ISSN 1118-0579

GLOBAL JOURNAL OF PURE AND APPLIED SCIENCES

Volume 5, No. 4,

September 1999

GLOBAL JOURNAL OF PURE AND APPLIED SCIENCES VOL.5 NO.4, SEPTEMBER, 1999
 ISSN 1118 - 0579

RAINFALL DISTRIBUTION EFFICIENCY AND MAIZE GROWTH IN SOUTHWESTERN NIGERIA

EKANEM EKANEM

(Received 28August, 1997; Revision accepted 6 October 1998)

ABSTRACT

Water is the major constituent of the physiologically active plant tissue. For the tropics where agriculture is still largely rain-fed, optimum crop yield can be achieved if water supply through rainfall well matches the crop water requirement during the different stages of crop growth. In this study the aim is to evaluate the efficiency of rainfall distribution for various phenological growth stage of the maize crop. The efficiency was examined in terms of rainfall – maize 'water consumptive use' ratio. The rainfall distribution efficiency rating scheme was then developed. The results showed that rainfall supply well matches the water requirements of early maize during all stages of growth except in the humid and moist sub-humid climates where water supply was excessive during the grain-filling stage. Supply situation was also found to be excessive for late maize during all stages of growth in the humid climates but inadequate during the flowering and grain-filling periods in sub-humid and semi-arid areas. On the other hand, rainfall distribution was found to well match water-requirement of late maize during all stages of growth in the moist sub-humid climates. On the basis of the result, some cultural practices, changes in the calendar of maize farming and variety were recommended.

KEY WORDS: RAINFALL, EFFICIENCY, MAIZE GROWTH, CONSUMPTIVE USE

INTRODUCTION

Water is an important factor that affects both the growth and yield of crops. Almost every process occurring in plants is affected by water (Jackson , 1977). Water is a major constituent of the physiological active plant tissue (William and Joseph, 1970). It is needed in the supply of carbon dioxide (CO_2) in solution to plant cells for photosynthesis and respiration, in the transport of raw materials manufactured and products within the plant and also for the maintenance of rigidity (fungidity) of plant structure (More, 1969). The dominance of water in tropical agriculture in particular is as a result of the seasonality of distribution and the high year- to – year variability exhibited by rainfall in the area.

Moisture condition expressed as total rainfall, in terms of rainfall during the growing season, or in terms of seasonality of rainfall distribution, is a major and significant factor of the environment that has great influence on the growth of crops. Various crops require varying degrees of moisture for optimum growth. For most crops excessive moisture in the soil or significant deficit could seriously affect the biological processes in the plant.

However, Critchfield (1974) has noted that the adverse effect of drought on plant growth and yield in the tropics far outweighs the of excess water supply. This is because when the available soil moisture is not sufficient to meet the evaporative demand of the atmosphere under drought conditions plant desiccation, wilting and finally crop failure usually result. This is because the soil moisture level affects the various chemical and biological processes, including the amount of oxygen (O_2) in the plant and this has implications for the formation of compounds that are toxic to plant roots. For northern Nigeria kowal and Kassam (1973a) reported a significant reduction in groundnut yield caused by water shortage.

AIMS AND SCOPE OF PRESENT STUDY

In the light of the discussions presented above the aim of this study is to evaluate the efficiency of rainfall distribution for effective germination, vegetation growth, flowering and grain-filling of the early and late varieties of maize in southwestern Nigeria. This is done by matching the water requirements of both maize varieties with water supply through rainfall during the different phenological period of growth namely the vegetative growing, flowering and grain-filling periods. The implications of the results obtained will also be examined for cultural practices and planning of the agriculture calendar for maize growth.

EKANEM EKANEM, Department of Geography & Regional Planning, University of Uyo, Uyo, Nigeria.

METHODS OF STUDY

The main objective of this study is to evaluate the efficiency of rainfall distribution for maize growth in southwestern Nigeria during the different phenological periods. This efficiency is examined in terms of rainfall maize water consumption use ratio, which is hereafter referred to as rainfall distribution efficiency index (RDE).

To match rainfall supply with the crop consumption use of water therefore requires the determination of maize consumption use of water.

