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Climate and the Planning of Agricultural Land Use in Nigeria: The NRBDA Area as a Case Study

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Abstract

The climatic requirements in terms of the length of the growing season and the moisture need of a selection of crops, namely: guinea corn, maize and rice (cereals), groundnut (oil seed), and sugarcane (industrial crop) were compiled for the Niger River Basin Development Authority area of Nigeria in this study. The probability of attaining the climatic requirements for the selected crops was assessed and used as a basis for evaluating the potential crop land for the cultivation of the specified crops from the climatological point of view.

By comparing the present and potential agricultural lands for the cultivation of the selected crops, identifications were made of the areas of the basin where it would be desirable to increase the cultivated area planted to specified crops or effect a re-structuring and diversification of the agricultural land use.

1. Introduction

The food requirements of Nigeria are increasingly being met by the importation of various food items into the country (Table 1). The shortage of food has reached such a crisis point that it was, among other reasons, presumably responsible for the military take-over of government of the country on December 31st, 1983. This threatening prospect of famine caused by the shortage of food raises the question of the country's capacity to maintain her rapidly growing population. In fact, the growth in population makes it imperative to increase, and indeed to maximise, agricultural production.

In practice, there are several courses of action open to increase agricultural production:

(i) intensification of the existing land use through programmes such as breeding of high-yielding varieties of different crops, greater application of fertilizers or control of pests and diseases affecting crops;

(ii) an increase in the cultivated area planted to specified crops, and

(iii) changing the pattern of land use by discontinuing the cultivation of unsuitable crops and by introducing new and more suitable crops.

This study is carried out with the last two objectives in view based on climatic considerations. Thus, the prospects of a spatial expansion of land under specified crops are being investigated. The other objective of this study is to investigate where it will be possible to effect a re-structuring or diversification of the agricultural land use or the cultivation of certain plants. In general, whichever strategy is followed, it is envisaged that land use would be geared to ensure optimal climatic conditions for the plants being cultivated.

To show how these objectives can be accomplished for the country, the Niger River Basin Development Authority (NRBDA) area is taken as an example. The NRBDA area is one of the eleven[1] river basin development authority areas created in Nigeria in 1976 for the management of the water and agricultural resources of the country

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1. This was the position up to May 7, 1984 when more river basins were created and the boundaries of the existing ones adjusted.

Table 1. Food importation in Nigeria

Year	Total Import Value in (₦ Million)	Rice Importation (Tons)
1962	46.786	–
1963	43.804	–
1964	41.240	–
1965	46.076	–
1966	51.568	–
1967	42.560	–
1968	28.392	–
1969	41.732	–
1970	57.694	1,700
1971	87.910	300
1972	95.104	5,900
1973	126.260	1,100
1974	155.708	4,000
1975	277.863	6,700
1976	438.927	45,000
1977	702.013	413,000
1978	1,108.662	770,000
1979	1,105.901	700,000
1980	Not Available	Not Available
1981	1,860.000	Not Available

Source: Nigerian Institute of Social and Economic Research, Ibadan.
Distinguished Lecture Series No. 1, April 1983.

* ₦ 0.75 = 1 U.S.$ up to 1981.

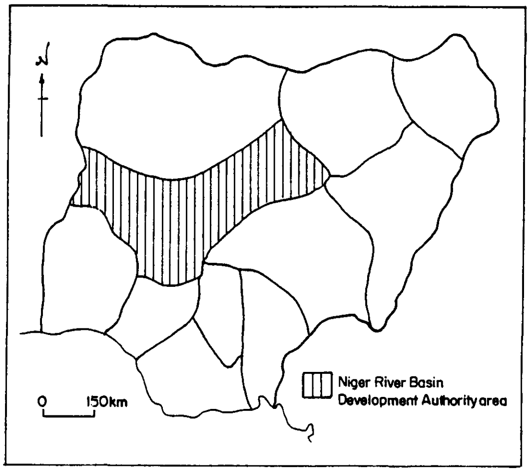

Fig. 1. River Basin Development Authority areas in Nigeria.

(Fig. 1). It is therefore a suitable framework for carrying out any agricultural land use policy.

