8.5 AGRICULTURAL PLANNING OF FARM OPERATIONS IN THE TROPICAL RAINFOREST AND GUINEA SAVANNA AREA OF NIGERIA

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ABSTRACT.

Agriculture in Nigeria is mostly rain fed; thus, farmers have always been assessing the size of their future harvest in relation to what they have sown and the prevailing rainfall situation. But rainfall alone cannot adequately determine the wetness or dryness of a place because rainfall is the most variable of all climatic elements. It was established that agricultural production is largely determined by climatic conditions rather than by the prevailing rainfall situations (Kumar, 1987).
In this work, sunshine hours, wind speed, vapor pressure and other meteorological parameters for estimating potential evapotranspiration (PET) were collected for the period 1975-1994 from 18 selected meteorological stations distributed over the tropical rainforest and the guinea savanna in Nigeria. Both Penman (1992) and Thornthwaite (1990) methods were used to estimate PET. The PET values were used on the Rainfall-PET model as given by Cocheme and Franquin (1967).
Results showed that; (a) for the temporal pattern, PET estimation by Penman (1992) increases northwards while that of Thornthwaite (1990) decreases northwards showing that overestimation of PET by Penman occurs in areas of high net radiation and temperature while overestimation of PET by Thornthwaite occurs in areas of low net radiation and temperature. (b) The spatial pattern shows that the estimation of PET by Penman formula increases northwards while that of Thornthwaite decreases northwards showing that Penman overestimates PET northwards while Thornthwaite overestimates PET southwards of the study area. Again, the result further showed that the beginning of growing period over Ilorin, Shaki, Ikeja, Abeokuta, Oshogbo, Akure, Enugu and Ikom falls into various dates in April while that over Ibadan, Ijebu-Ode, Benin City, Warri, PortHarcourt and Calabar falls into various dates in March. Finally, the study showed that Penman method of estimating PET is more reliable over Ikeja, Ibadan, Ijebu-Ode and Abeokuta while Thornthwaite is more reliable over the remaining stations except at Oshogbo and Enugu where both methods proved reliable.

1.0 INTRODUCTION:

The combination of evapotranspiration and rainfall is fundamental in the water balance of the environment. Evapotranspiration in the broad field of agro meteorology is probably the most important after photosynthesis. The concept of potential evapotranspiration (PET) according to Thornthwaite (1990) is the evapotranspiration from a large vegetation covered land surface with adequate moisture at all times. He felt that since the moisture supply was not restricted, the PET depends solely on available energy. Penman (1992) defined PET as the evapotranspiration from an actively growing short green vegetation completely shading the ground and never short of moisture availability. Though Penman's definition specifies the important characteristics of reference vegetation, it does not specify the name of vegetation.

Evapotranspiration has had a controlling influence on many 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 conditions and plant physiology. Because of this complexity, the concept of potential evapotranspiration (PET) has been introduced, which no longer depends so critically on soil and plant factors but mostly depend on climatic factors (Thornthwaite 1990; Penman, 1992). Attempts have been made to device techniques by which PET may be estimated (Penman, 1992; Thornthwaite, 1990). Of the methods applied in Nigeria, those of Thornthwaite (1990) and Penman (1992) have been found most popular as confirmed by Gbuyiro (1994), Bello (1995) and Idowu (1999).

Thornthwaite (1990) method is basically an empirical relationship between mean monthly PET and mean monthly temperature, wherein uniform values of wind and humidity have been assumed while Penman (1992) method, which combines energy-budget and aerodynamic approaches considered the additional meteorological parameters of humidity, wind and sunshine which significantly affect the PET.

However, as noted by Olaniran (1984) and Nieuwolt (1977), the process of moisture loss vis-à-vis evaporative demand of the atmosphere vary from place to place even as crop consumptive water use which is a complex function of climatic conditions, stage of crop development and soil water content varies from latitude to latitude and from one micro climatic environment to the other. Therefore it should not be surprising if values of PET derived from different empirical methods of estimation are not necessarily homogeneous (Jagtap and Jones, 1989).

