THE AGRO-CLIMATOLOGY OF MILLET PRODUCTION IN DESERT FRINGE ZONE OF NIGERIA A CASE STUDY OF KEBBI STATE

BY

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The thesis submitted to the Post Graduate School, Federal University of Technology, Minna - Niger State in partial fulfilment of the requirement for the award of Masters Degree of Technology (M.Tech) in Meteorology.

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CERTIFICATION

This is to certify that this research work has been undertaken by Girma Stephen Aiki in the Department of Geography, Federal University of Technology, Minna for the award of Master Degree of Technology (M.Tech) in Meteorology.

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DEDICATION

This work is dedicated to God who made it possible for me to successfully accomplish my studies. It is also dedicated to my family who for good course prayed for me without ceasing throughout my course.

ACKNOWLEDGEMENT

To God be the glory for his guidance and protection over me throughout my course of study. I lack adequate words to thank my supervisor Professor D. O. Adefolalu, whose useful corrections, suggestions and contributions towards the success of this project was measureless, because despite his tight schedules, was able to supervise my work. And also Dr. Umoh T. Umoh, Dr. Akinyeye, P. S., D.C.O Dominic E. Effiong and Mallam suleiman Mohammed for their meaningful contributions and advice. Mohammed shaba is another colleague who owe my special thanks. My special thanks goes to my dear family for their ability to bear with me as a student.

I also owe my gratitude to Mallam Zubairu Turaki, who was able to provide me with the necessary data from Kebbi Agricultural and Rural Development Authority (KARDA) for this project work and many other people whose names did not appear here in black and white but have contributed either in cash or in kind and spiritually or otherwise towards the success of this work. May the Lord God almighty reward you richly - Amen.

ABSTRACT

The major thrust of this study was to identify quantify and analyse the Agro-climatological conditions of millet production in desert fringe zone of Nigeria and Kebbi State in particular.

Two set of secondary data were collected from 19 stations distributed all over the state.

The sample covered all the 21 local Government areas of Kebbi State.

The simple percentage and multiple regression techniques were used in analysing the data. The research findings came out with the following conclusions: That the onset cessation of rains and the length of rainy season (LRS) are paramount features for understanding precipitation effectiveness in Kebbi State for General Agricultural Planning purposes. Although for planning in relation to crop development and yield, rainfall amount can not with certainty give a concise quantification of what crops need to give optimum yield. But essential computed applied parameters based on the same actual (observed) rainfall for effective planning are required. Such as the hydrological Growing Season (HGS). the hydrological ratio, and specific water consumption (W/F) requirements. Menacing problems of Agriculture should be handled with utmost attention. To be precise Government should assist small scale farmers in the care of produce and much more of agro-climatic parameters that aid

millet yield in the state. This could mean obtaining more reliable data for proper forecast of agriculturally viable arable land of the state.

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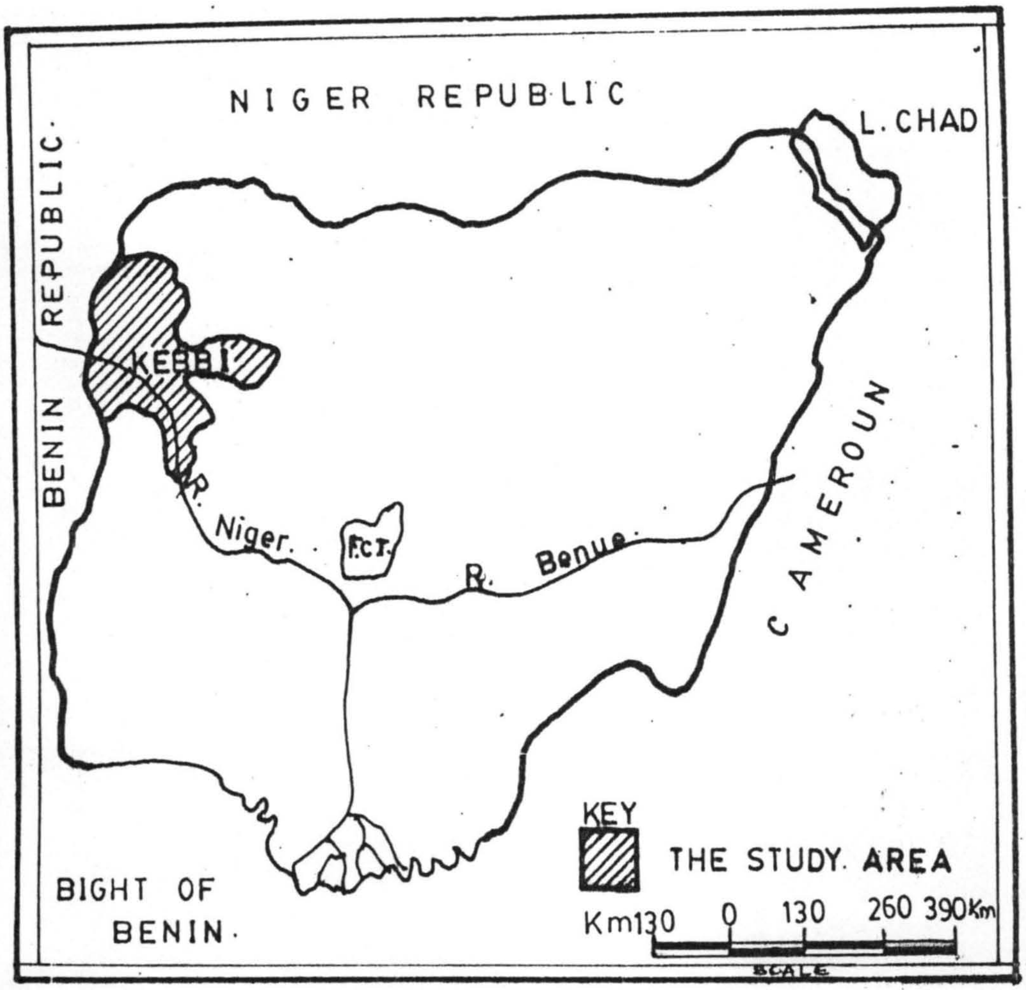


Fig. 2: **MAP OF NIGERIA SHOWING KEBBI STATE**

CHAPTER ONE

1.0 AGRICULTURAL PRODUCTION IN THE DESERT FRINGE ZONE OF NIGERIA - AN OVERVIEW

1.1 Introduction

Agriculture is an important occupation which engages the majority of the people in Nigeria especially in the desert fringe zone. Agriculture being the main stay of the people depended solely on rainfed agriculture for the production of cereals.

Rainfed agriculture is a type of planting operation which depends on precipitation for the time of sowing, crop growth, development and maturity/yield, in which all the stages are confined to the rainy season.

This type of agricultural practice does not require extra or additional supply of water through irrigation. It is solely dependent on the onset (C) of rains which determines the sowing period, rainfall cessation (C) which determines the plant or crop maturity, the length of rainy season (LRS) which determines productivity. While the amount of rainfall determines productivity or yield of the crop, a significant feature of rainfed agriculture is its full dependence on the temporal spread of the rainy season.

The areas known to be within the desert fringe zone of Nigeria include Kebbi, Sokoto, Zamfara, Katsina, Kano, Jigawa, Yobe, Borno, Bauchi and Gombe States (see Figure 1.1).

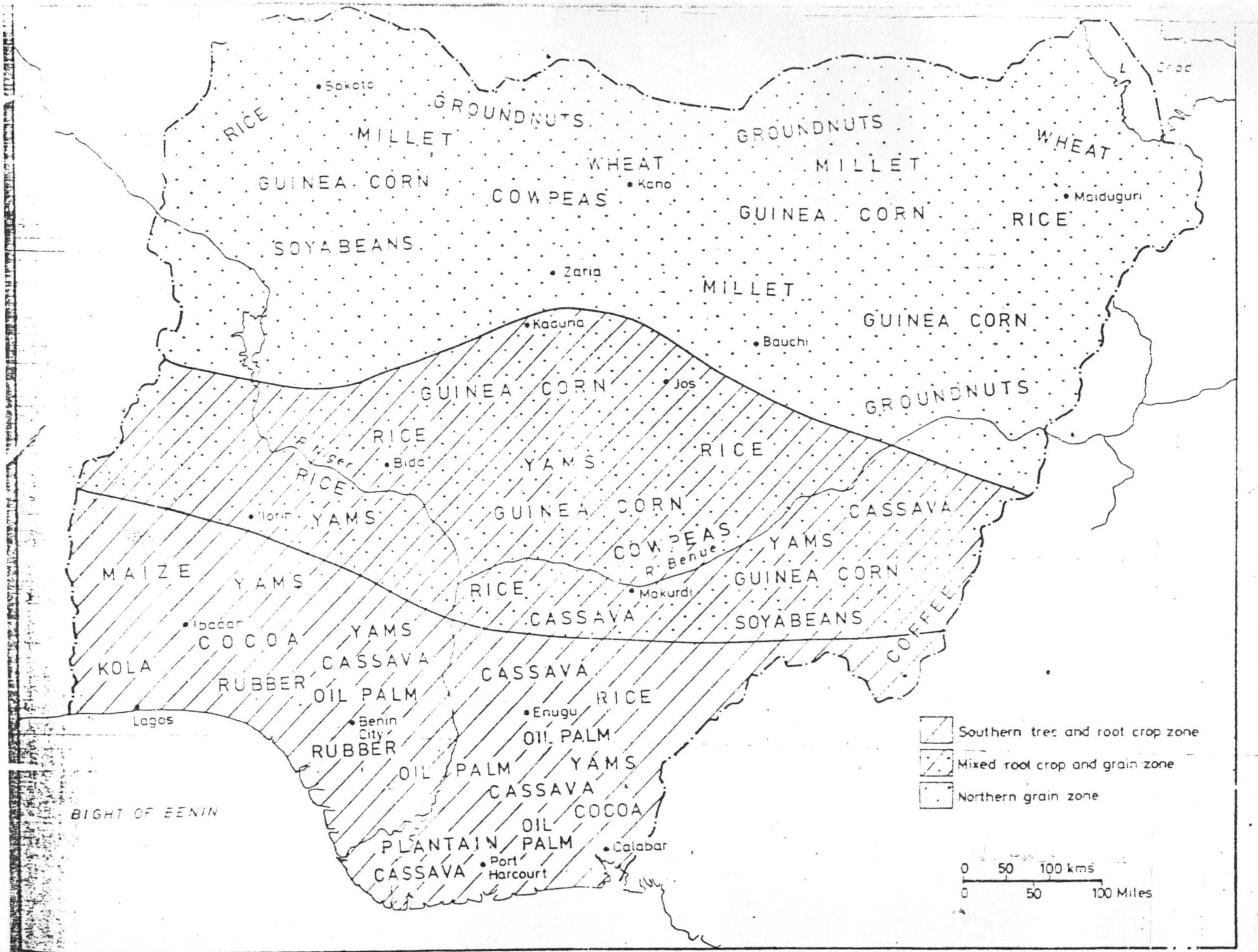


Fig.1: **FOOD CROP ZONES OF NIGERIA**

The cereals grown in the belt are Guinea corn (Sorghum), millet, maize, rice, wheat, soybeans etc. These are the staple food crops of rural dwellers within the desert fringe zone of Nigeria. These staple food crops are highly dependent on rainfed agriculture. Thus Nwafor (1982) identifies the north of the middle belt zone to be the cereal dominant area in which the water balance of plant soil system is a critical factor. This is because the low annual rainfall, short wet season of 2-3 months and high evaporation rate restrict the principal food crops to grains which have some tolerance for moisture stress.

In fact, Onyemelukwe (1982) stresses that cropping is restricted to quick growing varieties of grains chiefly because there is in effect only one short growing period. The cereal crop and livestock varieties are strictly selected within the zone because of rainfall conditions. Of particular significance are the frequent crop failures caused by the inadequacy or irregularity of the rainfall.

It is therefore imperative to appraise, assess or quantify the Agro-climatological factors influencing the growth, development and yield of cereals in the desert fringe zone of Nigeria in general and millet in particular with a hope of improving on their productivity.

Soil conditions are equally important in relation to water holding or retention capacity which is a factor of soil moisture stress. Although soil types have no significant effects on agricultural production, they are not as fundamental to agricultural zonation in Nigeria as rainfall.

Thus, apart from the socio-cultural factors which influence the decision of rural farmers, climatic variability constitutes the major limiting factor in the production of cereals. This is so because the bulk of locally produced cereals in Nigeria today are grown as rainfed crops.

In spite of its place as the pillar of any agrarian venture, climate, particularly precipitation, has not been accorded the deserved priority in agricultural planning in Nigeria. The general neglect of this natural resource might be based on the impression that the tropical climate is equitable. However, experiences have shown that several attempts to boost food production in Nigeria are being foiled by persistent drought spells (Adefolalu, 1991).

Thus, in order to evolve a lasting strategy to increase food production, there is the need to appraise climate as a natural resource affecting cereals production along side other agronomic factors. This will serve as a basis for realising the high potentials of arable lands for cereals cultivation which is the main thrust of this research, with particular reference to Kebbi State.

1.2 Statement of the Problem

Of all the factors influencing crop production such as climates, soil conditions, management practices of the farmers, pests and diseases etc., climate especially effective precipitation, is by far the most challenging factor that limits crop production. This is because , in spite of the advances in technology, the yield of cereals crop is still variable over time and space. This seems to suggest that technology alone does not increase crop production but rather, as noted by Thompson (1964) "a period of favourable weather interacts with technology to produce higher yield".