Before undertaking an evaluation of the present agricultural land use and the climatic-potential agricultural land use for the basin, its geography is first discussed.

2. Methods and Materials

2.1 The Study Area

The NRBDA area lies mainly between latitudes 7 and 12°N and between longitudes 3 and 9°E. It has a wide variety of relief features (Fig. 2a).

On the Thornthwaite and Mather climatic classification scheme (Thornthwaite and Mather, 1955), the area can be divided into three climatic regions (Fig. 2b). These are the dry sub-humid region which is the most extensive, the semi-arid region to the northwest of the basin, and a small area under moist sub-humid climate around Zonkwa.

The dry sub-humid region can be further divided on the basis of moisture regime, namely; the mean annual rainfall and the length of the growing season (Figs. 2c and d). Thus, it has a wetter zone to the south and a comparatively drier zone to the north. The wettest part of the basin is the Zonkwa area probably on account of the high topography.

2.2 Methods of Study

This study was conducted with the aim of producing concrete advice on the evaluation of the present and potential land use from a climatological point of view. With this aim in mind, the method used was as follows:

(1) A compilation of the general climatic requirements of crops. Only a selection of crops was considered – guinea corn, maize and rice (cereals), groundnut (oil seed), and sugarcane (industrial crop). Although, a number of crops have not been discussed (e.g. cassava, millet, tobacco, cotton, etc.) this coverage is sufficiently wide to demonstrate the methodology and illustrate the general points.

(2) As assessment of the probability of attaining the climatic requirements specified in stage 1 for the selected crops.

(3) An evaluation of the present and potential crop land for the cultivation of the specified crops.

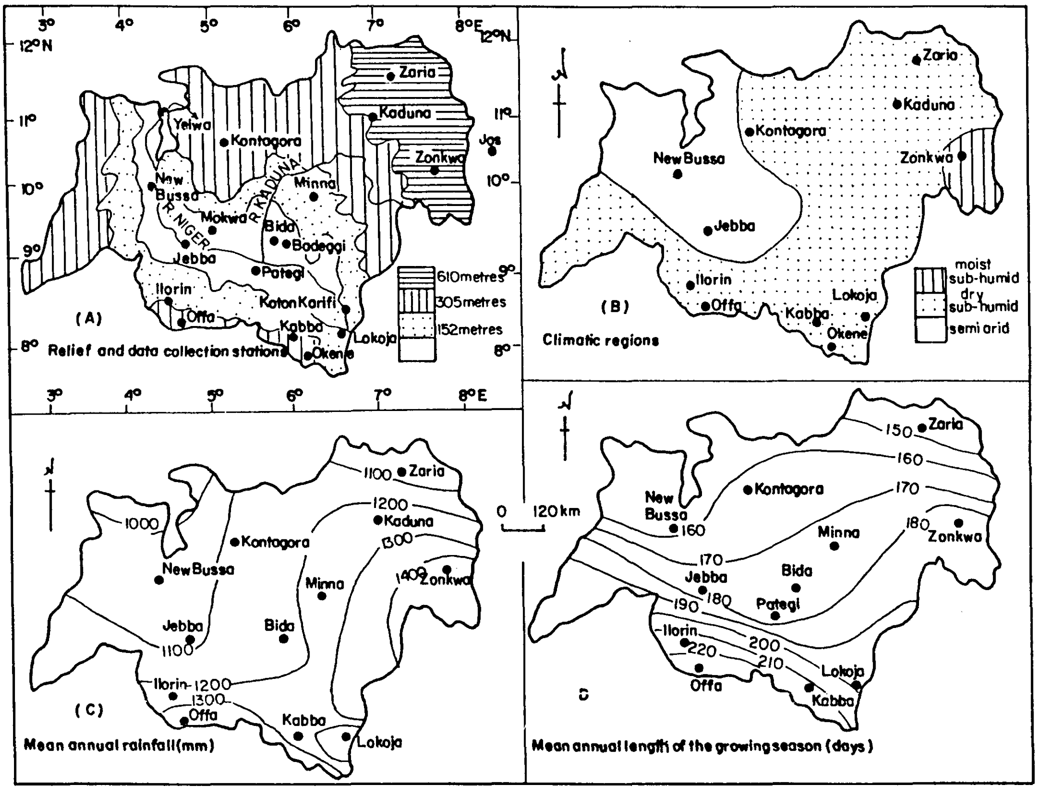

Fig. 2. The study area.