According to Hensen et al (1979) and Olaniran (1988) the evapotranspiration from a crop is the same as the consumptive use of water by that crop and it applies to the water requirement of that crop. If direct measurements are not available estimates could be made using an equation of the form.

$$U = K_{co}E_{tp} \quad (1)$$

U = consumptive use of water by the crop

K_{co} = crop coefficient, and

E_{tp} = evapotranspiration from the crop surface.

Porter (1976) has devised a formular for computing crop coefficient in term of the ratio E_t/E_o, where E_t represents the actual evapotranspiration from the crop surface determined according to the method of Penman (1948). Following Porter (1976) therefore equation (1) now takes the form

$$U = E_t / E_o \times E_o \quad \text{...........} (2)$$

For this study, values of E_t / E_o ratio were taken from the ratio are given in table 1. E_o values were then estimated using the method of Panman (1948).

The consumption use of water by maize was computed in this study for both the totals growing season and each phenological period. For the local maize cultivator on which this study is based, the length of the growing season is 112 days whilst the vegetative growing season occupies the first 56 days from the planting date, the flowering period the next 28 days and grain-filling the last 28 days (Olaniran and Babatolu, 1987).

To determine the period of the year occupied by the different phenological phases at each location, the start of the growing season for that location must first be ascertained.

In this study the planting date was determined according to the method of Benoit (1977). According to Benoit, the planting date can be taken as the date when the accumulated difference between rainfall and half of the potential evapotranspiration rate exceeds zero and remains so for the rest of the growing season provided a dry spell of five or more days does not occur in the week after this date.

In mathematical terms Benoit's formulae can be written as the date when.

$$\Sigma(P - 0.5PE) > 0$$

where P = Precipitation, and

PE = Potential evapotranspiration.

Benoit's method of determining the start of the growing season was selected in this study because it gives a good insight into crop-water relations and it is applicable with daily data (Olaniran, 1983).

The rainfall distribution efficiency index (RDE) was taken in this study as the ratio P/U where P represents precipitation (rainfall in our case) and U the consumptive use of water by maize as defined above. A rainfall distribution efficiency rating scale was then devised as follows:

(i) Inadequate: if the RDE value lies between 0 and 0.8,

(ii) Adequate: if the RDE value lies between 0.8 and 1.20, and

(iii) Excessive: if the RDE value exceeds 1.20.

Finally, it needs to be mentioned that all the computations referred to in this section have been based on data collected for the period 1991 - 1980 for all the stations (17) shown in Figure 1. Before discussing how rainfall matches the water requirements of two varieties of maize in southwestern Nigeria, information is first presented on some components of the agroclimate of the study area.

THE STUDY AREA.

This study relates to southwestern Nigeria (Fig. 1.) Southwestern Nigeria is the area bounded by river Niger to the north and east (excluding that portion North of River Teshi), to the west by the republic of Benin and to the South by the Atlantic Ocean). The study area lies between latitude 4° and 10° N, and between longitude 3° and 7°E. The study area covers about 10 out 36 states (Fig. 1)

According to Koppens climatic classification scheme (Koppen, 1918) two climatic types -the tropical wet climate (Af) and the tropical wet and dry climate (Aw) – can be recognized within the study area (Fig .2a)

However, using the thornthwaite's climatic classification scheme (Thornthwaite, 1948), the

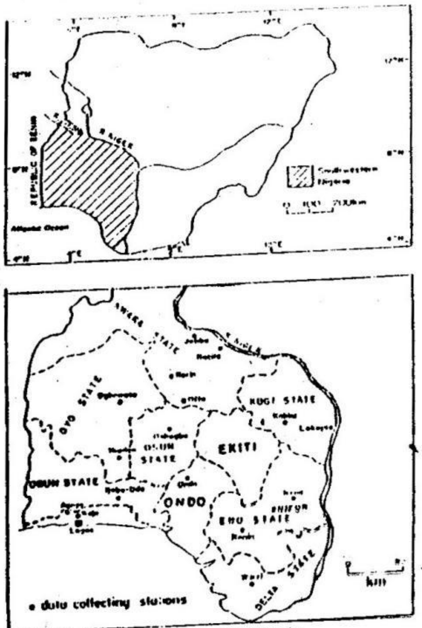

Fig.1. Top: Nigeria showing Southwestern Nigeria.
Bottom: The study area showing division into states and location of data collection stations.

