QUANTIFICATION OF PRECIPITATION CHARACTERISTICS IN RELATION TO AGRICULTURE IN ENUGU STATE – NIGERIA

BY

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CERTIFICATION

This thesis titled: Quantification of Precipitation Characteristics in Relation to Agriculture in Enugu State – Nigeria by: Effiong, Dominic Edem (PhD/SSSE/1999/34) meets the regulations governing the award of PhD of the Federal University of Technology, Minna and is approved for its contribution to scientific knowledge and literary presentation.

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DEDICATION

This work is dedicated to the memories of my late mother and my wife, Madam Mma Eyoh Effiong and Mrs. Margaret Dominic Effiong.

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ABSTRACT

Water occupies a unique position in agricultural production and its conservation through proper management for all life - support systems is a standard practice world over. For the period of 1991-2000, an estimated 5527 hectare of arable farm lands were cultivated in Enugu State with expected crop yield of 474,387 metric tonnes. Only 215.699 metric tonnes (45% of expected yield) was actually realized during the same period. An attempt is made in this work to expatiate on the various scenarios of water needs by crops in relation to the climate related problems of agriculture that have been hitherto neglected in Enugu State. The purpose of the study is to quantify precipitation characteristics in relation to agriculture and identify crops that are threatened by variations in climate in different parts of the State for the purpose of ensuring that planning for optimum growth and development of crops under rainfed agriculture. Data from 17 agricultural stations covering a total of 382 station - years were selected on the basis of their length of records, to compute observed and derived parameters of precipitation effectiveness including onset, cessation date of rains in estimating the length of rainy season, breaks (dry spells), hydrologic ratio (λ), specific water consumption or water equivalent to avert drought. In addition, a structured questionnaire was administered to collect data from the farmers. Chi-square analysis technique and other descriptive statistics were used in analyzing the data. Results showed that the onset dates of rains vary between March 21 and April 10 with rains starting 3 weeks earlier in the south west. The termination dates occur between October 27 in the eastern fringes and November 25 in the extreme western part with the maximum range of 30 days in the entire Enugu State. The rainy season has duration of 190- 210 days in the north, 230-250 days maximum in the central and 210-230 days in the south eastern sections respectively. The hydrologic ratio (λ) values ranges between 0.4 to 0.9 which implies that the value of 0.9 is near the hydro neutral value of 1.0 for optimum crop yield but some parts the value is 40% of required soil moisture for option yield. Thus crop yield will vary from near optimum in some parts to about 40% in other parts for improved yield; water supplementation strategies may be necessary. This is supported by deficit specific water consumption of between 250mm to a surplus of 360mm. across the state. Specifically, it is only in the extreme north and southeast that crop yield is optimum value. Thus, to do water supplementation in the north and southeast specific water consumption in the best indicator. The result from the questionnaire showed that people's opinion support combined rainfed and water supplementation practices. The finding will help for better understanding of yield and water relationship.

CHAPTER TWO

LITERATURE REVIEW

CHAPTER THREE

MATERIALS AND METHODS

CHAPTER FOUR

AGROCLIMATOLOGICAL CONDITIONS IN ENUGU STATE

CHAPTER FIVE

WATER USE AND AGRICULTURE IN ENUGU STATE

CHAPTER SIX

SUMMARY, CONCLUSION AND RECOMMENDATION

LIST OF TABLES

TABLE

LIST OF FIGURES

ABBREVIATIONS

ASWP	=	Available soil water at planting
B.C.	=	Before Christ
CCFR	=	Centre for Climate Change and Freshwater Resources
¢	=	Cessation dates of rains
D Dry	=	Length of Dry period in days
D wet	=	Length of wet period in days
E_0	=	Evaporation from water surface
E	=	Expected Frequency
ESADP	=	Enugu State Agricultural Development Project.
E_0	=	Total Evaporation for Hypothetical Open water Surface at Field conditions
Epan	=	Total evaporation from Class A – Pan
ET	=	Evapotranspiration
FACU	=	Federal Agricultural Coordinating Unit
FAO	=	Food and Agriculture Organization
FC	=	Field Capacity
HGS	=	Hydrologic Growing season
ICDI	=	International Commission on Irrigation and Drainage
LRS	=	Length of the Rainy season
mm	=	Millimeter
N	=	Number of items in a distribution
ϕ	=	Onset dates of rains