2.3 Climatic Requirements of the Selected Crops

The compilation of climatic requirements was done with particular reference to the length of the growing season and the moisture requirement of crops during this period. In the compilation temperature conditions were excluded because for the tropics, the seasonal temperature variations are small and as such agricultural productions can be sustained throughout the year and risks related to the temperature factor are small (Nieuwolt, 1977).

The information on the length of the growing season for the crops selected was compiled from the work of Dent and Young (1981). The details are given in Table 2. In general, the length of the growing season depends largely on variety and time of year when the crop is grown. Thus, the information will be mostly valid if planting begins at the start of the growing season in each case.

For the determination of moisture requirement the consumptive use of water by each crop was computed for the period of the growing season. According to Hansen et al. (1979) the consumptive use of water by a crop is the same as the evapotranspiration from that crop and it applies to the water requirement of that crop.

When direct measurements are not available climatic observations are used as an index of consumptive use. Such estimates of crop consumptive use are calculated from an equation of the form

$$U = K_{co} E_{tp} \tag{1}$$

where U = crop consumptive use of water,
K_{co} = crop coefficient,
E_{tp} = evapotranspiration from the reference surface.

From equation 1, estimates of crop consumptive use of water may therefore differ according to

(i) the crop coefficient, and
(ii) the method of calculating the evapotranspiration rate from the reference surface.

Some typical reference surfaces are water (Porter, 1976) and alfalfa (Hargreaves, 1977). For crop coefficients the American Society of Civil Engineering (ASCE) in 1974 reported typical values for different crops according to the percentage of their effective cover (see Hansen et al., 1979). On the other hand, in the method of Porter (1976), the crop coefficient is computed according to the ratio

E_t/E_o, where

E_t = actual evapotranspiration from the crop surface determined according to lysimeter studies, and

E_o = open water evaporation determined according to the method of Penman (1948).

In this case E_t takes into account the physiological age of the crop and the degree of leaf and ground cover.

The second basis for differences in the estimates of consumptive use of water by crops is the method of computing E_{tp} i.e. the evapotranspiration rate. According to Hansen et al. (1979), the evapotranspiration rate could be determined from either the Penman or Blaney-Criddle method, or by using Hargreaves equation. Of all these, Penman (1948) has made the most complete analysis using several climatic variables (radiation, humidity, air temperature and records of wind run), whereas temperature has been used as the principal variable to obtain an index of consumptive use by Blaney and Criddle (1950). Hargreaves (1977) used temperature and solar radiation to estimate the consumptive use of water by grass.

With this background in mind the method of Porter (1976) was therefore selected for computing the mean daily consumptive use of water for the selected crops. To use Porter's method equation 1 now takes the form

$$U = E_t/E_o \times E_o \qquad (2)$$

where all terms remain as previously explained.

Independent of the values of E_t/E_o therefore, the water requirement of the same variety of each crop may vary for different climatic regions because of the differences in the evaporative demand of the atmosphere (E_o). There is therefore the need for caution in adopting for use the various values of water requirements of different crops reported in the literature.

To compute U in this study the mean values of E_t/E_o used for the different crops are as follows:

Crop	Average value of E_t/E_o for the growing season	Source
Guinea corn	0.67	Kowal and Andrews (1973)
Maize	0.69	Dagg (1965)
Rice	1.17	Porter (1976)
Groundnut	0.75	Kowal and Kassam (1974)
Sugarcane	0.87	Blackie and Bjorking (1968)

The mean values of E_t/E_o ratio reported above for the different crops compare quite well with the values of crop coefficients reported by Hansen et al. (1979). Open water evaporation values (E_o) were then computed for Zaria (11°08'N, 07°41'E) according to the method of Penman (1948) using data for the period 1971–80. This location was chosen for two reasons. First it is at the northern limit of the basin thereby indicating an optimum evaporative demand of the atmosphere for the basin. Secondly, the station has the complete set of climatological records which are needed to compute E_o according to the method of Penman. The product of the mean daily consumptive use and the length of the growing season was therefore calculated to give the total moisture requirement of each crop. Details of these are given in Table 2.

