BLANEY-MORIN-NIGERIA (BMN) EVAPOTRANSPIRATION MODEL (A TECHNICAL NOTE)

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1. INTRODUCTION

Duru [1] presented a modified form of the Blaney-Morin potential evapotranspiration equation christened Blaney-Morin- Nigeria (BMN) Evapotranspiration (ET) model for use in Nigeria. In this work, Duru recognize the very wide variability of relative humidity in Nigeria and consequently the very important role this parameter is bound to play in the evapotranspiration process in this geographical region (Nigeria). Thus he (Duru) correctly surmised that any Et model that would reasonably estimate Potential evapotranspiration (PET) in Nigeria must involve humidity term as a crucial parameter.

The BMN model is currently the only Et model specifically developed for the Nigerian condition and, as would be expected, is enjoying wide use in the country. While the basic concept upon which the BMN ET model is based is very sound, certain aspects of the methodology adopted in developing it appear not only inappropriate but also require substantial modification. A brief of the methodology adopted in developing model will reveal the above assertion.

1.1 The BMN ET model and methodology of development

Equation 1 is the original Blaney-Morin equation.

$$PET = p\,\frac{(0.45t+8)(H-R^{m})}{100} \qquad (1)$$

where

PET = Potential evpotranspiration (mm/day).

P = ratio of maximum sunshine hours for the period of interest to the annual maximum

t = temp (^{0}C)

r = Relative humidity (%)

h,m = empirical constants. Since Equ. 1 has two unknowns (the empirical constants) it cannot be solved directly, Duru, therefore, rearranged it in the following form:

$$H = \frac{100PET+p(0.45t+8)R^{m}}{p(0.45t+8)} \qquad (2)$$

The basic methodology adopted in Duru's work was the analysis and evaluation of the right hand side (RHS) of Equ. 2; the basic concept of the analysis and evaluation being the determination of an "m" value that would yield a unique value of "H" using relevant methodological data of the country (Nigeria) for the other parameters or the equation. Consequently, arbitrary values were assigned to m (from m = 1.00 to m = 2.00 at increments of 0.01) and for each m value the numerator and denominator of the RHS of Equ. 2 were tabulated. Ten years of meteorological data from Samaru-Zaria, Nigeria, were used for this analysis giving a total of 200 (number of m values) data sets; each set having 120 data points. Each of these 120 data points consisted of two values, one for the numerator and the other for the denominator of the RHS of Equ. 2.

The tabulated numerator and denominator values for each m value (200 tabulations in all) were plotted to determine the pattern of scatter between (numerator and denominator). The corresponding m-values for the data set that produced the minimum scatter was adopted as the evaluated value of "m" of Equ. 1 while the slope of the straight line obtained from the plot was adopted as the evaluated value of ″H″ in the same equation. In this manner, Duru [1] evaluated the values of "m" and ″H″ as 1.31 and 520 respectively and consequently came up with the BMN ET model given as

$$PET = p\,\frac{(0.45t+8)(520-R^{131})}{100} \qquad (3)$$

Equ. 3 did not predict PET satisfactorily in Samaru Zaria for the months of Nov., Dec., and January because of the effect of the harmattan during these months [1]. To overcome this, the ratio, p in Equ. 3 was replaced by a radiation ratio r_f giving the final form of the BMN ET model as

$$PET = r_f\,\frac{(0.45t+8)(520-R^{131})}{100}$$
(3)

Where r_f is ratio of maximum possible radiation to the annual maximum. Equ. (4) was evaluated by applying it to selected locations in Nigeria which included Samaru- Zaria, Bakura, Kano, Maiduguri, Jos and Benin City.

1.2 Disturbing Aspects of the Methodology adopted in developing the BMN ET Model.

The following aspects of the methodology adopted in developing the model are not only disturbing but they are bound to have important/ critical effect on the form of the developed model.

1. The relevant meteorological data used in developing the model was obtained from Samaru-Zaria only. It will be noted that the model was developed for use throughout Nigeria and possibly the West African sub-region [1].
2. The method of analysis of data pots was not indicated by Duru.
3. The locations used for evaluating the model are not representative of the ecological regions/ zones of the country for which the model was developed.
4. The rational for adopting the m-value used in generating the data set (of numerator and denominator values of the RHS of Equ. 2) that produces minimum scatter and the consequent adoption of the slope of the straight line obtained from that plot as the unique value of H is based on Muskingum approach to analytical method of stream-flow routing. The applicability of this procedure for the determination of m and H of Equ. 2 require clarification.
5. The model developed was not exactly the same model that was evaluated. The model developed involves the ratio of maximum sunshine hours for the period of interest to annual maximum while this parameter was replaced by a radiation ratio r, when the model was evaluated.

2.0 DISCUSSION

The basic concept upon which the BMN ET model is based is the need to incorporate the relative humidity parameter which varies considerably throughout Nigeria [1]. It would therefore be most appropriate to introduce and incorporate this large variability of relative humidity in the data used in developing the model. The use of data from Samaru-Zaria only does not satisfy this crucial requirement. The use of data from Samaru-Zaria only would at best, yield a model appropriate for that zone. This is amply revealed by the almost perfect results obtained when the developed model was evaluated at Samaru-Zaria location when compared to the results obtained from other locations [1].

