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Regional and Seasonal Sensitivity Analysis of Different Evapotranspiration Methods for Different Climatic Conditions in Nigeria

Ogolo, E.O.
Department of Physics,
Federal University of Technology, Akure, Nigeria

Abstract

The responses of evapotranspiration to meteorological changes can be obtained by the determination of the dimensionless sensitivity coefficients. The method of computation of the sensitivity coefficient is based on partial derivatives and the standard deviation of each climatic variable with respect to the reference evapotranspiration. The climatic parameters used were the common parameters that are often used for the estimation of evapotranspiration and these include: relative humidity, temperature, wind speed and solar radiation. Reference evapotranspiration was obtained using the radiation based methods (Abtew, Hargreaves, Makkink, and Priestly-Taylor) and FAO-56 Penman-Monteith. The study was carried out for different climatic regions according to moisture and vegetation distribution in Nigeria and these are arid, midland, guinea savannah and the coastal region. The result of this study showed that global solar radiation (38%) followed by the wind speed has the greatest influence on the estimation of evapotranspiration by almost all the methods in both arid and coastal regions. While temperature was observed to have the maximum influence of 74% of sensitivity coefficients and followed by wind speed. On the seasonal consideration, there was an invariant sensitivity coefficients observed for some regions, for instance, solar radiation was found to be most sensitive in both seasons in arid and coastal regions during the dry and wet period; however, in midland and grassland savannah, temperature dominates in dry seasons with between 58% to 74% sensitivity coefficient while the wind speed was found to be more sensitive during the wet season with range of 46% to 82% of sensitive coefficients. On the annual timescale, solar radiation was found to be more sensitive to evapotranspiration in the arid (and partially in the coastal region as only determined by Priestly-Taylor), while windspeed influence is higher in both midland and guinea savannah regions and temperature in the coastal region.

Keywords: Sensitivity, Evaporation, coefficient, season annual model

1.0 Introduction

Generally, the concept of evapotranspiration is a land –atmospheric fluxes exchange phenomenon absolutely concerned with fluxes (moisture and heat) exchange between the surface and the atmosphere within the boundary layer. It involves evaporation of water from land surfaces and transpiration by vegetation which is essential for determining the water requirement for irrigation. (Allen et al. [1]). Reference evapotranspiration is often considered as the potential evapotranspiration of hypothetical surface of green grass of uniform height, actively growing and well watered, is one of the most important variables for scheduling irrigation systems, acquisition and treatment of input data for hydrological water-balance models, calculating actual evapotranspiration for any region (Blaney and Crridle, [2]; Dyck, [3]; Hobbins et al.al.[4]a,b; Xu and Li, [5]; Xu and Singh, [6] and Lebing Gong et al.[7]). Reference evapotranspiration is used to quantify the evaporative demand of the atmosphere that is autonomous from crop type, crop development and management practices.The evolution of reference evapotranspiration is greatly influenced by environmental atmospheric variables. Hence, reference evapotranspiration being a climatic parameter, it can only be computed from meteorological data (Allen et al. [1];Lebing Gong et al.[8]). In view of the expensive acquisition and costly maintenance of lysimeter and other measuring instrumentations, which had gone beyond the reach of many researchers and since there are no grants, researchers result to estimation by modelling ET from the environmental atmospheric variables.There are manyestimation methods and which have been classified into six classes according to Xu and Singh, [6] as follows: (1) water budget (e.g. Guitjens, [9]) , (2) empirical (e.g. Kohler et al.[10], Ogolo[11]), (3) energy budget(e.g. Fritschen[12]), (4) mass transfer (e.g. Harbeck[13]), (5) combination (e.g. Penman[14]), (6) radiation (e.g. Turc[15];Priestley and Taylor[16]). Overviews of many of these methods are found in review papers and books (e.g. Brutsaert[17]; Singh[18]; Jensen et al.[19],

Corresponding author: E-mail: emogolo@gmail.com

Morton[20],[21]). From the fundamental point of view,sensitivity analysis is a scheme for evaluating the impact of the change of the measured atmospheric variables to the predicted reference evapotranspiration with some chosen techniques. Several scientists (McCuen,[22]; Saxton, [23]; Coleman and DeCoursey[24]; Beven[25]; Babajimopoulos et.al.[26]; Muhammad and Rainer[27]; Gong et. al.,[8]; Irmark et. al.[28]; Ambas and Baltas[29]) have carried out diversestudies on the sensitivity analysis on hydrological models where sensitivity coefficients were calculated using the partial derivatives of evapotranspiration to the meteorological variables.

Scanty studies on regional and seasonal behaviour of the sensitivity coefficients of reference evapotranspiration had been published in literatures except the work carried out by Muhammad and Rainer [30] and no account of such study had been carried out for Nigerian climaticinhomogeneity. Hence, the present studies is being carried out to investigate the sensitivity analysis of ET to perturbations associated with one or more climatic variables as this will essentially improve our understanding of the relationship between climatic conditions and reference evapotranspiration variability in the face of climate change and assessing data availability and estimation accuracy of ET.

2.0 Site Description and Data Acquisition.

2.1 Site Description.

Nigeria is situated in the Tropics, in the Northern hemisphere and spanned 4^0 latitudinally from the coastal region to 14^0 the arid region. The climate regime in Nigeria is classified into four zones according to moisture distribution and vegetation types.(Olaniran et. al.[31]) The four zones from the extreme southern part spanning to the northern part of Nigeria include the tropical rainforest /coastal,the grassland savannah, Midland and the sahelzones. The full description of the climatic characteristics of each region is found reported in Ogolo [32]. The coastal /Tropical rainforest is designated by the Koppen climate classification and is found in the southern part of Nigeria and extends from along the coast up to 100-150km inland. It is influenced by the monsoon transported from into the country by the maritime tropical(mT) airmass that originate from the Atlantic Ocean. It is characterized by a warm moist. The southern part of the year experience rainfall almost throughout the whole year. The temperature ranges from the maximum of 28^0C to the lowest temperature 26^0C in the coldest month. The relative humidity is as high as 80% and the annual rainfall is about 300mm.This region is closely followed by the grassland zone otherwise known as the tropical savannah, as we move northward. This region is found further inland after the coastal region. It has a widespread vegetation belt characterized with an annual relative humidity and having an annual rainfall of between 100mm and 200mm. The duration of rainfall season is shorter when compared with the coastal and the grassland regions. Next to this region is the Midland regionis dominated by tropical continental air (cT) mass andis characterized with hills and mountains and the topography is responsible for the humid condition being almost throughout the year in this region as a result of localized convection. The region is a typical representation of desert conditionand also controlled by tropical continental air mass(cT); this type of climatic condition is noted for a wide annual and diurnal range of15-20^{o}C. Solar radiation ranges from 22.5Cal/day/m^2 in the arid to 15.8Cal/day/m^2in the coastal region. The mean annual windspeed varies from 3.0m/s in the arid to s2.1 m/s in the tropical stations that lie in the coastal region. This substantiates a related study that describes windspeed in the tropical stations in Nigeria as being characteristically low (Jegede,[33]).

2.2 Data Acquisition and Treatment

The data used in this study are extracted from the archives of the Nigerian Meteorological Agency (NIMET). This agency has weather observatories located in all the tropical stations involved in this study. All the observatories are fully equipped with standard instruments that meet with specifications of the World Meteorology Organisation (WMO) and were well maintained. Some of the equipment used for the measurement of the parameter include: maximum and minimum thermometer (for minimum and maximum temperature), wet and dry Bulb hygrometer (humidity), a 3-cup anemometer (windspeed), and Gun-Bellani Radiation Integrator (Global solar radiation). Relevant data based on the requirements of the models intended to be used for the study were collected and subjected to through checking for inconsistencies and cases of missing values. All the cases of missing values were filled by computing the monthly average for each station and for such variables.