O	=	observed frequency
0^C	=	degree Celsius
P/PE	=	Where p = means annual rainfall
	=	PE = means potential evaporation
P Dry	=	Average daily precipitation total during Dry period (in mm day – 1)
PE	=	f P Eo/Pan
	=	f = means factor to reflect the vegetal cover.
P Wet	=	Average daily precipitation total during wet period (in mm day-1)
RBDAS	=	River Basin Development Authorities
Rn	=	Net radiant energy available at the earth's surface
r	=	Pearson product moment correlation coefficient.
$\sum$	=	Summation
Q wet	=	Water demand equivalent of PE during wet period (in mm day-1)
λ	=	Hydrologic ratio
σ	=	Standard deviation
σ^2	=	Variance
W/F	=	Specific water consumption per unit area of land.
WMO	=	World Meteorological organisation
X^2	=	Chi-square distribution
$\hat{Y}$	=	Yield of crops

CHAPTER ONE

INTRODUCTION

1.1 Water and Agriculture – General Perspective

Water is essential for plant growth. As a limited resource, its efficient use is basic to the survival of the ever-increasing food demand of the world's over four billion people. There is need therefore for its conservation in irrigation support system for agriculture through proper management.

There are three basic environmental conditions that give rise to irrigation. First, where rainfall is low and cannot meet the yield, complete irrigation is called for and practiced. The second is, where rainfed agriculture is practiced to enhance crop production during drought spells, supplemental irrigation is necessary. This is to neutralize drought spells which could harm crops at critical stages. Thirdly, where drought is prevalent and predictable thereby causing poor agricultural activities protective irrigation is practiced. Irrigation is thus the application of water to the soil for the purpose of satisfying soil moisture requirements of crops. Irrigated agriculture make food and fiber supplies less dependent on fluctuations in climate.

The Nineteenth session of the Conference of Food and Agriculture Organization (FAO) Rome in 1977 recognizing the role of weather variability and climate in agricultural planning and production, urged all member nations to make full use of all available meteorological information and services in their planning and operational exercises. There is no doubt that climate and weather variability play an overriding role in determining the amount of the physical productivity of agricultural crops, livestock and forest, as well as the risk of failure of the productivity. In most food producing regions, the importance of rainfall overrides that of all other climatic factors which determines crop yield – for without water no growth will occur (Effiong, 1998).

Sustainable production systems are closely associated with water and soil management in a land use framework. Agricultural growth must come from both rainfed and irrigated agriculture through intensification, improved technology, improved farming practices, the efficient use of water resources, and the restoration and maintenance of soil fertility. Sustainable agricultural development is closely associated with economic growth through food security and strategies.

Effective management and utilization of water resources is necessary for Nigeria to increase crop production. Water is very vital to the economic growth of a country where many people are competing for finite environment. Concentration on rainfed production alone will not meet the need of the citizenry even if there were no interdiurnal variability of rainfall. This is why the present Government initiatives on fadama all year – round agriculture is laudable. Hence conscious efforts are required to make it a high-technology scheme through refined agroclimatological studies.

1.2 Attributes of Small Scale Irrigation as Against Large-Scale Irrigation

The practice of irrigation can be considered under two headings: traditional and formal. All types of irrigation involves some form of agricultural water management technique. These methods range from the cultivation of rice by controlled flooding to the irrigation of dry season vegetables by means of the shadoof and calabash. This is an age-old practice and has been in existence since the 19th century. It is a simple device consisting of a pole, bucked and counterpoise. These forms of agricultural techniques are carried out in the flood plains or fadamas of major and minor rivers, as well as other localized areas which are either prone to flooding or which over lie shallow ground water.

Traditional irrigation is almost all carried out on a small scale by individual farmers with virtually no assistance from government. Formal irrigation by which is meant the development and management of irrigated agriculture in a formally structured agency is very different. Formal irrigation projects are large scale, and often established with little prior involvement from farmers or land holders, they are usually managed by a structured government organization. The shadoof which is now in use throughout the northern Nigerian fadamas as well as the southern parts of the country in the dry season was probably adopted as a result of a technology transfer from Egypt – either brought in by Arab traders or seen by Nigeria pilgrims on their way to Mecca. The River Basin Development Authorities are large – scale and capital intensive projects which are designed to facilitate and ensure the year round cultivation of crops such as rice, wheat, maize, vegetables and raw materials for agro-allied industries.