Usually in the development of a model or relationship involving use of data, a part of the assembled/ accumulated total data representative of all conditions or all aspects of the given condition is used in the development while the other part is used for the evaluation of the developed model or relationship. Thus the ideal approach in the development of the BMN ET model should have been the use of relevant data from locations representative of all ecological zones/ regions of the country. This way the effect of the crucial relative humidity factor would be represented and expressed in the form of the model that finally emerges.

The method of analysis and evaluation of data plots was not indicated by Duru [1]. However, Duru [2] has explained that all analysis and evaluation were carried out manually. This implies evaluating/ calculating 200 x 120 or 24,000 data points of the numerators and denominators of Equ. 2 by hand. Moreover, each of the 200 data sets (each set comprising 120 data points) was manually plotted and the pattern of scatter visually observed and determined [2]. While there is nothing wrong with manual calculation and visual observation, there is definitely ample opportunity for errors in this approach.

Of all the locations/ zones/ regions of the country, only one location, Benin was used in the southern part of the country and this location may be considered to be within the northern section of the southern part of the country. Three of the remaining four locations (Kano, Sarnaru-Zaria and Jos) are confined in the north central section of the country while the last location (Maiduguri) is at the extreme north east of the country. Consequently the model was not evaluated at locations in the extreme southern parts, most of the entire western part and the middle parts of the country. These locations are areas of considerable variability of the crucial parameter (relative humidity) of the model. The results of the model evaluation at Benin City does not inspire much confidence for reasonably acceptable PET predications at locations in the southern parts of the country.

The analytical method of stream-flow routing expresses storage, S in a reach as

$$S = \frac{b}{a}[\chi I^{m/n} + (1-\chi)O^{m/n}] \quad (5)$$

Where a, b, x, m and n are constants and I and 0 are inflow and outflow respectively.

In the Muskingum approach to the analytical method of stream-flow routing, Equ. 5 is replaced by the expression

$$S = K[\chi I + (I - \chi)O] \quad (6)$$

(by assuming m/ n = **1** and b/a = K.

"K" is the storage constant and it is the ratio of storage to discharge and has dimension of time. It is approximately equal to the travel time through the reach and in the absence of better data is sometimes estimated in this way. Where flow data on previous floods are available, the Muskingum method determines the values of K and X in Equ. 6 by plotting S versus X I + (I - X) 0 for various values of X. The best values of X is that which causes the data to plot most nearly as a single-valued curve; a curve which the Muskingum method assumes is a straight line with slope k. This is the principle applied by Duru in determining the m and **H** values of Equ. 2. By re-arranging Equ. 6 in the form

$$K = \frac{S}{\chi I + (1-\chi)O} \quad (7)$$

there is no doubt that it takes the same form as Equ. 2. The term to be determined in Equ. 7 by applying the Muskingum approach is x, a straight linear term while the term to be evaluated by a similar approach in the BMN model is m, an exponential factor in Equ. 2. The question is whether Equ. 2, an equation involving an exponentially biased variable (R) would behave (and consequently have the exponential factor analyzed/ evaluated) in a similar manner as a purely linear equation (Equ. 6 or 7)?

Moreover, there s the need to consider the phenomena governing/

represented by Equ. 2 and 6 (one is evapotranspiration process and the other is a storage-flow process) and decide whether they (phenomena) are similar or operate in similar manner to warrant their analysis in a similar manner. In other words, will the type of relationship represented by Equ. 2 make it possible for any data set of numerator and denominator values of the RHS of the equation when plotted, to approach a single valued curve that can be assumed a straight line as required by the Muskingum method. Linsley et al [3] have pointed out that the Muskingum method assumes that K is constant an assumption that is generally adequate, but cautioned that when the storage-flow relation is nonlinear, an alternative approach must be adopted.

Finally, it will be noted that the ratio of maximum sunshine hours for the period of interest to the annual maximum, p, was used in the model development, but had to be replaced by the radiation factor, r_f for the model evaluation. The more acceptable results obtained for part of the year by using the new parameter, r_f implies that the two interchangeable parameters (p and r_f) yield substantially different model predictions at least for some part of the year. Hence, it will be correct to state that the BMN ET model developed by Duru [1] is considerably different from the model evaluated in the same work.

2.1 Proposed Modified BMN PET Model.

In order to modify the BMN ET model for use in all sections of Nigeria, it is suggested that relevant meteorological data be assembled from locations representative of all zones/ regions of the country. Such locations may include Kano, Samaru-Zaria, Maiduguri, Sokoto, Lagos, Ibadan, Benin, Ilorin, Minna, Jos, Bauchi, Makurdi, Yola, Enugu, Owerri, Port-Harcourt, Lokoja, Calabar, Badeji, Yelwa, Nguru, etc. Half of the data from such locations should be used for the model development while the other half should be used for evaluating the model.

A theoretically based methodology for determining the m and H values of Equ. 2 should be found/ developed and applied in the model development instead of the apparently doubtful Muskingum approach to analytical stream-flow routing that was applied. The radiation factor, r_f which has been shown to be more appropriate than the ratio of maximum possible hours of sunshine to the annual maximum, p, should be used for the model development. In view of the large amount of data involved in the above suggestions, the use of the computer for the required analysis and evaluation is not only desirable but imperative.

In conclusion, it is my considered opinion that based on the soundness of the overall concept of the BMN ET model (which is the need to incorporate the relative humidity term) a modified BMN model that would predict ET most reasonably in all parts of the country could possibly have zonal and probably seasonal m and H values. This opinion is based on the very wide variability of relative humidity at any given location across the country over the seasons of the year.

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