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Performance Evaluation of Romanenko's Reference Evapotranspiration Model against the Penman – Montieth in a Mangrove Rain Forest Belt

[1,2]Edebeatu, Chinedu C., [2]Okujagu, Charity U. & [2]Ononugbo, Philomina C.

[1]Department of Physics & Ind. Physics, Madonna University, Elele Campus, Nigeria
[2]Department of Physics, University of Port Harcourt, Port Harcourt, Nigeria
Email: edebeatuc@yahoo.com

ABSTRACT

The performance evaluation of Romanenko's temperature – water vapour empirical reference evapotranspiration model was carried out against the Penman – Monteith model for the period of 2000 – 2003. The result showed that the Romanenko's ETo is a sufficient model to estimate reference evapotranspiration in the garden city which lies within the mangrove rain forest belt of the South South of Nigeria. In this performance evaluation we introduced the used the Allen Table for the Standardization of the Reference Evapotranspiration in the mangrove rain forest belt of Nigeria. The Allen table standard has herethto been neglected table in the cause of analysis, evaluation and performance of evapotranspiration. This result is vital for the analysis and modeling of water management, irrigation scheduling as well hydrological management, urban planning and environmental impact assessment.

Keywords: Romanenko's ETo model, Penman – Monteith Model, Temperature – Water Vapour, Mangrove Belt, Port Harcourt

INTRODUCTION

Evapotranspiration is a combination of two separate processes that involve the removal of water. The loss of liquid water to water vapour from a surface such as water bodies like lake, rivers, streams, ponds, and soil surface as well as plant leaves etc to the atmosphere is termed evaporation. Transpiration is the vapourization of liquid water contained in plant tissue and its removal through the plant tissues to the atmosphere [1]. This combination is termed ***evapo-transpiration*** ET. ET is controlled by factors such as solar radiation, atmospheric water vapour, temperature and wind. Other environmental factors include crop type, crop growth stage, and crop management [1].

Evapotranspiration is a complex quantity to measure and demands sophisticated device to measure [2,3], the physical variables or soil water balance using lysimeters[4].

Different methods have been developed and deployed in a bid to obtain accurate measurement of evapotranspiration in different climatic regimes. To compute evapotranspiration requires complete meteorological and climatological parameters that use the combination equation model of the Penman – Monteith. Unfortunately, weather service stations and these instruments are not readily available mostly in developing countries like Nigeria [2,3]. The challenge is overcome by the use of empirical and semi – empirical equation models developed over the years in the absence of the full Penman – Monteith (PM) model. These empirical models have been tested in various geographical and climatological regions of the world varying from the tropical to the temperate regions [5;2;6-9].

MATERIALS AND METHOD

Materials

Study Location: The mangrove rain forest belt of Port Harcourt is located at latitude 4.75^0N and longitude 7.01^0E in the South South geopolitical zone of Nigeria.

Fig.1: Port Harcourt City and its neighbuoring towns

Method

The most recommended form of determining the agricultural field consumptive water use is the Penman – Monteith equation model by the Food and Agricultural Organization (FAO) tagged FAO – PM 56 repository document. This requires the full meteorological and climatological parameters for its modeling of the evapotranspiration in virtually in every climate. However, the absence of these meteorological and climatological variables in many weather stations across the globe has hindered the use of the model for many countries especially the third world countries [3]. The form of the FAO PM 56 (here referred to as FPM 56) use in this work is the short grass (short crop) and is given as;

$$ET_{oPM56} = \frac{0.408\Delta(R_n - G) + \gamma\left(\frac{900}{T+273}\right) + u_2(e_s - e_a)}{\Delta + \gamma(1 + 0.34u_2)} \quad \text{……………….1}$$

The ROM ETo is a temperature – based empirical model for estimating evapotranspiration in the absence of the PM 56. The form of the Romanenko's ETo model used is this work is written after [10;3] as;

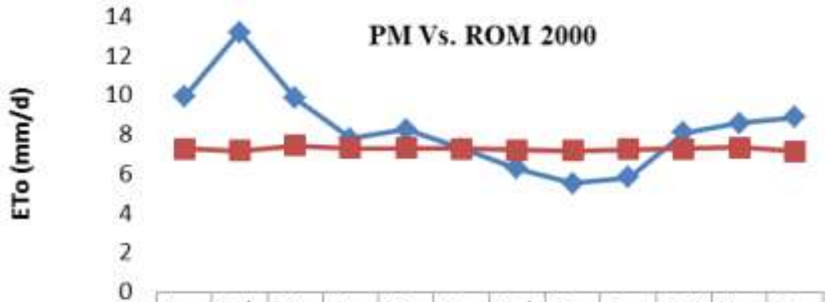
$$ET_{oROM} = 4.5\left[\left(1 + \frac{T_m}{25}\right)^2 - \left(1 - \frac{e_s}{e_a}\right)\right] \quad \text{……………….2}$$

