Relability Studies of Six Evapotranspiration Models for Owerri in South Eastern Nigeria

Research · June 2016

DOI: 10.13140/RG.2.2.12120.55046

4 authors, including:

Chukwudi Celestine Egwuonwu
Federal University of Technology Owerri

Ngozi A A Okereke
Federal University of Technology Owerri

Onyewuchi Nduwuishi Oguoma

P-ISSN: 2305-6622; E-ISSN: 2306-3599

International Journal of

Agriculture and Biosciences

www.ijagbio.com; editor@ijagbio.com

Research Article

Reliability Studies of Six Evapotranspiration Models for Owerri in South Eastern Nigeria

*Anyanwu VK, [1]Okereke NAA, [1]Egwuonwu CC and [2]Oguoma ON

[1]Department of Agricultural Engineering Federal University of Technology, Owerri, Nigeria
[2]Department of Mechanical Engineering Federal University of Technology, Owerri, Nigeria
***Corresponding author:** vkosisochukwu@yahoo.com

Article History: Received: January 21, 2016 Revised: May 24, 2016 Accepted: June 01, 2016

ABSTRACT

Penman modified (PM), Priestly Taylor (PT), Blaney-Morin Nigeria (BMN), Jensen-Haise (JH), Hargreaves-Samani (HS) and Thornthwaite (TH) models were used to estimate Reference Evapotranspiration (RET) for Owerri, in South-Eastern Nigeria from 1990 to 2010. The Penman modified model was chosen as a comparison for evaluating the other five empirical models. Good correlation was found between the RET values, estimated by each of the five radiation and temperature based and the Penman modified model, although there were some discrepancies. The mean annual RET estimated by the Penman modified model as the standard tool for Owerri was fund to be 1045.0mm. While the mean annual RET estimated by other five models were found to be 579.3mm, 1490.7mm, 516.7mm, 1548.3mm and 1370.7mm respectively. Conversely, the weather parameters influencing this station were found to be high due to the flatness terrain of the site. In addition, from the statistical regression analysis, Priestly Taylor (PT) had the highest T-scores and lowest Root Mean Square Error (RMSE), in the ranking the Thornthwaite, Blaney-Morin and Hargreaves-Samani predicted best among the five models in the station. Good correlation was found by the temperature based models when evaluated RET with data for Owerri Station. The Penman modified estimates was used to develop correction factors for the three models that predicted best in the station for their potential use without sensitive error. This was done in order to achieve accurate and reliable evapotranspiration.

Key words: Comparison, reliability, evapotranspiration, computing models, correction factors, Owerri, South-Eastern Nigeria

INTRODUCTION

Water is provided to the crops naturally through precipitation and subsurface moisture, but when these supplies prove to be inadequate for crop use, farmers must resort to irrigation. Water availability is also a critical variable for virtually every other economic activity, including industry, the energy sector, and public use (Sargent, 2002). To schedule irrigation properly, a farmer must know the environmental demand for surface water. For the farmer, this surface water loss occurs primarily through evapotranspiration (ET). Evapotranspiration (ET) has a controlling influence on hydrological and meteorological processes. In spite of the efforts of several scientists, reliable estimates of regional evapotranspiration are extremely difficult to obtain due probably to the complexity brought about by its dependence on soil condition and plant physiology. Because of this complexity, the concept of reference evapotranspiration (RET) has been introduced, which no longer depends so critically on soil and plant factors but has been shown to primarily depend on climatic factors and also one of the most important factors in agriculture water availability (Egwuonwu, 2011).