3.0 Method

3.1 Reference Evapotranspiration Models

The following methods for the estimation of reference evapotranspiration were used in this study. The choice of these methods out the available myriads of techniques was based on the availability/ easy accessibility to the required input variables and the simple application of the method which is void of any complex mathematical rigour. The techniques are described as follows:

3.1.1 FAO-56 Penman-Monteith Equation

According to Allen et al. [1] as it was reported by Bautista et al.[34], Penman-Monteith is method is considered to be the most physical and reliable method and had been recommended by the FAO as the sole standard to verify other empirical methods where the data on the in-situ measurements or reference evapotranspiration is not available. It is frequently used as it had been found to offer the best results with minimum possible error in relation to a living grass reference crop. The general form of the Penman-Monteith equation according to Allen et al.[1]is given as:

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

Where ET is the reference estimated evapotranspiration, ($mm^{-2}day^{-1}$); Δ slope of the saturation vapour pressure function (kPa^oC^{-1}); Rn net radiation($MJm^{-2}day^{-1}$); G = soil heat flux density, ($MJm^{-2}day^{-1}$); γ psychrometric constant (kPa^oC^{-1}); T = mean daily temperature (^oC); U_2 = mean 24-h wind speed at 2-m height (ms^{-1}); e_s is the saturation vapour pressure (kpa); e_a is the actual vapour pressure (kPa)

3.1.2 Abtew Method

Abtew[35], as was reported by Xu and Singh[6], employed a simple empirical equation which is expresses reference evapotranspiration as a function of solar radiation only and less subject to local variation, the equation is expressed as follows:

$$ET = 0.53R_s/\lambda \quad (2)$$

Where is the R_s is the global radiation (Watt/m2) and λ is the latent heat of vapourisation (MJ/kg)

3.1.3 Hargreaves

Hargreaves[36]equation is another method frequently used by scientists and researchers to estimate evapotranspiration; this is because it requires few data set and moreso, it is very simple, practical and givesaccurate result. Hargreaves expressed ET as a function of the two atmospheric variables which defined as follow:

$$ET = 0.0135(T+17.8)Rs/\lambda \quad (3)$$

Where T, R_s and λ are mean monthly temperature (^0C), solarradiation (Mj/day/hr) and psychometric constant (kPa^oC^{-1})respectively.

3.1.5 Priestly and Taylor

The Priestly and Taylor [37]methodis a simple method requiring only radiation and temperature for the estimation of evapotranspiration. It is a simplified version of the combination equation by Penman [38]. The aerodynamic component was deleted and the energy component was multiplied by a coefficient, α =1.26. Hence, it was proposed that estimation of ET can be done using the radiation component as defined below:

$$ET = 1.26\frac{\Delta}{\Delta+\gamma}\frac{R_n}{\gamma} \quad (4)$$

all the terms are as previously defined.

3.1.6 Makkink

Makkink [39] method is simplified version of the Priestly Taylor and only requires radiation and temperature for the estimation of evapotranspiration. The main difference in variable input is that Makkink utilizes solar radiation instead of net radiation used by Priestley-Taylor. This is reasonable because there is a good relationship between the two radiation components. The method is expressed as follows:

$$ET = 0.61\frac{\Delta}{\Delta+\gamma}\frac{R_S}{58.5} - 0.012 \quad (5)$$

Where all parameters are as earlier defined.

3.2 Relevant Theory on Sensitivity Analysis

According McCuen [22], Sensitivity analysis can be described as the measure of the consequential effect of change of one factor on another. In particular, this is thechange observed in reference evapotranspiration to the change in the meteorological variable and when it tends to zero, the resulting relative change defines the partial derivativeof reference evapotranspiration to the whole variable (Saxton[23]; Ambas[40]).Closely related to this is the concept of sensitivity coefficient which is concerned with the use of dimensionless values of the reference change to each variable.

In this study, a sensitivity coefficient analysis of some hydrological models (described above) for the estimation of reference evapotranspiration was carried out in relation to the input climatic parameters for different climatic regions in Nigeria. The technique adopted for the computation of sensitivity coefficients is a mathematical approach which is the differentiation of the above named equations (i.e. equations 1.0-5.0) with respect to each independent variable

Muhammad and Rainer [27] explained how Scarborough[40]use the following mathematicsprocedure to show that sensitivity can be developed for function:

$$N = f(X_1, X_2 \ldots Xn) \quad (6)$$

Equation 6 above denotes function of several independent variables $X_1, X_2, \ldots, X_n$which are subject to the errors $\Delta X_1, \Delta X_2, \ldots \Delta X_n$respectively. These errors in the x's will provoke an error ΔN in the function as expressed by the following relations

$$N+\Delta N = f(X_1+\Delta X_1, X_2+\Delta X_2, \ldots X_n+\Delta X_n) \quad (7)$$

The next task is to develop an expression for expand ΔN and to achieve this, the LHS of equation 7 is expanded using Taylor's Theorem, neglecting squares terms including products and higher powers in the expansion to obtain:

$$\Delta N = \frac{\partial N}{\partial x_1}\Delta X_1 + \frac{\partial N}{\partial x_2}\Delta X_2 + \ldots \quad (8)$$

Any observed change or error in any of the variable will cause all other terms to vanish, hence we have

$$\Delta N = \frac{\partial N}{\partial x_1}\Delta X_1 \qquad (9)$$

The relative change can be defined as

$$N\varepsilon = \Delta N/N \qquad (10)$$

$$N\varepsilon = \Delta X/X \qquad (11)$$

Putting 10 and 11 into 9 we have a general form of the solution expressed as

$$\frac{N\varepsilon}{X_1\varepsilon} = \frac{\partial N}{\partial X_1}\frac{X}{N} \qquad (12)$$

The right-hand of 12 defines the sensitivity coefficient (sc) which is defined as the fraction of change in X that is transmitted in to change in N. Hence, equation 12 is a choice equation for a non-dimensional sensitivity coefficient which has become a celebrated tool that is frequently used for the sensitivity analysis of the selected techniques used for the prediction of reference crop evapotranspiration (Scarborough, [40], Muhammad and Raine[27]. Thus, sensitivity coefficient is mathematically expressed as

$$Sci = \frac{\partial ET_o}{\partial X_i} * \frac{X_i}{ET_o} i = 1,2 \ldots n \qquad (13)$$

The above sensitivity equation is appropriate and relevant but difficult to determine the partial derivative of ETo with respect to some of the independent variables and the method of finite difference was suggested to approximate the partial derivatives. Hence, the above equation 13 was modified as follow

$$Sci = \frac{\Delta ET_o}{\Delta X_i} * \frac{X_i}{ET_o} i = 1,2 \ldots n \qquad (14)$$

Saxton[23] adopted the mathematical concept on sensitivity analysis formulated by Scarborough[40]which is the use of partial derivative to obtain the dimensionless sensitivity coefficients for each meteorological variable defined by equation 14 above. According to Gong et al. [8], many equivalents of equation 14 have been developed for both hydrological and ecological applications (McCuen[22]; Saxton[23]; Coleman and Coleman and DeCoursey[24]; Beven[40];Ambas and Baltas[29] depending on the purpose of the analysis. However, the method of Ampas[41] reported by Ambas and Baltas[29] was adopted for the computation of sensitivity coefficient in this study.Ampas[41] presented another equivalent approach which involve the use of standard deviation for the computation of sensitivity coefficient, defined below:

$$sci = \frac{\Delta ET_o}{\Delta X_i} * \frac{\sigma_i}{ET_o} i = 1,2 \ldots n \qquad 15$$

where σ_i represent the standard deviation of the meteorological variable while other quantities maintain their usual definitions. The sensitivity coefficient by the above method has an unusual advantage over the original equation can be zero as the standard deviation can be zero and it expresses the entire data set, also the values are not influenced by units, the value of the sensitivity coefficient by equation 15 above has a physical meaning for it by reveals the alteration to the model caused by the usual change of the variableswhile the original equation only indicate the ability of each variable to effect change on the model. Positive (negative) sensitivity coefficient implies an increase (decrease) with the increase in the atmospheric variable. Thelarger the absolute sensitivecoefficient, the greater the effect of the given variable on ET.

4.0 Results and Discussion

Using the equation 15, the sensitivity coefficients were determined on both monthly and annual timescales and also for the wet and dry seasons. The sensitivity coefficientswere obtained for the arid, semi-arid, guinea savannah and the coastal conditions in Nigeria. The partial derivative of the reference evapotranspiration to each of the meteorological variables (Minimum and maximum temperature, minimum and maximum relative humidity, wind speed, solar radiation) was calculated using the method of finite differences. The sensitivity coefficient for all the five evapotranspiration models conducted for five different climatic regions in Nigeria were shown in Tables1-4. The concept of percentage was also introduced to measure the contribution of each meteorological variable to the evolution of evapotranspiration in each region under consideration. The percentage of the sensitivity coefficient for each meteorological variable to the total sensitivity coefficients for each method for both the dry and wet season in the arid part of Nigeria is presented in figures2-5.

