PRECIPITATION PERIODICITY INDEX IN KADUNA STATE OF NIGERIA

A Thesis Submitted to the Department of Geography
Federal University of Technology, P.M.B 65, Minna,
Niger State, in partial fulfilment for the award of
Masters of Technology Degree in Meteorology

By

HASSAN SHUAIB MUSA
93/94/040

DECEMBER, 1996

CERTIFICATION

I certify that this work is carried out by Mallam Hassan Shuaib Musa under my supervision in the Department of Geography, School of Science and Science Education, Federal University of Technology, Minna, Niger.

THESIS SUPERVISOR

DEAN, POST GRADUATE STUDIES

DEAN - SSSE

H.O.D. GEOGRAPHY

EXTERNAL EXAMINER

MAL. S. M. HASSAN

DEDICATION

Halimatu Sadiya for her patience.

ACKNOWLEDGEMENTS

I wish to express my profound gratitude to Prof. D. O. Adefolalu, who insisted I go back for postgraduate programme. His continuous encouragement and advice and above all positive criticism of this work was an inspiration to. To my supervisor, Prof. J. M. Baba (Dean of School of Science and Science Education), whose moral support and confidence spurred me on, I am greatly indebted.

Similarly, my regards to Mr. Akinyeye, P. S., for his encouraging counsels, Dr. G. N. Nsofor (H.O.D Geography) and the rest members of staff of the Department of Geography, including the Secretary - Mal. Zam Mohammed. To Mallam Ibrahim Kassim of Microbiology for his moral and friendly support.

My very special thanks to my Darling - Halima - for her patience, understanding and encouragement, and Sa'id, my junior brother who has been encouraging me right from the start. I Cherish you both.

I also wish to offer my sincere gratitude to the following people for contribution in one way or the other: Kaduna state Land and survey department. Government House; Climate Change Centre, F.U.T, Minna for map and data respectively; my friend, Niyi Omoyegun of NEPA, Shiroro power station, Niger State, my father in-law, Mallam Yahaya Musa Edzu, Garba Maianguwa, computer centre, F.U.T, Minna and to my colleagues - I miss you all.

Finally, but the most worthy of praise, Almighty Allah (ALIHAMDU LILLAH), my perfect guardian and in Him my subsistence lies. I also glorify Him for leading me through to the end of yet another stage of my education.

ABSTRACT

Precipitation Periodicity Index (PPI) was used as the main method of analysis. This index was used to identified areas of precipitation variabiity of the magnitude of variations. This was based on highest monthly, the lowest monthly rainfall and the total annual rainfall in percentage.

The study shows that agricultural landuse practice can be divided into three Zones. The Southeastern part of the study area has been found to be the Zone of Uniform rainfall. The Zones of slight periodicity are the western, the central and the northwestern parts. The extreme north and extreme northwest have been found to be the Zones of excessive periodicity.

The significance of this is that various types of crops can be cultivated in the southeastern part of the study area. The study also reveals that agricultural landuse practice and animal husbandry can be effectively carried out in the study area because the onset, cessation and LRS are at tolerance level.

TABLE OF CONTENTS

CHAPTER ONE

1.1 INTRODUCTION

The necessity to know where there is abundant or deficient rainfall, has been well documented in various climatological studies, but it is perhaps more important to know the seasonal incidence of the rain (that is the rainfall regime). Broadly speaking, global climate to which rainfall is an element, is driven by net radiation differences between the Equator and the Poles with atmospheric circulation as the system that acts to reduce these latitudinal difference. The effects of the earth's rotation modified the latitudinal heat and energy transport.

Banded approximately by latitudes, 30°N and S of the Equator, convective activity is responsible for the circulation near the Equator, a region of general upward motion with low surface pressure called the equatorial trough or intertropical convergence Zone (ITCZ). This rising air forms a central common branch of two meridional circulations known as "Hadley cells". The ITCZ tends to lie a little north of the geographical Equator (varying between 5°S in winter to about 15°N in summer). Hence, the ITCZ moves with the seasons, following the changing Zenith of the sun, which controlled its latitudinal variation. The effect of the changing Zenith of the sun is equally reflected in similar but less extensive swing of pressure and wind belts north and south of the Equator. There is also the effect of continentality caused by large land masses, the result of which is the differential land - sea heating, which is the major cause of the monsoons;

largely governed by land/sea temperature contrasts, and is closely linked to seasonal migration of the ITCZ. This north and south movement of the ITCZ is the most important feature of the tropical climate system since it largely controls the spatial and seasonal distribution of rainfall.

The concept of variability in rainfall is an important one in climate study. This brings to mind the essential effects of the ITCZ movements, its resultant seasonality (the equinoxes and the two solstices - that is when the sun is overhead at the Equator and at either of the tropics) respectively). The magnitude of the seasonal variation of rainfall over an area is an indication of periodicity in its precipitation - as one of its characteristics.

Rainfall distribution over Nigeria is monsoonal from the coast becoming convectional at the interior, except during the peak of summer months when the whole country is under the influence of monsoon, interspersed with convectional rainfall produced by great heat. The spread of monsoonal rains across the country is controlled largely by the changing Zenith of the sun. There could be local deviations from this general pattern in some regions due to micro-climate associated with highlands. For example, around Jos Plateau and the highlands around the Eastern margin. The rainfall towards the end of raining season from the middle belt region up North of the Country is largely convectional. This is because the ITCZ is retreating toward the equator at this time of the year accompanied by great heat. This heat give rise to convective activities accompanied with lightning and thunder.

1.2 SUPAN INDEX OF PERIODICITY

This index was developed by a Frenchman who worked in the ALPS REGION IN THE LATE 50's. It was based on three threshold values that are used to identify areas of precipitation variability on the magnitude of variations. It takes into account the highest monthly rainfall, the lowest monthly rainfall and the total annual rainfall.

These threshold values are as follows:

1. $< 10\%$ - Uniform distribution
2. $> 10 \leq 20\%$ - Slight periodicity
3. $> 20\%$ - Excessive periodicity

Precipitation variability has been studied over Nigeria extensively, but periodicity is an aspect of rainfall characteristics yet to be explored.

1.3 PROBLEM STATEMENT

It has been widely believed that seasonal variation in precipitation over Nigeria has been well documented and understood. Various studies carried out in this area unfortunately made use of mean monthly and annual averages and totals only (Kowel et. al 1972). These are basic data sets that cannot on their own be used for effective landuse planning for sustainable development. Annual rainfall amounts or the monthly means are only measure of precipitation characteristics not of its effectiveness (Adefolalu, 1991). Recently, Adefolalu (1991, 1993), carried out an indepth analysis of other derived parameters (such as onset, cessation, length of rainy season etc.) for application in landuse planning. This could also provide a guide to aid the seasonal migration of herds that leave their impact on the environment through the passage of time.

For a country to continue to depend on a resource that is not replenishable (e.g. Petroleum) means no future; hence the need to study and understand the mechanisms of renewable resources such as climate, for the purpose of achieving more sustainable development. Although, the influence of climate on animal production and performance has long been recognised, a systematic, coherent application of climatic principles and information towards improvement of animal production and disease control has not been practised. This kind of assessment, especially in developing countries, is not yet accomplished. If and when accomplished, it may assist in boosting the economy of the developing nations.