Adefolalu (1981) equally points out that "water, being one of the most essential variables in the food production chain should receive primary attention especially in the four northern States rather than rely on the provision of other (planters, harvesters and sprayer), and imported high yielding grain hybrids". Adefolalu (1983) and (1991) further observes that cereal crops will wilt before reaching maturity because of irregular or inadequate rainfall.

It is against this background that the present study is designed to analyse and quantify the Agro-climatic factors of millet production in the desert fringe zone of Nigeria with particular reference to Kebbi State. This is so because it is important to highlight the contribution and problems that hinder farming in the study area especially those associated with ineffective precipitation otherwise known as drought.

Therefore, in order to identify and quantify those phenomena that influence variation in the yield of millet in Kebbi State, studies need to be carried out and analyses made on the weather elements that deserve appraisal and thus enhance crop production.

1.3 Aims and Objectives of the Study

The aim of the study is to appraise rainfed agriculture with specific emphasis on the relationship between millet cultivation, production and weather parameters.

1.3.1 Objectives

The specific objectives of the study include:

i. To obtain a comprehensive data on millet yield and simple readily available weather data such as rainfall, temperature (maximum and minimum) relative humidity, radiation and evapotranspiration for the study area.

ii. To analyse and quantify the Agro-climatic factors affecting millet production in Kebbi State. This will include computation of indices of precipitation effectiveness such as the Onset (C), cessation (C) and Length of Rainy Season (LRS) including rainfall seasonality, hydrologic ratio, specific wear consumption, dry spell and rainfall intensity.

iii. To delineate the state into proper Agro-climatological zones for millet production.

iv. To formulate a climate millet yield forecast model for the State.

1.4 Justification of the Study

It is important to note here that although the influence of climate is easily recognised in crop production, there is generally too little information on the climatic factors affecting millet production in Nigeria's desert fringe.

The situation is high pathetic and serious in Kebbi State despite the increasing attention being given to agriculture country wide. Millet is the basic staple food for about 80% of the population. Yet, there are no certified studies or its micro-economics with particular reference to phenological aspects. A study of this kind is therefore necessary to fill the gap existing between the agro-climatology of millet crop and its production potentials in Kebbi State.

In the desert fringe belt of Nigeria climatic parameters, especially precipitation effectiveness, are the primary control of crop yield. Thus analysis of agro-climatological conditions of Kebbi State will not only constitute a useful tool in planning but will also produce data in relation to other crops which may perform better irrigation. Dry season development of crops will also benefit from the outline of the study. Indeed, the availability of these crops in the State will provide an inexhaustible source of raw materials for Agro-allied industries.

1.5 Study Area

1.5.1 Location

Kebbi State is located approximately between latitudes 10° and 30°N and Longitudes 3° and 6°W, occupying most of the western and southern portions of the former Sokoto State. On its north and west borders are two of Nigeria's neighbouring, French speaking West African countries of Niger and Benin Republic, while internally it shares common boundaries with Sokoto and the newly created Zamfara State on the north and east, and Niger State to the south.

Its entire land mass, measuring about thirty six thousand, two hundred and twenty nine (36,229) square kilometres falls within the tropical savannah zone, which owing to its low vegetational cover provides good habitant for a wide variety of wild life and other domestic animals.

1.5.2 Climate

Relative to its geographical location, Kebbi State enjoys a tropical type of climatic condition generally characterized by two extremes of temperatures (hot and cold). Rainfall begins in about April and ends in October with heaviest fall in July and August and sometimes August and September, as observed by the rainfall stations in Fig.3.

The extremely cold harmattan periods is usually accompanied by dust laden winds and fog of alarming intensity, which prevails in about the month of November and ends in February or 2nd week of March. The mean annual temperatures vary considerably, but usually stands at 70°F - 100°F (21°C - 38°C) while mean annual rainfall is about 500mm to 700mm.

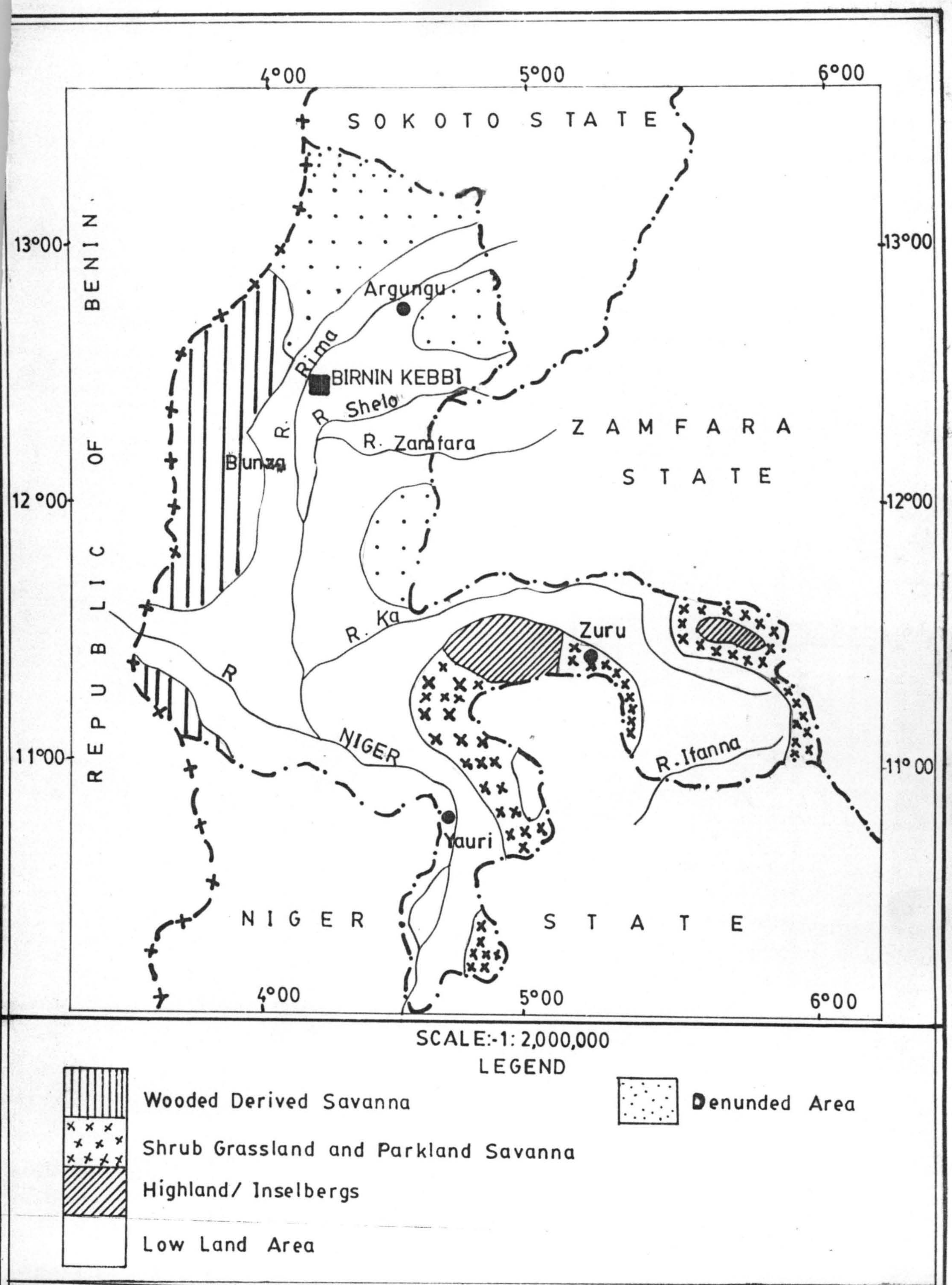
1.5.3 Topography

Kebbi State has vast expansive relatively flat terrain with a number of dotted hills in the south-eastern parts of the State particularly around Zuru, Danko/Wasagu, Sakaba and Fakai Local Government areas as well as Yauri Local Governments respectively.

The State is drained by many rivers, most of which are seasonal (ephemeral streams). The main rivers include: the River Niger, River Sokoto (Rima) which flows through Argungu in Kebbi State until it joins the River Niger around Lolo. Other rivers include rivers Ka, Germace and a host of other streams which are ephemeral in nature. See Fig. 4.

1.5.4 Vegetation

Kebbi State is marked by both Sahel and Sudan Zones of vegetation types. In the southern part of the State, there is mixed combretaceous woodland vegetation



PHYSIOGRAPHIC MAP OF KEBBI STATE

typical of Sudan savannah. The grasses are short (1 - 1.5m) and feathery in contrast to the tussock guinea grasses.

In many areas the grass cover is more or less continuous, interspersed by short savannah trees including fine leafed thorny trees such as Acacia spp. However, intense cultivation, together with overgrazing and bush burning have depleted the grass cover over large tracts. Gallery forests fringe the river courses. The vegetation consists of fairly closed forests of savannah tree species and patches of all grasses. In the northern part of the State, the sorghum grass and thorn shrubs dominates the area.

The trees are wildly dispersed, generally having very small thorny leaves. The vegetation consists of low-growing shrubs which form a dense bush in some parts, but underneath such bushes the ground is bore and sandy, while the grass cover is generally very sparse (Areola, 1973).

1.5.5 People

Kebbi State has an estimated population of about two million sixty two thousand, two hundred and twenty six (2,062,226) (1991 Census Figure). Among the major ethnic groups found in the area are hausa, Fulani, Dakarkari (Lelna), Dandawa, Kambari, Gungawa and Zabarmawa.

The State comprises of four (4) emirates namely, Gwandu, Argungu, Yauri, and Zuru. Out of the four emirates emerges twenty one (21) Local Government Area for effective and administrative convenience.

1.5.6 Occupation

Agriculture is the main stay of the people. Majority of them are peasant farmers who reside in the rural areas particularly along the river banks of the existing rivers and the vast fadama layout of the river Rima system.

There are areas with high yield potentials favourable for varied agricultural activities which is the main occupation of over eighty percent (80%) of the population.

majority of the farmers used old traditional crude methods in producing a wide variety of food crops such as millet, guinea corn, maize, rice, cassava, yam and may types of vegetables and fruits. They also engage in fishery because of the abundance of rivers.

To encourage farmers, the Government of Kebbi State has established an agency known as Kebbi Agricultural and Rural Development Authority (KARDA) to be responsible for the implementation of agricultural policies of the State.

Apart from the large expanse of arable land suitable for mechanised farming there are many rivers which provide opportunity for lucrative dry season farming.

The principal crops produced in commercial quantity throughout the State are rice, millet, maize, sorghum, cowpeas as well as cane, cassava, gum Arabic and potatoes.

A variety of citrus fruits are also produced such as mangoes, pawpaw, guava, wheat, pepper, garlic and tobacco etc. (Girma, 1995). See Fig. 5.

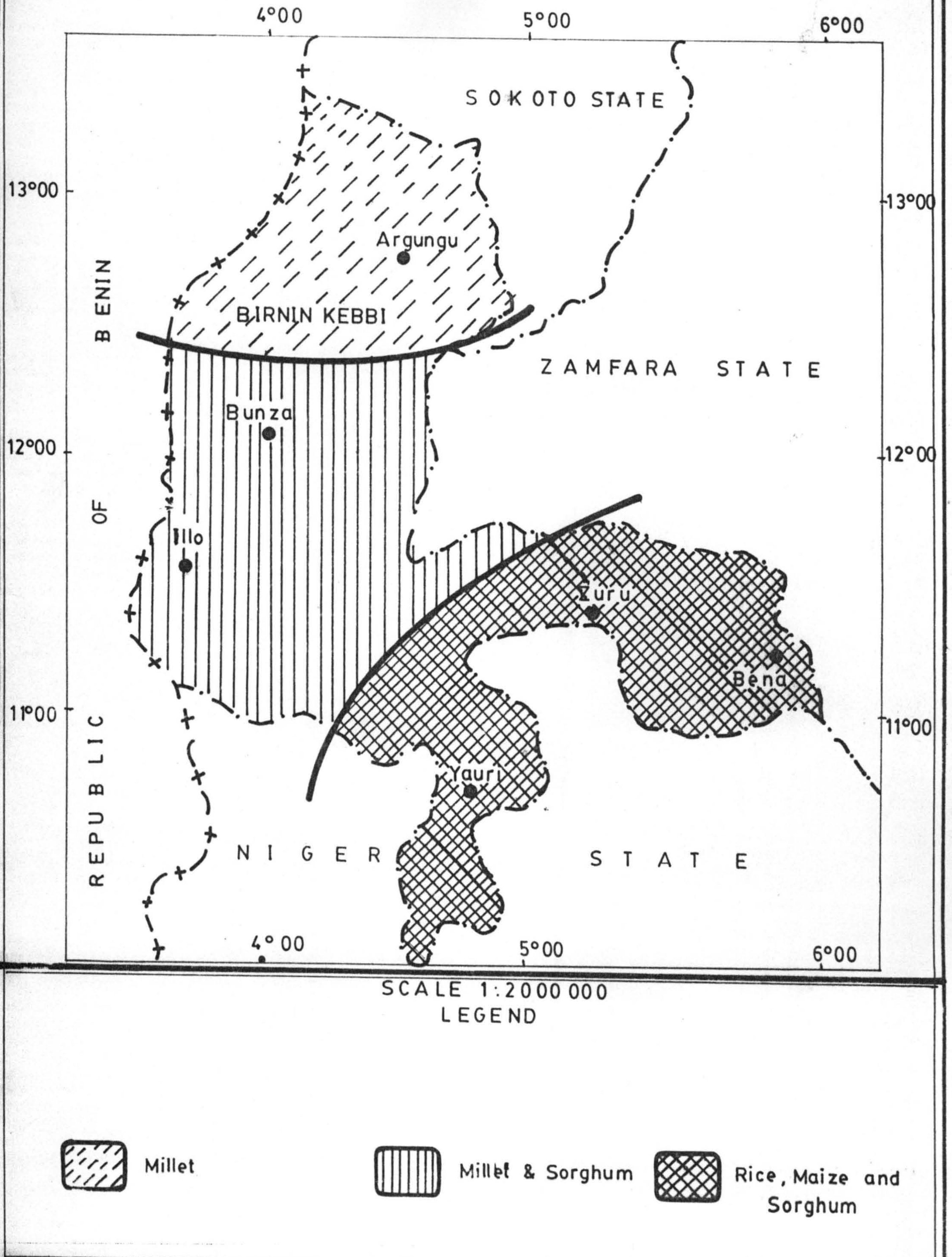


Fig. 5. CROP ZONES OF KEBBI STATE

CHAPTER TWO

2.0 LITERATURE REVIEW

This chapter gives a comprehensive account of what other researchers have said on millet production. This is tended to focus on five (5) aspects namely:-

i. Guinea corn (sorghum) and millet as important cereals in the desert fringe zone of Nigeria.

ii. Ecological requirements of millet

iii. Climatic factors of millet yield

iv. Other considerations influencing the cultivation of millet in Northern Nigeria

v. The problems and prospects of millet production in the desert fringe zone of Nigeria.