Table 1 below is the monthlydistribution of the sensitivity coefficients of the meteorological parameters for each of the model is presented for the arid condition in Nigeriawith the percentage distribution of the sensitivity coefficients of each meteorological variable for each method show in figure 2 below.For the FAO-56 Penman- Monteith method, the sensitivity coefficients of all the parameters (Temperature, windspeed, solar radiation and relative humidity) increases from wet season to the maximum values in dry periods. The windspeed has the greatest influence and this was found to be strong during the dry period.

The parameter sensitivity to evapotranspiration using Abtew method in the arid region follows the same trend as FAO-56 Penman-Monteith except that solar radiation, which is the energy term exhibited high tendency for greater influence, among other parameters, for the estimation of evapotranspiration in the region under consideration. The sensitivity coefficients of all the variables vary from low values wet period to high values in the dry seasons. This result confirms the fact the arid is the region characterized with heavy receipt of solar radiation with a clear sky.

The trend and variation of all the monthly parameter sensitivity coefficients using all the methods follows the same patter as already explained above. The parameter that was found to have the largest predominant influence on the evolution of evapotranspiration is solar radiation. This is the source of energy available to drive evapotranspiration andis one of the major factors that influence rate of evapotranspiration. Figure 2 is the respective percentage contribution of each parameter to the estimation of evapotranspiration by each of the method under consideration. The figure represents the scenario for the dry season, which is of a major concern to an average farmer because this is the period characterized with deficient water as a result of cessation of regular rainfall. This result into draught during this session and consequently, plant growth are adversely affected and most essential vegetables, grains and fruits disappear from the market. Farmers find it difficult to meet the demand of masses for all these essential commodities. Hence, the need for the regular supply of water, to sustain the growth of some crops, through irrigation practices. The practice of irrigation has increased astronomically in the recent time. This is in view of the World Bank sponsored Fadama project that is fast spreading to different parts of Nigeria. The project was founded with a view of promoting supply food supply in Nigeria. One of the basic reasons for irrigation farming is the provision of the sufficient amount of waterat the right time for plant growth and development (Dauda et al.[42]). According to recent survey conducted by MINCID [43], it was found that 39% of the land mass is potentially suitable for agriculture and out of which between 4.0 and 4.5 million ha (approximately 4.5 to5.0 % of the land) are found suitable for irrigated agriculture but only 1.1 million ha can be supported fully by the water available, the remaining 3.4 million ha. The period of dry season is characterized with shortage of water for plant growth hence the disappearance of some essential crops (vegetable, rice, maizee.t.c.) during the period. Hence, irrigation practice has become crucial in order to meet theincreasing demand for vegetable and other food items during the dry period. Hence, figures 2.-5 will concentrate on the period of dry season, when there is awidespread of water deficiencyobserved across all the regions in question. From figure 2, it can be seen, that during the dry period in the arid region, solar radiation was found to have a profound influence on the estimation of evapotranspiration as revealed by the relative percentage contribution of each meteorological parameter. However, wind speed has the highest percentage (65.6%) of sensitivity coefficient for FAO-56 PM method. The percentage contribution of solar radiationto evapotranspiration by the rest methods under consideration ranges from 39% to 56%.

Sensitivity coefficients of the meteorological variables are presented for all the ET estimation methods in Table 3. Wind speed has the highest influence on the estimation of evapotranspiration in the midland region for all the methods except Hargreaves which confirmed temperatureas the meteorological parameters when compared with other parameter. All the parameter sensitivity coefficients range from low values during the wet season to high values during the period of irrigation. Figures 3.0 is the description of the percentage contribution of the relative influence contribution of each parameter by each of the method to the evolution of evapotranspiration.

The percentage contribution of each meteorological parameter varies with each of the methods for this region. For instance, the wind speed has the highest influence for FAO-56 PM and Abtew methods and it ranges from 0% to 35%; for Hargreaves and Makkink, temperature has the highest influence on the estimation of evapotranspiration, it ranges from 18% to 73%; For Priestley-Taylor method, solar radiation exert greater influence on the estimation of evapotranspiration in the midland. This is so, because Midland condition in Nigeria has a peculiar weather system. Some parts (e.g. Jos) lie in the humid environment because of the prevalent highlands while the rest share arid climate.

Table 3 below represents the distribution of the weighty influence of the meteorology parameters on the estimation of evapotranspiration by the different methods of prediction.In the guinea savannah, wind speed is the major atmospheric parameter that has the greatest influence on the estimation of the evapotranspiration by all the methods in the guinea savannah. However, for FAO-56 PM, air temperature has the greatest influence on the evolution of evapotranspiration

Figure 3: Relative influence of Sensitivity Coefficients for each Evapotranspiration method during the Irrigation Period for the savannah Condition in Nigeria

Figure 3 below represents the percentage contribution of the sensitivity coefficient of each parameter to the estimation by each parameter. From the figure it is obvious that, air temperature has the greatest influence on the estimation of evapotranspiration by all the methods in the Midland. The percentage of parameter influence ranges from 30% to 60% and having an average percentage influence of 50. The coefficients range from low values in the wet period and peak in dry season.

Table 4 represents the monthly distribution of the sensitivity coefficients for all the parameters by the different methods in the coastal region.All the parameter sensitivity coefficients vary from month to month for all the methods but found low during the wet season and high in the dry period. For all the methods with the exception of Priestly-Taylor, wind speed was found to have the maximum influence on the estimation of the evapotranspiration. This result is reasonable because this region is in proximity to the Atlantic oceans, thus, the effect of land and sea breezeis obvious in all the locations within this region. It should be noted that other parameters whose influence compete keenly with wind speed, in this region, include relative humidity and air temperature. However, for the Priestly-Taylor method, the greatest influence was solar radiation and this was extremely greater than rest for the estimation of evapotranspiration in this region. Furthermore, the percentage of the contribution of each parameter on evolution of evapotranspiration during the dry irrigation period was also investigated in figure 4 above. In this region, solar radiation has the greatest influence on evapotranspiration estimation by all the methods except FAO-56 Penman-Monteith. The sensitivity coefficient contribution of solar radiation in percentage to the estimation during the irrigation period ranges from 10% to 90%. In addition to this is the temperature according to FAO-56 Penman-Monteith has 61% influences on estimation of evapotranspiration.

This study also investigates the seasonal contribution of each meteorological parameter by each method for the estimation of the evapotranspiration in all the regions under consideration and the result is summarized in Table 5 below. The Table is the seasonal distribution of the sensitivity coefficients of the weather parameters by each method across all the regions. For FAO-56 Penman-Monteith, the weather parameters that has greater influence for the estimation of evapotranspiration in dry and wet periods is solely wind speed in both arid and semi-arid regions.However, for savannah and the coastal regions, temperature has maximum influence in the dry period while wind speed and Temperature were found for dry and wet seasons respectively. On the annual time scale, wind speed has a strong influence in both arid and midland regions while temperature appeared to have stronger influence in the savannah and coastal environments.

In the arid region, ET (evapotranspiration) estimation by Abtew method is highly influenced by solar radiation in both seasons and by wind speed for dry and wet periods in Midland and Savannah regions. In the coastal environment, both solar radiation and temperature have larger and equal contribution in ET estimation by the Abtew method in dry and wet season respectively.

On the annualtimescale, wind speed influence is stronger in midland and Guineasavannah while solar radiation and temperature in both arid and the coastal environment.

For Hargreaves method, solar radiation was found to have greater contribution to ET estimation in the arid region for both season; the contributive influences of temperature and relative humidity for ET estimation by this method in the dry period are greater in the midland and savannah respectively. However, in the wet season, wind speed was found to have a domineering influence on ET estimation midland, savannah and the coastal environments.

For ET estimation by Makkink method, solar radiation and temperature have stronger influences in both seasons in the arid and midland regions. In addition, during the wet season, as revealed in this study, the contribution of solar radiation is more effective in arid and semi-arid while windspeed influences is stronger in the savannah and the coastal environments.

Finally, using Priestly-Taylor for ET estimation in the arid region, solar radiation was found to have a stronger influence (see table 5.0) in both dry and wet periods. Also, from the table, influences of temperature, relative humidity and solar radiation were stronger in the arid climate during the dry period. In the wet period, solar radiation contributes effectively to ET estimation in both the arid and the coastal areas while a wind speed influence was found to be stronger in the midland and guinea savannah. On the annual timescale, solar radiation was found to have stronger influence on ET estimation by all the methods in all the regions. This may be due to the availability of heavy solar receipt in the area. Wind speed was found to have a domineering influence on ET estimation in all the regions by all the methods. While temperature and solar radiation contribution is more effective in the coastal by FAO-56 Penman Monteith and Abtew methods respectively.