1.4 OBJECTIVES OF THE STUDY

Increase knowledge of precipitation dynamics will go a long way in unmasking its numerous areas of application to boost the economic well being of the state. The agricultural landuse and animal husbandry data are not available. This was due to the fact that majority of the people involved in farming are local and do not keep records of their practice; in terms of animal husbandry. Almost all the animal keepers are the migratory nomadic herdsmen. Some of the elite animal keepers also employ the services of these nomadic herdsmen, and so, no data. This is why the study is aimed at deductive application of only the precipitation characteristics on agricultural landuse and animal husbandry. The aim is to provide additional knowledge for better understanding of precipitation characteristics over Kaduna State.

The specific objectives of this study are:

i. to compute and define the magnitude of rainfall periodicity over space,

ii to use findings in (i) above in identifying areas suitable for animal husbandry

iii. to also apply the information obtained from (i) for effective agricultural land use planning.

1.5 JUSTIFICATION

This study is expected to offer understanding and proffered solutions to certain problems of under utilisation of our environmental resources. Potentially, recreational areas are either poorly developed or not adequately identified to enhance its development. Apart from the nomadic fulani who live a migratory life, other practising animal keepers are doing so for the sake of rearing them either for money or for meat. Most of the animal keepers are mindless of whether the zone is suitable for such venture weatherwise. This ignorance or in some cases, not recognising the significance of weather (climatic) information may have contributed largely to the failure of these ventures in the past. Recreational outings are often wrongly timed causing untold hardship to the tourists. Variety of crops are planted at a wrong place at a wrong time. Animals are grazed in moisture deficit areas making them less productive.

Previous studies carried out in areas of seasonal variations of precipitation lay more emphasis on the copious amount of rainfall received annually, without indepth analysis of other derived parameters for application except recently by Adefolalu (1991, 1993). The application of this study is hoped to assist in delineating areas of economic importance especially in agricultural landuse over Kaduna State.

1.6 LOCATION OF STUDY AREA

Kaduna State is located between latitudes 9° to 11°30 North of the Equator and longitudes 6°30' to 9°30' East of the Greenwich Meridian. It lies in the Guinea Savanna Zone of Nigeria. It is bounded by several States, with Katsina and Kano States to the north, Bauchi State to the east. In the South-east lies Plateau State, Federal Capital Territory (Abuja) and some parts of Niger State to the South. Niger State also extended to its South-west while sokoto State is to the North-west of Kaduna State. (See fig. 1).

1.6.1 Rainfall Characteristics

Kaduna State has mean annual rainfall of 125mm (Kowal, et al, 1972). It has been deduced from various studies, using isohyetal maps (Adefolalu, 1984, Kowal et. al, 1972), that Kaduna State has its rainfall onset dates from 1st to 10th April around Kafanchan and between 21st to 30th April around Samaru (Zaria). On the average Kaduna has April as the onset month of the rains. The cessation dates of the rains (that is the end of the raining season) is on or before 20th October. This means the State has at most six months of rainy season (growing season). The average Length of Rainy Season (LRS) is 180 days. It is 160 days around Kafanchan in the Southern part of the

State. It has mean annual potential evapotranspiration (ET) of 1431.50mm (Kowal et. al, 1972).

This means that the (ET) is greater than its mean annual rainfall of 125mm. This signified that except in some areas, where rainfall is near normal, the entire state is experiencing moisture deficit.

1.7 SCOPE OF THE STUDY

Kaduna State Department of Lands and Survey provided the base map on which this study is based. The map was on a scale of 1.500,000. This was reduced four (4) times its original size giving a new scale of 1:2,000,000.

Ten-year rainfall data obtained from the Climate Change Centre, Federal University of Technology, Minna, Niger State, were used for this study. This ten-year period is for the period between 1951 to 1960. We also limited ourselves to 37 stations. These limitations became necessary for the simple reason that these are stations with complete and continuous record sets within the ten-year period.

Agricultural landuse and animal husbandry data are not available due to the fact that majority of people involved in these practices are local farmers and the nomadic herdsmen that do not keep record of events. Therefore, only the rainfall and the derived periodicity index data are used in this study.

CHAPTER TWO

2.1 LITERATURE REVIEW

Macroclimate is the larger scale observable aspect of climate. This observed sequence of weather at a locality involves the ceaseless progression pass it of differing air masses and disturbances. The rainstorms on which biological productivity depends are carried along by winds that are governed by world-wide energy differences. Their effect is locally observable, but they work in response to large-scale, invisible processes-hence the word macroclimate (Hare, 1985).

Microclimate is the smallest scale on which we can observe climatic balances, exchanges and processes. Microclimates are measurable by means of instruments installed near the ground, or within the soil and now even with satellites. Desertification involves a drastic change in such microclimates. Change in microclimate are also ecological changes, with changes in the ecosystems. Hence desertification is not only a loss of biological productivity; it is also a degradation of surface microclimates (Hare, 1985). The recent episodes of harsh climate has been a vital lesson forced on us.

The events suggest that episodes such as the descation of subsaharan Africa may be parts of little-understood global processes that we can watch but not control. There are also a view that human interference with surface microclimates actually does feed back on the global macroclimate. For instance the present issue of global warming due to mash discharge of aerosols into the atmosphere, therefore the climate of any place is the result of interactions between local, regional and much larger scale factors. Thus, climate of Nigeria (in which Kaduna State is a part) cannot be considered in isolation. The basic driving force of the climate systems as states in chapter one, is the net absorbtion of solar radiation by the atmosphere, earth and ocean. Climatic variability is the result of changes in the total amount of absorbed radiative energy, and changes in the ways this energy is distributed and redistributed within these elements.

Climate is the synthesis of weather elements over a period long enough to establish its statistical properties (mean values, variances, probabilities of extreme events etc) and is largely independent of any instantaneous (weather) state. Climate information can be obtained by summarizing from a large data set (number of a particular month or year etc), at least ten years. Usually, thirty years of data are used to define climate statistics (or "normals"), but there is no physical reason for selecting this particular number. To be complete, any discussion of climate requires specification of the applicable time scale (inter-annuals decadal and son on). When meteorological instruments are both reliable and fairly widely distributed around the globe or a region, we can begin to make meaningful quantitative statements about past climatic fluctuations and change. However, the confidence that can be placed in such statements depends, critically on the particular climatic variable being considered, on the size of the area, and on its geographical location. This made the choice of the study location a viable one since extensive agricultural activities and rearing of animals have been going on for a very long time.

2.2 PRECIPITATION

As an element of climate whose characteristics have complex nature, requires indepth analysis. Although precipitation at global and regional scales may appear smooth with zonal symmetry, the 'picture' at sub-regional and state levels requires a more thorough understanding if the dentures exhibited are to be useful for physical planning (Adefolalu, 1991). Models are ways that the net effect of the complex of interacting processes that produce climate can be properly synthesized and they also allow the effects of individual factors to be rigorously identified. However, Adefolalu (1991), stated that, the seasonal and inter-seasonal features are normally to proceed such estimated parameters. This is because the 'character' of the rains which is better defined by the onset and cessation dates is often 'dictated' by the seasonality of rainfall.

2.2.1 Precipitation Periodicity

Monthly and annual rainfall mapping give general guide on the pattern of rainfall distribution across a domain (Adefolalu, 1991). As the rainfall is seasonally highly concentrated, the distribution within the rainy season and the timing of the start of the rains (onset dates) are very important. Several methods have been used to describe and quantify the intra-annual characteristics of rainfall; especially to distinguish between wet and dry months. Various Authors have used a range of techniques: Iso-percentage lines and accumulated totals (Walter, 1967); Wetness indices (Thomas, 1932); and rainy pentades, or five-day totals (Griffiths, 1960; Straliler, 1975) and Adefolalu, (1984), estimated rainfall variability in terms of percentage departure from the normal value applied on three different climatic types: i) Wet equatorial climate, ii) tropical desert climate, and iii) tropical wet-dry climate - based on monthly and annual "amounts". All these studies provided information on seasonality as far as amounts of rainfall received is concerned. The dynamics of precipitation are therefore masked - the derived parameters such as onset, cessation, LRS and for our primary concern 'the periodicity' of rainfall within these seasonalities. The index determines the areas of 'normal', moderate, and excessive fluctuation. These areas shall form the bases of our suggestions on effective agricultural landuse planning and animal husbandry.