2.1 Guinea Corn (Sorghum) and Millet as important Cereals in the Desert Fringe Zone of Nigeria

Guinea corn (sorghum) and millet originated from Africa in the zone south of the Sahara where several dosely related wild species are found. The cereals are members of the gramineae (poaceae) family, producing small edible seeds used as forage crops and as food.

Millets was probably first cultivated in Asia or Africa more than 4,000 years ago (Robert et al, 19993).

Millets and sorghum are important food staples in much of Asia, Russia and West Africa. The millets especially are high in carbohydrates, with protein content varying from 6 - 11% and fat varying 1.5 - 5%. They are somewhat strong in taste and cannot be made into leavened bread. Instead they are mainly consumed in flat breads and porridges or prepared and eaten much like rice. Robert et al (1993) estimated about 30,000,000 metric tonnage of millets produced annually chiefly in India, China, Nigeria and Russia.

Basically, Guinea corn and millet are used for cooking food (tuwon dawa and gero). The cereals are also used for making pap (kunu) and equally used for brewing wine (burukutu and pito) and fura as well. Guinea corn and millet are most important cereals in the economy of Kebbi State because they are the major commodities in the inter-state food crop trade between Kebbi and other States.

2.2 Ecological Requirements of Millet

Millet can grow well on medium-light alkaline sandy loam soils (Akinsami, 1981). Many authors such as (MacDonald et al, 1990), Norman et al (1984), Gibbn et al (1988) and a host of others observed that peral millet (pennisetum americanum) is suited to soils of low fertility and limited moisture. Therefore millet can be grown in areas where the rainfall is low and is usually grown as a rainfed.

The crop is usually grown as a rainfed crop in the dry tropics and is the most important cereal in the desert fringe zone south of the Sahara in Africa (Gibbon et al, 1988). He further stated that millet will adapt well to light, sandy, low nutrient soils and will generally produce some yield every year in areas where sorghum might periodically fail. He stressed that millet is often dry planted or planted on the onset of rains before the rains are established in order to take advantage of the flush of nitrogen in the soil that occurs with the first rains.

According to Normal et al (1984), rapid and deep root penetration accounts for the drought tolerance of pearl millet. Salter and Goode (1967) on the same vein concluded that millet's resistance to drought is probably because of its well developed root system and effective internal control over transpiration.

Adefolalu (1988) and Damota (1980), stated that the distribution of rainfall during the growth cycle of cereals is more crucial than monthly or annual rainfall.

For instance, a rainfall of 100mm per month distributed evenly is preferable to 200mm per month which all fall in 2 or 3 days. Adefolalu (1991) further reports that the understanding of rainfall pattern and distribution is a pre-requisite for successful crop establishment and yield. For pearl millet in India, Mahalakshni and Bidinger (1985) found that water stress prior to panicle initiation did not affect grain yield on the main shoot, but increases yield on the tillers resulting in increased total yield while stress during panicles development did reduce grain yield on the main shoot, but this was compensated by increased number of tiller panicles producing grains. However, stress during flowering and grain filling reduces both grain components. Normal et al (1984) stated that, a deficit from antithesis on wards means that auxiliary tillers fail to develop grains and reduced evaporation increases temperature thereby reducing the grain filling period and hence grain size is small.

2.3 Climatic Factors of Millet yield

Climate has been assumed to be second to no other factor in determining the productivity of agricultural products but only a few areas of the world have climatic conditions that allow a wide range of food and non-food agricultural products to be produced. Even in those areas, farmers are sill better-off if they specialise in the production of those products that they can produce most efficiently (Thompson, 1991) and trade them most effectively (Moyer and Hollander, 1985).

Therefore, whilst plant growth, development and yield in the tropics, as elsewhere, is influenced by a wide range of physical factors including various climatic elements such as temperature, radiation, wind and humidity. In many cases water availability to plants or crops is by far a major control. Only in the humid tropics does water shortage not have an impact, but even here the characteristics of tropical rainfall and the fact that many crops require dry periods at certain growth stages have a marked influence on agriculture.

2.3.1 Water

Adefolalu (1983) rightly points our that plants do not only depend on the amount of rainfall received for growth, development and yield but on how much water is available to them (plants) as soil moisture. When this amount becomes available and the length in days/months during which the soil is able to retain enough moisture required, it will enhance good yield. Nieu Wolt (1982) equally points out that rainfall in the principal controlling factor or element in agriculture. This is because the amount of rainfall normally received decides which type of agriculture can be carried out and which crops can be cultivated in a region. The seasonal distribution regulates the agricultural calendar and the rainfall variability from year to year is the main factor responsible for fluctuations in yields and total production. Therefore water is an essential element to plant growth. Its role in photosynthesis is important and is also acts as the solvent and transportation agent for plant nutrients and provides turgidity in stem and leaves. Water uses in plants takes place in the process of transpiration by which water, absorbed by the roots is transformed into water vapour exhaled by the stomata of the leaves. This process is also necessary because it serves as a coolant to leaves, especially when these are exposed to the sun for long periods and therefore in danger of being damaged by excessively high temperatures. Because of these many functions, it is not surprising that lack of water or moisture stress, reduces the growth and development of plants.

From the on-going discussions, MacDonald et al (1990), Agricultural Compendium (1989) concludes that millet can be the most effective crop of he desert fringe zone because it does not only tolerate drought (adaptable to drought), withstands hotter conditions and the water requirements for millets are the lowest of all the cereals. Generally 200-300mm of well distributed rainfall during the growing season will support a crop even if drought conditions can often be meteorological and agricultural.

2.3.2 Temperature

Temperatures are of course closely correlated with insulation and its therefore not always possible to separate the effects of these two factors on plant life. However, it is certain that most physical and chemical processes in plants are strongly affected by the temperature conditions.

For each plants species, there exists an optimum temperature range at which growth and development proceed with maximum intensity and speed. Each species also has minimum and maximum temperatures beyond which the plant might be killed or sustain damage.

The agricultural compendium (1989) observed the optimum average daily temperature of about 28°C for millet crop. It is generally observed that temperatures within the desert fringe zone for millet production is at the maximum considering its ability to adapt to drought conditions.

2.3.3 Radiation

This is the continuous process that takes place in the parts of the plants. Plants are generally and highly sensitive to photo-periodic stimuli during the process of photosynthesis. Solar radiation or visible radiation are utilised by chlorophyll to produce dry matter from water and carbon dioxide i.e. production of dry matter depends on incoming solar radiation which the type of energy plants uses to exploit or manufacture food.

The differences between the gross photosynthesis and the proportion of its products used in respiration, called net photosynthesis is the rate of accumulation of plant materials in the growing plant (Agoolą, 1979). When rights are sufficiently in-available, the rate of photosynthesis is said to be proportional to the intensity of insulation called saturation light intensity (Nieu Wolt, 1982).

2.3.4 Wind

This is another climatic variable that assists in not only the lifting mechanism of water vapour but also results in saturation. Wind results in the movement of fresh air into contact with the surface. Turbulence varies with the vertical wind speed gradients. Wind determines the humidity of an area and atmospheric conditions (Jackson, 1977).

Humidity on the other hand is the amount of water vapour in the atmosphere. This consequently determines the presence of moisture in the atmosphere and as well as condenzation which leads to precipitation processes.

2.4 Other considerations influencing the cultivation of Millet in Northern Nigeria

Agboola (1979) observed that millet overlaps with guinea corn where over 60% of the cultivated land is devoted to millet and guinea corn. Phillip (1977) looked at pearl millet as more and richer in nutritive value than guinea corn, that is why it is grown in the north. Millet distribution in Northern Nigeria is that a high proportion of the most important producing areas are located within the sahelian zone where moisture conditions are marginal for crop production.

The crops ability to thrive in areas of limited moisture supply and to withstand long periods of drought explains its cultivation in such marginal areas. Sutherland (1987) confirmed millet's adaptability to drought, thus its cultivation in dry conditions.

Despite the crop's preference for dry conditions, it is grown as far south of latitude 10°N in parts of Borgu Local Government in Niger State and latitude 8°N in parts of Benue

State. Later-maturing varieties of millet (Dauro or Maiwa) which are transplanted when the wet season is already well conditions and explain the production in such southern locations.

Other considerations influencing the cultivation of millet in northern Nigeria despite the marginal natural of rainfall in the northern-most millet producing areas are:-

a. Fluctuations in the underground water table which is probably capable of affecting the crop's survival and yields in these areas. Grove (1985) for example has drawn attention to the shrinking in underground water levels between Pontiskum an Damaturu following the increased population density and land utilization and similar examples in Sokoto Daura and Zaria regions.

b. In western Borno State, the destruction of woodland appears to have reduced the losses by transpiration of water brought up from depth by the tree roots, thereby increasing the volume left to percolate deeply into the porous sedimentary rocks underlying the area (Grove, 1961). If the underground water comes sufficiently near the surface it may have favourable influences on crop production in such difficult environments.

c. Cultural and economic factors also influence the cultivation of millet in these more northerly locations. Firstly, there appears to be a high demand for millet grains relative to other grains. This demand is partly created by nomadic Fulani herdsmen who live in parts of the area during the wet season.

d. The demand for millet grains is also high among the local residents of the far north, because the crops is considered a better food than sorghum and is eaten by the wealthy (Papadaki's 1966).

Since millet has numerous uses such as food (tuwo), porage for (Fura and Kunu) and for beer brewing, the esteem of the local people for the crop probably explains the high prices it fetches in the parts of Katsina, Borno, Taraba, Bauchi, Sokoto and Kebbi States, to mention but just a few of them.

The cultivation of millet varieties in most localities depends on tribal food preferences because others prefer Dauro or maiwa than Gero. Luning (1963), as noted by Agboola (1979) that Fulanis prefer gero millet variety. As a result of these varied influences, large parts of northern states of Nigeria especially the main millet producing areas account for almost 70% of the country's total production (Agboola 1979).

2.5 Problems and Prospects of Millet Production

In spite of millet varieties grouped into early (75 - 100 days) and late (120 - 200 days) types, the late types are length sensitive and do not head (flower) until near the end of the rains. This will allow them to escape serious fungal head mould and insect damage. Uguru (1981) summarised the factors that affect crop production generally as climate, the nature of the soil, the incidence of pests and diseases, topography and economic considerations. Leonard (1986) considers low soil moisture as a major factor limiting fertilizer response on millet, an d traditional varieties also tend to be less responsive to fertilizer.

CHAPTER THREE

3.0 RESEARCH METHODOLOGY

This chapter highlights the type and source of data collected as well as the methods used in data analysis.

Maunder (1970) has generally observed three days of establishing the importance of climate agriculture relationships:-

i. The study of the fundamentals of plat-climate relationship namely the radiation and moisture balance for various crops in various climatic environments.

ii. The study of agricultural and climatic data for a number of places within a given area in order to deduce agro-climatic relationships from the analysis of data.

iii. The method involves studying plant-climate relationship under controlled environment. Therefore in relation to the objectives of this study, the second method which involves the analysis of agricultural and climatic data will be considered.

The reasons for choosing this method is two fold. In addition to showing the association between several climatic elements and agricultural production, this method enables the prediction of agricultural production based on a statistical analysis of climate and crop yield.

3.1 Data

Two sets of secondary data will be collected for this study. These include, first millet yield (Kg/ha) on local government basis. The second one will be those of the basic agro-climatic elements influencing millet growth and yield. These will include:

But because of millets tolerance to drought, and its less susceptibility than other cereal crops within the desert fringe zone and its economic importance and food preference by many people in the northern states, its production should therefore be encouraged in order to reduce famine and hunger in times of severe drought attacks.

a. Observed and derived rainfall parameters such as:-

- Daily, monthly, annual rainfall and number of rain days
- Onset, cessation and length of rainy season
- Dry spell
- Hydrologic ratio (the degree of wetness and dryness)
- Specific water consumption

b. Air temperature °C (minimum and maximum)

c. Relative humidity (%)

d. Sunshine in hours

e. Evaporation (mm/days)

f. Total radiation (Cal cm^{-2})

Data on millet yield will be obtained from Kebbi State KARDA for each of the Local Government Headquarters for the period 1986 - 1996. This is the longest period for which records of millet yield are available in the State. Data on climatic elements will be collected from KARDA and Ministry of Agriculture Kebbi State for a period of at least 10 years for each of the Local Government Headquarters.