Evapotranspiration (evaporation and transpiration) may be quantified from soil surfaces, open water surfaces as well as vegetation surfaces for its applications to be reliable and achievable. This quantification can be done through direct measurement or by estimation using established models. The direct measurement of evapotranspiration is complex, expensive and time consuming (Ejieji, 2011), thus the estimation of evapotranspiration is usually done indirectly using the reference evapotranspiration (ET_o). Integrating ET_o with the respective surface or crop factors will give the evapotranspiration. The main purpose of the research

Cite This Article as: Anyanwu VK, NAA Okereke, CC Egwuonwu and ON Oguoma, 2016. Reliability studies of six evapotranspiration models for owerri in South Eastern Nigeria. Inter J Agri Biosci, 5(4): 147-150. www.ijagbio.com

reported in this paper was to evaluate the reliability of the five approximate RET prediction models as compared to the standard Penman modified (PM) model using data collected for Owerri in South-Eastern Nigeria. The mean monthly and annual RET values estimated by the five methods were compared with estimates by the standard PM method. The objective for such comparison is to examine the relationships and to determine the method that best predicted RET as compared to the PM method. The second objective was to evaluate the reliability of the methods when data from nearby stations are used for estimating RET. Thirdly, monthly correction factors for adjusting the models that predicted best were developed for their potential use at the study site.

MATERIALS AND METHODS

Six different methods (one combination: Penman Modified; two radiation based: Priestly Taylor and Jensen Haise and three temperature based: Hargreaves. Samani, Thornthwaite and Blaney-Morin Nigeria) were used to estimate RET in Owerri, Meteorological data were collected from meteorological stations distributed all over the study area for the period of 1990-2010 with the assistance of the computer unit of the Federal Meteorological Center Oshodi, Lagos. The weather parameters collected are mean monthly values of air temperature including maximum and minimum temperatures, sunshine hours, wind speed, vapour pressure, relative humidity and rainfall.

The short-wave radiation (Rn), possible sunshine duration (N), black body radiation (TK 4), rate of change of temperature with saturation vapour pressure (e_a), Psychometric coefficient (γ), Extra- terrestrial radiation(Q_A), were all obtained from meteorological monograph .The mean monthly RET was computed for each month using weather data for that month in the RET equation. Regressions analysis were performed to examine the relationships of the mean monthly RET estimates from the five methods with the mean monthly estimates by the standard Penman modified method. The regression equations computed was in the form

$$PM = mX+c \quad (1)$$

Where PM represents Penman modified model mean monthly RET, X is the mean monthly RET estimated from each of the other five methods, m and c are slope and intercept respectively. The Root Mean Square Error (RMSE) parameter was equally used to indicate the goodness of fit of RET estimates as compared to the standard PM method without any adjustment. Other best method used includes the slope of the regression (m), the intercept(c), the correlation coefficient(r) and the coefficient of determination (R^2) were also employed in the analysis of the results.

According to Parmele and McGuiness (1974), the best method is the one with c value closest to zero, m value to 1.0, the highest correlation of coefficient(r) and smallest RMSE. Abtew (1996), Parmele and McGuiness (1974) in their study used standard error and other statistical parameters for the evaluation of RET models. Pindyck and Rubinfield (1981) stated that "the goal of a model is to maximum the precision of predictions (the objective assumed), for an instance, an estimator with very low variance and some bias may be more desirable than an unbiased estimator with high variance. The useful objective in this manner is the goal of minimizing RMSE. Conclusions were further verified by calculating a t-statistics for each of these models as was suggested by Egwuonwu (2012); Jacovides and Kontaytinanis (1995). These authors in their study suggested that the t-statistic should be used in conjunction with the RMSE to better evaluate a model's performance. The conclusions were further verified by calculating a t-statistics for each of these models as was suggested by Jacovides and Kontaytinanis (1995). These authors suggested that the t-statistic should be used in conjunction with the RMSE to better evaluate a model's performance. Data from Owerri station were applied to compute radiation for estimating the RET in the region. Solar radiation (Rs) was first computed for Owerri station using the relation.

$$Rs = R_A (0.5n/N + 0.25) \quad (2)$$

Where Rs is solar radiation, R_A is Extra- terrestrial radiation, n is sun shine hours and N is possible sun shine hours.