Estimation of PET to obtain an accurate prediction of yield vis-à-vis water use efficiency by crops and its subsequent use on the rainfall-evapotrans-piration model as developed by (Cocheme and Franquin, 1967) is very important in agriculture. Climate change and variability, drought and other climate related natural disasters have direct influence on the quantity and quality of agricultural production and in many cases adversely affect it, especially in developing countries (such as Nigeria and in the south western Nigeria) where technological means are not available to counteract adverse effects of varying environmental conditions. Hence, appropriate schedule of farm operations by the use of the PET-rainfall model will help the farmers in general and those in southwestern Nigeria in particular to take preventive measures where feasible, to reduce losses and to arrange external assistance in a speedy and efficient manner in order to ensure sustainable agricultural planning.

The paper compared Penman and Thornthwaite methods of determining PET and then assessed their reliability and used both on the rainfall PET model to schedule appropriate farm planning for basic food crops such as Cassava, Maize and Melon with about 243-250 days of growing period over southwestern Nigeria.

2.0 DATA COLLECTION, DATA ANALYSIS, RESEARCH METHODOLOGY

2.1 *Study area*

The study area lies between latitudes 4°15'N and 8°55'N and longitudes 3°20'E and 10°45'E. The area comprises tropical rainforest and guinea savannah whose vegetation is made up of lowland forest, which is woodland forming the upper storey while short shrubs and shade tolerant herbs make the lower storey (or under-storey). There is also a coastal swamp around Ikeja, Warri and Calabar.

2.2 *Data collection*

Meteorological data for the period 1975-1994 were collected from 18 meteorological stations distributed all over the study area. The parameters obtained were mean monthly values of air temperature including maximum and minimum temperature, sunshine hours, wind speed, vapor pressure and rainfall. The meteorological instruments used to measure the above parameters were: dry bulb thermometer, Campbell stokes sunshine recorder, Anemometer, Humidity slide rule and Rainguage respectively. The net radiation (Rn), possible sunshine duration (N), rate of change with temperature of saturation vapor pressure (Δ), Psychometric constant (λ) and adjusted factor for the effect of day and night weather conditions (c) were all obtained from FAO radiation meteorological table.

2.3 *Data Processing and Analysis*

The average of each parameter was obtained for each station. The formulae of Revised Penman (1992) and Revised Thornthwaite (1990) were then used to determine the mean potential evapotranspiration for each month and for all the stations.

2.3.1 *Penman equation*:

$$PET=c\,[\Delta/(\Delta+\lambda).\ Rn+ \lambda/(\Delta+\lambda).\ f(u) \times (ea-ed)]$$

FAO, Samaru (1992).

Where,
PET=Potential evapotranspiration for a given period in mm.
Δ = the rate of change of saturation vapor pressure with temperature.
λ = psychometric constant.
Rn = net radiation in equivalent evaporation in mm/day.
f(u) = wind related function.
(ea-ed) = difference between the saturation vapor pressure at mean air temperature and mean actual vapor pressure of the air, both in mbar.
c = adjusted factor to compensate for the effect of day and night weather conditions.

2.3.2 *Thornthwaite Equation*

The equation is given as:

$$PET=16Y[(10Ta)^{m}/(HI)]$$

FAO, Samaru (1992).

$$HI = \sum_{i=1}^{12} (Ta/5)^{1.514}$$

$$m=6.7\times10^{-7}\, I^3-7.7\times10^{-5}I^2+1.8\times10^{-2}I+0.49$$

$$Y= N/12$$

Where
Y= the monthly adjustment factor related to hours of daylight.
N= Maximum possible sunshine hours
Ta= Monthly mean temperature in ^{0}C
HI= Heat Index for the year.