3.2 TECHNIQUES OF DATA ANALYSIS

3.2.1 Agro-climatological Analysis

The daily rainfall will be used in calculating the mean monthly, seasonal and annual rainfall for the State. From the records of rainfall, the following derived precipitation effectiveness indices will be computed as follows:-

i. The Onset, Cessation and Length of Rainy Season

Various methods from several scholars have been adopted for computing these indices e.g. by Walter (1967), Ilesanmi (1972), Olaniran (1988). However, it has been noted that the Ogive method using daily rainfall data is more accurate (Adefolalu, 1993). This method will be used in this study where daily rainfall data are available. Where daily rainfall are not available, the Olaniran (1988) modified version of Walter's (1967) method will be used.

The method is applied so that for the start of rainy season - days of the month:

$$\frac{51\ \text{Accumulated Rainfall Total of Previous month}}{\text{Total Rainfall for the month}}$$

Where the month under reference is that during which the accumulated total of rainfall is in excess of 51mm. However, if the month following is less than 51mm of rainfall, the previous month is disregarded and the next month with more than 51mm of rainfall is taken as the month of the start of rainy season. For the end of the growing season the formula is applied in the reverse order from December.

ii. **Rainfall Seasonality Index**

Rainfall seasonality index will be computed using the method of Walsh and Lawler (1981). According to their method, the seasonality index is the sum of the absolute deviations of mean monthly rainfalls from the over all monthly mean divided by the mean rainfall.

$(S^1 = 1/R\ /xn - R/12)$

here S.1 = Seasonality index

xn = Mean rainfall in month

R = Mean annual rainfall

iii. **Hydrologic Ratio** (λ)

As noted by Adefolalu (1988), Hydrologic Ratio could be defined as the ratio of mean annual rainfall to the potential evaporation (PE).

This value symbolizes soil moisture deficiency or surplus. According to Duckham (1994) this index helps with decision making in agriculture, because it provides a guide on the e best choice of the area/plot where a particular types of crop will not only thrive but will equally have high yield or reach optimum growth level.

iv. **Specific Water Consumption (w/f)**

This has been defined by Flohn et al (1974) as the water equivalent to avert drought in areas of rainfall deficiency. It is the exact amount of water that will be needed to irrigate a field for effective plant growth, development and yield. That is, the quality of water needed to bring to the field planted with crops to a point where the hydrologic ratio will be equal to unity.

The specific water consumption is calculated as follows:-

W/F = Length of Wet period + D dry (Q dry - p dry)

Where W/F = Specific water Consumption

Dwet = Length of wet period in days

Qwet = Water demand equivalent of PE during wet period in (mm/day)

Pwet = Average daily precipitation during wet period

Ddry = Length of dry period in days

Pdry = Maximum water demand equivalent of PE during dry period (mm/day)

Pdry = Average daily precipitation total during dry period (mm/day)

PE = Potential evapotranspiration

For semi arid environment, latitude 10 - 20°, where water demand is very high, Flohn et al (1974) used the following values:

Qwet = 4.78mm

Qdry = 3.88mm

These values will be used to compute W/F for the stations in Kebbi State that fall within the latitudinal range, while a correction factor based on the study of Adefolalu (1988) Q will be used for the places below Latitude 10°.

3.2.2 Analysis of Inter-relationship between Climatic Factors and Millet Yield

The relationship between millet yield and the estimated agro-climatic variables above will be analysed using multiple correlation and regression analysis. In order to identify the agro-climatic factors that are critical to millet yield, step-wise multiple regression analysis will be used. The step-wise multiple regression has the ability to include in the equation only those variables that contribute significantly to the variation in the dependent variable. This is achieved by systematically adding terms one at a time to the regression equation.

The general form of multiple regression model for K independent variables is $Y = a + bx1 + bx2 + bx3 \ldots bn$

Where Y = Yield of millet (Kg/ha).

$X_1, X_2, X_3, \ldots\ldots\ldots xn$ are the agro-climatic variables that are significantly correlated with millet yield.

3.2.3 Forecast Model

In order to predict the yield of millet in the State multivariate analysis namely multiple regression analysis will be adopted to design crop-climate model for millet in the study area.

3.2.4 Agro-Climatic Zoning for Millet Production

Based on the precipitation effectiveness indices outlined above, the State will be delineated into proper zones for millet production.

This will involve preparation of maps showing climatic potential areas suitable for the cultivation of millet.

CHAPTER FOUR

4.1 COMPREHENSIVE DATA ON MILLET YIELD

A comprehensive data on millet yield was obtained at the various zones of Kebbi Agricultural and Rural Development Authority (KARDA). These zones are Argungu, Yauri and Zuru. Argungu zone 1, Yauri Zone II and Zuru zone III. This data including that of rainfall for the state was mainly for 6 years.

The weather parameters within which the data was available was rainfall, Temperature, Relative Humidity; and Radiation. This data was compiled in appendix 1-5 respectively.

Table 1: MILLET YIELD IN THE THREE ZONES

ZONE	MILLET YIELD IN TONNES
I	428261.40
II	215393.85
III	32503.83
TOTAL	676159,08

Source: KARDA, 1997.

From the data so far collected, it is clearly shown that Zone I which is Argungu area produced more millet than other zones, followed by Zuru and Yauri Zones. This could be because in that zone, millet is the predominant crop cultivated and it is the staple food crop of the teaming population living around the zone. Because of non-availability of adequate data on millet yield by local governments in Kebbi State, a comprehensive table on millet is not prepared.

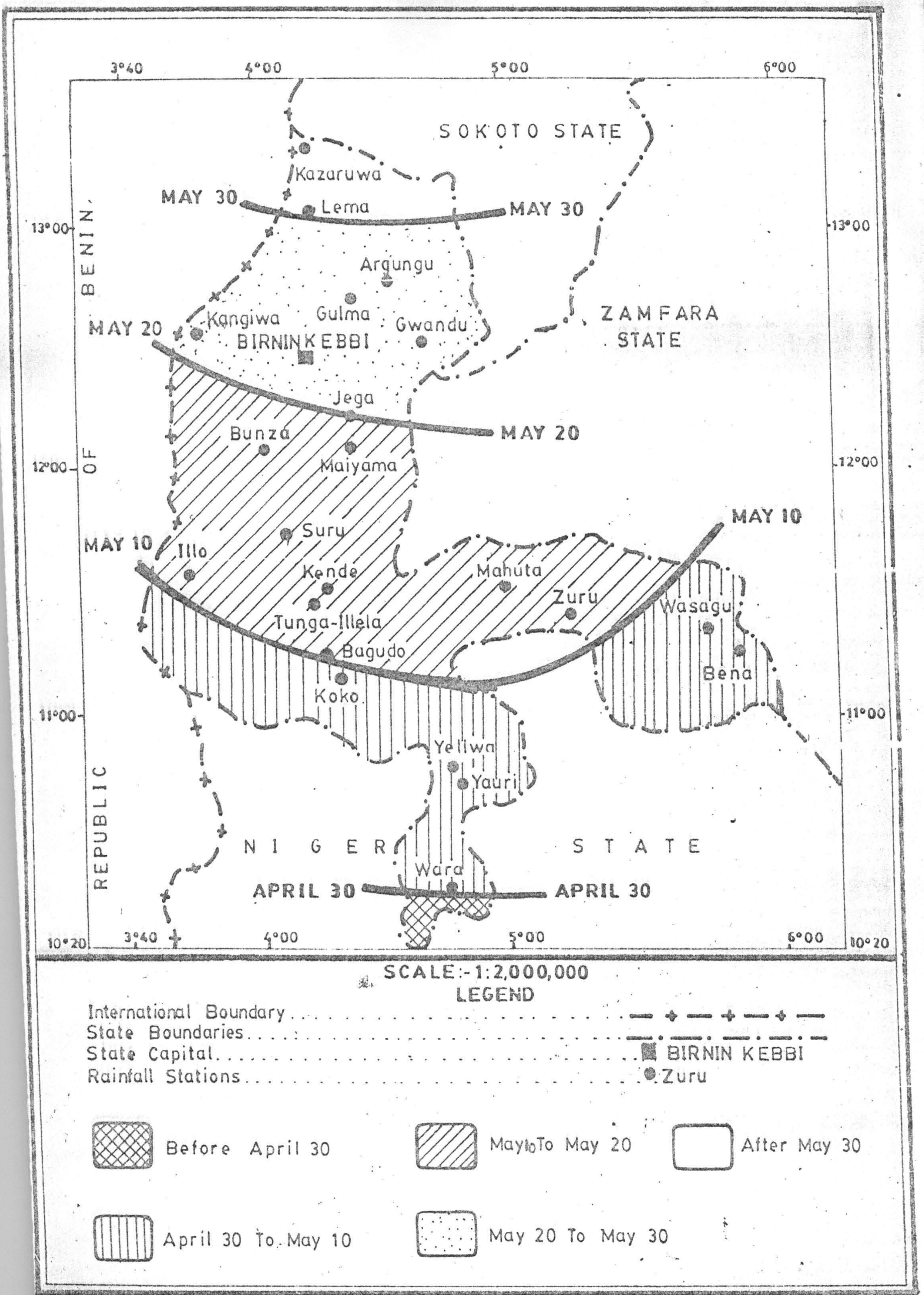
4.2 ANALYSIS OF AGRO-CLIMATIC FACTORS AFFECTING MILLET YIELD

The Agro-climatic factor affecting millet yield are mainly precipitation indices such as the onset (∅) dates of rains, Cessation (⊄) dates and the length of rainy season (LRS).

The onset of rain affects millet yield because it determines the planting or sowing period. That is, if the sowing date of millet is early, it will enhance its proper development, maturity and yield. The onset of rains enables the farmer to plan the planting date in order to ensure unanimously distributed planting date to reduce the evading activities of birds and other insect pests which attack the crop at its production stage.

The cessation dates determined the crop maturity while the length of rainy season determines the crop productivity and yield. Fig. 6(a) - (c) explains the onset dates, cessation and the length of rainy season in Kebbi State.

In Kebbi state, the pattern of rainy season moves in a transition form, from the southern part to Northwards. In the southern part of the state beginning from Utono in Ngaski Local Government area, the onset date of rainy are around April 30 to May 10. All other stations or areas receive a progressive transition from one area to the other at the onset dates from May 10 to May 30 onwards towards the tip end of Kebbi state. However, with climate anomalies (fluctuations) the onset dates could be before May and sometimes it could be extended to June. Meanwhile, the onset dates of rains divides the state into 5 transition zones as it is shown in fig. 6a.


3°40
4°00
5°00
6°00
SOKOTO STATE
Kazaruwa
MAY 30
Lema
MAY 30
13°00
BENIN
Argungu
Gulma
Kangiwa
Gwandu
ZAMFARA
STATE
MAY 20
BIRNINKEBBI
Jega
Bunza
MAY 20
Maiyama
OF
12°00
MAY 10
Suru
MAY 10
Illo
Kende
Mahuta
Zuru
Tunga-Illela
Wasagu
Bagudo
Bena
Koko
11°00
Yeliwa
Yauri
REPUBLIC
NIGER STATE
Wara
APRIL 30
APRIL 30
10°20
SCALE:-1:2,000,000
LEGEND
International Boundary
State Boundaries
State Capital
BIRNIN KEBBI
Rainfall Stations
Zuru
Before April 30
May 10 To May 20
After May 30
April 30 To May 10
May 20 To May 30

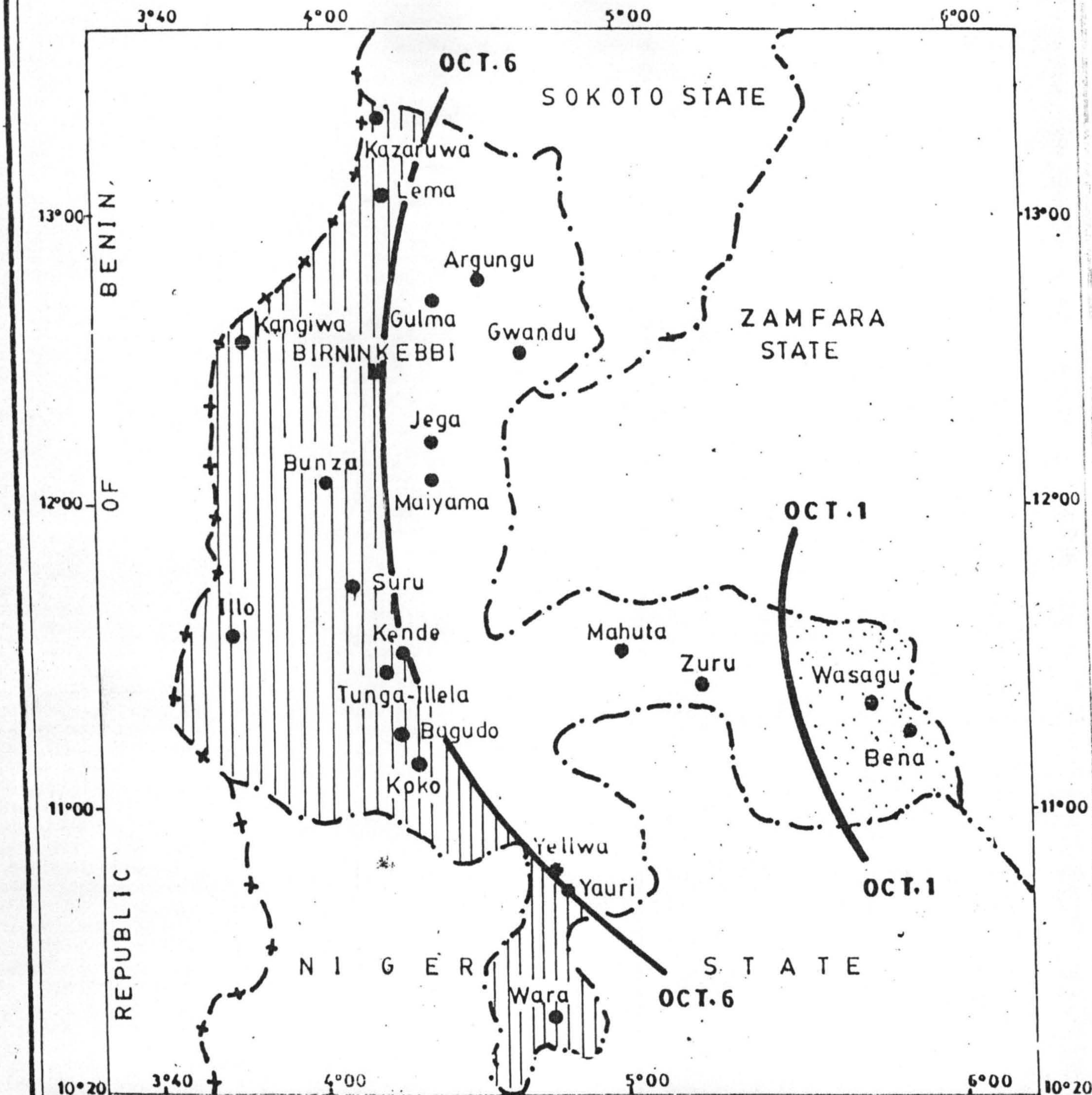
The cessation dates zoned Kebbi State into three (3) major segments. The first two segments covering about 1¼/3 of the state while the third portion covered only ½/3. The first segment showed a cessation date to be after October 6, the second from October 6 to October 1 and the third could be before October 1, see fig. 6(b).