RESULTS AND DISCUSSION

The mean monthly and mean annual RET obtained by averaging the monthly and annual values across the period of record for the station is summarized in Table 2. Blaney Morin Nigeria (BMN), Hargreaves-Samani (HS) and Thornthwaites (TH) overestimated the Penman modified (PM) RET which was used as a standard by 43%, 48% and 31% respectively while Jensen- Haise(JH) and Priestly Taylor (PT) under-estimated the Penman modified (PM) RET by 51% and 45% respectively. It was suspected to be partly due to high climatic parameters and flatness of the region. The summary of statistics for regression of mean monthly RET estimated by each of the five methods against that estimated by the standard Penman modified method is presented in Table 3.

The best method for estimating RET (as stated in the methodology) compared to Penman modified method is the one with c closest to zero, m closest to 1.0, the smallest RMSE and t statistics values and the highest r with greater emphasis on the RMSE and t values. Based on this results, the Thornthwaite, Blaney-Morin Nigeria and Hargreaves -Samani models ranked first , second and third respectively with the lowest RMSE and t- score for RET predictions in Owerri Station as illustrated in Table 3. The statistics for the Priestly Taylor models was nearly as good, making it the fourth best predictor even though it had a better r, m and c than Thornthwaite model. The reliability of each RET method was tested by using the regression result obtained by calibration for Owerri station using the values for Imo State was compared to the estimates by the Penman modified method using measured data at Owerri station as shown in Tables 4.

The degree of fit of the regression on a monthly basis improved considerably from that achieved with the measured weather data for same period. The Thornthwaite model again performed better as there was significant improvement in all most all of its statistical parameters compared to other models since it ranked first in the station, most especially to that of radiation based. Hence, it is important to note that the positive results achieved highlighted above was probably due to a strong correlation of temperature obtained by using empirical relationships with data from the stations.

Finally, monthly correction factors were deduced for the three models that predicted best in the station for their potential use as shown in table (6). The reason is to give or achieve a more accurate and reliable estimate without a sensitive error as compared to the standard Penman Modified.

A graphical representation was equally considered for the station to best showcase or ascertains the relationships among the models (See Figure 1). Also, it was clearly showed that the temperature based models predicted and performed better than that of radiation based models.

Conclusion

Based on the mean monthly RET estimates, statistical regression analysis and comparative analysis of the results for the station, the estimates of the five different methods (two radiations based: Priestly Taylor and Jensen Haise and three temperatures based: Hargreaves. Samani, Thornthwaite and Blaney-Morin Nigeria) when compared with the one combination; Penman modified (PM) RET which was used as a standard, the following conclusions were drawn from the results of the research.

Table 1: Long Term (1990-2010) Mean Monthly Weather Parameters for Owerri Station.

Month	J	F	M	A	M	J	JL	A	S	O	N	D
TMAX (°C)	27.1	31.7	31.0	30.2	29.2	26.4	29.7	26.4	27.3	29.7	29.6	30.6
TMIN (°C)	18.3	22.0	21.0	22.0	21.5	21.2	21.9	19.6	19.7	21.0	21.4	19.7
AVET (°C)	22.7	26.9	26.0	26.1	25.4	23.8	25.8	23.0	23.5	25.3	25.5	25.1
RAIN.F (mm)	22.5	38.2	91.0	167.7	244.0	301.2	372.1	315.9	356.7	249.0	53.0	6.8
SUNHRS (W/m^2)	1.9	2.3	1.7	1.8	2.2	1.1	0.9	0.7	1.0	1.3	2.1	2.0
RH (%)	53.3	59.4	66.3	72.9	75.6	71.4	79.0	83.5	82.2	79.4	71.1	61.3
VAP (mb)	21.5	25.6	27.7	29.4	29.3	26.5	26.8	28.2	29.2	29.4	28.8	25.5
WID Speed (mph)	90.2	99.2	122.5	112.7	131.1	105.3	117.3	151.1	124.1	122.1	110.8	112.0
Ra	14.6	15.2	15.6	15.6	15.1	14.6	14.8	15.2	15.3	15.2	14.7	14.4
Rs	3.0	3.4	3.1	3.1	3.2	2.5	2.4	2.3	2.5	2.7	3.1	3.0
Rs/A	0.08746	0.09912	0.09037	0.09379	0.09329	0.07288	0.06997	0.06705	0.07288	0.07871	0.09037	0.08746