2.3.3. *Rainfall PET model*

This method shows the relationship between rainfall and evapotranspiration, which defines the characteristics of the growing season. This approach takes into consideration the processes of moisture transfer in plant environment. The mean monthly rainfall amount obtained for each station is plotted against each month. The mean monthly PET values estimated by both methods were therefore superimposed on the plots of 0.5PET and 0.1PET to determine the appropriate dates for farming operations.
The period when rainfall lies between 0.1PET and 0.5PET is the preparatory period during which land preparation takes place. The intermediate period occurs when rainfall is between 0.5PET and 1PET during which sowing takes place. Where rainfall curve crosses the PET curve at 1PET the humid period starts. The humid period ends where rainfall curve crosses again the PET curve at 1PET. The following period, at where rainfall crosses 0.5PET is a second intermediate period. The two intermediate periods and the humid period constitute the moist periods. The intermediate periods take account of the fact that crop water use at the start and finish of the season is generally much less than potential evapotranspiration. The point where 0.5PET meet the rainfall curve is the beginning and end of the growing periods respectively.

3.0 *Methodology*

The values of 0.5PET and 0.1PET were calculated and used in the PET-rainfall model to prepare an appropriate planning of farm activities in the study region.
The temporal trends of PET values from both methods were examined by plotting the mean monthly values of the calculated PET against each month on the rainfall PET model (Table 1). PET values from both methods over the growing periods were plotted on the map of the study region and isolines were drawn. (Figs 1 and 2).

To schedule the preparation of the farmland, the planting/sowing of the seed and harvesting of the crop operations, the rainfall-PET model by Cocheme and Franquin, (1967) explained above was used. In the study, the reliability of Penman and/or Thornthwaite methods for use in the PET-rainfall model is paramount. Walter's method of determining the onset and cessation of the rains was used as normal (Bello, 1995) and the corresponding deviations from it as given by both Penman and Thornthwaite methods were used to determine the most reliable dates for the various agricultural planning in the area (Tables1 and 2).
The equation taken from Walters (1967) is as stated below:

Onset / Cessation =

$$\frac{\text{days in the month(DM) x (51-accumulated total rainfall of previous month (DMP)}}{\text{Total rainfall for the month(TM)}}$$

$$= \frac{DM \times (51 - DMP)}{TM}$$

The dates of start and end of the growing season were determined for each station by this method (Walter, 1967). This was used as a reference to the most reliable date given by the use of Penman and/or Thornthwaite PET values estimated on the rainfall –PET model. The date with largest deviation from Walter's was considered least reliable for the station. The date with the smallest deviation was considered most reliable. This will in a sense, determine the method of estimating PET (Penman or Thornthwaite) that will be most preferable in each of the station from which the appropriate dates of the farming operations will therefore be scheduled.

4.0 *Results and Discussion*

The results for the temporal pattern of potential evapotranspiration in the study region showed that the estimation of PET by Penman formula increases northwards while that of Thornthwaite decreases northwards. This indicated that overestimation of PET by Penman occurs in areas of high net radiation and temperature. The overestimation of PET by Thornthwaite occurs in areas of low net radiation and temperature. The results from the spatial pattern shows that Penman PET increases northwards while Thornthwaite PET decreases northwards. This showed that Penman overestimates PET northwards while Thornthwaite over estimates PET southwards. However, there exists zone of transition over Oshogbo and Enugu as shown by Penman's distribution while a zone of transition exists over Shaki as shown by Thornthwaite distribution. These variations according to Jackson (1977) may be due to difference in altitude and latitude of locations, cloud cover, wind speed and humidity. The results for the dates of beginning and end of growing season in the study region extracted from the rainfall-PET model by the use of each of the methods of estimating PET and also from the Walter computation were presented in Table 1.
The deviation of dates by Penman and Thornthwaite methods from Walter's method is also shown. Negative on the values show the days after and positive shows the days before. Hence, table 3 was prepared after the decision on the most reliable method to be used in each of the station for a suitable schedule of farm operations was made. On the table (3), the approach used to schedule the farm operations is stated. The dates of

onset and cessation presented is clear and show that stations up North: Ilorin, Shaki, Enugu and Ogoja clearly agreed on the use of Thornthwaite in the schedule of farm operations because of their relatively high temperature which amounts to overestimation in the use of Penman, while stations in the down south: Ikeja, Ibadan, IjebuOde, Abeokuta except Akure, Benin-City, Warri, Asaba, PortHarcourt and Calabar agreed on the use of Penman PET in the schedule of farm operations due to overestimation by Thornthwaite over there. Akure, Benin city, PortHarcourt, Calabar and Warri, which behaves differently, may be due to specific changes in their environmental and edaphic factors. Warri's soil is swampy, which may mean that it holds a lot of water and consequently Penman overestimates, hence Thornthwaite is preferred.