The study area had average of six months of rainfall. The rest of the months are dominated by heavy sun shine and harmattan. Sustaining the economy under such condition requires proper planning with special consideration on salient features of precipitation as an element of climate. Due largely to ignorance on environmental matters, deficiency in rainfall amounts has over the years been blamed for poor crop yields. Deficit in rainfall amount by itself, may be less problematic since plants do not depend on the amount of rainfall received for good water growth, development and high yield but on how much water is available to them as soil moisture, when this amount becomes available and the lengths in days/months during which the soil is able to retain enough moisture required for enhanced yield (Adefolalu, 1991).

2.3 EFFECTIVE AGRICULTURAL LANDUSE PLANNING

All over Africa tons of soil per hectare are lost to erosion each year (Quatlara et al, 1993), adapted by Adefolalu, 1994). Lost soils implies lower food production. Erosion affect soil fertility and reduces crop yield by an estimated 2 to 3% per every 10 metric tons of soil per hectare (Adefolalu, 1994). Nigerian as a tropical country cannot be considered in isolation when it comes to agricultural landuse planning. One basic climatic factor that enhances soil erosion in a region is precipitation which is of primary concern of this study.

The goals of a Western farmer is to maximize profit; that of the developing country peasant farmer is to minimize risk (Nicholas, 1974). Climate and weather variability lay an overriding role in determining the amount of the physical productivity of agricultural crops and Livestock as well as the risk of failure of the productivity (Chang, 1968, WMO, 1971 and 1975). WMO-No. 536 (1980) illustrates elsewhere how landuse planning was unsuccessful because climate was not properly considered:

> "Large reforestation programmes in Northern America failed because attempts were made to introduce species which were unsuitable for the given local climatic conditions (this was in the early part of this century). Attempts in early post-war years to open up parts of the Amazon River area for agriculture were un-successful, because there was no understanding of the special ecological problems of the tropical rainforest."

Also back home, the Nigerian wheat project of the last few years, although proved viable, collapsed due to misplacement of priorities on the part of the Government and the refusal to acknowledge and implement climatological conditions governing wheat production in the tropics, one of which is precipitation effectiveness.

Most of the important food crops on earth have closely circumscribed climatic limits in which they can be optimally grown. They have specific requirement for water and a minimum period in which they can ripen. The so-called growing season, sets the pole ward limit of agriculture with some 'pockets' of variations due to influences of orography and areas adjacent coastlines.

Water need by human beings for agriculture (both for crops and livestock production) is on the rise. The greatest consumption of water is for agricultural irrigation. It is an essential technology for optimal crop production. All this water is supplied from the sky. The incoming water from precipitation depends on the weather conditions of a given year or season. We are dealing here with probably the most fickle of all weather elements, varying from cloudburst to drought. The reliability of rain depends greatly on the climate. In semi-arid and monsoon fed areas, the variation (swings) from one to the next can be extraordinarily wide (Landsberg, 1986). In most regions, it is axiomatic that the sections receiving the least average rainfall have the highest variability, and also have the highest risk to their water supplied. Landsberg (1986) also stated that "it is equally important to remember that there is no region which does not occasionally have a drought or periods of excessive rain".

The logical, and extremely important, consequence for the planner is that he will have to prepare for adequate water storage in reservoirs, especially for livestock. In areas with high evaporation (e.g. Kaduna State, see section 1.6.2) these have to be underground or watering points (borehole) (Adefolalu, 1991) to avoid excessive losses.

2.4 ANIMAL HUSBANDRY

Livestock, depending on the specie and level of productivity, have an optimal environmental zone and they must be maintained within this zone for optimal growth and reproductive functions. The thermoneutral zone for various animals has been described by Bianca (1965), Jahnson (1965), Yousef et al (1965) and others; but the total environmental complex has not been fully documented to determine the optimal environment for growth and reproduction of livestock, including normal physiological and behavioural actions (Johnson, 1965).

Bioclimate generally refers to the physical or meteorological and biological environment surrounding an animal. Bioclimatology therefore, is the science of biological and meteorological influences and interactive influences on animal and plant functions and their performance. The influence of bioclimates on animal production has long been recognised by the animal industry (advanced nations), but a systematic coherent application of bioclimatic principles and information to improvement of animal production and disease control has not been practised (Johnson, 1987).

The essential element of climate, water (on which life depend), is a product of precipitation. Animal performance, production, milk yield and various other factors depend on the availability of water and when it is actually needed. Adefolalu (1991) stated that "water intake to livestock varies according to temperature, season, age, weight and condition of the animal, quantity and nature of food intake etc. In general, intake increases with increase of temperature from 20°C to 40°C and also as the herbage dry matter increase during the dry season. Acknowledgement and implementation of climatic information contribute to the practice which is able to keep pest and diseases of livestock in check.

(see table 1.0). The table now form the fundamental data set on which other various analysis are based. Isoline, running averages, scattergram and deviation from the mean analysis were also carried out. Each of these is explain below.

3.3.1 Isoline

From table 1.0, the periodicity values were plotted on the state map as data points. This was then analysed by drawing isolines over the station. (see Fig. 1.0 chap. 4). This information was then used to delineate area of uniform rainfall, slight periodicity and excessive periodicity. The line is drawn by joining stations with the same value (see. fig. 2.0 in chap. 4). This method will show the trend of the precipitation periodicity over the state.

3.3.2 Moving Averages Curve

The aim of moving average is to smoothen out the sharp and marked irregularities associated with any data. This implies that any number of years being used, for example, five year running mean, the first value will be the average of five years: 1.5: the second value will be the average of years 2-6; etc until the final five years of the period under study. Any number of years may be the basis for such a smoothing technique (see table 2).

3.4.1 Correlation Analysis

This is a method used in various ways to indicate the degree of interrelationship between two or more variables. This is a common tool with a two-dimensional graph called a Scattergram for portraying the relationship or associations between two variables.

Two types of information - direction and strength of association - can be identified from the scattergram. This is because the line placed through the pattern of point in the scattergramm summarizes the relationship between the two variables. This method is scientifically important, because the main value lies in suggesting lines along which further research can be directed in a search for possible cause - and - effect relations in complex situations and can also be used to explain casual relationships that have already been assumed. The slope of this line indicates the direction of the relationship, and amount of scatter of points about the line reveals the strength of association.

Correlation is the geometric mean of the two regression coefficients. This is given by:

$$r = \frac{\sum (x-x)\,(y-y)}{\sqrt{\sum (x-x)^2 \sum (y-y)^2}}$$

or

$$r = \frac{\sum xy - (\sum x)\,(\sum y)\,/N}{(\sum x^2 - (\sum x)^2/N)\,(\sum y^2 (\sum y)^2/N)}$$

The values of r must not be outside the range of -1 and +1. The value r = 1 occurs only when all the data points lie perfectly on a straight line with a positive slope; r = -1 is also a perfect linear relation in which the line has a negative slope. A value of r close to either of these extremes corresponds to a tight clustering of data point around a straight line, meaning strong linear relation.