Table 1.1: Irrigation potential for small-scale irrigation in Nigeria Savanna

State	Potential area (ha)	Development area (ha)	Percentage
Bauchi	236,346	17,662	7.47
Benue	289,100	540	0.19
Borno	200,100	1,500	0.19
Gongola Adamawa	366,400	1,855	0.51
Kaduna	81,000	21,000	25.9
Katsina	N.A	4,000	0
Kano	163,000	42,000	0.26
Kwara	142,000	872	0.61
Niger	N.A	1,500	0
Plateau	N.A	3,000	0
Sokoto	100,000	12,505	12.505
Total	1,886,846	106,704	5.67

Source: FACU(1988)

However, the gains that these projects have made must be considered against the huge financial cost involved. Apart from the fact that they have not been cost effective, the individual farmers has limited control over water allocation. The River Basin Development Authorities jointly planned for the irrigation of about 1.4 million hectare in the savanna zone by 1992 and developed only 107. 100 hectares while 1.8 million hectare was planned with a total of 106, 704 hectare development under the same period by the small – scale irrigation scheme representing 7.4% and 5.7% respectively as shown in Tables 1.1 and 1.2.

Table 1.2: Irrigation Potential for Large-scale Irrigation in Nigeria Savanna

State	Potential area (ha)	Development area (ha)	Percentage
Chad Basin	157,500	12,000	7.62
Hadejia-Jama'are	75,009	16,600	22.13
Lower Benue	130,050	N.A	0
Upper Benue	309,700	N.A	0
Niger	243,200	N.A	0
Sokoto-Rima	108,800	23,500	21.59
Non-River Project	418,500	55,000	13.14
Total	1,443,459	107,400	7.4

Source: Owonubi et al (1989)

Another important consideration regarding the activities in the long term is their effect on the environment. Moran et al (1980) found that, only one out of every four litres of water drawn for irrigation is actually taken up by plants. Seepage from irrigation canals can be so substantial that, it raises the water table, creates a marsh, i.e. waterlogging deter growth and development of young plants, especially non amphibious ones. There may be build up of inorganic compounds within the topsoil layers due to high evaporation, under such a condition, crop yield will declines as soil salinity increases. The Federal Agricultural Co-ordinating Unit, FACU (1988) on its Technical Committee Report on small-scale Irrigation Development in Nigeria found that, environmental and social degradation, increase water losses, increased pest prevalence, threat of dam failures, poor management and water quality are all associated with large-scale irrigation.

Small-scale irrigation will enable the farmers to construct and maintain their equipment with local labour and technology since the system is cheaper. It will ensure the community participation at every stage of planning and construction. In other words, there is water user association as is very cost-effective and more efficient in operation than large-scale irrigation. This is because its size permits cleaning and repairs to be undertaken quickly. It does not require resettlement and social disruption associated with the large scale irrigation. Small-scale irrigation systems does not require investment nor complex infrastructures. They can be constructed and developed quickly in the same way as they can be either serviced and renovated or demolished, if they are no longer required.

Agu (1994) found that the small scale irrigation have reduced impact on land-use, ecosystems and minimized threat of dam failure whereas large scale irrigation could cover valuable agricultural, forestry or mineral resources, special habitats, scenic or scientific features and sites of historical, cultural or archaeological sites. Large scale irrigation project can affect the local climate and thereby altering the albedo of the area cropped. It can reduced the number of species of soil micro flora, spread disease and transmits pollutants. Sanda et al (1980) observed that, the vegetation which grew around the small-scale irrigation will check erosion and aid in soil conservation practices in erosion prone areas.

Small – scale irrigation will help to reclaim the less productive lands and thereby boast food production in the state. There is clearly defined water right in small-scale irrigation and improved agricultural services, improved water harvesting techniques, minimum tillage etc. it will create employment in disfavoured rural areas in the state, thereby mitigating one cause by urban migration. Agu (1988) did the study on the sustainable use of Mini-dams in adapting to climate variation noted that: the construction and use of mini or micro-dams or barrages across small streams which normally flow through the farmlands had come to symbolize social advancement and technological process. He found out that, mini dams are very cost effective and more efficient in their operations than mega dams as they neither require major investment nor complex infrastructures.