Apart from information on length of the growing season and water requirement during this period, Table 2 also contains information on specific moisture constraints to good crop yield.

3. Results and Discussion

3.1 Water Requirements Probability Assessment for Selected Crops

Because the risks related to the temperature factor are small in the tropics, agricultural planning is done on the basis of many features of rainfall in the region. Porter (1976) listed those features as total annual precipitation, the seasonal pattern, precipitation effectiveness, rainfall variability and rainfall probability.

In this study rainfall probability assessment was undertaken as a basis for agricultural land use planning in the NRBDA area because according to Hanna (1971), the method is suitable for assessing the risk of crop failure and judging land potential for production of specified crops.

Probability assessments were undertaken in this

Table 2. The growing season, consumptive use of water and specific moisture constraints of selected crops in the Niger River Basin Development Authority area of Nigeria

Crop	Growing Period* (days)	Consumptive Use of Water During the Growing Season** (mm)		Specific Moisture Constraints
		Early Maturing Variety	Late Maturing Variety	
Guinea corn	100–140	380	543	Increased moisture and shadiness are constraints to good crop yield (Agboola, 1979)
Maize	100–140	391	559	–
Rice	90–150	597	1016	–
Groundnut	90–140	383	608	Increased moisture causes a high incidence of rosette infection (Jackson, 1977)
Sugar cane	270–365	1186	1604	–

* Taken from Dent and Young (1981)
** Computed by the Author

study with respect to two aspects of the climatic requirements of the selected crops:

(i) length of the growing season, and
(ii) total water requirement during the growing period.

The length of the growing season was determined according to a modified version of Walter's (1967) method. This method is illustrated with data in the appendix.

For the water requirements probability assessment monthly rainfall values were collected for a 30-year period, 1951–80 for the 19 stations shown in Fig. 2a. Maps of probability for the critical water requirements and the required lengths of the growing season reported in Table 2 were then prepared (Figs. 3 and 4). These maps form a useful basis for evaluating the potential land use under the specified crops.

3.2 The Evaluation of the Actual and Potential Agricultural Land Use

Maps of the present land use for the specified crops were first prepared from the work of Agboola (1979). These are shown in Fig. 5.

Concerning the evaluation of the potential land use Porter (1976) suggested planning agriculture around conditions which can be attained 80 per cent of the time. Accordingly, four categories of climatic-potential suitability for the cultivation of each crop were identified as follows:

Optimal: If the critical water requirement and the required length of the growing season can be attained together 80 per cent of the time.

Favourable: If one condition is attained 80 per cent of the time and the other for at least 60 per cent of the time.

Difficult: If both conditions can only be attained together only 60 per cent of the time.

Unsuitable: If both conditions cannot be attained together for at least 60 per cent of the time.

With this guideline, the evaluation of the present and potential land use under the selected crops can now be undertaken.

Guinea Corn

Figure 5a shows the percentage of the crop-land within the basin devoted to guinea corn. Before applying the climatic-potential suitability scheme to land use for this crop, it may first be necessary to exclude the wet zone for which Agboola (1979) noted that increased moisture constitutes a constraint to good guinea corn yield. The southern part of the basin area where the mean length of