3.4.2 Linear Regression Analysis

Lime correlation bivariate regression attempt to determine how one variable relates to another. In correlation, the two variables are assigned arbitrarily to the horizontal and vertical axes, and variables are not identified as being either independent or dependent. It merely determined the degree of association between variables.

This is the means of estimating the dependence of one observed variable (with an expected value that is assumed to be in a functional form) upon another or several variables. This method therefore, is the means of estimating the numerical relationship between two or more variables. The techniques of regression may be classified into two:

1. testing the concordance of the observation with the assumed model, and
2. carrying out estimation, or other sorts of inferences about the parameters when the model is assumed to be correct.

The function is written in the form:-

$$Y = a + bx$$

Where a, is the y intercept when x = 0, and b, is the slope

The coefficient of a, and b, are determined by the following formula:-

$$b = \frac{n\sum xy - (\sum x)(\sum y)}{n\sum x^2 - (\sum x)^2}$$

$$a = \frac{\sum y - b\sum x}{n}$$

Where Σx = sum of the values for variable x

Σy = sum of the value for variable y

Σx^2 = sum of the squared values for variable x

Σxy = sum of the product of corresponding x and y value

n = number of observations.

b = slope

a = intercept

3.5 DEVIATION FROM THE MEAN

3.5.1 Precipitation

This is the means of verifying the two extremes - the deficit and the surplus period or region. The critical periods or regions can be identifed by this method. The limitation of this work is that the data set used only for 10 years due to reasons highlighted in chapter 2. This was calculated and plotted based on the ten year period. This study made use of station (region) deviation from the climatological mean. This method can be used as a final test in this study.

3.5.2 Periodicity

This is the means of confirming the critical areas of deficit or surplus precipitation. Those areas with precipitation value above the mean in figure 4.3 chapter four, will show negative sign of deviation from the mean (see fig. 4.5). Whereas areas with rainfall below the mean in fig. 4.3 will show positive deviation in fig. 4.5.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

The Study found two agricultural zones in the State based on (fig 4.3) available rainfall. One of this zones, the South Eastern Zone may not require irrigation during the rainy months but the other zone, which is larger may require irrigation to supplment moisture supply from the rains for sustainable agricultural practice and animal rearing.

The general findings are discussed below:

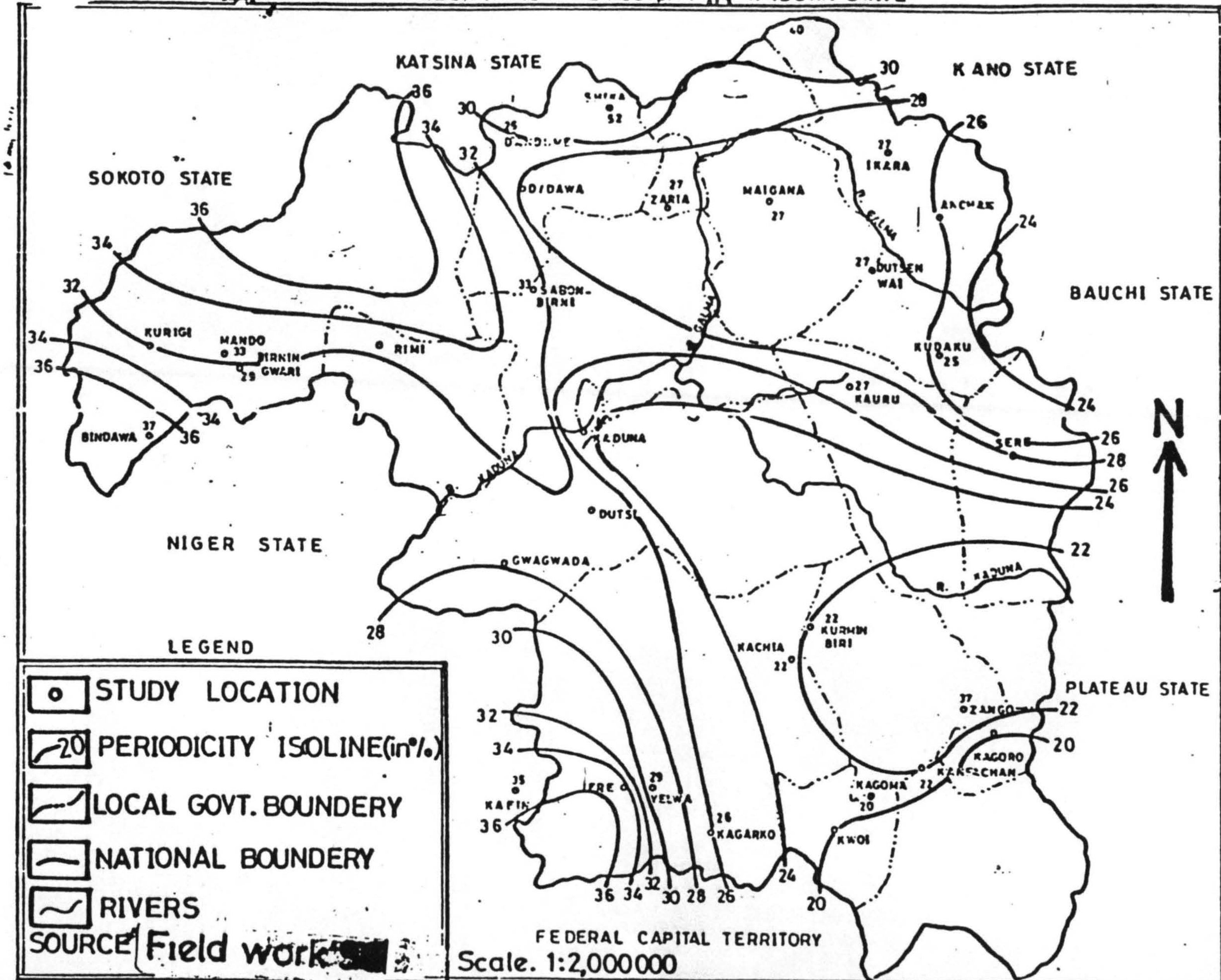
Fig. 4.1 PRECIPITATION PERIODICITY

(a) Areas of Uniform Spread of Precipitation (Sp $\leq$ 20%)

The figure 4.1 is derived from Table 1. The area with Sp $\leq$ 20% can be seen in the figure to be a small one at the extreme Southeastern part of the map. This is around Kafanchan, Kwoi, Kagoro and Kagoma. Looking at Table 1 it is easily noticeable that this particular zone has the highest amount of average annual rainfall in the state. A better understanding of this trend is presented in figure 4.2. Although, the areas northward of this zone have high average annual rainfall, relative of the geographical location, the precipitation periodicity is slightly above 20%. Corresponding rainfall is $\geq$ 1500mm annually. The zone therefore has its precipitation above the annual mean and also greater than the mean annual potential evapotranspiration. This is the only area in the state that is experiencing uniform precipitation according to this study.

(b) **Region of Slight Periodicity (Sp > 20% ≤ 30%**. This covers a wider part of Kaduna State (fig.2). The bulk of the northeast and the eastern part through the central area (Zaria and Kaduna town) Southward through Kagarko. There is a little arm westward through Gwagwada toward Niger State where River Kaduna enters into Niger

Fig 4.1 PRECIPITATION PERIODICITY IN KADUNA STATE



State. The corresponding rainfall amount of this zone is slightly lower than that of zone (a). In fact it is < 1500mm - region of moisture deficit since the mean annual rainfall is also less than the potential evapotranspiration.