The particular case of Oshogbo and Enugu, which prefer both methods, may be due to significant prevalent atmospheric and edaphic conditions that are suitable for the use of the two methods. Also Osogbo is known as a major zone of transition in the study region.

Thus, the schedule of farm operations in the study region as suggested by this paper is given in table 3.

5.0 *Conclusion and recommendations*

From this paper, it was therefore established that Rainfall-PET model produced a more reliable dates for various agricultural planning of farm operations in the tropical rainforest and guinea savanna area of Nigeria.

It was also established that overestimation of PET by Penman occurs in areas of high net radiation and temperature while overestimation of PET by Thornthwaite occurs in areas of low net radiation and temperature. More so, the beginning of growing period over Ilorin, Shaki, Ikeja, Abeokuta, Oshogbo, Akure, Enugu and Ikom falls into various dates in April while that over Ibadan, Ijebu Ode, Benin city, Warri, PortHarcourt and Calabar falls into various dates in March. (Table 3)

Effective use of the paper will help in adequate agricultural farm planning for food crops such as cassava, maize and melon and as such reduce crop failure. It will help government and other private bodies to take preventive measures where feasible to reduce losses and arrange external assistance in a speedy and efficient manner in order to ensure food security.

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Table1: Dates of beginning and end of growing season determined by Walter (1967), Thornthwaite (1990) and Penman (1992) methods on Rainfall-PET model with the number of days of deviation from Walter by both Penman and Thornthwaite methods.

Stations	Walter (1967) Method		Thornthwaite method		Penman method		Number of days of Deviation			
							Thornthwaite		Penman	
	Beginning	End	Beginning	End	Begin-ning	End	Begin-ning	End	Begin-ning	End
Ilorin	12th March	24th Oct.	16th April	17th Nov	24th April	16th Nov	-35	-24	-43	-23
Shaki	18th March	19th Oct	25th April	12th Nov	30th April	7th Nov	-38	-24	-43	-19
Ikeja	23rd Feb	23rd Nov	9th April	25th Nov	3rd April	7thDec	-45	-2	-39	-14
Ibadan	5th March	29th Oct	28th March	21st Nov	27th March	23rd Nov	-23	-23	-22	-26
Ijebu ode	5th March	7th Nov	3rd April	25th Nov	31st March	25th Nov	-29	-18	-26	-18
Abeokuta	6th March	26th Oct	19th April	12th Nov	3rd April	17th Nov	-44	-17	-28	-22
Oshogbo	6th March	30th Oct	7th April	24th Nov	7th April	24th Nov	-32	-25	-32	-25
Benin-City	18th March	22nd Nov	22nd March	5th Dec	9th March	7th Dec	-4	-13	+9	-15
Akure	28th Feb	30th Oct	4th April	19th Nov	6th April	19th Nov	-35	-20	-37	-20
Warri	19th March	24th Nov	12th March	13th Dec	5th March	18th Dec	+7	-19	+14	-24
Enugu	3rd March	16th Nov.	6th April	20th Nov	20th April	16th Nov	-40	-20	-43	-19
Ogoja	2nd March	21st Nov.	29th March	16th Nov	16th April	13h Nov	-36	-24	-41	-22
Ikom	1st March	26th Nov	16th April	16th Nov	15th April	12th Nov.	-30	-6	-36	-7
Owerri	28th Feb.	29th Nov.	12th March	30th Nov	12th April	30th Nov	-29	-16	-29	-16
Asaba	28th Feb.	27th Nov	11th March	28th Nov	2nd April	1st Dec	-8	-20	-24	-11
Calabar	20th Feb	12th Dec	26th Feb	2nd Dec	2nd March	2nd Dec.,	+2	-16	-10	-15
Port Harcourt	20th Feb	12th Dec	26th Feb	8th Dec	10th March	9th Dec	+3	-17	+4	-17
Eket	18th Feb	14th Dec	20th Feb	9th Dec	8th March	19th Dec	+6	-19	-6	-20

Note: Negative (-) = Days after   Positive (+)= Days before

Table 2: The length of growing seasons, the total PET values and the mean PET values for the growing seasons from both Penman and Thornthwaite methods used on the rainfall-PET model.

