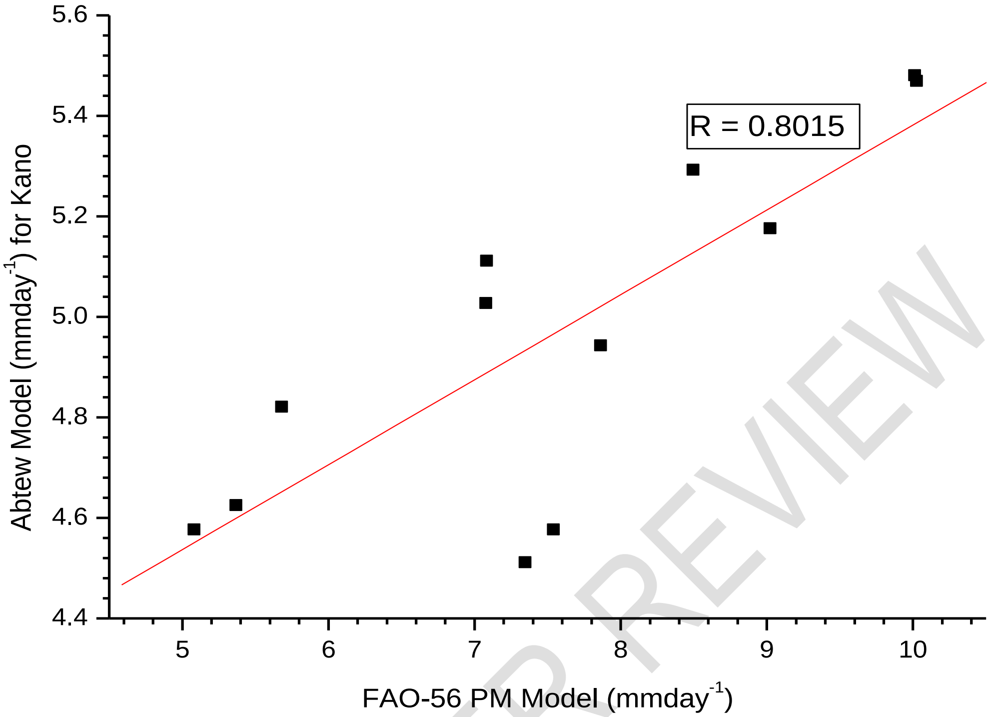

Fig. 7. Fitted regression line of Abstew model with reference FAO – 56 PM model

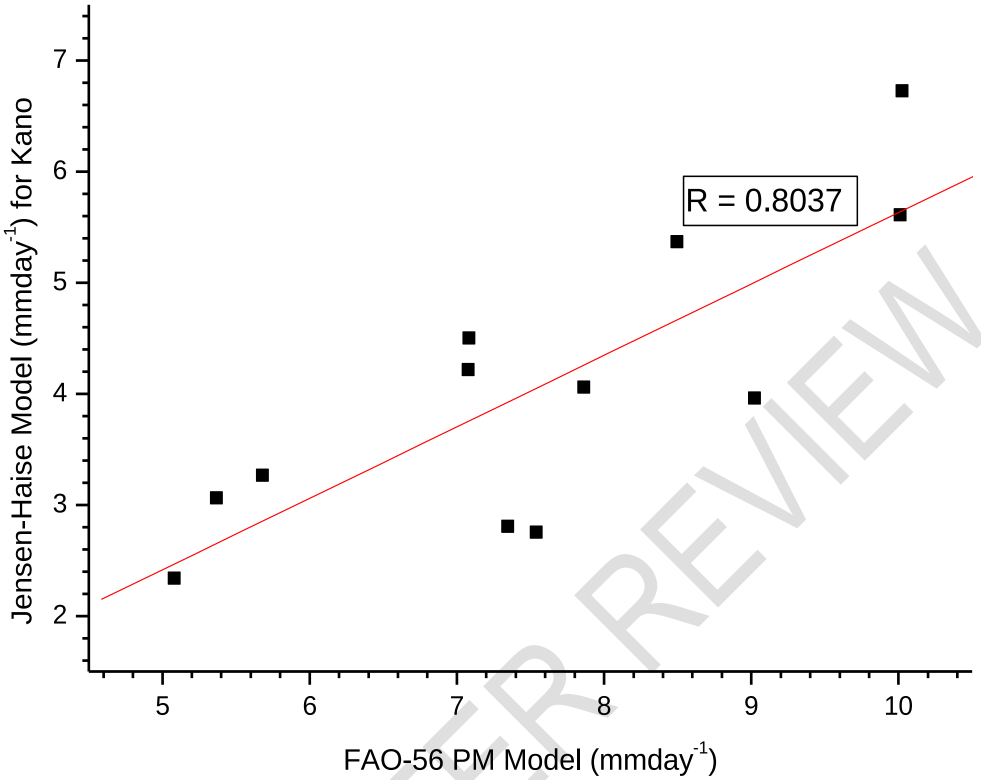

Fig. 8. Fitted regression line of Jessen – Haise model with reference FAO – 56 PM model

The fitted regression lines obtained in the regression analysis using the reference FAO – 56 PM model and the computed models are shown on figure (3 – 8). The Blaney – Morin Nigeria model achieved the best fit resulting in correlation coefficient with 0.9790 showing a peak positive correlation between the Blaney – Morin Nigeria model and FAO – 56 PM models, followed by Jessen – Haise model with correlation coefficient with 0.8037. The lowest correlation coefficient is observed for priestley and Taylor model with 0.0841.

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

Models	MBE	RMSE	MAE	R
BMNM	-1.4634	1.5078	1.4634	0.9790
PTM	-1.9228	2.5784	1.9228	0.0841
Mak	-3.2154	3.4875	3.2154	0.6615
HSM	5.3287	5.4833	5.3287	0.7161
Abstew	-2.5819	2.9057	2.5819	0.8015
JHM	-3.4948	3.6199	3.4948	0.8037

The table 1a shows the different statistical indicators of RMSE, MBE, MAE and R which were carried out to verified the performance of the six models used in this study 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 -1.4634 mm/day of the Blaney – Morin Nigeria model to 5.3287 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 least value with underestimation of 1.4634 mm/day in its estimated value and was reported the best. The RMSE values ranged from 1.5078 mm/day of the Blaney – Morin Nigeria model to 5.4833 mm/day of the Hangreaves and Samani model. Due to the least RMSE value of the Blaney – Morin Nigeria model (1.5078 mm/day) makes the Blaney – Morin Nigeria model