The small-scale irrigation will enable the state to achieve self-sufficiency in crop production and reduce vulnerability of the state economy. There is need therefore to harness the state's water resources and offset irregular rainfall through small scale irrigation system as the most appropriate one to: Land Tenure System in which land is fractionalized into small holdings. The building of dam over the disputing boundaries and frontiers would reduce to the barest minimum the bottleneck associated with land tenure system.

The small-scale irrigation will permit double cropping and increase yield by ensuring supply of sufficient water during the growing season. It will serve as a natural source of water for many homes.

Other positive impacts of the effects of small-scale irrigation as a possible solution to some of the problems of agriculture in Enugu State includes:

(a) Enough moisture for all seasons farming

(b) Recharge of water table makes sinking of productive wells and borehole possible.

(c) Reclamation of less productive lands

(d) Increased food production (quantity, quantity and variety).

(e) Establishment of fish ponds

(f) Mixed and balanced diet ensured

(g) Increased in farmers income

(h) Improved feeding habits which may lead to population increase

(i) Establishment of agro-based industries

(j) Development of rural infrastructure resulting from increased income

(k) Employment opportunities and reduction in rural urban drift.

(l) Introduction of irrigation pumps

(m) Great need for education and increase in social and political awareness. Improved knowledge and effective extension services to disseminate knowledge, which can lead to better decision-making in agricultural planning.

(n) Increased in government revenue.

1.3 Statement of Problem

Environmental constraints against sustained agricultural production is becoming increasingly severe due, largely to less water (in the form of soil moisture) being available from the most occurring natural source, precipitation in Enugu State. This characteristics of water supply and demand has posed a serious problem to the agricultural production in the area (Jackson, 1997). There is need for scientific orientation of agriculture in which climate is recognised as a major economic input in the production processes with emphasis on the precipitation effectiveness as the main source of available water as a resource to be adequately managed in the area. This is with a view to adopting strategies and plan logistics for adapting to change. Due to the lack of sustainable agricultural extension services, crop production has been on the decline while arable lands have not been fully exploited especially all year round.

Decrease in rainfall amount as observed by Ojo (1987) has reduced the production potentials of crops grown in Enugu State thereby affecting the income of the farmers and others whose occupation are depend upon farming. In the extreme, unemployment, starvation and ever death result, the state economy cannot be sustained under such a condition without proper planning. Plants do not depend on amount of rainfall received for growth, development and high yield but on how much water that is available to them as soil moisture. Adefolalu (1983) and Adebayo (1997) found that late onset, shorter length of the growing season, uneven distribution of rainfall in time and space and a southward shift in the main axis of maximum weather activity affect crop yield potentials in Nigeria.

In adequate rainfall due to its seasonality and highly variable from year to year, this account for low level of agricultural output in Enugu state. These situations are explained in Tables 1.3-1.6. Intercomparison between estimated hectare of major food crop production cultivated, estimated yield expected per hectare, the actual yield realized per hactare and total rainfall amount received for the period of 1991-2000 in Enugu State are illustrated. There are apparent differences between the hactare crop production, estimated yield expected, actual yield realized and annual total rainfall distribution patterns received in the area during the same period. For instance, an estimated 5526.57hectare of land was cultivated with the expected crop yield of 47438.679 metric tonnes per hectare, only 214. 699 (4.5%) metric tonnes per hectare was actually realized with the mean total rainfall amount of 16616.6 milimeters in the same period. Table 1.5 showed the crop yield in relation to the rainfall distribution in Table 1.6.

Table 1.3 Enugu State Estimated Area Cultivated of Major Food Crop Production in Hectare (1991-2000) ('000)

Crop	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	Row Total
Cassava	276.900	293.000	312.100	302.100	277.087	299.340	224.505	225.363	202.659	161.320	2574.374
Yam	150.800	175.900	184.400	297.100	273.970	294.700	221.025	227.351	209.016	126.103	2160.365
Maize	36.320	40.310	40.200	66.760	63.880	54.953	41.214	42.016	37.500	42.502	465.655
Rice	35.100	36.200	43.700	46.790	58.355	37.840	30.255	7.260	11.603	19.073	326.176
Column Total	499.12	545.41	580.00	712.75	673.292	686.833	516.963	501.99	460.778	349.058	5526.57