	Thornthwaite Method			Penman method		
Stations	Length of growing season	Total PET value (mm)	Mean PET value (mm)	Length of growing season	Total PET value (mm)	Mean PET value (mm)
ILORIN	April-Nov	943.7	118.0	April-Nov	1110.6	139.0
SHAKI	April-Nov	997.0	125.0	April-Nov	1205.1	157.0
IKEJA	April-Nov	1068.8	134.0	April-Dec	1094.1	122.0
IBADAN	March-Nov	1131.4	126.0	March-Nov	1187.6	132.0
IJEBU-ODE	April-Nov	1023.9	128.0	April-Nov	1105.1	123.0
ABEOKUTA	April-Nov	1116.5	140.0	April-Nov	907.9	114.0
OSHOGBO	April-Nov	928.3	116.0	April-Nov	931.3	116.0
BENINCITY	March-Dec	1159.1	116.0	March-Dec	1087.3	109.0
AKURE	April-Nov	944.8	118.0	April-Nov	972.7	122.0
WARRI	March-Dec	1317.3	132.0	March-Dec	1108.2	111.0
ENUGU	April-Nov	956.2	116.0	April-Nov	1021.2	126.0
OGOJA	April-Nov	999.2	124.0	April-Nov	1012.1	112.0
IKOM	April-Nov	1016.2	123.0	April-Nov	1012.6	111.0
OWERRI	March-Dec	1216.3	123.0	March-Dec	1121.2	112.0
ASABA	March-Dec	1226.2	122.0	March-Dec	1212.1	117.0
CALABAR	March-Dec	1320.3	133.0	March-Dec	1311.3	110.0
PORTHAT	March-Dec	1321.6	134.0	March-Dec	1296.2	106.0
EKET	March-Dec	1326.2	135.0	March-Dec	1301.1	100.0

Table 3: Schedule of farm operations at the stations in the study region as suggested by this study. (T=Thornthwaite; P=Penman)

Station	Preparatory period	Beginning of growing period	1st intermediate period	Humid period	2nd intermediate period	End of growing period	Approach used
Ilorin	19th Feb. to 16th April	16th April	16th April to 26th May	26th May to 31st Oct	31st Oct to 17th Nov	17th Nov	T
Shaki	6th March to 25th April	25th April	25th April to 13th June	13th June to 25th Oct	25th Oct to 17th Nov	17th Nov	T
Ikeja	7th Dec (of last yr.) to 3rd April	3rd April	3rd April to 7th May	7th May to 22nd Oct	22nd Oct to 7th Dec	7th Dec	P
Ibadan	12th Feb to 28th March	28th March	28th March to 6th June	6th June to 11th Nov	11th Nov to 23rd Nov	23rd Nov	P
Ijebu Ode	3rd Feb to 31st March	31st March	31st March to 30th April	30th April to 18th Nov	18th Nov to 25th Nov	25th Nov	P
Abeokuta	8th Feb to 3rd April	3rd April	3rd April to 17th May	17th May to 28th Oct	28th Oct to 17th Nov	17th Nov	P
Oshogbo	11th Feb to 7th April	7th April	7th April to 16th May	16th May to 17th Nov	17th Nov to 24th Nov	24th Nov	P/T
Benin-city	1st Feb to 22nd March	22nd March	22nd March to 1st May	1st May to 23rd Nov	23rd Nov to 5th Dec	5th Dec	T
Akure	11th Feb to 4th April	4th April	4th April to 18th May	18th May to 8th Nov	8th Nov to 19th Nov	19th Nov	T
Warri	13thDec (of last yr.) to 12th March	12th March	12th March to 17th April	17th April to 28th Nov	28th Nov to 13th Dec	13th Dec	T
Enugu	20th Feb. to 12th April	12th April	12th April to 30th May	30th May to 20th Oct	20th Oct to 11th Nov	11th Nov	P/T
Ogoja	26th Feb to 8th April	8th April	8th April to 24th May	24th May to 16th Nov	16th Nov to 30th Nov	30th Nov	T
Ikom	20th Feb to 7th April	7th April	7th April to 25th May	25th May to 18th Nov	18th Nov to 28th Nov	28th Nov	P
Owerri	2nd Feb to 30th March	30th March	30th March to 8th May	8th May to 20th Nov	20th Nov to 29th Nov	29th Nov	P
Asaba	5th Feb to 1st March	1st March	1st March to 10th April	10th April to 28th Nov	28th Nov to 6th Dec	6th Dec	P
Calabar	31st Dec (of last yr.) to 26th Feb	26th Feb	26th Feb to 15th March	15th March to 1st Dec	1stth Dec to 12th Dec	12th Nov	T
PHC	30th Dec (of last yr.) to 28th Feb	28th Feb	28th Feb to 17th March	17th March to 1st Dec	1st Dec to 13th Dec	13th Dec	T
Eket	29th Dec (of last yr.) to 28th Feb	28th Feb	28th Feb to 18th March	18th March to 1st Dec	1st Dec to 14th Dec	14th Dec	T