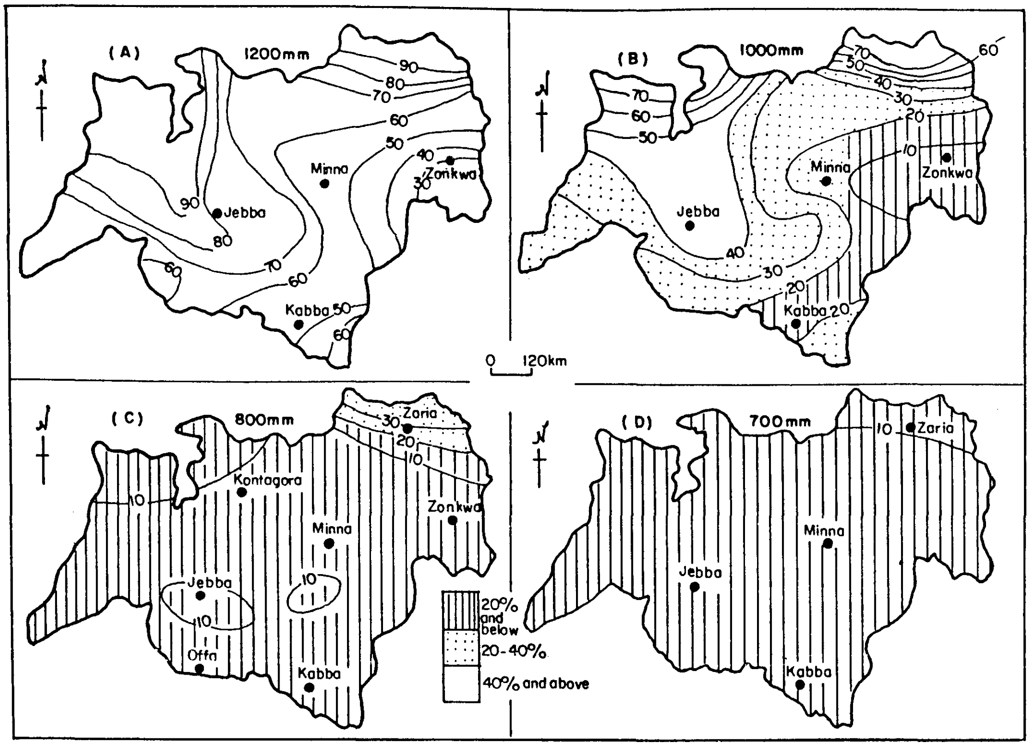

Fig. 3. Niger River Basin Development Authority area of Nigeria: Probability of obtaining less than critical rainfall amounts during the growing season.