Table 1.4 Estimated Yield Expected in ('000) Tonnes Hectares (1991-2000)

Crop	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	Row Total
Cassava	1797.912	1904.500	2072.344	2348.098	2572.476	3277.474	2522.314	2310.277	2188.515	2048.273	23042.183
Yam	880.823	1117.317	4069.520	2639.734	2639.734	2700.926	2127.145	2322.325	2240.861	2043.487	22781.874
Maize	39.589	64.496	68.983	86.988	99.525	104.136	74.226	90.842	69.638	84.154	782.577
Rice	66.339	68.201	98.981	129.808	163.394	109.599	87.588	20.482	33.103	54.550	832.045
Column Total	2784.663	3154.514	6309.828	5204.628	5475.129	6192.135	4811.273	4743.926	4532.117	4230.464	474386.79

Table 1.5 Actual Yield in ('000) Metric Tonnes (Hectare) (1991-2000)

Crop	Year										
	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	Row Total
Cassava	6.493	6.500	6.640	7.760	9.284	10.949	11.235	10.251	10.799	11.000	90.911
Yam	5.141	6.352	5.800	8.05	8.885	9.165	9.624	10.210	8.00	10.800	81.227
Maize	1.090	1.600	1.716	1.303	1.558	1.895	1.801	1.895	1.857	1.980	16.695
Rice	1.890	1.884	2.265	2.763	2.800	2.843	2.895	2.812	2.853	2.861	25.866
Total	14.614	16.336	16.421	19.876	22.527	24.852	25.555	25.168	23.509	26.641	214.699

Table 1.6 Annual Rainfall (mm) (1991 – 2000)

Year	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	Total
Annual Rainfall	1994.8	1699.5	1713.5	1526	1691.7	1963.1	1824	1247.8	1393.9	1562.3	16616.6

Source: Enugu State Agricultural Development Projects (2003)

The absolute lower crop yields support inadequate rainfall distribution. And although absolute values of rainfall amount are higher, it showed that crops do not depend on amount of rainfall received for its growth, development and high yield but on how much water is available to them 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 for enhanced yield. The evidence of this is also manifested by the trends in the thermal characteristics particularly temperature and pattern of occurrance and spatial distribution of moisture meteorological indices particularly rainfall in the area. Enugu State suffer from seasonal and inter annual climatic variabilities and there have been droughts and effective desertification processes.

Bello (1999) observed that the periodic stresses of extreme and persistent nature during drought has potential impacts on the quality of the components of the terrestrial ecosystems. He noted that, the current climate models identified the indices of climate change to include a change in any or combination of change among others: direct onset and cessation of the rains, rainfall seasonality and reliability, duration of the growing season and annual precipitation rates and shift in rainfall belts in Nigeria. Agu(1988) observed that increase temperature results in higher evaporation and reduce the effectiveness of any increase in precipitation thereby causing lower crop yields (Table 1.5).

Generally, the rain come in the form of intensive, violent showers of short duration, especially at the beginning (March/April) and end October/November of the rainy season. While rain may fall continuously for two, three or more hours, it is observed that most of it comes during the first minutes or so of the period. The overall effects of the fluctuating rainfall is that crops tend to wilt and sometimes the eventually die (due to very high temperature and evaporation).

In some years, farmers are forced to plant twice or more due to failure of seeds sowed during unsteady onset dates of rains. This often leads to increased overhead costs as more mandays and resources are spent in a single growing season (Gisilanbe, 1994b). Also, at time the crops never grow to maturity before the rain ceases, this resulting in total or near total loss or crop failure, especially annual crops in Enugu state (documented yield and annual rainfall for 1991-2000) that are adversely affected and summarized in Table 1.5 and 1.6.

There have been major transformation in agricultural practices due to decrease in rainfall and increase in temperature which lead to a considerable change in the chemical composition and organic matter content of the soil. This is due to increase in the climate variabilities which lead to frequent changes in agroclimatic. Variabilities and increased variability in (Tables 1.5 – 1.6). Inadequate rainfall and unrealiable pattern of distribution especially with regard to onset and retreat are important features of drought and its impacts on agricultural production in the area. Agricultural system is therefore affected through the impacts on crop calendar and lengths of growing season.