performed best followed by the Priestley and Taylor model (2.5784 mm/day). The MAE values ranged from 1.4634 mm/day of the Blaney – Morin Nigeria model to 5.3287 mm/day of the Hangreaves and Samani model. Due to the least value of the MAE, it shows that the Blaney – Morin Nigeria model (1.4634 mm/day) performed best followed by the Priestley and Taylor model (1.9228 mm/day). Based on the high value of the correlation coefficient of the Blaney – Morin Nigeria model performed better with coefficient of 0.9790 (97.90 %) followed by the Hangreaves and Samani model with coefficient of 0.8037 (80.37 %). The overall results show that the Blaney – Morin Nigeria model performed better in term of MBE, RMSE, MAE and R.

Table 1b. Ranking of evaluated models as per statistical indication for estimating ET_0 for Kano

Model	MBE	RMSE	MAE	R	Total	Rank
BMNM	1	1	1	1	4	1
PTM	2	2	2	6	10	3
MakM	4	4	4	5	17	4
HSM	6	6	6	4	22	6
Abs M	3	3	3	3	12	2
JH	5	5	5	2	17	4

Table 1b shows the ranking of the models used in computing ET_0 tells which of the models serves as an alternative with the FAO – 56 PM model, this ranking of the selected models was done based on the statistical validation test of MBE, RMSE, MAE and r. The total ranks acquired by the different models were in the ranged of 4.00 to 22.00. The Blaney – Morin Nigeria model was found to performed better based on the total ranked acquired. So, it was found suitable for estimating ET_0 followed by Abstew model which came 2nd. Priestley and Taylor model was ranked 3rd, Makkink model and Jessen – Haise model were ranked 4th and Hangreaves and Samani model was ranked 6th. Thus, the Blaney – Morin Nigeria model was ranked 1st serves as a benchmark model for estimating ET_0 for this study area.