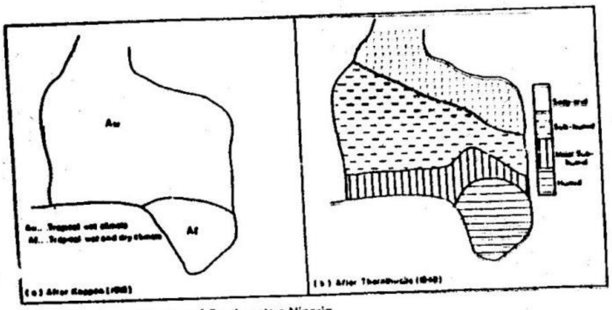

Fig 2: Climate classification of Southwestern Nigeria.

area divides into four climatic zones (Fig 2b). This are humid climatic zone in the southeastern sector, the moist sub-humid climatic zone which occupies a narrow coastal belt, the sub-humid climatic area which occupies the largest part of the study area and the semi-arid climatic zone which occupies the extreme northern part of the study area (Fig 2b). Figure 2b therefore gives an indication of moisture supply decrease in south- north direction of the study area.

Thorhthwiate's climatic classification scheme is based on the water balance concept thereby making it suitable for studies on agoclimate especially in tropics. For this reason, this scheme is preferred in this study.

RESULTS AND DISCUSSION

Rainfall distribution during the growing season of both maize varieties (Fig. 3a, 3b) generally

Rainfall distribution over the study area shows a pattern of west- east increase over the south part only during the vegetative growing period of late maize (Fig 3b). The highest amount of rainfall in each area is received during the vegetative period of both maize varieties. This is due in parts to the different length of time occupied by the different phases of growth (56 days for the vegetative period compared with 28 days of each of the flowering and grain filling) and also in part due to the time of the year occupied by each phase. Thus, on a comparative basis for most areas, more rainfall is received during the vegetative phase of the late

follows the south- north pattern noted for arrangement of the climatic types in Figure 2b.

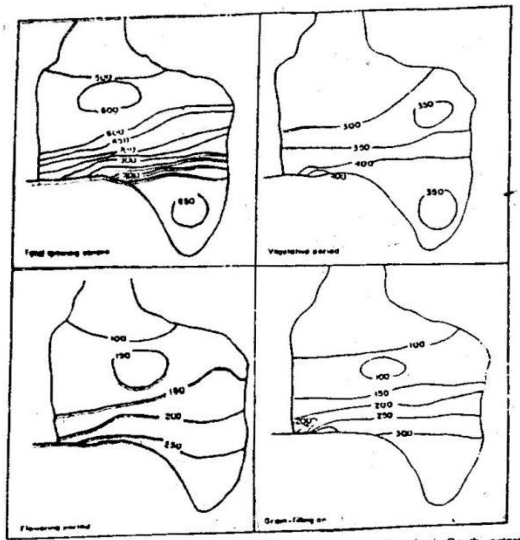

Fig. 3a. Mean rainfall distribution during the growing season of early maize in Southwestern Nigeria. (mm)

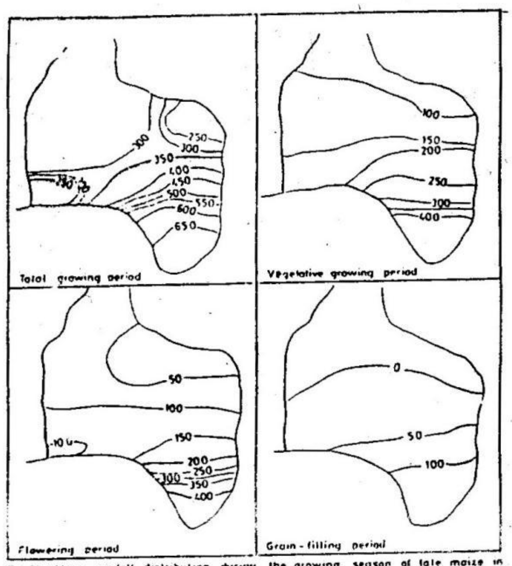

Fig. 3b Mean rainfall distribution during the growing season of late maize in Southwestern Nigeria. (mm)

maize than during the vegetative phase of early maize because the former coincides with the peak of rainfall but the latter with the onset of rainfall in the study area.