The main constraints to crop production, to meet the required aggregate food and fibre needs in Enugu State have been identified by the state Ministry of Agriculture and Rural Development (1999) to include: soil constraints, pests and disease, population pressure on land, environmental degradation and its elements such as flooding, soil erosion, drought, pollution, desertification and strong winds. The extent of soil erosion and flooding constitutes a serious threat to the environment, agricultural activities (which involves food production) and quality of life in the state. The combined effects of floods and strong wind often result in massive destruction of maturing crops especially cereals like maize (zea mays), millet (penniseta typoid) and sorghum (sorghum bicolor). These cereals are ready victim of strong winds, which often break their stems. Legumes such as groundnut and beans are easily destroyed due to water logging as a result of floods. These constituted one of the major causes of low agricultural production and threatening famine and food shortages as well as the escalating food prices. Resource availability problems have to do with planting material and breeding stock, agricultural credits, funding, labour supply and agro-chemical inputs. Poor management of crops and soil, which tends to limit output even when more land is brought under cultivation, causes yield problems.

Other problems includes marketing, storage and processing facilities, research and extension constraints, land tenure problem, and poor response by the farmers to economic incentives and innovations. Most of these problems of course, derive from the fact that an overwhelming proportion of crop production in the state is in the hands of peasant farmers operating within the framework of traditional system of agriculture. The systems of land tenure constitute serious limitations to land utilization and consequent modernization of traditional agriculture.

Irrespective of the impact of environmental constraints to agricultural production in the area, the people are coping and are all the while trying to ameliorate the hazards facing them and their agricultural activity. Taking these into consideration, the key questions that are posed within the framework of this study are; to what extent is the change in climate affect or cause a decline in agricultural production? Which are Economic, cash crops and which are for subsistence? What are the crops of socio-economic values that are affected by the change in climate? To what extent has climate change influenced yield? Can the farmers modify their agricultural practices in other to cope with the change in climate and thereby increasing their productivities? To what extent are the corrective measures already employed are effective. Tables 1.5 and 1.6 were correlated with each other to determine the degree of relationship between rainfall and the crop yield. The results showed that rainfall has a high positive correlation value of 0.87 with the crop yield (Appendix 2). From the results, the variations in the yield of crops is directly related to rainfall distribution in Enugu State. It implies that crop depend on rainfall and therefore more work is required in order to achieve self sufficiency in crop production and reduce vulnerability in Enugu State economy.

1.4 Aim and Objectives

The main aim of this study will be to assess the impact of climate change to the variations in crop yields. This is with view to determining the water needs by crops in Enugu State given the environmental conditions. Since the major thrust of this research is on the application of agroclimatology to small scale irrigation in Enugu State, then the research will have the following objectives:

(i) Quantify precipitation characteristics in relation to agriculture.

(ii) Identify the crops of socio-economic values in the Enugu State and examine those that are now threatened by variations in climate.

(iii) Assess water supply for agriculture in relation to irrigation development in Enugu State.

(iv) Attempt a model of achieving moisture requirements for optimum crop growth and development when rainfall low or less than required.

1.5 Justification of Study:

Agriculture dominates the economy of Enugu State. It provides employment for over 60 percent of its rural population involved in farming at a small scale or subsistence level. The output collectively is significant making the state one of the major basket for food production in the country. Food in the form of plant and animal products is one of the first necessities of life. Many of the manufacturing industries make use of agricultural products as the raw materials from which finished products are made. The selling of agricultural products provide income to the farmers.

Climate is one of the primary controls of food production Hogg (1964). Even this age of advanced technology the food supply is largely at the mercy of weather and climate. This vulnerability is quite evident in the study area as it is worst hit by a series of weather extremes. The rainfall scenario is characterized by a mixture of good and bad seasons. Some years had adequate rainfall in terms of timing, intensity and duration. Others had delayed rains that are erratic in nature, low intensity and lasted for short duration. Sometimes with some mid-season droughts (dry spells) during the rainy season. Temperatures are always high, soil moisture are quickly exhausted. The overall effects of this fluctuating rainfalls is generally low level of agricultural output. Yet the rapidly increasing population must be fed.

The only practical alternative is to learn to live with this climatic change and be prepared to modify our agricultural practices accordingly. In fact with the shift in climate, the people in the state find it necessary to adapt to this changing not only on their agricultural practices, but also their attitudes towards food storage and reserves.