5.0 Conclusion

The effect of climate change on the environment is incredibly ominous and almost all the physical processes in at the surface layer within the boundary layer of the lower atmosphere have undergone tremendous change. The impact of the consequential changes of meteorological parameters on hydrological processes can be determined by the magnitude of the sensitivity coefficients of such parameters. Sensitivitycoefficients of some hydrological models were calculated and their spatial–cum-temporal variations were examined for different climatic regions in Nigeria. The models involved in the study include FAO-56 Penman Monteith, Abtew, Hargreaves, Makkink and Priestly and Taylor. The input parameters, whose influences and impacts on the evolution of evapotranspiration include temperature, relative humidity, global solar radiation, wind speed were studied as well. A monotonous variation in the environmental influence of the meteorological parameters by the various techniques on the estimation of evapotranspiration was observed. Solar radiation has the maximum influence in both the arid and the coastal while temperature was noted for the midland and the savannah.On the seasonal consideration, the regional sensitivity coefficients vary largely and stagger between global solar radiation and temperature and in some case wind speed inclusive. In both arid and coastal regions, global solar radiation has the largest impact on the evolution of evapotranspiration during the dry and wet seasons; for the midland and the savannah, temperature and wind speed are the most influential parameters during the dry and wet seasons respectively. This information is crucial for the researchers on the design of models for the regional estimation of evapotranspiration in Nigeria.

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Table 1:The sensitivity coefficient of some Hydrometeorological Parameters to ET Model for the estimation of Reference Evapotranspiration in the Arid Condition of Nigeria

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
PM												
Tmin	0.011722	0.003415	0.027013	0.029135	0.061688	0.086311	0.052932	0.076369	0.036559	0.045403	0.012139	-0.02212
Tmax	0.007378	-0.01128	-0.01054	0.05527	0.072811	0.11852	0.050304	0.031879	-0.0071	-0.02102	0.012919	-0.04331
Tmn	0.012029	0.00366	0.021502	0.019357	0.085651	0.086122	0.043	0.040425	0.053695	0.051212	0.011489	-0.02434
Rmin	-0.0603	-0.03351	0.035496	-0.03585	-0.0272	0.037328	-0.06407	-0.03308	-0.15206	-0.01121	-0.01142	0.003693
Rmax	-0.04673	-0.0718	-0.02542	-0.04684	-0.03573	0.036293	0.010116	-0.04213	0.070379	0.054324	-0.01302	0.064659
U	0.040232	0.076363	0.045548	0.024155	0.004564	0.097319	0.064981	0.217625	0.094564	0.065813	0.06774	0.041915
Rs	-0.15056	-0.10446	-0.07538	-0.05301	0.010386	-0.08601	0.178666	-0.00737	0.048408	-0.03759	-0.02212	-0.02634
Abtew												
Rmn	0.020946	0.006016	-0.0008	0.011827	0.005407	0.000921	-0.01849	-0.04203	-0.00055	-0.01837	-0.00669	-0.01347
U	0.001607	-0.001	0.002079	-0.00171	-0.00771	-0.00548	-0.02739	-0.03363	-0.00254	-0.01403	-0.00911	-0.01703
Rs	0.000754	0.004453	-0.00589	-0.01767	0.053079	0.03821	0.089062	0.120045	0.075972	0.057807	0.061052	0.081671
Tmn	0.030486	0.023748	-0.00237	0.006286	0.024794	0.046841	0.056642	0.044308	0.010226	-0.01164	-0.01676	0.00425
ETHargr												
Rmn	0.020431	0.005473	-0.00067	0.009296	0.004271	0.000755	-0.01589	-0.03672	-0.00048	-0.01557	-0.00602	-0.01313
U	0.001568	-0.00091	0.001731	-0.00134	-0.00609	-0.00449	-0.02354	-0.02938	-0.0022	-0.0119	-0.0082	-0.01661
Rs	0.004838	0.003939	-0.00124	-0.00682	0.002205	-0.00601	0.050585	0.061675	0.030759	0.020504	0.007004	0.015222
Tmn	0.022992	0.009232	-0.00387	-0.00816	0.016196	0.00619	0.042622	0.028692	0.013069	0.005656	-0.00588	0.006422
ETMakk												
Rmn	0.017136	0.012122	0.000864	0.015439	-0.0051	-0.02109	-0.0278	-0.04635	0.005871	-0.01671	-0.00382	-0.02416
U	0.001986	-0.00119	0.002473	-0.00201	-0.00882	-0.00592	-0.02927	-0.0355	-0.00268	-0.01473	-0.01016	-0.02073
Rs	0.00613	0.005163	-0.00177	-0.0102	0.003192	-0.00793	0.0629	0.074508	0.037445	0.025374	0.008673	0.018999
Tmn	0.029133	0.0121	-0.00553	-0.01221	0.023453	0.008168	0.052998	0.034662	0.015909	0.007	-0.00728	0.008016
Etpt												
Rmn	0.019154	0.013795	0.000898	0.014077	-0.00418	-0.00077	-0.02229	-0.0387	0.005356	-0.01624	-0.00391	-0.0268
U	-0.0406	-0.03147	-0.00968	0.007502	-0.0034	0.004119	-0.01726	-0.04304	-0.00828	-0.01685	-0.02689	-0.05482
Rs	0.003294	0.011459	-0.0051	-0.01862	0.036761	0.02887	0.084382	0.109424	0.072206	0.05616	0.05734	0.086305
Tmn	0.036198	0.03734	0.001715	0.00617	0.027996	0.009758	0.032057	0.050176	0.011132	-0.00379	-0.00239	0.020983

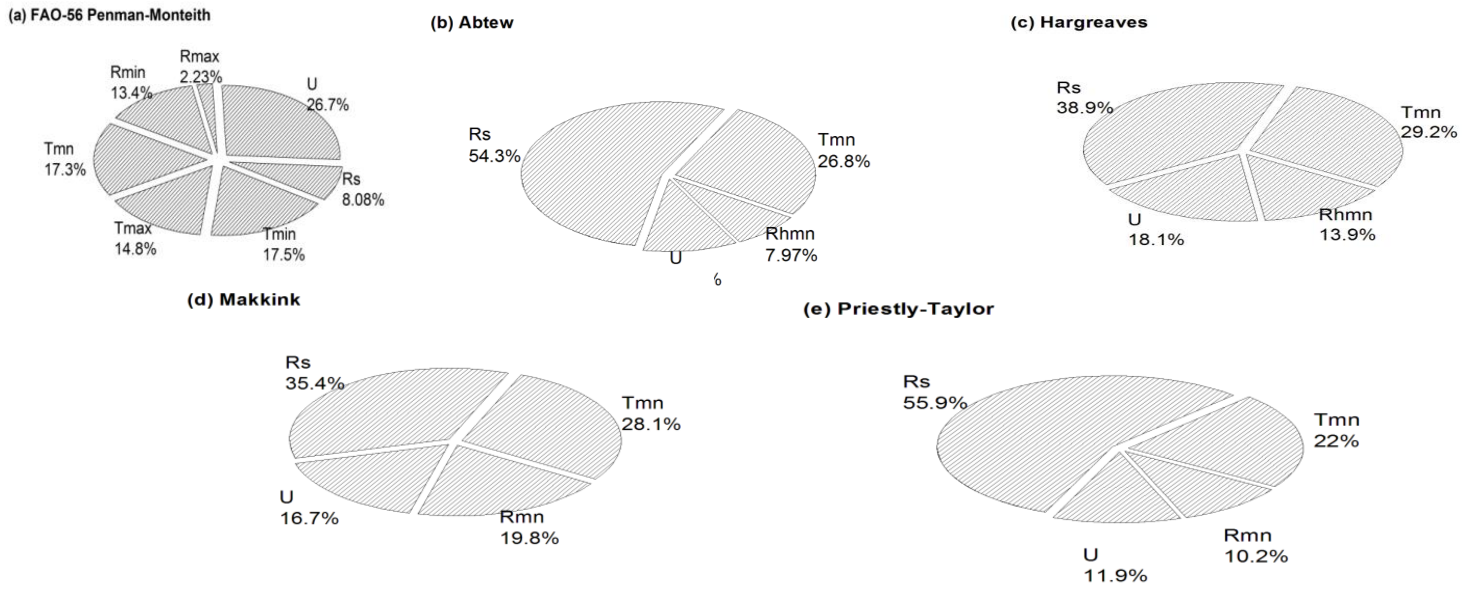

Figure 2: Relative influence of sensitivity coefficients for each evapotranspiration method during the Irrigation Period for Arid Condition in Nigeria