As should be expected, the lowest rainfall amount in the study area is received during the late maize grain – filling period, which generally coincides with the time of retreat of rainfall (Fig.3b).

Information on the average time of planting of early and late maize varieties under rain fed agriculture in the study area is given in Fig 4.

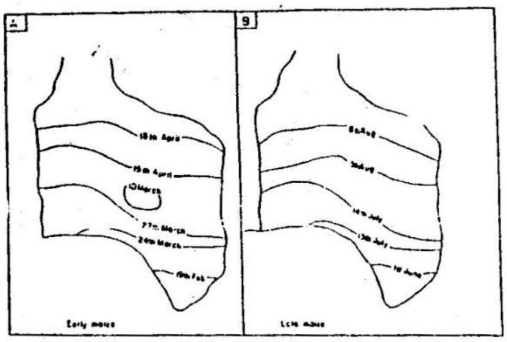

Fig 4: Mean start of growing season for early and late maize in Southwestern Nigeria

Thus, whereas planting of early maize can begin by the end of the third week in February in the extreme southern part of humid climate, this cannot take place in the semi-arid part until about the end of the third week in April (Fig. 4a). There is therefore a difference of about 2 months in the start of early maize planting between the extremely humid and extremely arid parts of the study area. A difference of an almost equal length of time is also maintained in the time of planting of late maize in the study area (Fig. 4b).

RAINFALL DISTRUBUTION EFFICIENCY FOR MAIZE GROWTH

Early Maize

The efficiency of rainfall distribution is important at all stages of growth and during the total growing season of crops. The distribution efficiency of the rainfall for the growth of early maize in southwestern Nigeria as indicated by the RDE is shown in Figure 5.

Taken together moisture supply is adequate during the total growing season of early maize in all the climatic zones of the study area (Fig. 5a). During the vegetative growing period of early maize (Fig. 5b), all the climatic zones in the area can also be said to receive adequate rainfall supply accept in the humid climatic zone where this can be said to be marginally excessive. For example the rainfall efficiency is about 1.5 in the humid zone but between 1.0 – 1.5 in the moist sub-humid, the sub-humid and the semi-arid zones of the study area. The rainfall distribution efficiency situation described for the vegetative period of early maize above also persists during the flowering period over the study area (Fig. 5c).

Both the humid and the moist sub-humid zones experience excessive rainfall supply for early maize during the grain-filling period with the excessive supply being more pronounced in the former than in the latter (Fig. 5d). Thus, whilst

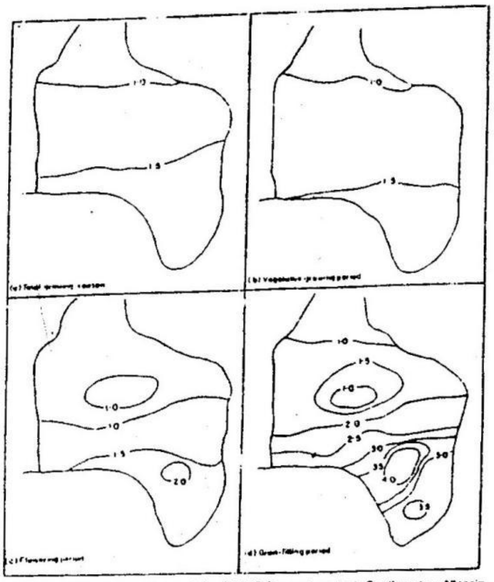

Fig.5 Rainfall distribution efficiency index (R.D.E.) for early maize in Southwestern Nigeria.

the RDE value during this period over humid zone ranges between 3.0 and 4.0 for the moist sub humid climate it varies between 2.0 and 3.0. On the other hand, water supply for rain – fed early maize during the grain- filling period in the sub –humid and semi - arid areas of the study area can be described as just adequate (Fig.5d)

The results presented in figure 5 have shown the benefits of analyzing water supply for both the totals growing seasons as well the phenological periods of crops' growth. Thus, while rainfall supply is shown to be about adequate for the total growing season of early maize in southwestern Nigeria, analysis on the phenological time scale shows the supply to be excessive during the grain-filling stage in the humid and moist sub-humid climatic zones of the area. Excess rainfall supply about this period can cause problem of moulding for the maize grains. Further reference is made to this below.