And modified in this work as;

$$ET_{oROM} = 4.5\left[\left(1 + \frac{T_m}{75}\right)^2 - \left(1 - \frac{e_s}{e_a}\right)\right] \quad \text{……………….3}$$

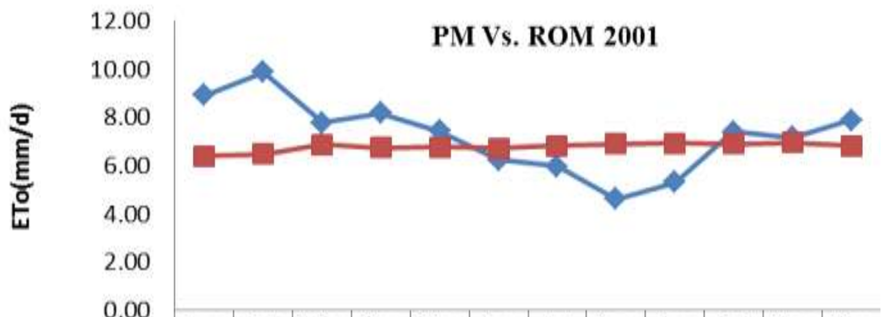
RESULTS AND DISCUSSION

Results



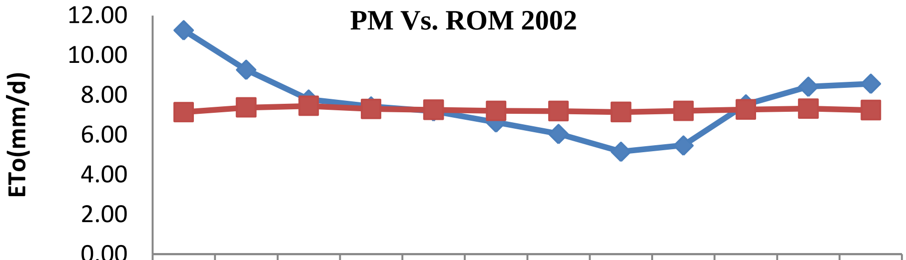
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
PM	9.89	13.2	9.84	7.79	8.25	7.26	6.26	5.5	5.82	8.09	8.57	8.88
RAM	7.28	7.19	7.42	7.3	7.32	7.28	7.21	7.17	7.23	7.26	7.35	7.13

Figure 1: PM & ROM ETo models for 2000



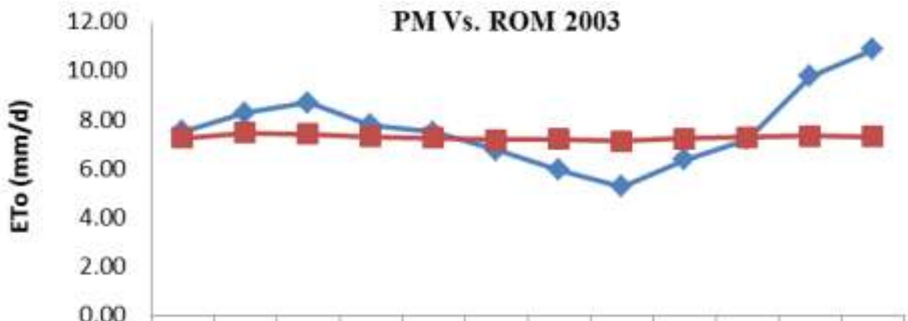
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
PM	8.92	9.88	7.77	8.18	7.45	6.25	5.98	4.61	5.31	7.42	7.17	7.89
RAM	6.40	6.48	6.89	6.75	6.79	6.73	6.83	6.91	6.92	6.92	6.96	6.83

Figure 2: PM & RAM ETo models for 2001



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
PM	11.	9.2	7.7	7.4	7.1	6.6	6.0	5.1	5.4	7.5	8.4	8.5
RAM	7.1	7.3	7.4	7.3	7.2	7.2	7.2	7.1	7.2	7.2	7.3	7.2

Figure 3: PM & RAM ETo models for 2002



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
PM	7.51	8.27	8.68	7.77	7.48	6.75	5.93	5.26	6.35	7.19	9.77	10.8
RAM	7.24	7.45	7.40	7.29	7.24	7.18	7.18	7.13	7.23	7.27	7.34	7.29

Figure 4: PM & RAM ETo models for 2003

DISCUSSION

The annual and seasonal evaluation of the Romanenko's ETo model carried out in Port Harcourt against the Penman – Monteith model showed good estimate of the former's model performance in both the annual and seasonal variations. The four year work was evaluated, analyzed and compared with the Food and Agricultural Organization (FAO) of the Penman – Monteith (FAO-PM56). Figure1, shows the various ETo models for the period of 2000 – 2003 as analyzed, while figure 2, compare the analysis performance of the evaluated model of Romanenko against the Penman – Monteith from 2000 – 2003.