FIG. 1 ISOLINES OF THE MEAN PET VALUES (USING THORNTWAITE METHOD) OVER THE GROWING PERIODS (MM)

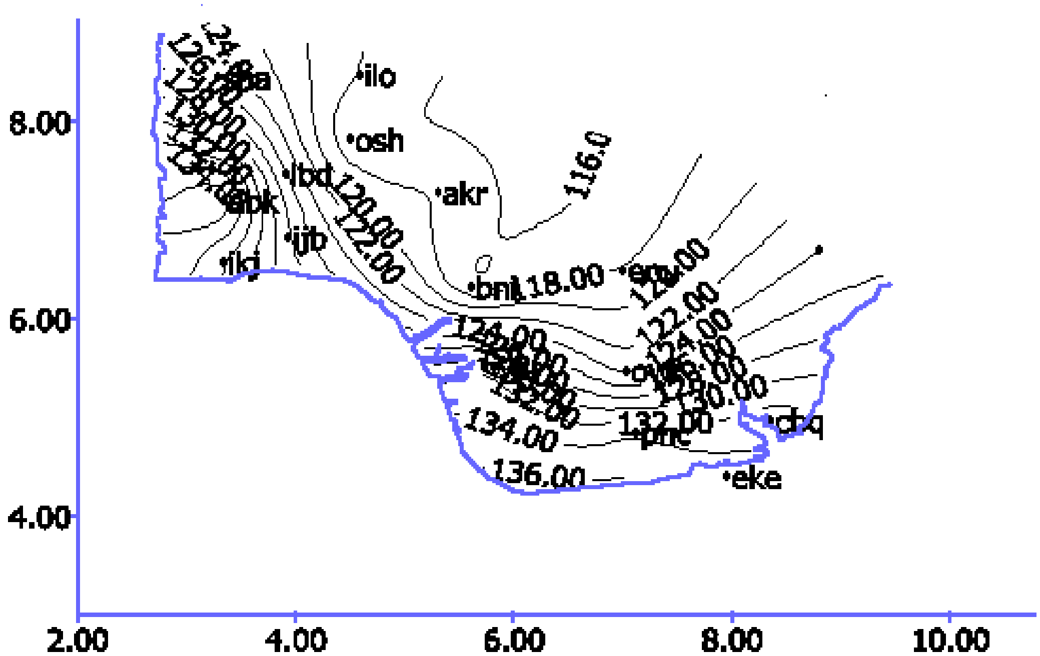

FIG. 2: ISOLINES OF THE MEAN PET VALUES (USING PENMAN METHOD) OVER THE GROWING PERIODS (MM)