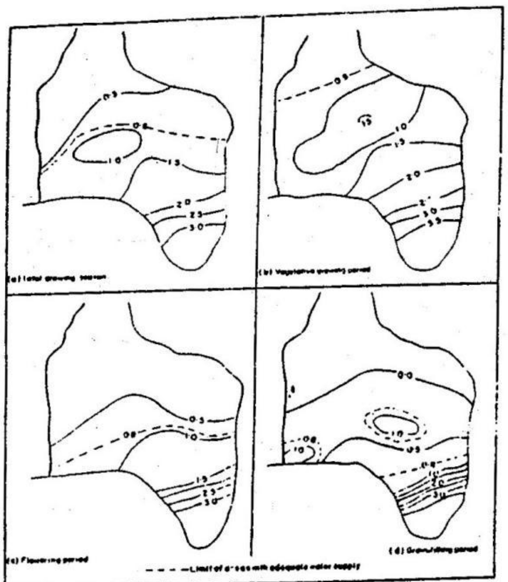

Fig.6: Rainfall distribution efficiency index (R.D.E.) for late maize in Southwestern Nigeria.

Figure 6 shows an extreme situation of rainfall supply for the total growing season of late maize

TABLE 1: E_t / E_o Ratio Used During Different Phenological Periods

PHENOLOGICAL PERIOD	E_t / E_o
Vegetative Growing Period	0.86
Flowering Period	1.04
Grain-Filling	0.62
Mean	0.84

Source: Kowal and Kassam (1973b)

in southwestern Nigeria. Thus, whilst the northern half of the sub-humid climate and the whole of the semi-arid area experience inadequate rainfall during the total growing season of late maize (RDE 0.8) virtually the whole of the humid climate experiences excessive water supply during the same period over study area as exemplified by the RDE value of 2.0 - 3.0 over this zone. In general therefore. rainfall distribution well matches the moisture requirement of late maize only in the moist sub-humid and in the southern part of the sub-humid climates of the study area when the total growing season is used as the time scale of analysis (Fig. 6a).

During the vegetative growing period of late maize in southwestern Nigeria, rainfall supply is marginally excessive in the eastern sector of the moist sub-humid climate (RDE value vary from 1.5 - 2.0 here) and highly excessive in the humid climate which records RDE value of 2.0 - 3.5. Rainfall supply is adequate in the rest of the study area - in the western sector of the moist sub-humid climate, in the whole of the sub-humid climate and in the semi-arid zone excluding the extreme northern part (Fig. 6b).

Examined on our rainfall distribution efficiency rating scale, late maize will experience inadequate rainfall during flowering and grain-filling period in the sub-humid and semi-arid areas of southwestern Nigeria (Figs. 6c and 6d). The situation of inadequate moisture supply in these climates for late maize is particularly pronounced during the grain-filling period (Fig. 6d). In the moist sub-humid climate rainfall supply is adequate for late maize during flowering but not during the grain-filling period (Figs. 6c and 6d). During these periods moisture supply is excessive in the southern part of the humid region of the study area (Figs. 6c and 6d).

IMPLICATIONS OF RAINFALL DISTRIBUTION FOR MAIZE FARMING

It was found that rainfall supply matches the water requirement of early maize in the study area during all stages of growth except in the humid and in the moist sub-humid regions where rainfall supply is excessive in relation to maize water need during the grain-filling stage. One option is to shift forward the time of early maize planting in this area by a few weeks such that the maturity period will not go too far into the period of excessive water supply. Alternately, the crop can be sprayed with insecticides during this period in these climates in order to forestall the problem of moulding.