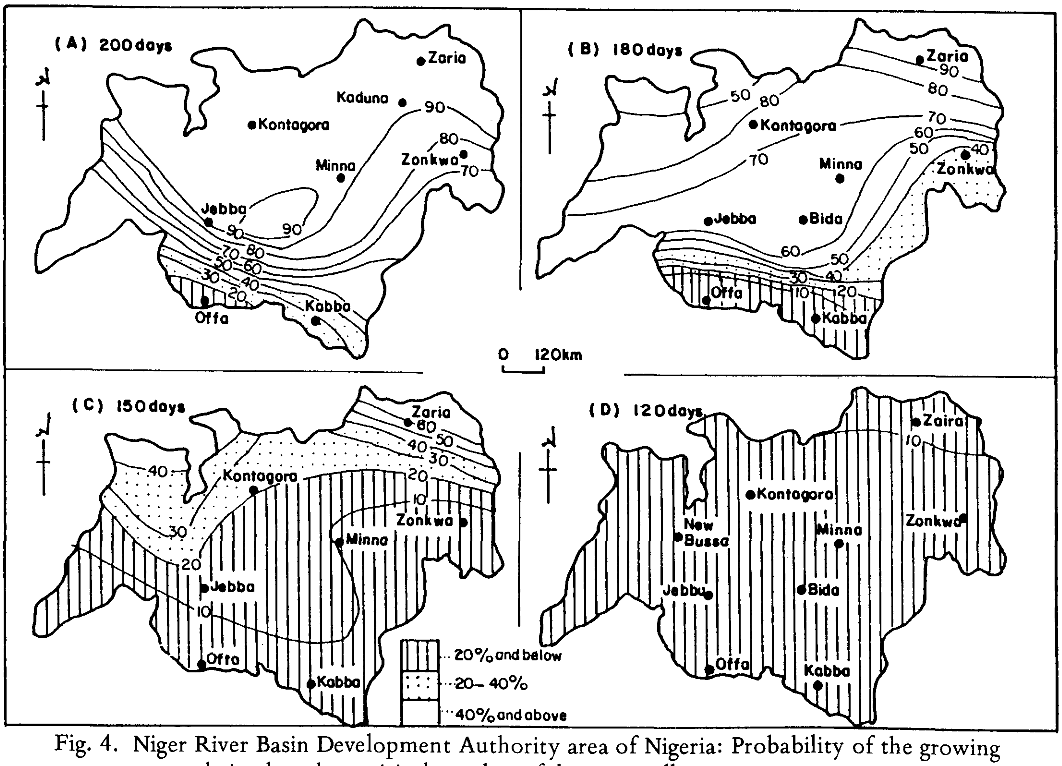

Fig. 4. Niger River Basin Development Authority area of Nigeria: Probability of the growing season being less than critical number of days annually.

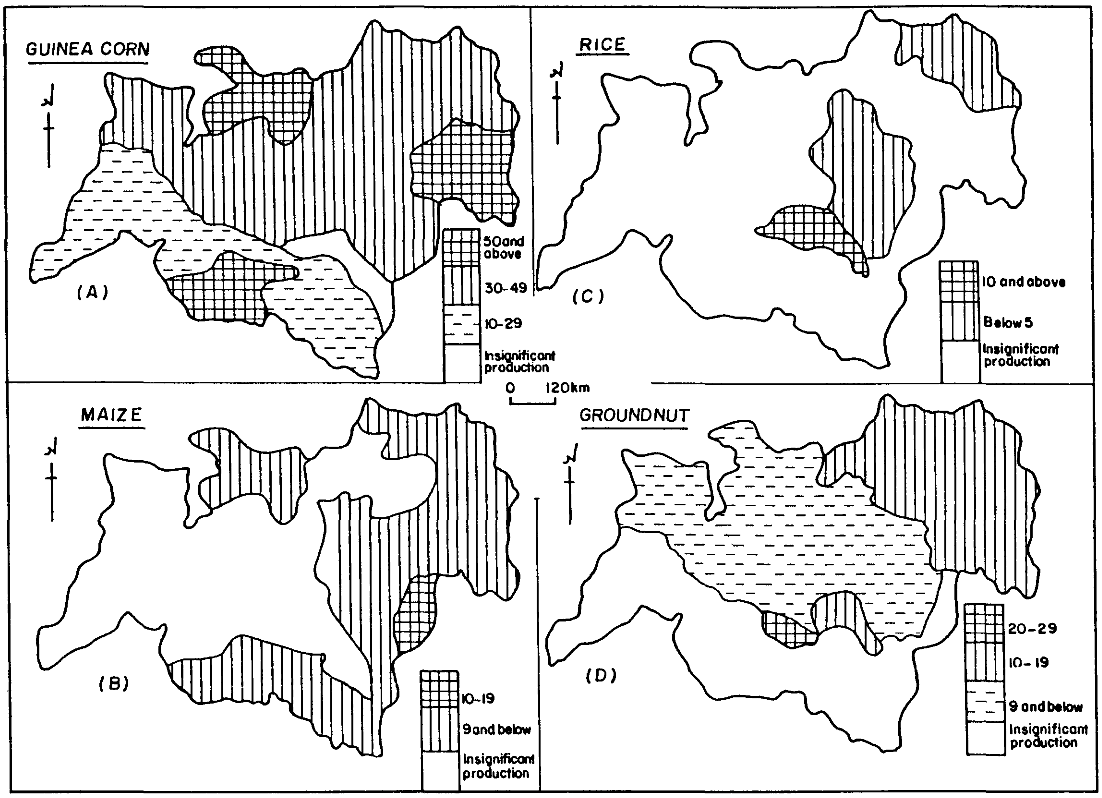

Fig. 5. Niger River Development Authority area of Nigeria: Percentage of cropland devoted to some crops.

the growing season per year is about 190 days or more is prone to this constraint. (Fig. 2d). Thus, the major guinea corn growing area in the southern part of the dry sub-humid region will therefore not prove suitable under the crop (Fig. 5a).