Buckkey R.B. in a classic work on irrigation in India, wrote in 1919, "the beneficial results which both the security and increase of out-turn (i.e. crops) confer on the people are incomparably more valuable than the large revenue derived by the state. For instance, bringing in an additional 6 million hectares into irrigated agriculture could increase cereals and grains production by 25 to 30 million metric tons annually (World Bank Technical Paper No. 331 on African Technical Department Series). Therefore, the use of water in agriculture should become more efficient through proper pricing and conservation measures. Increasing food supply in the country is closely linked to water utilization and access to water. Food security means not only availability but also stability and access to food.

Israelsen (1950) stated that, "if the population of the world continues to increase at the present rate, where is the food for these people to come from? The men and women with knowledge of irrigation will be called upon to assist". It is the view of this study that faced with food scarcity as a result of increasing population, the problems of climatic variations already witnessed in the state and failure of the large-scale irrigation schemes, it is necessary to adopt strategies and plan logistics for adopting to changes.

The study is expected to generate the resources that would enable the state to benefit from the effect of climatic change through more efficient management of available surface and underground water resources to meet up with the food needs of the state teaming population. It is also expected to play a significant role in improving and modernizing on Farm irrigation systems to increase water use efficiency and crop production, not only in the study area, but throughout the country thereby ensuring security of harvest.

The study is expected to address the problem of water deficiencies caused by inadequate rainfall which is, in fact, the major hydrometeorogical factor that poses threats to agricultural activities in Enugu state. Similarly, areas under water supply these same methods will help to alleviate the drainage problems caused by excess water as the method will help to prevent nutrients from being washed down into the sub-soil. The findings will help for better understanding of yield and water relationship.

Lastly, the study will contribute to academic knowledge and so, it is justified to embark upon.

1.6 Scope and Limitation of the Study:

This study covers the entire Enugu State of Nigeria in relation to the application of agroclimatology to small scale irrigation in the area. The state is situated in the transitional belt zones of Nigeria between the humid steamy equatorial region to the south and the guinea savanna belt in the North (Ofomata, 1972). It lies within latitudes $06^0$30' and $07^0$40' East of the Greenwish Meridian (Fig. 1.1). The state lies within the agricultural prolific zone in Nigeria.

Data on agroclimatic elements as well as the oral interview data during the field survey were used for detail analysis. The data on agroclimatic elements were obtained from the 17 agricultural stations covering a total of three hundred and eighty two (382) station years.

One of the limitations of the study is the general low level of education of the people interviewed. There were suspicion and fear on them who regarded such an inquiry as a way of assessing their income earnings with a view to raising their taxes.

Another limitation is the scope in terms of area coverage. The agroclimatic data were collected from locations and may be if they were to be collected over a wider area a different picture would have emerged. Other limitations includes, the contemporary patterns of crop production among subsistence cultivators in the data acquisition, low level of technology, finance, this research cannot cover all the weather hazards that affect agricultural planning in the state. Inspite of these limitations, the study will provide insight for agricultural planning.