TABLE 1: PRECIPITATION PERIODICITY INDEX (%) AND THE CORRESPONDING RAINFALL AVERAGE (1951-1960)

S/No	Stations	Periodicity (%)	Rainfall Average (mm)	S/No	Stations	Periodicity	Rainfall average (mm)
1	KAFANCHAN	22	1725	24	B/GWARI	29	1193
2	KWOI	20	1843	25	MASHI	35	725
3	KAGORO	20	1500				
4	KAGOMA	20	1707	26	KANKARA	31	1000
5	MAIGANA	27	1225	27	BAURE	40	650
6	ZARIA	27	1125	28	MANDO	33	825
7	DAUDAWA	28	1075	29	SAFANA	32	841
8	GWAGWDA	28	975	30	RIMI	32	741
9	KUDARU	25	1425	31	KURIGI	32	824
10	DANDUME	26	1086				
11	JUNCTION(KD)	24	1259	32	ZANGO	37	758
12	SAMARU	26	1147	33	BINDAWA	37	764
13	FUNTUA	27	1076				
14	AERODRONE	23	1338	34	JERE	36	651
15	LERE	28	968	35	SABON BIRNI	33	753
16	KURMIN BIRI	22	1291	36	DUTSE	32	672
17	KAGARKO	26	1362	37	SHIKA	52	1943
18	KACHIA	22	1499				
19	DUTSENWAI	27	1043				
20	IKARA	27	962				
21	ANCHUA	26	1076				
22	YELWA	29	768				
23	KAURU	27	923				

SOURCE: Result from data analysed (1951-1960).

(c) Areas of Excessive Periodicity (Sp > 30%).

These are the South Western part, the north Western and a small portion of the extreme north around shika and Baure (border towns between Kaduna and Katsina, Kano States respectively). These zones have the lowest amount of average annual rainfall ($\leq$ 1000mm), see table 1. There is an exceptional feature around Shika (a border town between Kaduna and Katsina State) which has the highest amount of average annual rainfall but incidentally recorded the highest periodicity (1943mm/52%), (see Table 1 and Fig. 4.3).

Fig. 4.2 FIVE YEAR MOVING AVERAGE

This technique was chosen because it precisely delineate the state in three zones (uniform, slight and excessive periodicity). These are depicted in figure 4.2. the south eastern zone of the state, from Kagarko in the south through west of Kachia and Kaduna aerodrome eastward through Lere north of River Kaduna's point of entrance into the state from plateau - all lies under the SP $\leq$ 20%. This zone may not require supplementary water supply during summer for planting purposes. This section can been seen in fig 4.1 to have its average annual rainfall > evapotranspiration - adequate moisture.

Fig. 4.2 MEAN RAINFALL PERIODICITY IN KADUNA STATE

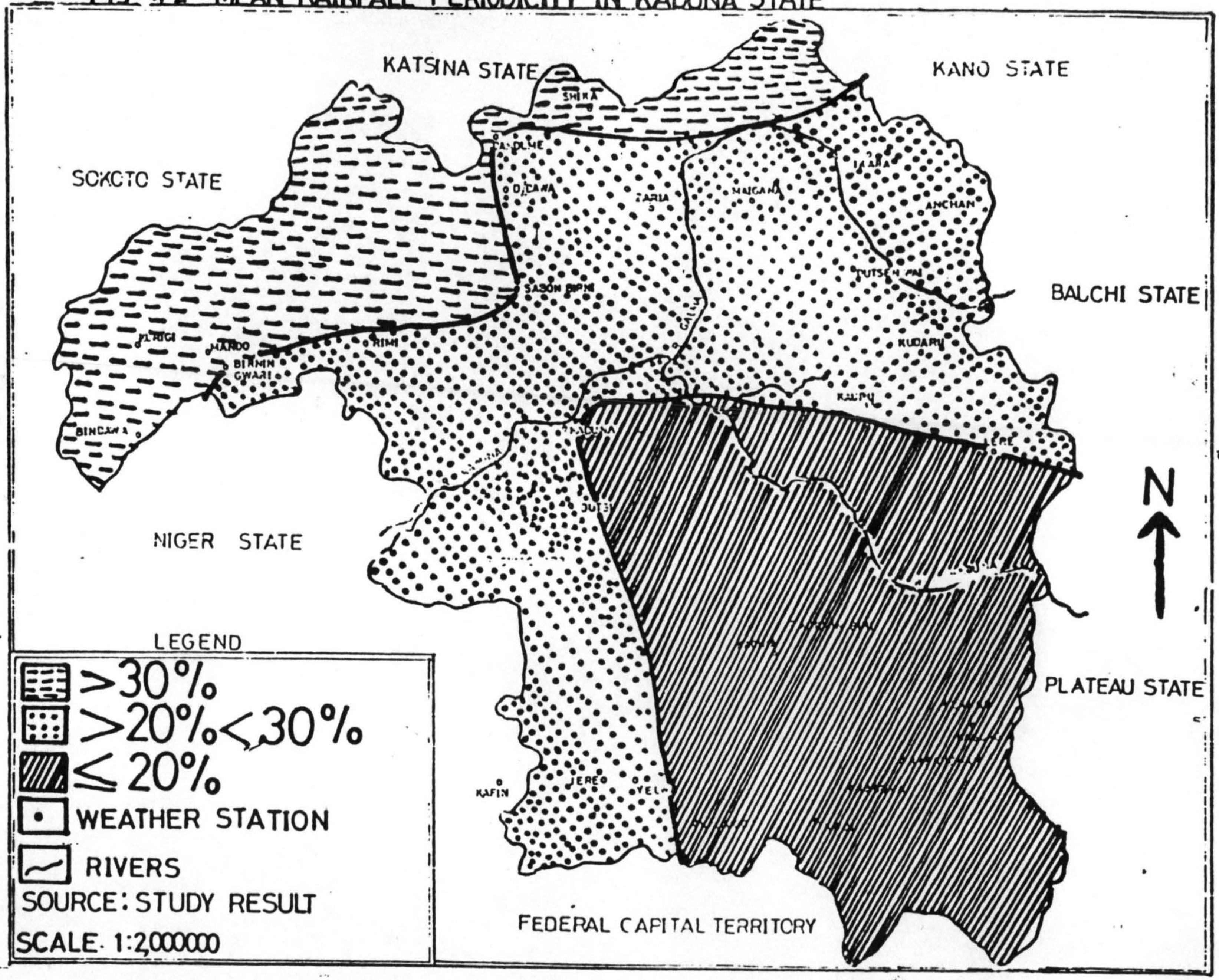


Table 2: Five year running mean (1951-1960) in percentage

PRECIPITATION AVERAGE

Location	1	2	3	4	5	6
Kwoi	17	18	18	24	12	19
Kagoma	18	26	20	20	19	20
Katanchan	22	23	25	24	24	23
Kagoro	20	22	21	21	20	18
Yelwa	29	29	30	31	31	30
Kagarko	30	19	17	21	19	22
G/Lada	25	28	29	29	30	31
Kachia	33	22	27	25	17	17
K/Biri	18	25	25	22	15	26
Kaduna	22	21	21	22	23	23
Dutsi	33	34	33	40	31	31
Lere	30	39	27	31	37	45
Kauru	15	26	32	17	24	26
Kudaru	24	27	25	25	25	26
Dusanwai	25	26	28	30	31	30
Anchau	24	25	26	28	28	27
Ikara 28	30	30	30	30	25	
Maigana	25	26	27	28	28	28
Zaria 27	27	29	29	27	27	
Samaru	28	27	24	25	24	23
Bindawa	29	33	31	33	41	45
Kurigi	31	33	31	33	33	34
Mando	32	33	33	35	34	35
B/Gwari	28	29	32	30	30	29
Rimi	28	29	28	32	35	36
S/Biri	32	32	30	33	35	34
Damdume	26	29	31	30	26	26
Shika	54	58	58	58	48	49
Daudawa	28	28	30	30	29	28

The Western flank through the central part of the state towards the northeastern flank fall under the slight periodicity value ($\leq$ 30%). This makes the greater percentage of the state to be within this category of periodicity. The greater part of River Kaduna (the major river in the state) with its major tributary (river Galma) traversed this zone (See fig. 4.2).