According to the result obtain in this study water supply through rainfall is excessive for late maize during all the phenological period of growth in the humid climate of southwestern Nigeria.

The solution that offers promise in this case is to delay late maize planting in this climate by about a month. This will ensure that rainfall supply is less excessive during each phase while the crop can also mature on stores soil moisture.

In the moist sub-humid climate of southwestern Nigeria, rainfall distribution can be said to be just right for the growth of late maize. Although water supply can be said to be marginally inadequate during grain-filling, the RDE value is not below 0.5 during this time implying that the crop can mature on stored soil moisture.

The moisture problem confronting the growth of late maize in the sub-humid and semi-arid climates of southwestern Nigeria is that of inadequate supply rather than of excessive rainfall. This problem has been shown to be clearly manifested during the flowering and grain-filling period in these climates. As a way out of this problem extra early maturing maize varieties which mature in 90 days can be subsisted for the local cultivators which require a growing season of 112 days. Alternatively if preference is high for the local variety, supplemental irrigation can be introduced during these periods.

CONCLUSION

For the tropics where agriculture is still largely rain-fed optimum crop yield can only be achieved if water supply through rainfall well matches the crop water

In this study therefore a simple method has been evolved for assessing the efficiency of rainfall distribution for crop growth. The methodology has been demonstrated for maize growth in southwestern Nigeria. There is, however, no reason why the study cannot be extended to other crops and to other areas of the tropics. The usefulness of the results obtained for maize growth in southwestern Nigeria in this study makes such an extension quite worthwhile.

REFERENCES

BENOIT, P. 1977. The start of the growing season in Northern Nigeria, Agricultural. meteorology 8, 91-99.

CHANG, J.H 1968, Climate and Agriculture: An Ecological Survey, Aldine Press: Chicago, 296 PP.

CRITCHDFIELD, H. J 1994, General Climatology (3rd edn), Prentice-Hall: New Jersey, 446PP.

HANSEN, V.E ET AL 1979, Irritation Principles and Practices (4th ed.), John Wiley: New York, 417PP.

JACKSON, I. J 1977, Climate, Water and Agriculture in the Tropics. Longman: London, 248PP.

KOPPEN, W. 1918, Classification der klimate nach Temperature, Niederschlag and Jahresablanf, Petermanns Geogr. 64, 193 - 203, 243 -248.

KOWAL, J.M AND KASSAM, A. H 1973a, An appraisal of drought in 1973 affecting groundnut production in Guinea and Sudan Savanna areas of Nigeria, Savanna: 2(2) 159 - 164.

KOWAL, J.M. AND KASSAM, .H 1973b, Water use, energy balance and growth of maize in Samaru, Northern Nigeria, Agricultural. Meteorology, 12, 391 - 406.

MORE, R. J 1969, Water and crops', in Chorley, R.J. et al (eds) Water, Earth and Man, Methuen: London, 197 - 208.

OLANIRAN, O. J 1983, The Onset of the Rains and the Start of the Growing Season in Nigerian. Nigerian Geographical Journal, 26, 81 - 88.

OLANIRAN, O. J 1988, Climate and the Planning of Agricultural Land use in Nigeria: The Niger River basin development authority area as a case study, Journal of Agricultural Meteorology 43 (4) 285 - 294

OLANIRAN, O. J AND BABATOLU, J. S 1987, The Effect of Climate on the Growth of Early Maize in Kabba, Nigeria, Geojournal, 14 (1), 71 - 75.

PENMAN, H. L 1948, Natural Evaporation from Open Water Bare Ground and Grass Surfaces. Proceeding of Royal Society of Meteorology, London. Series A, 193, 120 - 145.

PORTER, P. W 1976, Climate and Agriculture in East Africa, In Contemporary Africa. By Knight, C.G and Newman, J. L. (eds.), Prentice-Hall Presses New Jersey, 112 - 139.

THORNTHWAITE, C. W. 1948, An Approach Towards a Rational Classification of Climate, Geographical Review, 38, 55 - 94.

WILLIAM, C. N. AND JOSEPH, K. T. 1970, Climate, Soil and Crop Production in Humid Tropics, Oxford University Press: London, 177pp.