Fig. 6(c) tends to summarise the whole mean onset and cessation dates. It has rather zoned the state into southern from latitude $10^{0}20'$N to Latitude $10^{0}55'$N and the Northern part from Latitude 11^{0}N to Latitude 13^{0}N of areas over Kebbi state.

4.3 IMPLICATION TO MILLET PRODUCTION:

Sowing date had significant effect on the yield of millet. This is because the onset date of rain determined when millet could be planted. Although diversification of crop is more widely practised in the southern part of the study area, it declined gradually into the Northern part of the state virtually to the three major crops viz:- Millet, Sorghum and Cowpea. These patterns were in tune with the agro-climatic conditions of the three regions. Absolute area under different crops in terms of sole crop equivalent are presented in table 2 below.

Though sorghum is grown by more households, but in terms of area, millet accounted for the single largest share crop area followed by sorghum cowpea and maize. Over the years, this allocation remained fairly the same. Two crops which have been gaining ground over the years are maize and ground nuts. The farmer being the more important.



SCALE:-1:2,000,000

LEGEND

International Boundary
State Boundaries
State Capital .... BIRNIN KEBBI
Rainfall Stations .... Zuru

After October 6

October 6 To October 1.

Before October 1

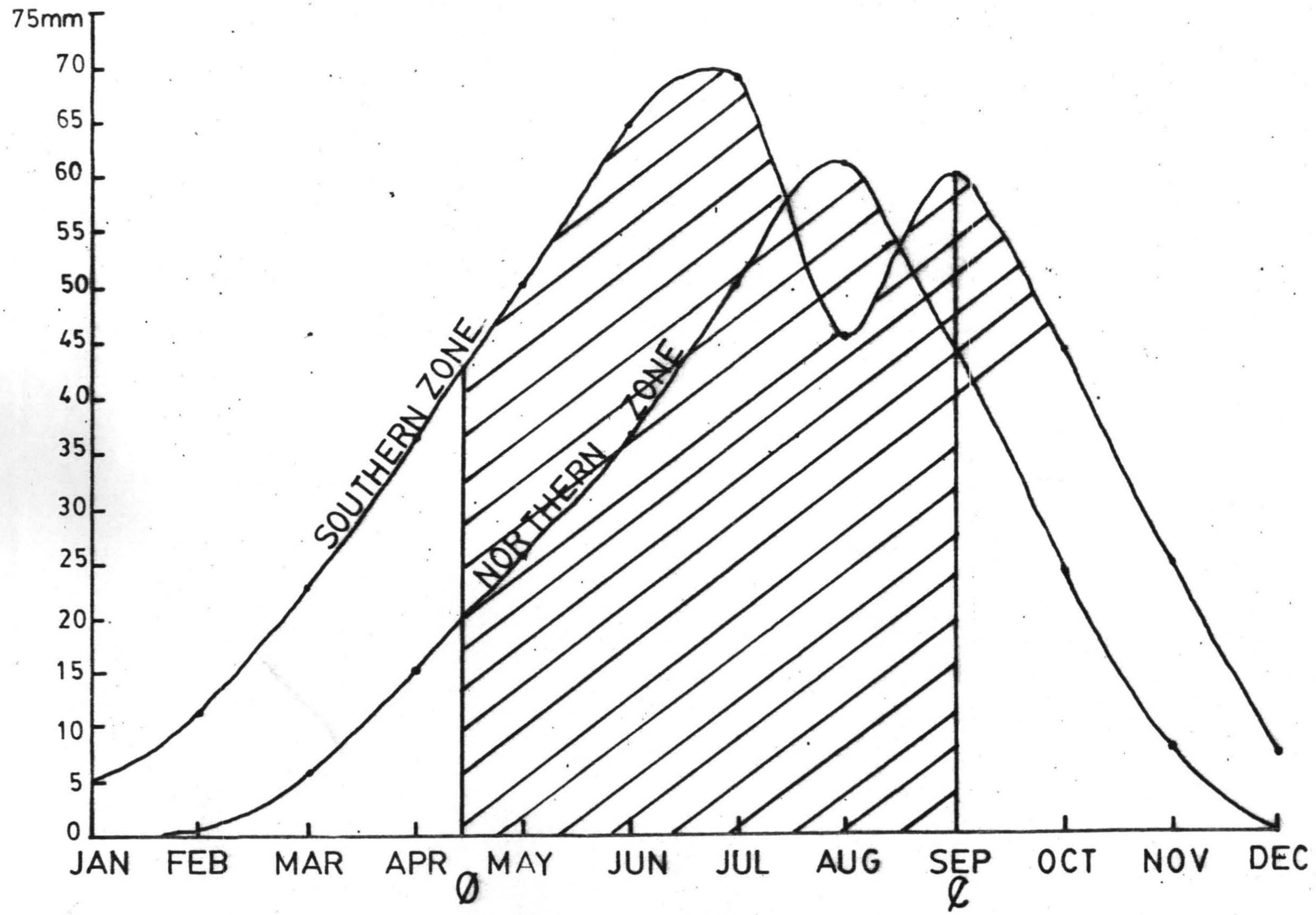


FIGURE 6(c) Mean Rainfall For The Southern (Southern to Latitude 10° 55'N) and the Northern (Latitude 11°N to Latitude 13°N) Areas Over Kebbi State.

Local varieties of maize were grown on a small scale for a long time and these were mainly for table purposes. Of late, thanks to stoppage of import of maize, commercial cultivation with improved varieties has begun. Areas under rice mustard and other minor crops fluctuate with rainfall pattern. Good and heavy rains help both rainfed and deep water rice cultivation. Good rains in July-August and forecast of good rains to follow till October leads to increase in area under rice. Other minor crops occupy the areas which are later for planting or those plots which become fallow after the first planted crops dry away, but too late for replanting.

The important trends emerging in respect of crop patterns are:

- Crop mixtures are more favoured and may be more rotational
- Three crops mixture is being adopted increasingly by farmers.
- Cash crops like maize and groundnut are slowly gaining importance in the cropped area.

Millet as a crop under study is more preferred by the farmers because of the tolerance of the crop to drought, because of food preference and because of the varieties that are planted within the year. It is possible to plant the crop twice in a year, the way several other crops are planted in the southern part of the country.

The millet grown within the study area are of three types including: Gero which is the early type. It is planted at the onset dates of rains. It is also of two categories: the hairy type which protects the grains from attack of birds (queller-birds) from destroying the grains and the non hairy type.

The late type which is planted between the months of July and August ending includes Maiwa and Dauro. The farmers believe that the late crops, Maiwa and Dauro, are leisure crops because the farmers grow them "at will". That is, the crops are grown after most of the tedious work of other early planted farms must have been exhausted or been completed.

4.4 KEBBI STATE RAIN FALL REGIONS:

Table 2 shows the average rainfall in Kabbi state.

REGION	AVERAGE RAINFALL (mm)	NUMBER OF RAIN DAYS	NORMAL RAINY PERIOD
SOUTHERN BELT	783	52	EARLY APRIL - LATE OCTOBER
MIDDLE BELT	650	46	LATE APRIL-EARLY OCTOBER
NORTHERN BELT	600	40	EARLY MAY - LATE SEPTEMBER

As mixed cropping is the tradition of farmers in Kebbi State, millet is always sown first, sorghum a week or 10 days later. If rains get delayed, the early planting season is missed and thereby the early season crops or if subsequent rains are not favourable, the late season crops are not planted. Even when planting takes place regularly, germination may be poor or nil due to prolonged stress period immediately after planting where hope for replanting may not exist and therefore the field may remain a sole crop field with one of the crops that weather the stress.

The inherited wisdom of farmers by experience, that mixed cropping is an insurance against risks from erratic rains, is still enforced or practised.

In fact, according to Imam (1983) and Bamidele (1986), early planting (thereby meaning early rains) leads to higher yield of crops, other things remaining equals. It has also been observed that breaks (i.e. dry spells) during the course of a particular rainy season, especially 1997 within the study area, that false onset of rains are equally important to note in the planting planning purposes as prolonged dry spells are injurious to plant life, while late rains may cause potential losses. It is now recognised that these last characteristics of summer rains cause more drastic drop in crop yields than what 50 percent reduction in actual recorded rainfall may 'create'.

The false onset of rains made farmers to plant early, and they later become discouraged as the rains become erratic, which consequently leads to the wilting of crops after germination.

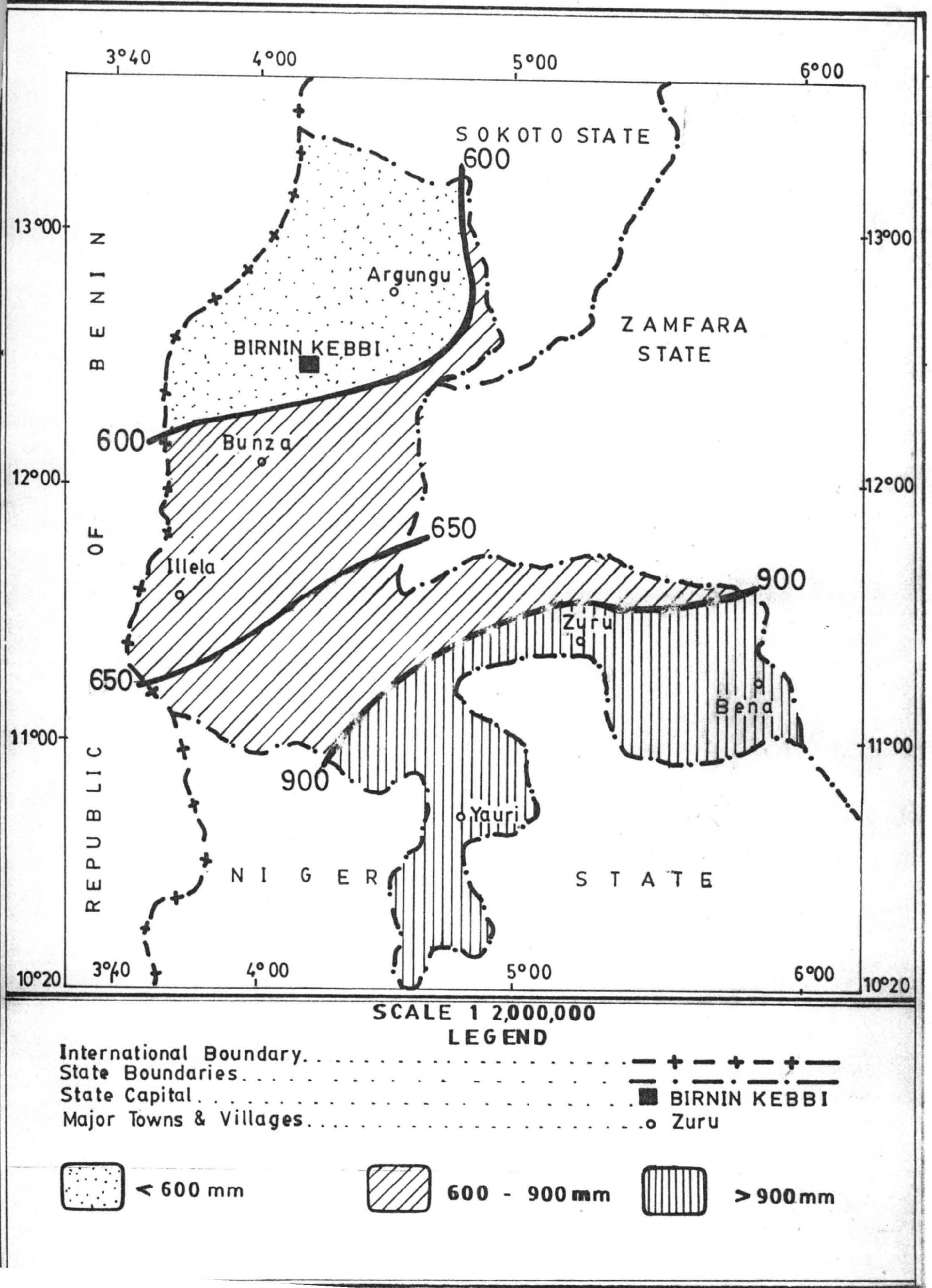
In other areas where the rains are somewhat stable and normal, and bumper harvest anticipated, the incidence of pests like the stem borers and brister beetle insects cause a general draw-back in millet production, especially the year 1997 (see fig. 7).