Table 2: Mean Monthly and Annual RET estimated by different methods for Owerri Station

Mont	BMN	HS	JH	PM	PT	TH
J	166.5	125.1	41.3	82.9	41.7	83.6
F	172.6	136.3	55.9	82.0	51.8	131.8
M	152.7	154.1	54.6	102.2	54.6	131.1
A	130.9	135.3	48.7	89.9	54.7	131.5
M	129.8	129.1	48.4	102.5	56.8	125.3
J	103.0	95.6	27.2	92.5	41.0	98.8
JL	91.0	128.5	37.4	92.5	45.8	131.8
A	72.8	115.3	28.4	85.5	40.9	90.1
S	80.2	120.2	32.6	73.1	43.0	92.8
O	100.2	137.8	43.1	82.3	49.8	119.9
N	133.8	125.8	47.1	74.9	51.7	118.2
D	157.2	145.4	52.2	84.9	47.5	115.5
Annual	1490.7	1548.3	516.7	1045.0	579.3	1370.7

Table 3: Results of the regression analysis of mean monthly RET estimated by five methods against that estimated by Penman Modified RET methods for Owerri station.

Estimation Method	Regression Equation	R	RMSE	T-Value	P
BMN	PM = 1.14 + 0.696 BMN	0.996	24.56	19.5	0.000
HS	PM= 0.18 + 0.674 HS	0.999	12.33	52.5	0.000
JH	PM = 0.75 + 2.01 JH	0.997	20.22	51.0	0.000
PT	PM = 0.14 + 1.80 PT	0.999	10.77	68.3	0.000
TH	PM = 0.28 + 0.761 TH	0.999	12.92	30.1	0.000

Table 4: Results of Comparative Statistics of Penman Modified RET Prediction by five methods for the period 1990-2010 for Owerri stations using Actual Data

	BMN	HS	JH	PT	TH
Total Annual RET (mm)	1490.738	1548.3	516.7487	579.3323	1370.656
Intercept	1.14	0.18	0.75	0.14	0.28
Slope	0.70	0.67	2.01	1.80	0.76
T-Value	19.5	52.5	51.0	68.3	30.1
P-Value	0.00	0.00	0.00	0.00	0.00
R	0.996	0.999	0.997	0.999	0.999
R-Sq. (%)	99.20	99.80	99.50	99.80	99.80
RMSE	24.56	12.33	20.22	10.77	12.92
F-Value	1396.4	5569.67	2062.24	7308.52	5062.99