Table 2: Regional sensitivity coefficients of some Hydrometeorological Parameters to ET Model for the estimation of Reference Evapotranspiration in the Midland Condition of Nigeria

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
PM												
Tmin	0.011	-0.024	0.005	-0.021	0.014	0.015	0.001	0.002	0.018	-0.009	-0.008	-0.032
Tmax	0.013	0.048	0.008	0.016	0.043	-0.019	-0.017	-0.026	-0.014	0.004	-0.016	0.053
Tmn	0.022	0.016	0.008	0.003	0.031	-0.004	-0.010	-0.019	0.004	-0.001	-0.015	0.003
Rmin	0.043	-0.004	0.006	-0.002	-0.037	0.027	0.012	0.020	0.006	-0.012	0.012	0.041
Rmax	0.007	-0.026	0.011	0.031	0.011	0.020	0.013	0.011	-0.003	0.005	0.037	0.011
U	0.049	0.028	0.079	0.114	0.064	-0.010	0.037	0.013	-0.011	0.016	0.012	-0.048
Rs	0.006	-0.010	-0.007	-0.003	-0.011	0.005	-0.001	0.007	0.009	-0.001	-0.003	0.001
Abtew												
Rmn	0.037	0.003	-0.024	0.010	-0.028	-0.010	-0.026	-0.004	0.021	0.000	0.020	0.025
U	0.434	0.041	0.014	0.049	0.067	0.063	-0.041	0.021	-0.027	-0.009	0.012	0.135
Rs	0.028	0.023	0.024	-0.012	0.025	0.019	-0.015	0.015	-0.006	0.001	0.005	-0.011
Tmn	0.019	-0.011	-0.001	-0.014	0.019	-0.016	-0.004	0.007	-0.001	0.006	-0.005	0.027
ETHargr												
Rhmn	0.038	-0.003	-0.014	0.002	-0.051	-0.012	-0.033	-0.004	0.028	0.003	0.022	0.036
U	0.092	0.004	-0.235	-0.108	0.043	-0.104	-0.066	-0.003	-0.016	0.019	-0.190	0.049
Rs	0.028	0.026	0.018	-0.014	0.045	0.017	-0.010	0.024	0.002	0.015	-0.002	-0.014
Tmn	0.112	-0.098	-0.028	-0.168	0.289	-0.138	0.018	0.125	0.053	0.091	-0.122	0.189
ETMakk												
Rhmn	0.029	0.002	-0.020	0.015	-0.031	-0.011	-0.029	0.012	0.018	-0.011	0.023	0.014
U	0.023	0.015	-0.010	-0.006	-0.016	-0.014	-0.003	-0.043	-0.033	-0.039	-0.014	-0.006
Rs	0.023	0.019	0.025	-0.010	0.031	0.024	-0.021	0.002	-0.029	-0.011	0.011	0.000
Tmn	0.076	-0.078	0.000	-0.215	0.124	-0.212	-0.039	-0.133	-0.179	0.078	0.042	0.156
ETpt												
Rhmn	0.001	-0.004	0.039	0.006	-0.025	-0.007	-0.017	0.004	0.011	-0.022	0.028	0.022
U	0.508	0.047	0.035	0.083	0.073	0.065	-0.049	-0.007	-0.082	-0.039	0.046	0.090
Rs	-0.031	0.012	0.011	0.022	0.028	0.013	-0.010	0.011	-0.012	-0.015	0.013	0.028
Tmn	-0.177	-0.228	0.169	-0.043	0.140	-0.152	0.001	0.032	-0.034	0.091	0.195	0.033

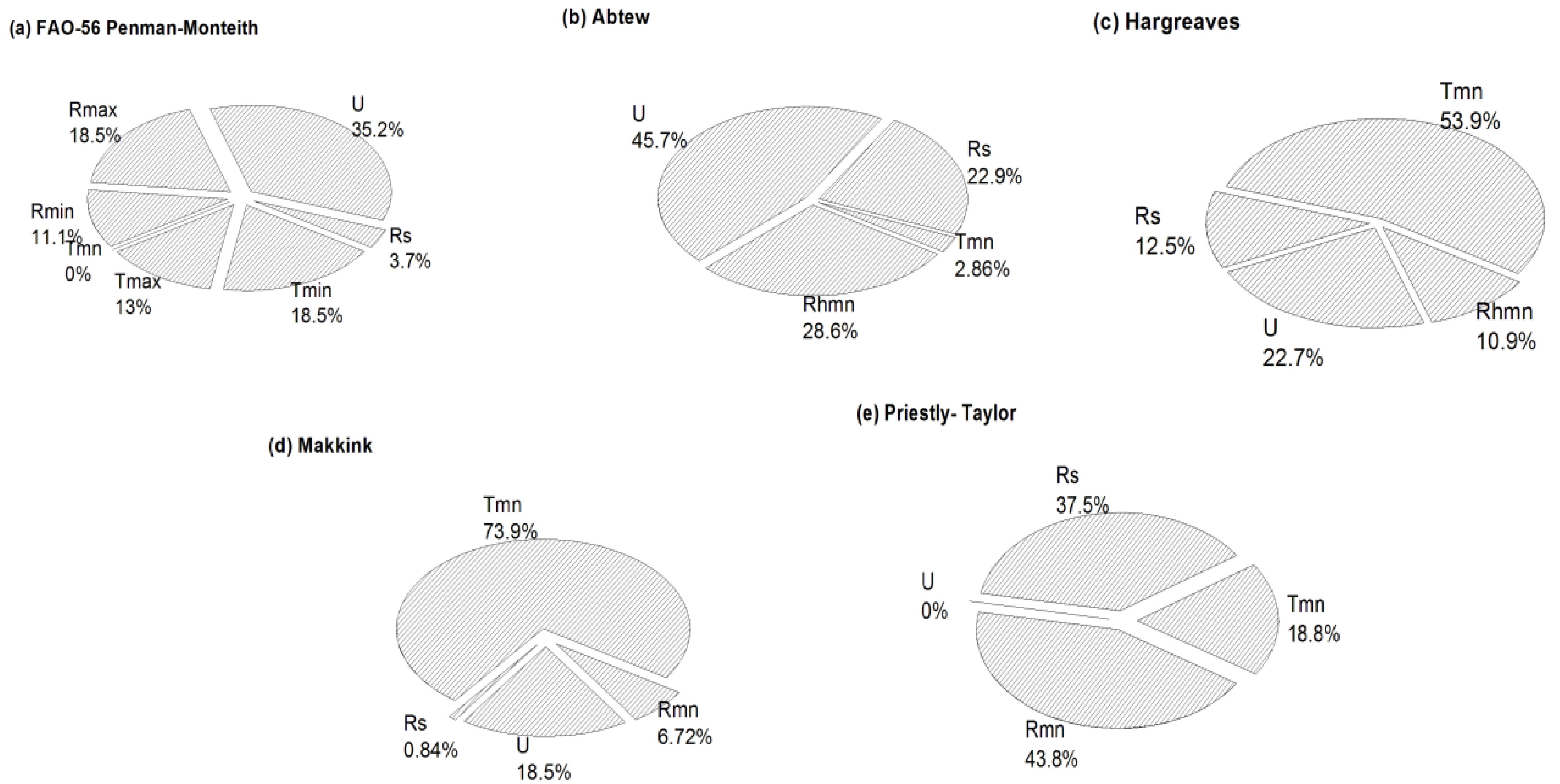

Figure 2: Relative influence of Sensitivity Coefficients for each Evapotranspiration method during the Irrigation Period for Semi- Arid (Midland) Condition in N

Table 3:The sensitivity coefficient of some Hydrometeorological Parameters to ET Model for the estimation of Reference Evapotranspiration in the Savannah Condition