4. CONCLUSION

This study makes use of 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 compute and compare six ET models with a view to ascertain the most suitable model that is capable of estimating ET in Kano situated in the Sahelian climatic zone of Nigeria, the FAO – 56 PM was used as the standard ET model. The result for this study shows that the highest value of ET was found in the month of April with 10.0256 mm/day and the lowest value of 5.0804 mm/day in the month of August. The Blaney – Morin Nigeria model was found most appropriate for computing ET based on the statistical test carried out as compared to other models in Kano. This study provides information on evapotranspiration, if properly utilized, can provide correct estimates of daily usage of water and therefore helps the irrigation managers in Kano and those with similar climatic information with the important decisions of when water is to be applied and the quantity of water to apply for the design, operation and management of irrigation systems.

REFERENCES

1. Brun P, Zimmermann NE, Hari C, Pellissier L, Karger DN. preprint. Global climate – related predictors at Kilometre resolution for the past and future. Earth syst. Sci. Data Discuss 2023; https://doi.org/10.5194/essd-2022-212

2. Allen, R. G., Pereira, L. S., Raes, D. and Smith, M. Crop Evapotranspiration- Guidelines for computing crop water requirements. FAO Irrigation and Drainage Paper 56. Food and Agriculture Organization. Rome. 1998;

3. Trajkovic S, Zivkovic S. Effect of actual vapour pressure on estimating evapotranspiration at Serbia.Architecture and Civil Engineering.2009; 7(2), 171 – 178.

4. Yusuf HA, Agbaje N, Olorunfemi IE. Estimation of evapotranspiration rate in the sahelian region of Nigeria using generalized regression neural network and feed forward neural network. Agricultural Engineering International: CIGR Journal.2020; 22 (4): 31-39.

5. Onwuegbunam NE, Onwuegbunam DO, Dare A. Estimation and comparison of reference evapotranspiration within Kaduna central district, Nigeria using four different methods. Nigeria journal of technology (NIJOTEC). 2020; 39(1): 306 – 314.

6. Zarie AR, Zarie S, Paranchi AW. Comparison of several methods to estimatereference evapotranspiration. West Africa journal of applied ecology: 2015; 23(2): 17-25.

7. Akpootu DO, Iliyasu MI. A comparison of various evapotranspiration models for estimating reference Evapotranspiration in Sokoto, North Western, Nigeria. Physical Science International Journal.2017; 14(2), 1 – 14. DOI: 10.9734/PSIJ/2017/32720

8. Adekunle BT, lukman AS, Ayodele PO, Oladimeji AB, Olawale EA, Olanrewaju OSA, Muriala AA, Opeyemi RO, Omodara EO. Evaluation of the performance of some Evapotranspiration Models at a Tropical location in Ile- Ife, Nigeria. Asian journal of Applied Sciences.2020; 8(6): 325- 334.

9. Allen GR, Walter IA, Elliot RL, Howell TA, Itenfizu D, Jensen ME, Snyder RL. The ASCE standardized reference evapotranspiration equation. Committee of standardization of reference evapotranspiration of the environmental and Water Resources Institute of the American Society of Civil Engineers.2005;.

10. Łabędzki L, Kanecka-Geszke E, Bak B, Slowinska S. Estimation of Reference Evapotranspiration using the FAO Penman-Monteith Method for Climatic Conditions of Poland, In: Evapotranspiration, Labedzki.L (Ed.), In Tech. 2011; 275-294.

11. Duru JO Blaney- Morin- Nigeria evapotranspiration model. Journal of Hydrology. 1984;70:71- 83.

12. Priestley CHB, Taylor RJ. On the assessment of surface heat flux and evaporation using large-scale parameters. Monthly Weather Rev.1972; 100(2):8192.

13. Makkink GF. Testing the penman formula by means of lysimeters. Journal of The Institution of Water Engineering. 1975;11(3):277-288.

14. Amatya DM, Skaggs RW, Gregory JD. Comparison of Methods for Estimating REF-ET. Journal of Irrigation and Drainage Engineering.1995; 121(6):427-435.

15. Hargreaves GH Samani ZA. Reference crop evapotranspiration from temperature. Applied Engineering in Agriculture. 1985; 1(2):96-99.

16. Gavilán P, Lorite IJ, Tornero S, Berengena J. Regional calibration of Hargreaves equation for estimating reference ET in a semiarid environment. Agriculture Water Management. 2006; 81:257–281.