4.5 YIELD LEVELS

Since sole cropping is not widely practised in Kebbi State, it is difficult to work out the average performance of different crop varieties. Further, among other things, rainfall pattern has very strong influence on the crop yields as shown by the high correlation co-efficient as given below.

TABLE 3: CORRELATION CO-EFFICIENT: RAINFALL v/s YIELD

DEPENDANT VARIABLE			INDEPENDENT VARIABLE
	RAINY DAYS	DURATION OF RAINY SEASON	OCTOBER RAINS
MILLET YIELD	0.496	0.590	0.216
SORGHUM YIELD	0.865	0.883	0.664


3°40
4°00
5°00
6°00
SOKOTO STATE
600
13°00
12°00
11°00
10°20
Argungu
BIRNIN KEBBI
ZAMFARA
STATE
REPUBLIC OF BENIN
600
Bunza
650
Illela
900
Zuru
650
Bena
900
Yauri
NIGER STATE
SCALE 1 2,000,000
LEGEND
International Boundary
State Boundaries
State Capital
BIRNIN KEBBI
Major Towns & Villages
Zuru
< 600 mm
600 - 900 mm
> 900 mm

COWPEA YIELD	0.901	0.932	0.700

Thus, the yield levels do fluctuate with rainfall pattern. There was, however a clear trend of increasing yield levels of almost all crops. Over the years, either as sole crop or mixtures among the crops, millet showed a consistency in yield and steady progress. Millet seemed to be more tolerant to vagaries of weather and other practices. It has both drought resistance and drought evasiveness and as such this is the first line of crop grown as food security enterprise while others follow depending on the rain.

Rains at grain formation state ensure good yield of late season or long duration crops. In normal years, millet grown as mixed with sorghum and cowpea than sole crops yielded better (Hussaini, 1987).

4.6 CROP RESPONSE TO FERTILIZERS

This exercise would have required data on the base soil nutrients and nutrients added, but the data used here is only that of added nutrients. This is because the soils in some parts of Kebbi State have been found to be deficient in nutrients particularly nitrogen. The survey done by the Land use planning section of Sokoto Agricultural and Rural Development Authority (SARDA 1986) and the present low level of fertilizer application, the non-availability of data relating to base soil nutrients will not be a major short coming to the extent of affecting the results.

The simplest method of assessing the crop response is to compare the mean yields of crops of fertilized and un-fertilised fields. To this a (T) test can be administered to find out if there is any significant difference between these means. This method of comparing mean yields, however, is often criticised as inappropriate due to the likelihood of fertilizer application practice by farmers based on the soil fertility than crop enterprise, and as such unfertilised plots are likely to be more fertile than fertilised plots. This problem can be overcome by a regression analysis with crop yields as dependent variable and fertilizer quantity as independent variable. All these methods have been attempted in this exercise. The discussion on fertilizer response is restricted to three major crops viz:- millet, sorghum and cowpeas. They account for nearly 70 per cent of the fertilized area.

All the fertilizers have been converted into their active ingredients and further transformed into Nitrogen equivalent using the price differential for different nutrients. The major results of crop for response will therefore be presented as response to Nitrogen. From this data, a frequency table for yield ranges to pre-determined nitrogen levels was prepared. The frequencies thus arrived at were multiplied by the midpoint of the yield ranges under each level of Nitrogen. This formed the basis for arriving at mean yield for a specific nitrogen level.

4.6.1 CROP YIELDS UNDER FERTILIZED CONDITION:-

Crop yield under unfertilized and fertilized conditions as practised by farmers and yields under project package demonstrations for the yeas 1993 to 1996 presented in Table 4 clearly indicated the substantial yield gap.

TABLE 4: YIELD GAP ANALYSIS

(YIELD KG/Ha - 1993 - 1996 Average)

CROPS	UN-FERTILIZED		FERTILIZED
MILLET	809	1043 (29)	1449 (79)
SORGHUM	806	1146 (48)	1757 (118)
COWPEA	612	1244 (103)	1620 (155)

The figures in brackets are percentage increases over unfertilized plots, project package. Out yields impressively both unfertilized and fertilized yield levels of farmers. Fertilized fields were better in yield levels. Highest potential exists in cowpea followed by sorghum and millet in that order. Behzad (1984) founded similar trend in other parts of Sokoto State, by following the recommended fertilizer package. There is scope to double the yield when proper and adequate fertilizer package is applied.

Specific crop response were worked out for these crops presented in tables, though the correlation Co-efficient were low, positive relationship was shown by sorghum and millet to fertilizer. This was basically because of very high variability off data. For millet, the responses could have been higher if the fertilizer application methods were proper. The present practice of farmers is in-effective due to loss through evaporation and leaching. The regression analysis discussed elsewhere in the study brought out the effect of fertilizer more clearly.

Although investigators have long tried to find out the precise relations between Agricultural output, as expressed in terms of crop yield or production by simple readily available weather data such as temperature and rainfall, in many cases these studies are still the only ones possible, since more refined measures of climatic environments are not available, In recent years, however, with improved instrumentation, it has been possible to begin to relate Agricultural output to such factors as soil temperature or soil moisture content, to radiation or derived climatic indices that reflect how well the vegetation is untilizing the energy and water potential for the growth and development. Use of these more active climatic factors has resulted in the achievement of significant correlation between climatic factors and yields.

Other climatic indices that need consideration are the Hydrologic Ratio (A) and water equivalent to avert drought which are discussed as parameters for effective precipitation.

4.7 PARAMETERS OF PRECIPITATION EFFECTIVENESS IN KEBBI STATE

The characteristics and other rainfall, amounts constitute an important data set for understanding the rainfall features of Kebbi State for general planning purposes. However, planning in relation to crop yield, rainfall amount alone can not give adequate certainty in terms of what crops need to give optimum yield. Therefore it is essential to compute applied parameters based on the same actual (observed) rainfall for effective planning (Adefolalu, 1993). Two of those applied parameters which are used recently are the hydrologic ratio and specific water consumption (W/F) as postulated by (Adefolalu, 1988, 1993). and (Duckhan 1994). The spatial variations of these parameters and their implication to Agricultural planning in Kebbi State are of paramount importance and need to be discussed.

4.7.1 HYDROLOGIC RATIO (λ)

The term hydrologic ratio has been defined as the ratio of mean annual rainfall to the potential evapotranspiration which means soil moisture deficiency or surplus with the value equal to unity defined as hydroneutral condition. The index helps in making decisions in Agriculture because it serves as a guide on the best choice of area or plot where a particular type of crop will not only thrive, but will equally produce higher or optimum yield.

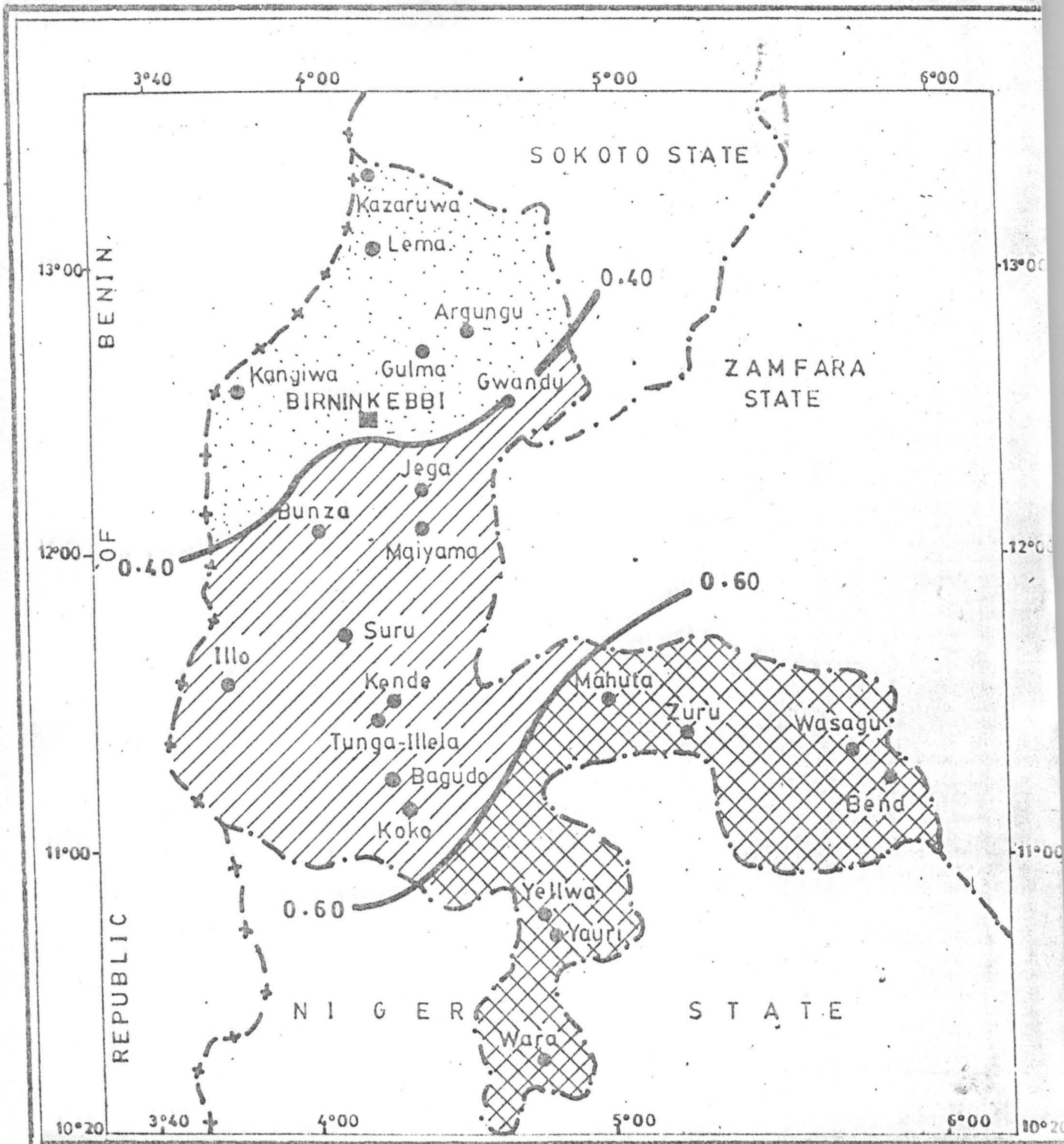
The pattern of hydrologic ratio in Kebbi state is illustrated in fig. 8 thus:

There is no hydroneutral zone in the state. The hydrologic ratio ranges from 0.60 in the south to 0.20 in the extreme North western part of the state. For about two thirds ($^2/_3$) of the state (latitude 12^0N and above) the ratio is less than 0.40. This zone has long dry season of at least seven months. Because crop yield is expected to be poor in this zone, therefore, irrigation farming is highly required.

Hydrologic ratio of 0.40 to 0.59 are found between latitude $11^0$20'N and 12^0N. This zone will also require supplementary irrigation during drought spells for crops to reach maximum potential yield level.

Pure rainfed agriculture for short variety crops are possible between 10^o00N and $12^0$30'N where the values of hydrologic ratio ranges between 0.45 and 0.60.

For the rest of the state south of Zuru (latitude 11^0.00'N) downwards the hydrologic ratio is above 0.60. In this zone rainfed agriculture for all types of crops can be practised.



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LEGEND

International Boundary . . . .

State Boundaries . . . .

State Capital . . . . BIRNIN KEBBI

Rainfall Stations . . . . Zuru

Good Soil Moisture Surplus During Rainy Season.

Fairly Satisfactory Soil Moisture Surplus During Rainy Season.

Dry Zone Low Soil Moisture all the Year Round Due to high Evaporation.