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
PM												
Tmin	0.038	0.046	0.048	0.001	0.025	-0.040	0.079	0.014	0.020	0.036	0.047	0.048
Tmax	0.022	0.053	0.070	-0.053	0.046	-0.039	-0.009	0.006	-0.017	-0.001	0.030	0.021
Tmn	0.036	0.057	0.077	-0.034	0.045	-0.044	0.040	0.011	-0.009	0.017	0.048	0.040
Rmin	0.019	-0.010	0.027	0.031	-0.017	-0.004	0.031	0.000	0.037	0.027	0.004	0.001
Rmax	-0.028	-0.017	0.014	0.020	-0.020	0.026	-0.023	-0.020	0.002	-0.003	-0.007	-0.046
U	-0.007	0.020	-0.014	-0.013	-0.013	-0.042	-0.029	0.006	0.011	-0.022	-0.043	0.014
Rs	-0.048	-0.032	0.058	0.012	0.012	-0.040	-0.017	0.013	-0.010	0.000	-0.008	-0.001
Abtew												
Rmn	-0.012	0.017	-0.004	0.001	0.002	-0.047	0.007	0.034	0.089	0.031	-0.007	0.000
U	-0.024	-0.005	0.026	-0.023	-0.004	0.094	-0.001	0.105	0.063	-0.016	-0.001	-0.021
Rs	-0.002	-0.009	-0.043	-0.001	0.016	-0.047	-0.006	-0.001	0.025	0.020	-0.006	0.040
Tmn	0.009	-0.006	0.007	0.027	-0.011	0.006	-0.020	-0.043	-0.078	-0.031	-0.001	-0.028
ETHargr												
Rmn	-0.004	0.005	-0.014	-0.015	-0.016	-0.047	-0.010	0.033	0.072	0.032	-0.015	0.004
U	-0.025	-0.006	0.017	-0.018	-0.012	0.056	-0.015	0.080	0.051	-0.014	0.006	-0.009
Rs	0.000	-0.018	-0.037	0.020	0.033	-0.036	-0.002	0.003	0.028	0.021	0.010	0.029
Tmn	0.015	0.004	0.016	0.032	0.013	0.017	-0.004	-0.034	-0.058	-0.011	0.007	-0.020
ETMakk												
Rmn	-0.018	0.022	0.004	0.011	0.012	-0.040	0.011	0.045	0.114	0.021	0.003	0.007
U	-0.011	-0.002	0.033	-0.025	0.002	0.133	0.013	0.151	0.094	-0.001	0.008	-0.036
s	0.006	-0.008	-0.054	-0.006	0.006	-0.065	0.005	-0.010	0.041	0.056	-0.012	0.038
Tmn	-0.011	-0.020	0.002	0.014	-0.026	0.006	-0.023	-0.058	-0.118	-0.034	-0.009	-0.036
Etpt												
Rmn	-0.013	0.020	0.014	-0.003	0.004	-0.025	-0.002	0.026	0.070	0.013	0.012	0.013
U	0.021	-0.010	0.019	-0.018	-0.002	0.076	-0.008	0.067	0.051	-0.004	0.005	-0.018
Rs	0.000	-0.018	-0.037	0.020	0.033	-0.036	-0.002	0.003	0.028	0.021	0.010	0.029
Tmn	-0.018	-0.028	-0.016	0.018	-0.013	0.008	-0.012	-0.026	-0.069	-0.019	0.016	-0.017

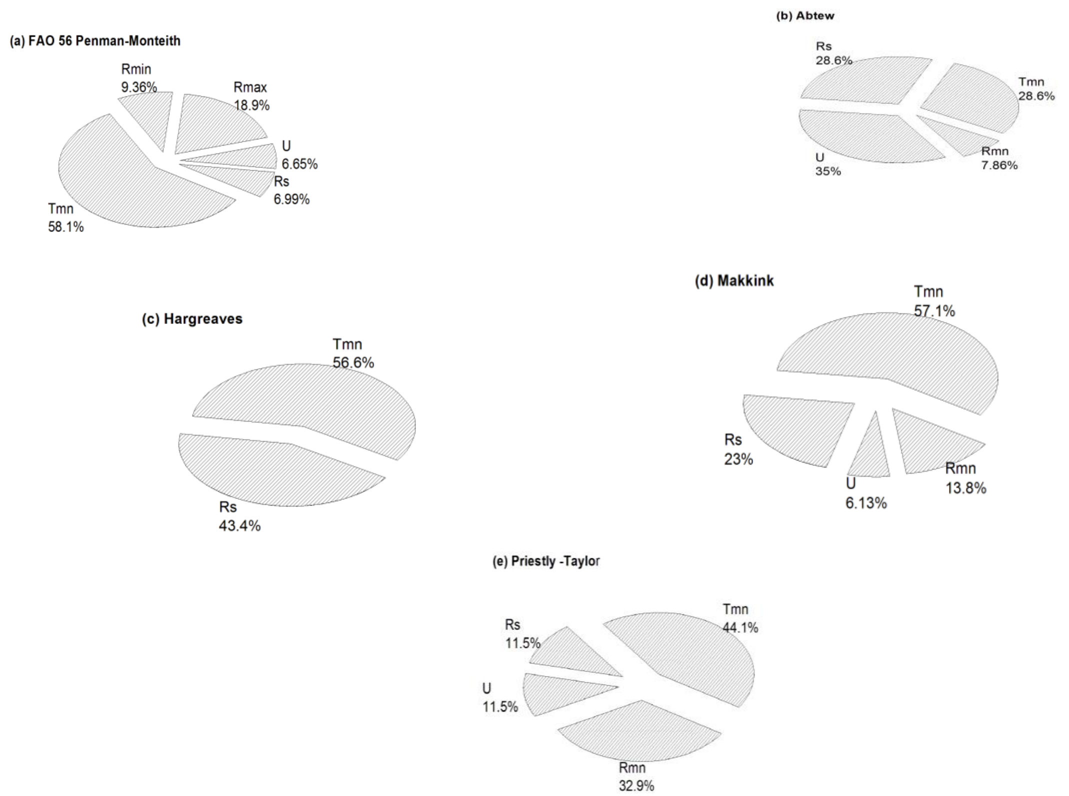
(a) FAO 56 Penman-Monteith
Rmin 9.36%
Rmax 18.9%
U 6.65%
Rs 6.99%
Tmn 58.1%
(b) Abtew
Rs 28.6%
Tmn 28.6%
Rmn 7.86%
U 35%
(c) Hargreaves
Tmn 56.6%
Rs 43.4%
(d) Makkink
Tmn 57.1%
Rs 23%
U 6.13%
Rmn 13.8%
(e) Priestly -Taylor
Rs 11.5%
Tmn 44.1%
U 11.5%
Rmn 32.9%

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Table 4:The sensitivity coefficient of some Hydrometeorological Parameters to ET Model for the estimation of Reference Evapotranspiration in the Coastal Condition of

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
PM												
Tmin	0.002	-0.027	-0.311	-0.173	-0.436	-0.410	-0.312	-0.591	-0.646	-0.515	-0.170	0.019
Tmax	-0.017	0.028	-0.031	-0.012	-0.032	-0.007	-0.005	-0.024	-0.033	-0.006	-0.020	0.003
Tmn	-0.006	0.021	-0.057	-0.020	-0.043	-0.034	-0.027	-0.048	-0.051	-0.031	-0.030	-0.001
Rmin	0.027	0.011	0.040	0.012	0.011	-0.022	-0.043	-0.022	-0.009	0.000	-0.014	-0.008
Rmax	0.032	0.015	0.031	0.006	0.005	-0.028	-0.057	-0.045	-0.066	-0.026	-0.002	-0.006
U	0.017	0.003	0.002	-0.001	0.026	0.026	0.020	0.070	0.054	0.046	0.025	0.006
Rs	-0.024	-0.006	0.001	0.018	0.004	0.010	0.013	0.011	-0.005	-0.004	0.003	0.014
Abtew												
Rmn	-0.014	0.034	0.043	-0.015	-0.001	-0.038	-0.058	-0.055	-0.002	0.019	-0.011	0.005
U	-0.020	0.011	-0.009	-0.006	0.040	0.011	0.004	0.066	0.055	0.030	0.001	-0.018
Rs	0.023	0.012	0.021	0.025	0.013	0.016	0.019	0.038	0.002	0.005	0.007	0.023
Tmn	0.000	0.000	-0.028	-0.018	-0.049	-0.012	-0.015	-0.045	-0.046	-0.020	-0.015	0.023
ETHargr												
Rmn	-0.012	0.029	0.037	-0.013	-0.001	-0.034	-0.053	-0.050	-0.002	0.017	-0.010	0.005
U	-0.017	0.009	-0.007	-0.005	0.035	0.010	0.003	0.061	0.049	0.027	0.001	-0.016
Rs	0.020	0.010	0.018	0.021	0.011	0.015	0.018	0.035	0.001	0.005	0.006	0.020
Tmn	0.000	0.000	-0.024	-0.016	-0.043	-0.011	-0.014	-0.041	-0.041	-0.018	-0.013	0.021
ETMakk												
Rmn	-0.014	0.035	0.045	-0.015	-0.001	-0.041	-0.062	-0.059	-0.002	0.020	-0.012	0.006
U	-0.021	0.011	-0.009	-0.006	0.042	0.011	0.004	0.071	0.058	0.032	0.001	-0.019
Rs	0.024	0.013	0.022	0.026	0.013	0.017	0.021	0.041	0.002	0.006	0.007	0.024
Tmn	0.000	0.000	-0.029	-0.019	-0.052	-0.013	-0.016	-0.048	-0.049	-0.021	-0.015	0.025
Etpt												
Rmn	-0.006	0.023	0.036	-0.009	0.001	-0.032	-0.039	-0.034	0.005	0.006	-0.014	0.014
U	-0.032	0.001	-0.014	-0.017	0.022	0.001	0.003	0.037	0.032	0.014	-0.013	-0.013
Rs	0.218	0.152	0.148	0.219	0.229	0.097	0.175	0.173	-0.029	0.071	0.090	0.260
Tmn	0.014	-0.003	-0.022	-0.008	-0.033	-0.005	-0.001	-0.021	-0.020	-0.006	-0.005	0.010