We may deductively state that these flanks do not have enough moisture content to sustained agricultural practice and animal husbandry during the period of requirement. It is necessary therefore to supplement this by various means suitable for such geographical location. This could be through watering points (bore hole) for the animals and irrigation facilities by building earth dams on the major river and its tributary. However, these regions are engaged in heavy agricultural practice.

The northwestern part of the state, from Bimdawa through Shika (extreme north) and terminating around Baure, a border settlement between Kaduna and Kano state (fig. 4.2) is under the SP > 30%. The average periodicities of each weather station based on the five year moving average is shown in table 2.

Generally, moving averages can be used to estimate the future occurrence of a phenomenon and, in this study to even delineate each zone (SP $\leq$ 20%; SP > 20 $\leq$ 30%; and SP > 30%). However, this does not mean that the rainfall in some of these stations are inadequate to support agricultural practice. But when generalised as we learnt in chapter one, except in some areas, where precipitation is near normal, the rainfall in the state is less than the evapotranspiration.

Fig. 4.3 DEVIATION FROM THE MEAN PRECIPITATION

This deviation from the mean is a means of verifying the period of deficit and surplus phenomenon. This was calculated and plotted based on the records of 1951 - 1960 and the state mean of 1250mm rainfall annually. Based on this value the figure was plotted. The area $\geq$ the mean of 1250mm lies to the southeastern flank of the state in which lies those prominent settlements such as Kafanchan, Kagoma, Kwoi, Kagoro and even the Kaduna town itself at the central area of the state. There are small pockets in the east around Kudaru and Shika at the extreme north at the borders with Bauchi and Katsina State respectively.

Area having precipitation above the mean signified adequate moisture within the context of that geographical region and may not require supplementary moisture supply in terms of agricultural landuse. However, this mean may be a serious deficit in some areas.

The most important thing to note here though is the onset/cessation dates of the rains and the length of the raining season (LRS). This will go further to assist the farmers to know when to plant and what to plant. This figure 4.3 and its above average area confirm and agreed with figure 4.2 (the southeastern part having $\leq$ 20% periodicity). This goes to say that those areas having rainfall above the mean may be less periodic at or less than 20%.

The greater part of the state have precipitation below the mean - the western, central and the entire northern and the north eastern flanks. Except around Shika and Kudaru. These part of the State that are below the mean may be considered critical when it comes to agricultural landuse planning and especially animal husbandry. But as earlier stated, some of these areas may have near normal rainfall, especially around Zaria and Samaru. It is necessary to embark on an aggressive alternative source of water supply to supplement the below average rainfall. Without this supplementary source of water supply, both the crop and animals may perform far below expectation. This is because there are more breaks of dry spell during the wet months while at the same time those areas with high average rainfall experiences little breaks.

Fig. 4.4 THE SCATTERGRAM OF RAINFALL AND ITS PERIODICITY

Since the mean rainfall periodicity and the deviation from the mean are in agreement (fig. 4.3 and 4.4), we can further express the point with a scientific proof (statistical analysis). Since our interest here is the degree os association between the rainfall and its periodicity (derived parameter) there would not have been a better choice than the correlation analysis.

Looking at fig. 4.4 it is clear that the correlation is a negative one. And it is in perfect agreement with what fig. 4.2 and 4.3 depicts. The higher the precipitation the higher the periodicity (see table 1). The linear regression line also plotted in fig. 4.4 is to test the concordance of the observation with the model. This therefore confirms the reverse (negative) - as the predicted value - relationship between the rainfall and its periodicity.

Fig. 4.5 DEVIATION FROM THE MEAN PERIODICITY

Fig. 4.5 confirms the pattern in fig 3 and 4. Those areas have periodicity $\leq$ 20% in fig. 4.2 and above the mean in fig. 4.3 show negative deviation in fig. 4.5.