17. Akpootu DO, Iliyasu MI, Nouhou I, Aina AO, Idris M, Mustapha W, Ohaji DE, Muhammad AD. Estimation and Variation of Saturation Mixing Ratio and Mixing Ratio over Potiskum, Nigeria. Nigerian Journal of Basic and Applied Science. 2022; 30(1), 49-54. DOI: http://dx.doi.org/10.4314/njbas.v30i1.7

18. Akpootu DO, Mustapha W, Rabiu AM, Iliyasu MI, Abubakar MB, Yusuf SO, Salifu SI. Estimation of Surface Water Vapour Density and Its Variation with Other Meteorological Parameters Over Owerri, South Eastern, Nigeria. Hydrology.2019;**7**(3): 46-55.

19. Abtew W. Evapotranspiration measurements and modeling for three wetland systems. Journal of the American Water Resources Association. 1996;32(3): 465-473.

20. Jensen ME, Haise HR. Estimating evapotranspiration from solar radiation. J. Irrigation and Drainage Div., ASCE. 1963; 89:15-41.

21. James LG. Principles of farm irrigation system design. New York: John Willey and Sons Inc.1988;.

22. Willmott CJ. Some comments on the evaluation of model performance. American Meteorological Soc.1982; 63(11):1309 – 1313.

23. Jacovides CP, andKontoyiannis H. Statistical procedures for the evaluation of evapotranspiration computing models. Agric Water Management. 1995; 74:87-97

24. Vazquez RF, Feyen J. (2003). Effect of potential evapotranspiration estimates on effective parameteters and performance of the MIKESHE code applied to a medium-size.Journal of Hydrology. 2003;309–327.

25. Ram KS, Anju B. Monitoring of evapotranspiration in major districts of Haryana using penman-monteith method. International journal of Science and Technology. 2012; 4(7):418-433.

26. Akpootu DO, Tijjani BI, Gana UM. Empirical models for predicting global solar radiation using meteorological parameters for Sokoto, Nigeria. InternationalJournal of Physical Research. 2019a; 7(2): 48 – 60. DOI: 10.14419/ijpr.v7i2.29160

27. Zekai S. Solar energy fundamentals and modeling techniques. Atmosphere, Environment, climate change and renewable energy., first ed. Springer, London. 2008;

28. Akpootu DO, Tijjani BI, GanaUM. Sunshine and Temperature Dependent Models for Estimating Global Solar Radiation Across the Guinea Savannah Climatic Zone of Nigeria. American Journal of Physics andApplications. 2019b; 7(5): 125-135. doi: 10.11648/j.ajpa.20190705.15.

29. Akpootu DO, Tijjani BI, Gana UM.New temperature dependent models for estimating global solar radiation across the midland climatic zone of Nigeria.International Journal of Physical Research. 2019c; 7(2): 70 – 80. DOI: 10.14419/ijpr.v7i2.29214

30. Akpootu DO, Tijjani BI, Gana UM. New temperature dependent models for estimating global solar radiation across the coastal climatic zone of Nigeria.International Journal of Advances in Scientific Research and Engineering (ijasre).2019d; 5(9): 126 – 141. DOI: 10.31695/IJASRE.2019.33523

31. Akpootu DO, Abdullahi Z. DEVELOPMENT OF SUNSHINE BASED MODELS FOR ESTIMATING GLOBAL SOLAR RADIATION OVER KANO AND IKEJA, NIGERIA. FUDMA Journal of Sciences (FJS).2022;Vol. 6 No. 3, June, 2022, pp 290 – 300. DOI: https://doi.org/10.33003/fjs-2022-0603-1001

32. Akpootu DO, Iliyasu MI, Olomiyesan BM, Fagbemi SA, Sharafa SB, Idris M, Abdullahi Z, Meseke NO. MULTIVARIATE MODELS FOR ESTIMATING GLOBAL SOLAR RADIATION IN JOS, NIGERIA. Matrix Science Mathematic (MSMK).2022; 6(1) 05-12. DOI: http://doi.org/10.26480/mkmk.01.2022.05.12

33. Akpootu DO, Alaiyemola SR, Abdulsalam MK, Bello G, Umar M, Aruna S, Isah AK, Aminu Z, Abdullahi Z,Badmus TO.Sunshine and Temperature Based Models for Estimating Global Solar Radiation in Maiduguri, Nigeria. Saudi Journal of Engineering and Technology. 2023;8(5): 82-90. DOI: 10.36348/sjet.2023.v08i05.001

34. Isikwue CB, Audu OM, Isikwue OM. Evaluation of evapotranspiration using FAO Penman-Monteith method in Kano Nigeria. International Journal of Science and Technology. 2014; 3(11). 698–703.