4.7.2 PERCENTAGE OF OCCURRENCE OF RAIN HOURS

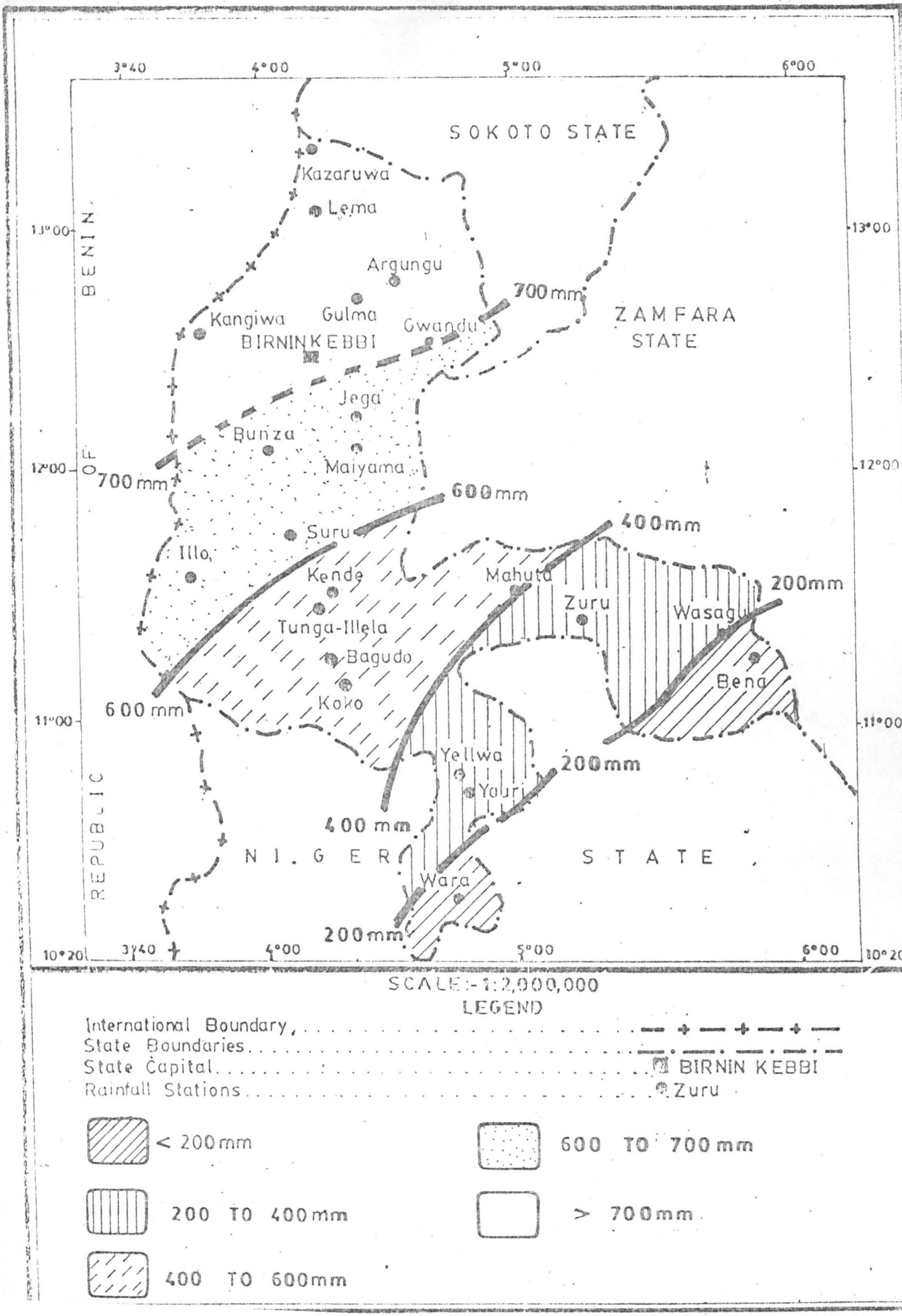
Although the dry season is of a much longer duration than may be observed for all the places considered so far, it commences as early as at the end of September and ends as late as mid June.

The rainy season is this brief and limited to the period mid-June to late September, with low probability values. The highest rainfall probability occurs from night time to early hours of the morning. This shows that lines squalls contribute more to local rainfall than local storms even in September when a late evening maximum probability is observed, this interpretation still holds.

4.7.3 SPECIFIC WATER CONSUMPTION (w/f)

The dry spells and other hazards posed by high rainfall variability to agriculture within the tropics, there may be the need to provide additional water in form of irrigation to ensure adequate soil moisture for plants during the growing season. The method of quantifying the amount of water needed to irrigate a plot of land at a given location is the specific water consumption (w/f). Flohn et al (1974) defined this as the water equivalent to avert drought. It is the exact amount of water that will be needed to irrigate a field for effective plant growth, development and yield.

Kebbi State can be divided into two zones: the zone of deficit soil moisture (positive w/f) and the zone of surplus soil moisture (negative w/f). The zone of deficit occupies about $^2/_3$


3°40
4°00
5°00
6°00
13°00
12°00
11°00
10°20
SOKOTO STATE
ZAMFARA STATE
BENIN
REPUBLIC OF
NIGER STATE
Kazaruwa
Lema
Argungu
Gulma
Kangiwa
Gwandu
BIRNINKEBBI
Jega
Bunza
Maiyama
Suru
Illo
Kende
Tunga-Illela
Bagudo
Koko
Mahuta
Zuru
Wasagu
Bena
Yellwa
Youri
Wara
700mm
600mm
400mm
200mm
SCALE:-1:2,000,000
LEGEND
International Boundary
State Boundaries
State Capital
Rainfall Stations
BIRNIN KEBBI
Zuru
< 200mm
200 TO 400mm
400 TO 600mm
600 TO 700mm
> 700mm

of the state consisting of all places above Latitude $11^0.30'$N. In this zone W/F ranges from +5 to +850. Generally there is a south-north increase in the w/f values. The zone of surplus water occupies the remaining $^1/_3$ of the state, south of latitude 11^0N. See fig 9.

In the Northern part of the state a delay in the onset of rains can be disastrous. This is because it is in the zone of climate variability where precipitation creates the worst drought hazards where a slight departure from the mean may be a critical factor in crop failure. There are degrees of drought and consequently drought damage prolonged drought alter the pattern of Agricultural land-use in a major scale in the state. For instance, the people of Kukan Tonkara had to migrate to the neighbouring Niger State as a solution to drought incidence. Therefore refined means to sustain agriculture and modify constant drought stricken areas through irrigation and irrigation schemes need be pursued.

4.8 CROP ZONES OF KEBBI STATE:

It is a well known fact that rainfall intensity determines the cropping pattern in the country. As the plant population density decreases Northwards in an upward trend in rainfall, the type and nature of crop equally follows the same pattern.

In the southern zone of Kebbi state, people plant longer duration crops like Guinea corn, maize and rice and the variety of millet is planted twice, especially Gero, maiwa and Dauro species.

In the middle belt of Kebbi State, longer duration crop declines in planting as the millet increases. While at the extreme Northern belt, millet dominants all other crops except cowpea of quick yielding variety. Fig. 5 shows proper delineation of crop zones as dictated by agro-climatological zonation of Kebbi State.

TABLE 5 CROPPING PATTERN

(PROPORTION OF CULTIVATED AREA: 1990-1996)

Crops	1990	1991	1992	1993	1994	1995	1996	Total	Average
MILLET	38.8	33.2	35.9	36.0	38.9	34.9	37.5	225.2	36.46
SORGHUM	28.9	30.9	29.2	29.3	28.9	30.8	29.7	207.7	29.67
MAIZE	0.4	3.0	3.4	2.3	3.5	3.3	2.6	18.5	2.64
COWPEA	22.0	18.5	25.7	22.1	20.9	23.1	22.5	154.8	22.11
G/NUT	1.8	2.6	3.4	2.6	4.0	3.8	3.3	21.5	3.07
RICE	1.2	2.4	10.5	25.1	20.8	22.0	22.1	104.1	14.87
OTHERS	6.4	8.6	0.2	5.1	6.8	5.7	5.6	38.4	5.49

SOURCE: KARDA 1997.

Of all these crops mentioned above, the onset of rains determines the planting season of them especially millet, sorghum, maize, rice etc. and the length of rainy season determines their growth development and yield. Fig. 6a-c summarises both the onset (Ø), cessation (¢) and the length f rainy season (LRS) simultaneously as they affect crop development and yield.

One definite indication available from the data is that rainfall is a positive and substantive factor in determining agricultural production under rainfed cultivation. The study area has been sub-divided into three rainfall regions for easy identification and analysis of crop performance as shown elsewhere in table 3 above.

Plate 1. Typical maiwa farm crop in Birinin Kebbi area

Unweeded farm land at the milking level of the crop.

Plate 11 Typical Dauro farm crop in Zuru area.

Plate 111. typical Guinea corn farm crop in zuru area.

Guinea corn farm at the maturing state.

Plate iv. Typical maize farm crop in yauri aeea.

Plate 2a and b Maize and cowpea mixture.

4.9 REGRESSION ANALYSIS

In order to find out the effect of various factors affecting yield level of crop, regression analysis was carried out. The regression model used was a multiple linear regression:

$$Y = a + b x 1 + b x 2 + \text{----} bx n.$$

4.9.1 IDENTIFICATION OF THE VARIABLES

In identifying the variables, the basic characteristics of Agriculture in the region have to be kept in view. These characteristics include, the rain dependant upland agriculture which constitutes 90 percent of the cultivated area, low level of fertilizer adoption, plant spacing and other interculture operations needed.

DEPENDENT VARIABLE

YIELD:

This is the dependent variable. The analysis in the study is confined to dominant crops, viz: Millet-Sorghum-Cowpea. Yield as a dependent variable is treated as total yield of all the component crops in the mixture and as individual crops.

4.9.2 RAIN FALL:

The rainfall as a single or general variable was considered inappropriate as the planting practice followed here and the pattern of rainfall posed some specific problems. For instance, millet is the earliest crop to be planted and earliest to be harvested. This is followed by sorghum and then cowpea. Among the dominant crops sorghum and cowpea are harvested last. Thus, it needs specific attention in selecting the appropriate variable.

Further, rainfall is not assured and the pattern experiences several stress periods variation in quantity of precipitation per rainy days, length of the rainy season etc. In the light of the above, selection of rainfall variables was decided as follows: rainfall in millimetres (mm), number of rainy days, duration of rainy season and rainfall in October. These were considered adequate and appropriate to take care of the variation and differing influence of rainfall.

4.9.3 FERTILIZER USE:

It is universally recognised that fertilizer is a yield increasing input. There are however, contrary opinions that fertilizer use in Northern Nigeria is not productive enough to justify its proportion and subdivision, particularly for millet.

The general feature of land holding pattern and fertilizer use here are signified by small and scattered nature of cultivated area, poor adoption rate, multivarious types of fertilizer use etc. In order to have a uniformity, all the fertilizer were converted into their actual nutrients and their actual use per hectare was taken as a variable.

Since crop specific application is not commonly practised, fertilizer use in the field was taken as common for all its crops.

4.9.4 PLANT POPULATION

Optimum plant population ensures good yields. Sub-normal or other population affects the crop yields adversely. This is more so with non-fillering crops like sorghum. It is generally observed that farmers in the study area adopt very wide spacing the effect of which needs to be studied. Plant population, therefore, has been taken as a variable. This variable here has been treated independently for the specific crops and combined population in mixed cropping situation.

Regression analysis's result of different combinations of variables are presented in tables. The simple correlation matrix worked out for the variables indicate the need for deleting some variables or identify the most appropriate ones.

The rainfall variable showed a very high inter-correlation. For instance among the rainfall variables, duration of the rainfall was found to be the most crucial variable because it is not how heavy the rain falls that matters but how long it takes to keep the soil moist.

The final variables included in the regression analysis are:

Ym	=	millet yield
Ys	=	sorghum yield
Yc	=	cowpea yield
X1	=	plant population
X2	=	Fertilizer/Hactare (Ha)
X3	=	Number of weeding
X4	=	Rain in mm
X5	=	Duration of rainfall.

Significance of 'T' values are denoted as:

- Significant T = 0.05

- Highly significant T = 0.01 *** very highly significant T = 0.005 of all the many regressions tried, the most relevant ones are presented and discussed below. Wherever necessary references are drawn to tables for additional information and understanding.

MILLET:

$$Ym = -10.5698 + 0.0933 \times 1 - 0½0347 \times 2$$

$$+ 0.1546 \times 3 + 0.4010 \times 5$$

$$(1.0385) \qquad (2.6188)\ ***$$

multiple correlation co-efficient: 0.4386

Figures in bracket are 'T' values.

TABLE 6: REGRESSION CO-EFFICIENT OF DIFFERENT DETERMINANT VARIABLES ON THE YIELD OF MILLET

INDEPENDENT VARIABLES	REG. 1	REG.2	REG.3	REG.4	REG.5
Plant population	0.271 (1.866)	0.093 (0.633)	0.093 (0.643)	-	-
Fertilizer	0.027 (0.177)	-	-	0.045 (0.213)	-
Rain days	0.353 (1.434)	-	-	-	-
Duration (days)	0.434 (2.389)**	0.391 (2.310)**	0.393 (2.670)***	-	-
Rainfall (mm)	0.200 (1.136)	0.003 (0.019)	-	0.700 (2.960)***	0.723 (3.517)***
October rain (mm)	-0.405 (3.243)***				
Weeding (number	0.133 (0.407)	0.149 (0.992)	0.149 (0.027)	-0.479 (2.274)**	-0.478 (2.326) **

(a) Quantum of rainfall and duration of rainfall are the most important determinants of yield level of millet.

(b) Though plant population ha shown a positive relationship with yield, it was not statistically significant. Millet being a tillering crop (unlike sorghum), adequate rainfall and other timely and appropriate agronomic practices probably compensates at times of sub optimal population.

(c) Weeding generally has a positive (though not significant) influence on millet yield. Millet being a short duration crop and generally grows up to maturity in the middle of main rainy season itself, it does not probably suffer the limitations encountered by sorghum. Weeding practice on millet however, also needs to be examined carefully. The negative co-efficient for weeding regression 5 of table 5 indicates careful planning need in this practice. Only under adequate plant population level and long duration of rain situation, weeding has a strong positive relationship to millet yield. Intensity of rain, though it helps yield level, probably increases the weed menace and the need for more weeding but ultimately has a negative effect on yield same was the effect when fertilizer and weeding alone were taken for regression. Probably, land preparation at the planting state to reduce weed menace may be a desirable practice.

d. The negative or weak co-efficient of fertilizer on millet yield indicate that millet does not respond well to fertilizer. In other words, the local varieties of millet (grown on 90 percent of millet area) are probably not fertilizer responsive types. Fertilizers in this area are not generally applied as a basal dose.

As a top dressing if the application is delayed, it may not be very effective on millet which is a shorter duration crop. This however needs further investigations.

MILLET - SORGHUM - COWPEA MIXTURE FOR THE YEAR 1995

Yield = -67.4325

$-0.0040X + 0.0294X_3 + 0.5916X_5$

(0.0327) (0.2485) (4.9100)

$+ 0.3666X_1$

(3.1191)

Multiple Correlation Co-efficient: 0.6989

Co-efficient of determination: 0.4885.