Fig 4.4 SCATTERGRAM OF RAINFALL & PERIODICITY

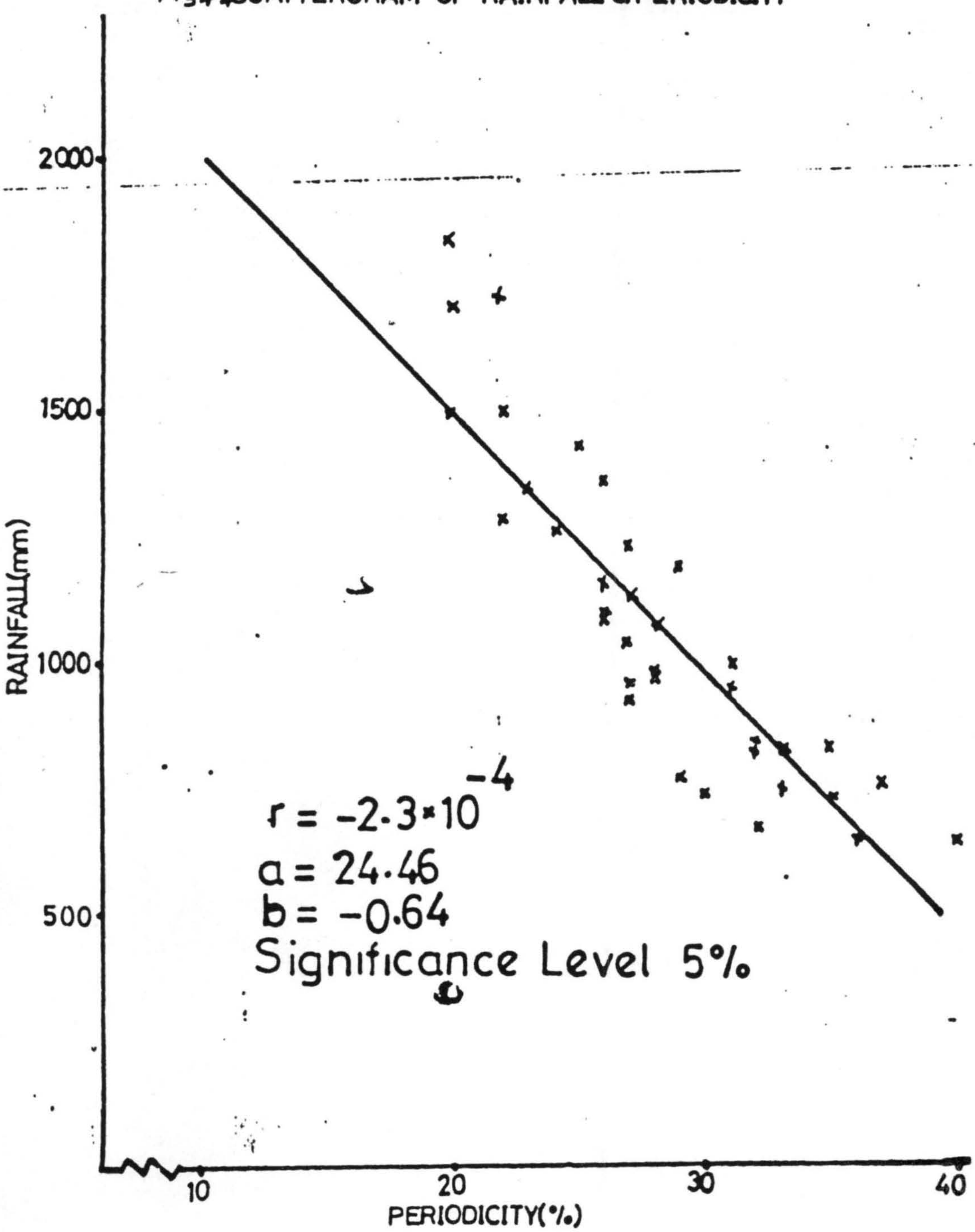
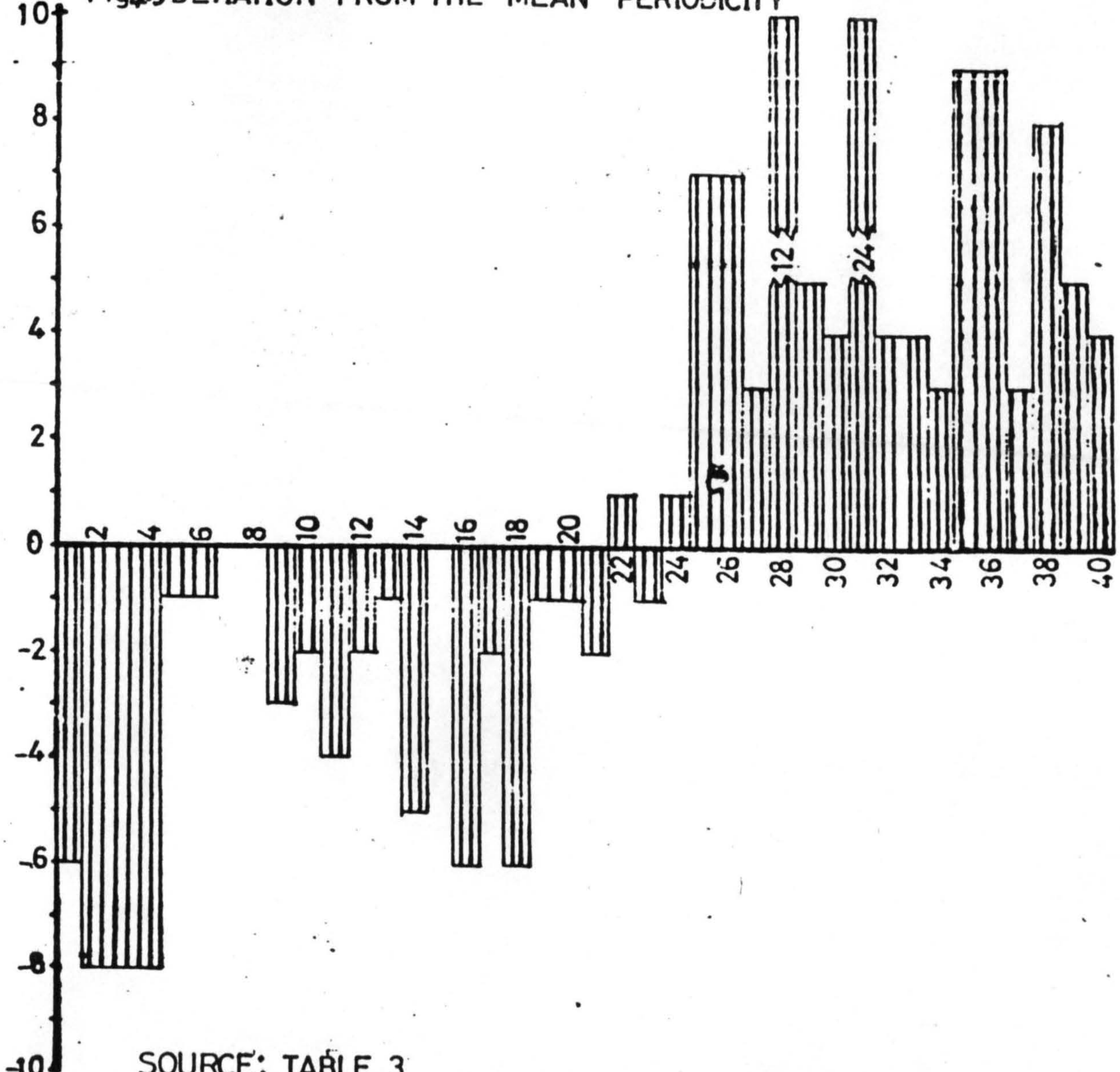


Fig4.5 DEVIATION FROM THE MEAN PERIODICITY



SOURCE: TABLE. 3

Those areas (the western flank, the northwest and northeastern flank) > 20% and above the mean in figures 4.2 and 4.3 respectively correspond with areas having positive deviation in fig. 4.5. This figure is derived from Table 3. We can therefore state that the station that shows negative deviation are the areas having adequate moisture (near normal rainfall). Agro and Animal husbandry practices in these areas may not suffer when the onset/cessation dates are observed. This zone (Southeast) unless otherwise excessively exploited by man - which is true of this zone - may not experience serious erosion problems.

Table 3: STATION DEVIATION FROM THE MEAN PERIODICITY

S/NO	STATION	(%) PERIODICITY	DEVIATION
1	Kafanchan	22	-6
2	Kwoi	20	-8
3	Kagoro	20	-8
4	Kagama	20	-8
5	Maigana	27	-1
6	Zaria	27	-1
7	Daudawa	28	0
8	Gwagwada	28	0
9	Kudaru	25	-3
10	Damdume	26	-2
11	Kaduna	24	-4
12	Samaru	26	-2
13	Funtua	27	-1
14	K/Areodrome	23	-5
15	Lere	28	-5
16	Kurmin Biri	22	-6

17	Kagarko	26	-2
18	Kachia	22	-6
19	Dutsenwai	27	-1
20	Ikara	27	-1
21	Anchau	26	-2
22	Yelwa	29	1
23	Kauru	27	-1
24	Birnin Gwari	29	+1
25	Mashi	35	7
26	Kafin	35	7
27	Kankara	31	3
28	Baure	40	12
29	Mando	33	5
30	Safana	32	4
31	Shika	52	24
32	Rimi	32	4
33	Kurigi	32	4
34	Danja	31	3
35	Zamgo	37	9
36	Bondawa	37	9
37	Bakori	31	3
38	Jere	36	8
39	Sabon Birni	33	5
40	Dutsi	32	4

Source: 1995 Field Work.

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 CONCLUSION

An understanding of the basic principles of precipitation characteristics is essential for a sustainable agricultural practice. On one hand our land is patched by drought (moisture deficit) at the other it is ravished by floods. In between these extremes are salient average conditions which if adequately appraised and understood will bridge the gap between humanity and resource development.

H. H. Thomas, (1976) stated that 'Hydrology may be a new science but man in ages has been conscious of his need for water. We have come to understand also that this water is sustained on the earth only by precipitation. This precipitation which is one of the elements of meteorology, has several characteristics. Unless these characteristics are critically highlighted through various researches, we may continue to record failure in our environmental projects which may lead to environmental degradation due to our action. The science with which to determine accurately the intensity and duration, onset and cessation and the frequency of occurrence is meteorology which can also be used to estimate the future behaviour of each weather elements as climatic characteristic. In a way the essence of meteorology is 'making use of what is to guard against what to be (S.M. Hassan, 1992 unpublished first degree thesis).