Reference Evapotranspiration Models Evaluated

In the year 2000, the seasonal record of the RAM ETo picked highest at 7.51mm/d whereas the PM 56 stood at 5.19mm/d both in the month of February. The least value of the duo stood at 1.04mm/d and 2.16mm/d in the months of September for RAM and August for PM 56 respectively. The average annual ETo for the RAM is 2.95mm/yr, while the annual ETo sum for this same period stood at 35.48mm/yr. The PM 56 annual average ETo was recorded as 3.26mm/yr, while the annual ETo sum is 39.11mm/yr. the seasonal RMSE for the period stood slightly above zero (0), but less than one (1) ($0 \leq RMSE \leq 1$) which is a very good performance evaluation. The mean annual average of the RMSE was found to be 0.29mm/yr and the annual sum is 3.47mm/yr. The coefficient of determination R^2 for the year 2000 is 0.885 as shown figure 1a.

The seasonal variation of the year 2001 had a maximum ETo of 5.56mm/d in February and 3.89mm/d for the PM 56 also in the same month of February. The minimum ETo for RAM and PM 56 occurred in the month of August at 1.07mm/d and 1.82mm/d apiece. The annual average and sum occurred at 2.85mm/yr and 31.52mm/yr for RAM, and 2.85mm/yr and 34.18mm/yr respectively. The annual average and sum of the RMSE were recorded as 0.18mm/yr and 2.15mm/yr respectively. The seasonal maximum RMSE occurred in the month of January at 0.48mm/d while the minimum occurred in December at0.002mm/d. In otherwords, it lies in the range of ($0 \leq RMSE \leq 1$). R^2 value correlated at 0.8498 as displayed in figure 1b.

The 2002 records of the seasonal ETo maximum for RAM was recorded in the month of January at 6.12mm/d and minimum in the month of August at 1.29mm/d respectively. The maximum for PM 56 occurred also in the month of January at 4.43mm/d, whereas the minimum was found in the month of September at 2.15mm/d. The annual average and sum for the year 2002 was found to stand at 2.72mm/yr and 32.68mm/yr for RAM. Similarly, the PM 56 annual average and sum were at 2.98mm/yr and 35.72mm/yr respectively. The maximum RMSE occurred at 0.48mm/d, while the minimum RMSE recorded a frequency of occurrences at 0.026mm/d in the month of March, April and December respectively. It also lays within the range ($0 \leq RMSE \leq 1$) an indication of

standard statistical evaluation with R^2 at 0.864 in figure 1c.
The seasonal variations for the period of 2003 ETo recorded maximum at 4.08mm/d in February and minimum at 1.15mm/d in the month of September as modeled by the RAM. The seasonal variation modeled by the PM 56 recorded maximum at 4.28mm/d in December and minimum at 2.07mm/d in August. Annual average and sum of both models in the mangrove forest belt for RAM and PM 56were recorded as 2.44mm/yr, 29.23mm/yr and 3.01mm/yr, 3615mm/yr respectively. The seasonal RMSE occurred at 0.49mm/d in the month of November and 0.029mm/d in April as maximum and minimum. The annual average and sum of the RMSE were 0.24mm/yr and 2.85mm/yr. The coefficient of determination for the mangrove swamp recorded least value of R^2 in 2003 at 0.4759 as shown in figure 1b. However, the RMSE lies within the range (0 ≤RMSE ≤1) standard of error estimate evaluation.

CONCLUSION

Accurate estimation of reference evapotranspiration is a san-qua-non for agricultural crop productivity and water management. It is an essential tool in overcoming food security challenges as it improves crop production, water irrigation scheduling and management towards modern agricultural practices other than rainfed agriculture. Understanding the applications of ET is a boost towards economic revolution of a State. The evaluation of the Romanenko's reference evapotranspiration in the mangrove rain forest belt of Nigeria has performed greatly well. It is an indication of modeling water requirement for agricultural activities, crop production and urban water development basin. The adjusted ETo of the Romanenko improved greatly in its performance evaluation, hence a requirement for the modeling of reference evapotranspiration within micro – climates with similar regimes and when compared tom the standard Allen, (1998) table for the analysis, comparison, performance evaluation modeled evapotranspiration water demand of any field.

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