FOR THE YEAR 1996:

Yield = -108.134

$-0.1158X_1 + 0.1334X_2 + 0.1334X_3 + 0.8439X_5$

(1.7065) (1.7435) (1.8503) (12.0215)

Multiple correlation co-efficient 0.9342

Co-efficient of determination: 0.8727

Figures in brackets are 'T' values.

The regression analysis of the crop mixture millet-sorghum, cowpea, carried out independently for 1995 and 1996 showed a striking contrast in the response of plant population and fertilizer to crop yields. The underlying factor in both the cases, therefore, appear to be the crucial role played by the duration of rainfall in these years.

The year 1995 was a relatively poor rainfall year as compared to 1996. This may probably provide a possible explanation for the negative response of fertilizer but a very highly significant response to plant population in 1995. When the rainfall is inadequate plant population has a compensatory effect on yield as fertilizer up-date may be reduced if the rains are inadequate.

On the contrary, the negative relationship between plant population and crop yields in 1996 is hard to explain. It may, however be pertinent to quote a conclusion drawn by Makumba (1986) in a study which specifically studied the stand density aspect of crops in Northern Nigeria. Adoption of lower density by farmers on closer examination seem to be dictated by the need for moisture conservation, available tools and easy facility for Inter-cultivation. It is also believed that high yield per stand will compensate the lower density.

The results of the regression analysis of millet - sorghum - cowpea, mixture, however gives out more significant and overall determinants of consequence. The major conclusions that could be drawn from the analysis are:-]

(I) Yield of all crops largely depend on the duration of the rainfall of sufficient intensity.

(ii) In good rainfall year, plant population and duration of rainfall were sufficient to provide good yields.

(iii) Again, with appropriate weeding practices, crop response to fertilizer could be quite considerable. Appropriate manipulation of the use of these two variables would ensure high yield. See plates 1a & b and 2a &b respectively.

4.10 MILLET YIELD FORECAST IN KEBBI STATE

Since millet production is the main thrust of this study, it is therefore important to examine and forecast millet yield as a strategy to enhance its production capabilities. In view of this, the analysis was carried out to ascertain the nature and extent of relationship between millet yield as a dependent variable and climatic parameters as independent variables. This was conducted for the period 1992-1997. The independent variables used include mean rainfall for the state, Temperature, relative humidity and radiation.

Table 7: below shows vividly the parameters used in calculating millet yield forecast.

Year	Millet Yield	Rainfall	Temp.	R/H	Radiation
1992	149085.8	1036.8	311.7	80.1	13.6
1993	149085.1	706.8	31.6	80.4	13.6
1994	13091.31	736.27	31.4	79.7	15.2
1995	215393.85	1097.60	31.3	78.4	14.2
1996	16521.08	697.2	32.1	79.0	14.6
1997	15982.75	764.80	31.6	78.9	15.1

Source: KARDA, 1997.

The statistical analysis used to analyse this data set is the step-wise multiple regression analysis. This is mainly used to identify the Agro-climatic factors that are crucial to millet yield, because it has the ability to include in the equation only those variables that contribute significantly to the variation in the dependent variable.

In the analysis, the following results were obtained:

The regression equation for rainfall is:

Y = -2202 + 27.6 Rainfall

S = 64831

R-Sq = 57.4%

R-Sq (Adj) = 46.7%

The regression equation for Temperature is:

Y = 4439741 - 137476 Temperature.

S = 89571

R-Sq = 18.6%

R-Sq (Adj) = 0.0%

The regression equation for Relative humidity is:

Y = -386717 + 6043 R/H

S = 99156

R-Sq = 0.3%

R-Sq(Adj) = 0.0%

The regression equation for Radiation is:

Y = 1522831 - 99395 Radiation

S = 60937

R-Sq = 62.3%

R-Sq(Adj) = 52.9%

From the results obtained by stepwise method, one can infer that radiation, relative humidity, rainfall and temperature contributed significantly to millet yield.

Although both parameters contributed significantly, the result further showed that radiation and relative humidity are major contributors to millet yield while rainfall and temperature contributed less, may be because millet is a drought tolerant crop.

In general, the analysis shows that there is a relationship between climatic factors and millet production in the study area.

4.10.1 FORECAST ON MILLET YIELD:

Table 8 below shows the predicted values of millet yield in Kebbi State for 6 years

Year	Actual Yield	Rainfall	Temp.	R/H	Radiation	Predicted	Residual
1992	149085.08	1036.8	31.7	80.1	13.6	1512.15	-2129.5
1993	149085.01	706.8	31.6	80.4	13.6	149976	-891.4
1994	23091.85	736.27	31.4	79.7	15.2	6894	6197.6
1995	215393.85	1097.60	31.3	78.4	14.2	212312	3082.1
1996	16521.08	697.2	32.1	79.0	14.6	11767	4754.2
1997	15985.75	764.80	31.6	78.9	15.1	26999	-11013.1

From the results obtained on the predicted values, one can infer that there were deficits on millet yield between the years 1994-1996 probably because of the problems inflicted on millet as already highlighted elsewhere within this research.

4.10.2 A FORECAST MODEL ON MILLET YIELD FOR KEBBI STATE:

The forecast model is important to ascertain the progress increases or decreases in millet production annually, because the aim of the forecast is to estimate using agro-climatic variables to find out the yield of millet in the state. The multiple regression analysis in this effect was used to develop the model.

The predictors in the equation are the four climatic variables. These variables include rainfall, temperature, radiation and relative humidity. The regression equation for predicting millet yield is shown below:

Y = 10282304 + 7.0 Rainfall -148575 Temperature + 45996 R/H -128250 Radiation otherwise written as:

$$Y = a + b1x - B2x + b3x - b4x$$

Based on the above equation, the actual and predicted millet yield for Kebbi state including the yield differences and the computed residual mean square error are shown. This indicates that the model is reliable as a good predictor of millet in Kebbi State.

4.11 PROBABLE PROBLEMS OF MILLET PRODUCTION

A bumper harvest from early planting season millet is always highly anticipated and patiently awaited or expected but sometimes faced with the problems of incidence of pests and diseases and other agronomic problems. These problems mentioned above thwart the bumper harvest. Others include:

- The false onset of rains and those who planted with the advent of the false onset of rains not only had their crops wilted but equally eaten by the grasshoppers after germination.
- Sometimes when crops grow, the stem borers burrow holes on the stem of the crop. These stem borers include termites, worms etc.
- At the milking stage the bristle beetle insects such away all the milk of the grains. Also quellar birds pick the grains, culminating into less yield in the early planting season millet (Gero).

CHAPTER FIVE

5.0 SUMMARY AND CONCLUSION

5.1 Summary

It has been both observed and tested that rainfall is by far the most determinant of plant growth, development and yield especially under rainfed agriculture in the desert fringe zone of Nigeria.

The sowing date are determined by the onset of rains other variables like temperature, humidity, solar radiation wind or air been available. Although the false onset of rains may create a problem especially to the early millet as Thompson (1991) rightly pointed out that climate has been assumed to be second to no other factor in determining the productivity of agricultural products and that only a few areas of the world have climatic conditions that allow a wide range of food and non-food agricultural products to be produced.

From the results obtained, it was observed that late Maiwa and Dauro millet are markedly out-yielded the early yielding millet (Gero) by a margin of 60%. This was likely due to favourable soil moisture and weather conditions of optimum temperature, moderate humidity, adequate sunshine hours and rainfall during the reproductive phase of the crop. During this phase, the crop was able to synthesise enough photosytesis and translocate them into the developing grains before the cessation of the rains unlike the early planted millet which was not favoured by the weather conditions at the reproductive phase as the rains was much at the flowing period. Therefore the rainfall stress probably resulted in the abortion of many flowers leading to no yield. This tend to confirm the fact as clearly stated that millet thrives mostly in the desert fringe zones of Nigeria where the rainfall is low between 500mm to 600mm per annum.

In predominantly rainfed agricultural region, diversification of crops appear to be rather limited. But tracts of better rainfall there is scope for diversification and needs to be pursued with improved aspects. This has not gained sufficient attention in the present strategies.

Though there has been an overall improvement in the adoption of improve agricultural practices, the achievement are rather smaller than expectations. Now crop varieties, though better yields, did not catch up as they did not fit into the farming systems and did not fully meet the farmers requirements. Mixed cropping is the most popular and strong favourite of the farmers. As for the farmers the method is the best risk aversion system under the existing conditions. The farmers believe that the strong possibilities for increasing production under mixed cropping is by increasing crop density.

Millet and sorghum continues to dominate the crop pattern. In years of good rainfall, bumper harvest leads to serious gluts and steep fall in prices. Adequate attention has not been paid to this aspect in the strategies. Maize is growing popular slowly and groundnut is regaining ground.

Fertilizer demand has been growing and adoption rate increasing. It's use is still limited to a few crops in wet season. Many constraints, like price hike, distribution bottle necks and inadequate supply particularly the most preferred fertilizer are impediment to increased fertilizer use. On the other hand, their availability at the time of need and they are not region - specific. Crop response is likely to be higher when basal application is done and improves further when land is prepared before fertilizer application. Somehow, proper fertilizer application methods are yet to seep through to the farmers.

Weeding is an established agronomic practice to ensure good crop yields. But, under rainfed condition, particularly in the study area which is prone to frequent stress periods in many rainy season, it appears to have a negative response on crop yields. At the same time, when weeding is not done, crop response to fertilizer reduces. This aspect of agronomic problems has not been fully realised by the concerned.

yield levels in the study area has been showing consistent improvements but yields still fluctuate with rainfall. In other words, stability in yield level has not been achieved due to erratic rains.

5.2 Conclusion

From the results and analysis of the study, the following conclusions could be drawn.

i. Optimum yield could be obtained when the crop (millet) is sown early in the season. About 60% of this crop's yield potential could be lost due to late sowing. In fact because of the potentials in yield levels of Gero millet at early sowing, some farmers even practice advance sowing before the onset of rains to meet up the requirements of the planting dates.

ii. Millet being the drought tolerant crop, it therefore becomes an important crop of the desert fringe zone of Nigeria, because the limited and well distributed rainfall in the desert fringe zone will promote millet development and yield.

iii. The essence of planting millet early in the season is that farmers give priority to food crop not only to alleviate hunger but to avert and modify frequent crop failures in the state. It is therefore expedient that the use of these varieties of crops and the mixture of millet with other crops such as sorghum, maize and cowpea is to avoid losses in crop production. Although weeding and use of inputs are equally important ingredients of millet yield, well distributed rainfall is second to none in the promotion of millet growth, development and yield.

iv. If Government should provide necessary equipment to aid harness agriculturally viable land of the state hunger will be curtailed and drought stricken areas modified.

5.3 Suggestions

The post-harvest glit, particularly in good rainfall years pushes down the area under cultivation in the next season. The un-attractive prices dampen the farmers spirit for increasing production. In an under-defined and un-organised market structure and lack of good storage facilities like that prevailing in the study area, the above consequences are inevitable. Strategic intervention in the form of promoting expert potential crops like maize, millet and groundnut in the place of the existing cereals and in new areas should be vigorously pursued. It may even be economically be worthwhile to provide incentives to grow such crops wherever possible.

Though pests and diseases have not attained menacing proportion, yet, the incidence is on the increase particularly the locusts, grasshoppers and brister beetle etc. The existing state or institutional machinery to tackle such emergency is woefully inadequate. Promotion of plant protection practices by farmers is very important. Introduction of appropriate and cheaper chemicals in small quantities (present packs are in drums and gallons) to meet a small farmers' requirement should be taken up without any further delay.

Promotion of basal application of fertilisers through more demonstration and other extension efforts is another aspect which needs special attention.

There should be selection and breeding of drought resistant crop and the short duration yielding crops as millet to fight against hunger and starvation in desert fringe zone. Similarly, to minimise migration habits of animal rearers, stabilization of pasture lands need to be adequately enhanced. Selection and breeding of low moisture requiring nutritive forage crops are essential.

The suitable farming system for the area should be worked out for not only to fight against desert encroachment but to substantiate high rate of albedo in the region under study.

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APPENDIX 1

MEAN MONTHLY RAINFALL

YEAR	APRIL	MAY	JUNE	JULY	AUG.	SEPT.	OCT.
1992	32.8	90.0	239.3	253.8	325.0	53.4	42.5
1993	3.4	191.0	55.1	172.5	213.9	28.9	36.9
1994	20.0	40.8	59.3	280.0	450.3	225.8	43.7
1995	20.8	20.2	68.4	154.4	140.8	240.0	93.1
1996	28.2	100.1	104.0	121.6	191.4	110.7	41.2
1997	44.8	20.33	171.9	54.33	303.9	146.4	23.14

APPENDIX 3

MEAN MONTHLY RELATIVE HUMIDITY

YEAR	APRIL	MAY	JUNE	JULY	AUG.	SEPT.	OCT.
1992	70	79	82	84	84	83	79
1993	73	68	80	82	86	84	80
1994	69	79	79	81	86	85	79
1995	65	75	79	83	85	83	79
1996	68	77	80	84	86	83	75
1997	70	71	80	81	86	84	80

APPENDIX 4

MEAN MONTHLY RADIATION

YEAR	APRIL	MAY	JUNE	JULY	AUG.	SEPT.	OCT.
1992	15.2	13.9	13.2	10.8	13.0	14.0	15.2
1993	16.4	14.8	12.5	11.6	10.7	14.2	15.3
1994	16.5	16.9	17.2	12.5	13.8	15.2	14.3
1995	15.7	16.7	14.2	13.7	10.8	14.0	14.2
1996	17.4	16.5	16.3	13.9	10.9	13.0	14.2
1997	15.7	15.8	13.9	15.2	14.8	15.2	14.8