Meteorology therefore is an environmental science used in solving and highlighting environmental problems through various methods. This is to assist in providing a basis for planning against t the potential danger that sever weather events (droughts and floods for instance) constitute to agrarian practice.

5.2 EFFECTIVE AGRICULTURAL LAND USE PRACTICE

The Isoline analysis is vague and did not clearly delineate the zones. But all the same it provided the general idea about the nature of rainfall distribution over Kaduna State (fig. 4.1). The clear demarcations become evident in fig. 4.2. (The mean Rainfall Periodicity) with 3 zones. The normal rainfed zone is in the south east of the State where unless in the years of droughts, the agricultural practice does not require moisture supplement. The Second Zone is in the North east through the central part to the western flank of the State. Although not critical, rainfall alone cannot on its own sustained agricultural practice. There must be a supplementary supply of moisture to the lands. The most critical zone in the State is in the North and North-West. Most crops may fail here if moisture is not added to the soil from available source.

Fig. 4.3 Summarise the zones into two parts. The normal zone is again in the southeast sector (same as in fig. 4.2) where precipitation is above the State mean. the other parts of the State fall under the zone in which precipitation is below the mean. This generally means there are two major zones (areas below and above the mean) in the State. The significance of this is that various types of crops can be cultivated in the moisture surplus zone during planting season without fear of crop failure unless otherwise dictated by the natural 'cyclic' condition of drought. The moisture deficit zone can only support drought tolerant crops. It is very necessary to supplement rain fall with irrigation schemes either through 'earthdams' or bore holes.

5.3 ANIMAL HUSBANDRY

Animal performance, productivity, milk yield etc, depend on the availability of water (the very essence of life) and when it is actually needed. Since water intake of livestock varies according to temperature, season, age, quantity and nature of food intake, the water requirement for livestock in these two zones may differ. Water requirement for livestock in the area below the mean may be higher since the zone is expected to have higher range of temperature due to dryness that leads to less vegetal cover. This equally means that this zone may be experiencing higher albedo rate (total reflectively of the surface) and of higher herbage dry matter.

The moisture surplus zone on the other hand will require less amount of water to produce the same number of livestock at a better result. This is because most of the environmental conditions necessary for livestock production are near normal. There is less herbage dry matter, abundant food (both herbage and grains) and enough water supply during the raining seasons and less evapotranspiration-a condition that leads to comfort. This made the South-east zone best for Animal husbandry. The animal performance is there assured and so their productivity, milk yield etc.

5.5 RECOMMENDATION

Since more than half of the State is under moisture deficit, it is very important for the State to embark on various irrigational schemes in order to be self sustained through agricultural activities. The continued survival of the livestock greatly rest on supplementary water supply. These can be done through numerous earth dams and watering points (bore holes).

Extensive reafforestation is needed in the less rainfed sector and proper soil management and aggressive tree planting in the southeastern sector to curtail and avoid the desertification process now threatening the northern part of the country. It is also very important to note that the importation and application of additional water to an area caries with it its own seeds of destruction. Many once productive irrigation areas have failed and many are now at risk or at least, losing part of their productive land, just as excessive bore hole drilling may affect the surface moisture that may lead to less vegetal cover due to lowering of the water table. The only way out to prolong the productive life of the lands is by acknowledging the weather characteristics and using that knowledge for careful soil management.

Any activities (Agro, Animal husbandry) must be conducted in an environmentally friendly manner, otherwise the already precarious position of the State in terms of environmental degradation will be worsened.

5.5.1 Area For Further Research

It is therefore necessary to carry out further research in areas of 'the role of climate on the animals nutritional and physiological responses; Heat Test to determine the temperature for the animals acclimatization; Soil test to determine the type of crops best suited for such soil or carry out ecological zones; and agro-climatological landuse assessment of the State. Another viable area that requires further research is in Periodicity and Resort activities - a very important economic venture.

REFERENCE

1. Abubakar A. S. 1990 Climatic Factors of Constraint to the Performance of hydroelectric Power Stations, F. U. T. Minna, Nigeria.

2. Adefolalu, D. O., 1991. Towards Combating Drought and Desertification in Nigeria. A Project proposal submitted to the Federal Ministry of Science and Technology, Lagos. Federal University of Technology, Minna, Niger State, Nigeria.

3. Adefolalu, D. O., 1991, Ecological and Agricultural Landuse Mapping Project of Niger State. Federal University of Technology, Minna, Nigeria.

4. Adefolalu, D. O., 1992. Agroclimatological Studies of Ondo State, Nigeria. Federal University of Technology, Minna.

5. Adefolalu, D. O., 1994. Project Document on Agricultural Landuse Planning (Submitted to the Department of Agriculture and Land Resources, Abuja). Federal Ministry of Agriculture and Natural Resources. Federal University of Technology, Minna, Niger State.

6. Bianca, W. 1965. Review of the Progress of Dairy Science Section. A Physiology of Cattle in a hot environment. J. Dairy Res.

7. Bruce, J. P. and Clerk, R. H., 1966. Introduction to Hydrometeorology. Pergamon Press Ltd., Headington Hill Hall, Oxford.

8. Change Jen-Hu, 1968. Climate and Agriculture: An ecological survey. Aldine Publishing Company, Chicago.

9. Hare, F. k. 1985, Climate Variations, Drought and Desertification, WMO, N. 653, Geneva.

10. Hassan, S. M. 1992. Baseline Hydro-Climatological Data for Planning Hydroelectric Power Stations. F. U. T., Minna, Nigeria.

11. Johnson, H. D., 1965. Response of Animals to heat meteorological monographs. Elsevier Science Publishing Company Inc. New york.

12. John, H. D., 1987. Bioclimatological and Adaptation of Livestock. Elsevier Science Publishing Company inc. New York.

13. Landsberg H. E., 1986. Potentialities and Limitations of Conventional Climatological data for Desertification Monitoring and Control. Climate Change Vol. 9. 123-128 D. Reidel Publishing Company, U.S.A.

14. Magre J. C. jr. and Monroe C. B., 1993. An Introduction to Statistical Problem Solving in Geography. WBC, WMC Brown Publisher, Dubuque. Iowa, Melbourne, Australia. Oxford, England.

15. Nicholas Wade, 1974, Green Revolution (ii): Problems of Adapting a Western Technology, (Science, 186).

16. Strahler, A. N., 1975. Physical Geography, Fourth Edition, John Wiley and Sons Inc. U.S.A.

17. Thomas H. H., 1976. The Engineering of Large Dams Part I. John Wiley and Sons, PP. 99 - 10.

18. WMO, 1971: Climatological Normals for CLIMATE AND CLIMASHIP Stations for the Period 1931 - 1960. WMO - No. 117, Geneva.

19. WMO, 1975: Meteorology in Relation to National Economic Development Plans. WMO - No. 422, Geneva.

20. WMO, 1975: Application of Meteorology to Landuse and Agriculture MWO - No. 422, Geneva.

21. WMO, 1980: The Role of Geometeorology in Agricultural Development. An Investment Projects. WMO - No., 536, Geneva.

22. Yousef, M. K. and John, H. D., 1965, Some Blood Constituents of Diary Cattle. Influence of Thyroxine and High Environmental Temperature. J. Dairy Science, Res.