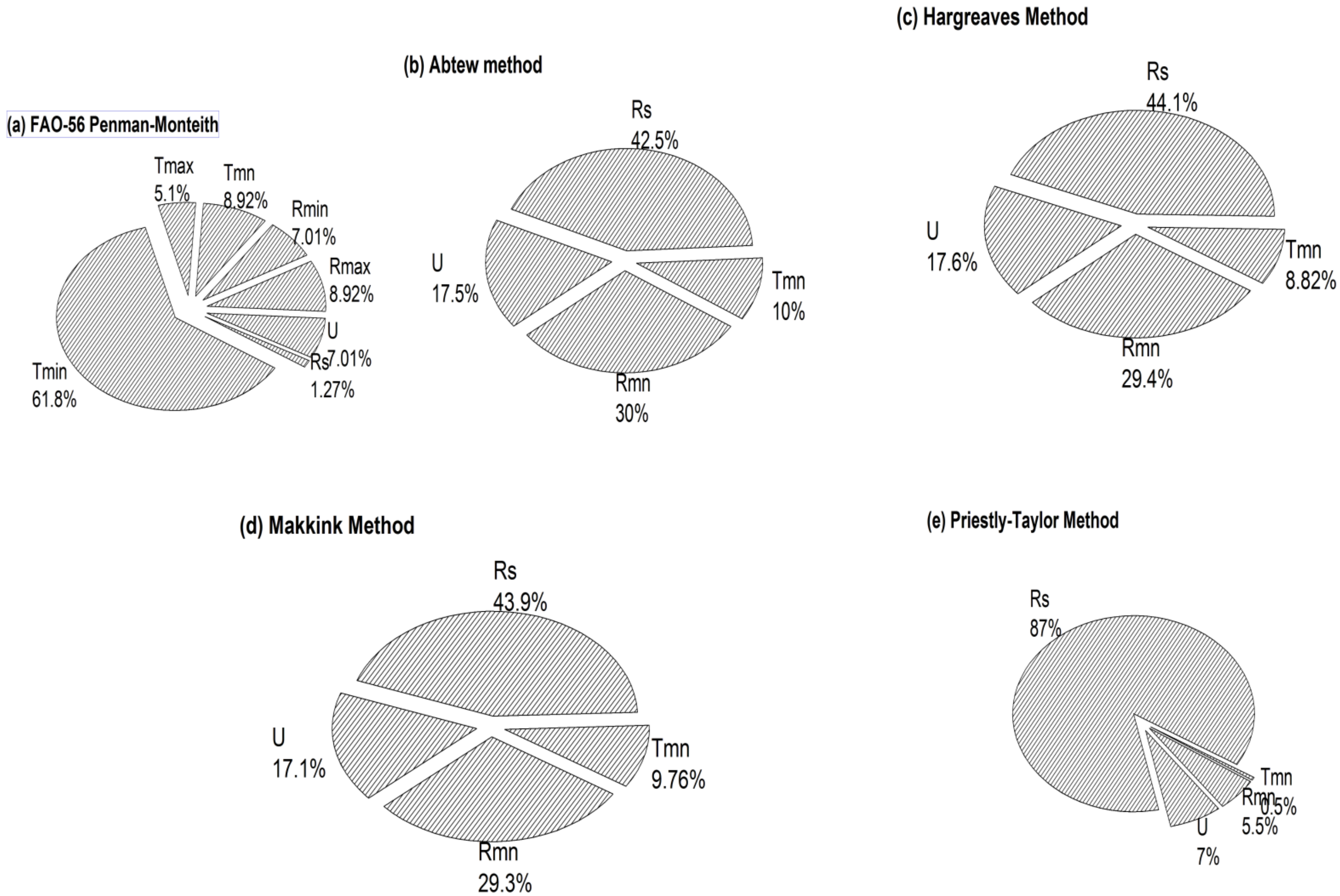

Figure 4.0: Relative influence of sensitivity coefficients for some radiation based Reference evapotranspiration techniques during the dry season in the Coastal Region of Nigeria

Table 5:The seasonal Characteristic of sensitivity coefficients of some HydrometeorologicalParameters for Evapotranspiration E

Arid				Midland			Grassland			Coastal		
	Dry	Wet Season	Annual	Dry	Wet Season	Annual	Dry	Wet Season	Annual	Dry	Wet Season	Annual
FAO-PM												
Tmn	0.062	0.014	0.034	0.000	0.005	0.003	0.051	0.004	0.024	-0.014	-0.036	-0.027
Rmin	-0.048	0.021	-0.029	0.006	0.012	0.009	0.008	0.015	0.012	0.011	-0.010	-0.001
Rmax	0.008	0.029	-0.004	0.010	0.011	0.011	-0.017	-0.003	-0.008	0.014	-0.030	-0.012
U	0.096	0.052	0.070	0.019	0.036	0.029	-0.006	-0.015	-0.011	0.011	0.034	0.025
Rs	0.029	0.027	-0.027	0.002	-0.002	-0.001	-0.006	-0.004	-0.005	-0.002	0.007	0.003
ABTEW												
Rmn	-0.011	0.000	-0.005	-0.010	0.010	0.002	-0.001	0.017	0.009	0.012	-0.022	-0.008
U	-0.015	-0.006	-0.010	0.016	0.097	0.063	-0.005	0.031	0.016	-0.007	0.029	0.014
Rs	0.075	0.026	0.047	0.008	0.008	0.008	-0.004	0.001	-0.001	0.017	0.017	0.017
Tmn	0.037	0.005	0.018	0.001	0.003	0.002	-0.004	-0.021	-0.014	-0.004	-0.029	-0.019
HARGREAVES												
Rmn	-0.010	0.000	-0.004	-0.014	0.012	0.002	-0.005	0.007	0.002	0.010	-0.020	-0.007
U	-0.013	-0.005	-0.008	-0.029	-0.053	-0.043	-0.003	0.018	0.009	-0.006	0.026	0.012
Rs	0.028	0.006	0.015	0.016	0.008	0.001	-0.003	0.010	0.004	0.015	0.015	0.015
Tmn	0.021	0.004	0.011	0.069	-0.003	0.027	0.004	-0.006	-0.002	-0.003	-0.026	-0.017
MAKKINK												
Rmn	-0.019	0.000	-0.008	-0.008	0.007	0.001	0.004	0.025	0.016	0.012	-0.023	-0.008
U	-0.016	-0.006	-0.011	-0.022	-0.005	-0.012	-0.002	0.053	0.030	-0.007	0.030	0.015
Rs	0.034	0.007	0.019	0.001	0.008	0.005	-0.006	0.004	0.000	0.018	0.018	0.018
Tmn	0.027	0.004	0.014	-0.088	0.008	-0.032	-0.015	-0.034	-0.026	-0.004	-0.031	-0.020
PRIESTLY-												
Rmn	-0.012	0.000	-0.005	-0.007	0.010	0.003	0.009	0.012	0.011	0.011	-0.015	-0.004
U	-0.014	-0.025	-0.020	0.000	0.110	0.064	0.003	0.023	0.015	-0.014	0.013	0.002
Rs	0.066	0.027	0.044	0.006	0.006	0.006	0.003	0.010	0.004	0.174	0.134	0.150
Tmn	0.026	0.014	0.019	-0.003	0.006	0.002	0.013	-0.016	-0.015	-0.001	-0.013	-0.008