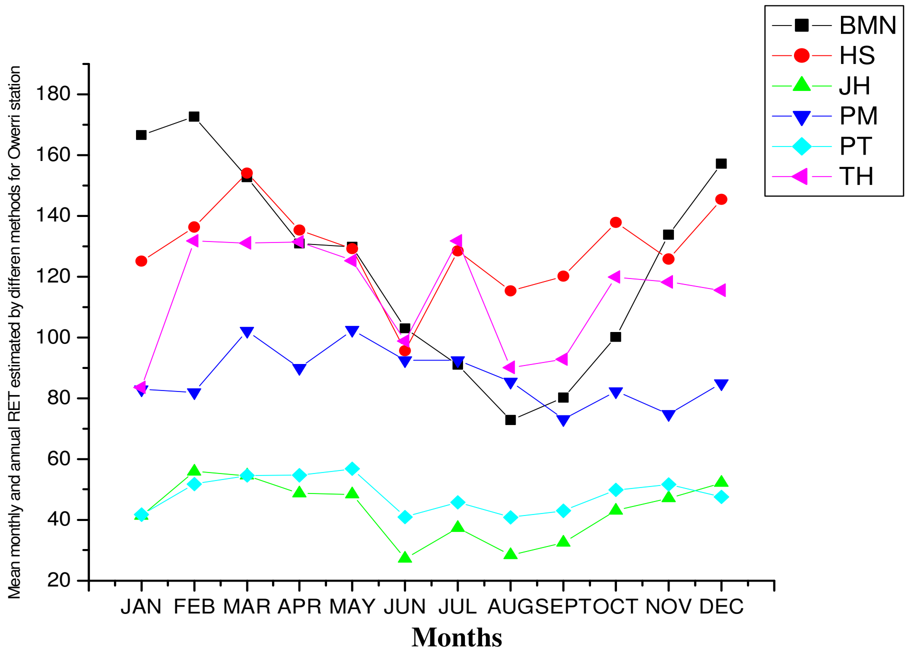

Fig. 1: Graph of mean monthly annual RET estimated by different methods for Owerri station.

1. The mean annual RET estimated by the Penman Modified method as the standard for Owerri was found to be 1045.0 mm.
2. The mean annual RET estimated by the other methods namely Blaney-Morin, Hargreaves-samnai, Jensen-Haise, Priestly-Taylor and Thornthwaites were found to be 1490.7mm, 1548.3mm, 516.7mm, 579.3mm and 1370.7mm for Owerri respectively.
3. From study, the best RET estimate for Owerri station was given by Thornthwaite model.
4. The temperature based models from the RET estimate obtained was highly reliable since it predicted best and also ranked first in all the analysis for the station.
5. Monthly correction factors were developed for Thornthwiate, Blaney-Morin Nigeria and Hargreaves-Samani since they ranked first, second and third in the station. The reason is to get an accurate and reliable ET without sensitive error.
6. The comparison of methods for estimating RET in different stations is very paramount since the accurate estimation of ET, hence, crop water requirement is highly essential for efficient planning, operation and management of irrigation systems.
7. From T- tabulated, 22 degrees at freedom and 0.005 significant level was found to be 2.819 which means that the models that predicted best were significant since T-tabulated is less than T-calculated.

Acknowledgement

The authors would like to acknowledge the assistance of the computer unit of the Federal Meteorological Centre; Oshodi for the data provided which made this work possible.

REFERENCES

Abtew W, 1996. Evapotranspiration measurements and modelling for three wetland systems in South Florida, AWRA Resources Bulletin 32: 465-474.

Duru JO, 1984. Blaney-Marin-Nigeria. Evapotranspiration Model. J Hydrol, 70: 71-83.

Egwuonwu CC, 2012. A comparison of the reliability of six evapotranspiration computing models for Abeokuta in South Western Nigeria. Greener J Phys Sci, 2: 1-6

Egwuonwu CC, 2011. Characterisations of erodibility using soil strength and stress-strain indices for soils in South- Eastern Nigeria. Unpulished PhD Thesis.

Ejieji CJ, 2011. Performance of three empirical reference evapotranspiration models under three sky conditions using two solar radiation estimation methods at Ilorin, Nigeria. Agric Engr Int CIGR J, 13:3.

Jacovides CP and H Kontayinanis, 1995. Statistical procedures for the evaluation of evapotranspiration computing models. Agric Water Manag, 27: 365-371.

Parmele LH and JL McGuiness, 1974. Comparisons of measured and estimated daily potential evapotrans-piration in a humid region. J Hydrol, 22: 239-251.

Pindyck RS and DL Rubinfiled, 1981. Econometric models and economic forecasts. McGraw-Hill Book Co. New York.

Sargent BP, 2002. Water use in Louisiana. Water resources special report No. 15. Louisiana Department of Transportation and Development: Baton Rouge, JA.