For the rest of the basin, conditions are optimal for the cultivation of the early maturing variety of guinea corn (Table 2, Figs. 3d and 4d) while for late maturing variety it is only in two areas where conditions are difficult – the narrow strips of the basin in the northwest and northeast respectively (Table 2, Figs. 3d and 4c). However, from Fig. 5a it is only in the Zonkwa area and the north-central part of the basin that the optimal and favourable conditions for the cultivation of guinea corn have been fully utilized. It will therefore prove profitable to increase the percentage of crop land devoted to the crop in the area approximately north of the latitude of Jebba within the basin should the need for this arise.

Maize

In Fig. 5b, the areas where maize is grown in the NRBDA area are shown. Evidently from this map maize is not a popular crop in the basin area given the extent of land area devoted to its cultivation.

However, from Table 2 and Figs. 3d and 4d optimal conditions exist in virtually all the basin area for the cultivation of the early variety of maize. Also it is only in the narrow strips of the northwest and northeast of the basin that conditions are difficult for the cultivation of the late maturing variety of the crop (Table 2, Fig. 3d and Fig. 4c). Thus, to increase maize cultivation within the basin maize growing can be extended westwards of the present maize growing area (Fig. 5b). Alternatively, the percentage of crop land devoted to maize cultivation in the present maize growing areas of the basin can be increased.

For double cropping what matters mostly is the probability of attaining up to 2 growing cycles in the year. According to Table 2, the minimum requirement for this is a growing season of at least 200 days. Thus, independent of the rainfall amount received, the only area of the basin where this is possible is a narrow strip in the southern part of the dry sub-humid region (Fig. 4a).

Rice

Rice is not widely grown in the NRBDA area in spite of its status as a major staple food crop for Nigeria (Fig. 5c). However, with a water requirement of 600mm during a growing season period of 90 days (Table 2), conditions are optimal for the cultivation of the early maturing variety in virtually all the basin area (Figs. 3d and 4d). In contrast, if the requirements for rice growth are defined in terms of a growing period of 150 days and water consumptive use of 1000mm during growth (Table 2), then only the narrow strip of land east of the present rice growing areas in the basin has optimal conditions for the cultivation of the late maturing variety of rice (Figs. 3b, 4c and 5c). Accordingly, the rest of the basin excluding the Zaria region in the north and the semi-arid region in the northwest fall in the region where conditions are favourable for the cultivation of this rice variety. Thus, extending rice growing into these areas where topographical and soil conditions permit will prove quite fruitful.

Conditions will be difficult for growing the late maturing variety of rice in the semi-arid area of the northwest while there are no good prospects of a good yield of this rice variety in the Zaria region. (Table 2, Figs. 3b and 4c).

Groundnut

In Fig. 5d, the areas of NRBDA area devoted to groundnut production are shown. Apparently from this map, in the wet zone of the basin (i.e. south of the latitude of Jebba) groundnut cultivation is of no significance. The high incidence of rosette infection which is common in wet regions (Table 2) may explain this pattern.

In terms of the length of the growing season and the consumptive use of water by groundnut during growth (Table 2) the whole of the basin can be said to have favourable conditions for the cultivation of both the early and late varieties of groundnut from the climatic point of view (Figs. 3d and 4c). From Fig. 5d, however, this potential has been utilized to different degrees probably on account of varying soil conditions or different socio-cultural factors. Where these different factors do not prove to be serious constraints increasing the proportion of crop land under groundnut cultivation is a promising venture in particular north of the latitude of Jebba which is rosette infection free.

Sugar Cane

Sugar cane is planted in a relatively small area of the basin. This is at Bacita near Jebba on an approximately 3,240 hectare (8,000 acre) estate with the aid of irrigation. It is important to note that Bacita is located within the flood plain of Niger river.

The low acreage of cropland devoted to sugar cane cultivation should not be surprising. This is because the minimum requirements of about 1200mm of water required for the consumptive use of the crop during a minimum growing period of 270 days (Table 2) cannot be attained anywhere in the NRBDA area (Figs. 3a and 4a). Thus, the prospects of increasing the land area under sugar cane cultivation are limited to the flood plains of rivers Niger and Kaduna such as at Lafiagi and Sunti near Bida (Agboola, 1979).