References

[1]. Allen, R.G.; Pereira, L.S.Raes, D. and Smith, M. (1998): Crop evapotranspiration: Guidelines for computing crop water requirements. Irrigation and Drainage Paper, No. 56,Food andAgriculture Organisation of the United Nations, Rome, 300pp.
[2]. Blaney, H.F and Cridle, W.D. (1950): Determining Water Requirements in irrigated Area from Climatological Irrigation Data, US Department of Agriculture, Soil conservation service, TechnicalPaper No. 96, pp48.
[3]. Dyck, S (1983): Overview on the present status of the concepts of water balance models. New Approaches in water balance computations. In: Van der Beken, A.,
[4]. Herman, A. (Eds), proceedings of the Hamburg Workshop, IAHS Publication No. 148, pp. 3-19.
[5]. Hobbin, M.T, Ramirez, J.A., Brown, T.C., Claessens, L.H.J.M. (2001b): The complementary relationship in estimation of regional evapotranspiration and advection-Ariditymodels. Water Resource Research 37(5), 1367-1387.
[6]. Xu, Z. X., and Li J.Y.(2003): A distributed approach for estimating basin evapotranspiration: comparison of the combination equation and the complimentary relationship approaches. Hydrological Process 17, 1509-1523.
[7]. Xu, C. Y. and Singh, V. P., (2000): Evaluation and generalization of radiation-based methods for calculatingevaporation. Hydrological Processes 14 p. 339-349
[8]. Lebing Gong, Chong-yuXu, Deliang Chen, Sven Halldin, Yongqin David Chen,(2006): Sensitivity of the Penman–Monteith reference evapotranspiration to key climatic variables in the Changjiang (Yangtze River) basin, Journal of Hydrology: 329, 620– 629.
[9]. Gong, L., Xu, C., Chen, D., Haldin, S. and Chen, Y.D. (2006): Sensitivity f the Penman-Monteith evapotranspiration. Water Resour. Bull., 10(3): 486-498.
[10]. Guitjens J. C. (1982): Models of alfalfa yield and evapotranspiration. Journal of the Irrigation and Drainage Division, Proceedings of the American Society of Civil Engineers 108(IR3)
[11]. Kohler MA, Nordenson T. J, Fox WE. (1955): Evaporation from pans and lakes. Weather Bureau Research Paper 38, US Department of Commerce: Washington, DC.
[12]. Ogolo, E.O. (2010): Evaluating the performance of some predictive models for estimating global solar radiation across varying climatic conditions in Nigeria. Indian Journal of Radio and Space Physics.Vol. 39, pp121-131.
[13]. Fritschen LJ. (1966): Energy balance method. Proceedings of the American Society of Agricultural Engineers Conference on Evapotranspiration and its role in WaterResources Management
[14]. Harbeck GE. (1962): A practical ®eld technique for measuring reservoir evaporation utilizing mass-transfer theory. United States Geological Survey Professional Paper 272-E: 101-105.
[15]. Penman, H. L. (1948): Natural evaporation from open water, bare soil and grass. Proceedings of the Royal Society of London 193: 120-145.
[16]. Turc L. (1961): Estimation of irrigation water requirements, potential evapotranspiration: a simple climatic formula evolved up to date. Annals of Agronomy 12: 13-49.
[17]. Priestley C. H. B, Taylor R. J. (1972): On the assessment of the surface heat flux and evaporation using large-scale parameters. Monthly Weather Review 100: 81-92
[18]. Brutsaert, W.(1982):Evaporation into the Atmosphere: theory, history, and applications, Kluwer Academic Publishers, ISBN 90-277-1247-6 Dordrecht, The Netherland.
[19]. Singh VP. (1989): Hydrologic Systems, Vol. 2 Watershed Modeling. Prentice-Hall: Englewood Cliffs, New Jersey
[20]. Jensen ME, Burman RD, Allen RG. (1990): Evapotranspiration and Irrigation Water Requirements. American Society of Civil Engineers: New York.
[21]. Morton FI. 1990. Studies in evaporation and their lessons for the environmental sciences. Canadian Water Resources Journal 15(3):261-285.
[22]. Morton FI. 1994. Evaporation research Ð a critical review and its lessons for the environmental sciences. Critical Reviews inEnvironmental Science and Technology 24(3): 237-280.
[23]. McCuen, R.H. (1974): A sensitivity and error analysis of procedures used for estimatingevaporation. Water Resources Bull. 3: 486-497.
[24]. Saxton, K.E. (1975): Sensitivity analysis of the combination of evapotranspiration equation. Agri. Meteoro.,. 15: 343-353
[25]. Coleman, G., DeCoursey, D.G. (1976): Sensitivity and model variance analysis applied tosome evaporation and evapotranspiration models.Water Resource Research 12 (5), 873–879
[26]. Beven, K. (1979): A sensitivity analysis of the Penman-Monteith actual evapotranspiration estimates. J. Hydro. 44: 169-190.
[27]. Babajimopoulos,Ch., Antonopoulos, B. Grigoriadis, D. and LLIas, A.(1992): Sensitivity analysis of the Penman method, Proceeding of 5th conference of H.Y.U., P.132-140.

[28]. Muhammad and Rainer(1993): Sensitivity Analysis of selected methods for predicting reference crop evapotranspiration. Pak. J. Agri. sa; Vol. 30, No.4, 1993
[29]. Irmak Suat; José O. Payero; Derrel L. Martin; Ayse Irmak; and Terry A. Howell (2006):Sensitivity Analyses and Sensitivity Coefficients of Standardized Daily ASCE-Penman-MonteithEquation, JOURNAL OF IRRIGATION AND DRAINAGE ENGINEERING, NOVEMBERDECEMBER, 564- 578.
[30]. Ambas, A.Th. andE.Baltas,(2011): Sensitivity analysis of different evapotranspiration methods with a new sensitivity coefficient,Proceedings of the 12th International conference on Environmental Science and Technology Rhodes, Greece, 46-53
[31]. Olaniran, O.J. and Summer, G.N.(1989): A study of Climate and Variability in Nigeria based on the Onse, Retreat and length of the rainy season. International journal of climatology, 9:253-269
[32]. Ogolo, E.O.(2011): Regional Estimation of Pan Evaporation using Rountinal Meteorological Variables in Nigeria. Journal of Pure and Applied Physics, 4(2): 78-86, Federal University of Technology, Akure. Nigeria.
[33]. Jegede, O.O. (1998): A field study of the mean surface layer structure in Sub-Saharan West Africa: The Pre-monsoon(Dry) season. MAUSAM, 48, 361-370.

[34]. Bautista F, Bautista D, Delgado-Carranza (2009): Calibration of the equations of Hargreaves and Thornthwaites to estimate the potential evapotranspiration in semi-arid and sub-humid tropical climates for regional applications. Atmósfera 22(4):331-348
[35]. Abtew W. (1996): Evapotranspiration measurement and modelling for three wetland systems in South Florida. Water Resources Bulletin32: 465-473
[36]. Hargreaves G. H. (1975): Moisture availability and crop production. *Transactions of the American Society of Agricultural Engineers* **18**:980–984
[37]. Priestly, C. H. B. and Taylor, R. J.(1972): On assessment of surface heat flux and evaporation using large-scale parameters. Monthly Weather Review 100 p. 81-92.
[38]. PenmanPenman, H.L. 1948: Natural evaporationfrom open water bare soils and grass. Proc, Royal Soc. Series A, 193: 120-145.
[39]. Makkink G. F. (1957): Testing the Penman formula by means oflysimeter. Journal of the Institution of Water Engineers 11: 277-288.
[40]. Scarborough, J.B. (1962): Numerical Mathematical Analysis. John Hopkins Press, New York, USA.
[41]. Beven, K. 1979: A sensitivity analysis of thePenman-Monteith actual evapotranspiration estimates. J. Hydro. 44: 169-190
[42]. Ampas V., Baltas., Papamichail D. and Georgoriadis P.(2009):Sensitivity analysis of FAO Penman Monteith method to key climatic variables in Florina Region. Proc. of common conf. 11th HHA-7th GCWRM. Volos 2009, pp355-362.
[43]. Dauda, T.O, Asiribo,O.E., Akinbode, S.O., Saka, J.O. and Salahu, B.F.(2009): An Assessment of the Roles of
[44]. Irrigation farming in the millienium development goal African journal of Agric. Research vol4 (5) pp445-450.
[45]. NINCID (Nigerian National Committee on Irrigation and Drainage) (2009): Directory: Country Profile-Nigeria downloaded from http://www.icid.org/cp_nigeria.html.