4. Conclusion

In this study, it has been shown that in the Niger River Basin Development Authority (NRBDA) area of Nigeria, differences exist between the present and the climatic-potential agricultural land for the cultivation of different crops. To minimize these differences, it was found that the agricultural land devoted to the cultivation of guinea corn (cereal) must be restructured while those of groundnut (oil seed), on the one hand, and on the other hand those of maize and rice (cereals), must both be intensified and spatially expanded. The study also shows that there are no good prospects of increasing the cropland devoted to sugar cane cultivation in the basin area except in the flood plains of the major rivers. To attain a condition whereby land use is geared to ensure optimal climatic conditions for the crops being cultivated in the NRBDA area, and indeed in the other river basins in Nigeria, it will therefore be necessary to extend the study to other major crops and the other river basins in the country.

APPENDIX:

Sample Working Sheet for Computing the Start and End of the Growing Season from Monthly Rainfall Values

Month:	J	F	M	A	M	J
Rainfall (mm)	0.0	5.1	49.9	20.6	309.6	179.1
Month:	**J**	**A**	**S**	**O**	**N**	**D**
Rainfall (mm)	115.1	79.8	222.5	309.9	1.8	3.1

Start of the Growing Season

Walter (1967) computed the start of the rains as follows:

$$\text{Days in the Month} \times \left[\frac{51 - \text{accumulated rainfall total of previous month}}{\text{Total rainfall for the month}}\right]$$

where the month under reference is that in which the accumulated total of rainfall is in excess of 51mm. For computing the end of the rains the formula is applied in the reverse order from December. It is hereby hypothesized that for the available moisture to continue to meet the evaporative demand for the atmosphere, total rainfall of the month following this date should not be less than 51mm.

From the table above, the accumulated rainfall from January exceeds 51mm at the end of March. Thus, the month of the start of the growing season is March.

Accumulated rainfall total of previous months (i.e. up to February ending) then is 5.1mm.

Rainfall total for March is 49.9. The number of days in March is 31.

In Walter's original method, the date of expected start of the growing season will be given as $31 \times \left[\frac{51.0 - 5.1}{49.9}\right]$ or 29th March.

However, total rainfall in April is 20.6mm thereby indicating that the planting date of March 29, may be followed by a prolonged dry spell. Therefore, rainfall distribution up to March is disregarded and by applying Walter's method thereafter, the growing season starts in May and the exact date will be given as $31 \times \left[\frac{51.0 - 20.6}{309.6}\right]$ or 3rd of May.

This is the modified version of Walter's method.

End of the Growing Season

If the rainfall values are accumulated from December backwards, the accumulated total will exceed 51mm in October which thus becomes the month of the end of the growing season. Accumulated rainfall totals of previous months (i.e. up to November) is 4.9mm.

Total rainfall for October is 309.9mm.

The number of days in October is 31.

The exact date considered backward from October ending as given by Walter's original method then is $31 \times \left[\frac{51.0 - 4.9}{309.9}\right]$ or five days from October ending i.e. 26th of October.

The month of October is not preceded by a month with less than 51mm of rainfall. Hence the application of the modified version of Walter's method is not required.

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気候と農業用土地利用計画
—ナイジェリアにおけるニジェール川流域開発公社の開発地域を例として—

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要　　約

この研究は，ナイジェリアのニジェール川流域開発公社の農用地開発地域において，栽培に適した農作物（例えば，ギニア小麦，トウモロコシ，米(穀類)，落花生(油種)，サトウキビ(工業用作物)など）を選択するにあたり，これらの作物の生育期にどのような気候条件および水分条件が必要であるかというデータを収集したものである。各々の農作物に対し，必要な気候条件を満たす確率を調べ，それぞれの作物を栽培する上で，その土地が将来性のある農地であるか否かを気候学的に評価する際の根拠とした。

現在，農地として利用している地域との比較により，特定の作物の耕作に適した地域あるいは土地利用の再編や多角化の効果が得られる可能性のある地域を見出すことができた。