1.7 The Study Area

1.7.1 Location

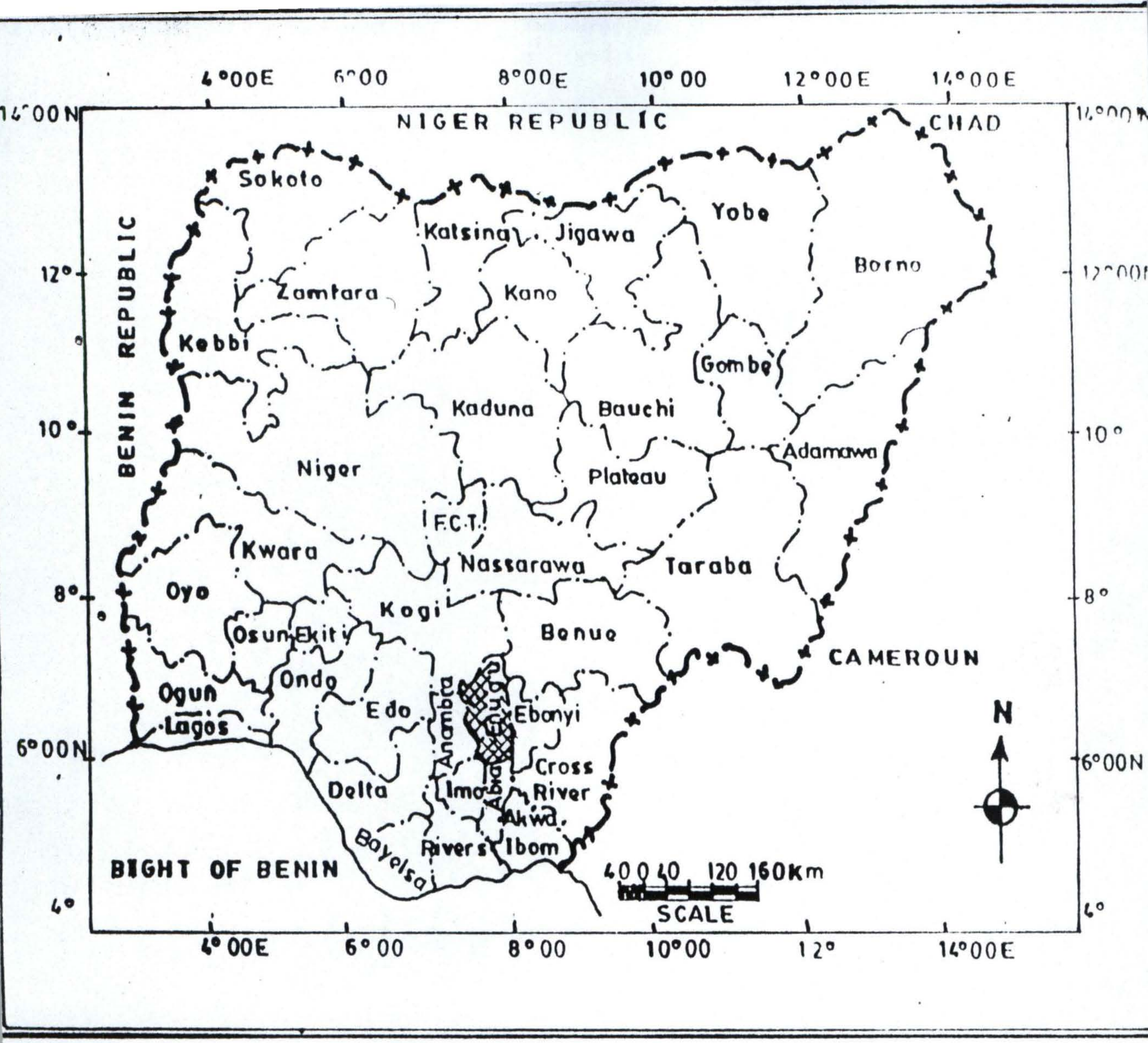
The Study area of this work is Enugu State with an estimated population of 2.7 million people. It occupies an area of 12.791 square kilometers, which is about 1.39 percent of the total landmass of Nigeria (Fig 1.0). It lies within latitude06^{0}00' and 7^{0}05' North of the Equator and between longitude 06^{0}30" and 07^{0}40" East of Greenwish meridian. The state shares common boundaries with Abia and Imo States in the South, Benue and Kogi States in the North, Ebonyi and Anambra States in the East and West respectively (Fig 1.1).

1.7.2 Geomorphology and Geology:

Three main topographic Units can be recognized in the state. These are plateau, the escarpment and the plains Nwachukwu (1976). These rocks are grouped into six formations: Agwu shale, Enugu shale, Mama formation, Ajali sandstone, Nsukka formation and Imo shale formation (Fig 1.2).

1.7.3 Relief and Drainage:

The state is situated on much of the highlands at Agwu. Udi and Nsukka hills and the rolling lawlands of the Ebonyi River basins to the East and Oji River Basin to the West. This gives an outline of the lithology, structure and topography of the area. The area has a high central zone which lies generally over 365 metres above the sea level, with isolated peaks reaching over 545 metres. The highest point known in the area lies at 590 metres above sea level.



LEGEND

National Boundaries..+—+—+ State Boundaries.......—.—.— Study Area......

Fig.1.0: Map of Nigeria showing Enugu State as the study Area.

Source:- Cartography Unit of Department of Geography, F U T Minna (2005)

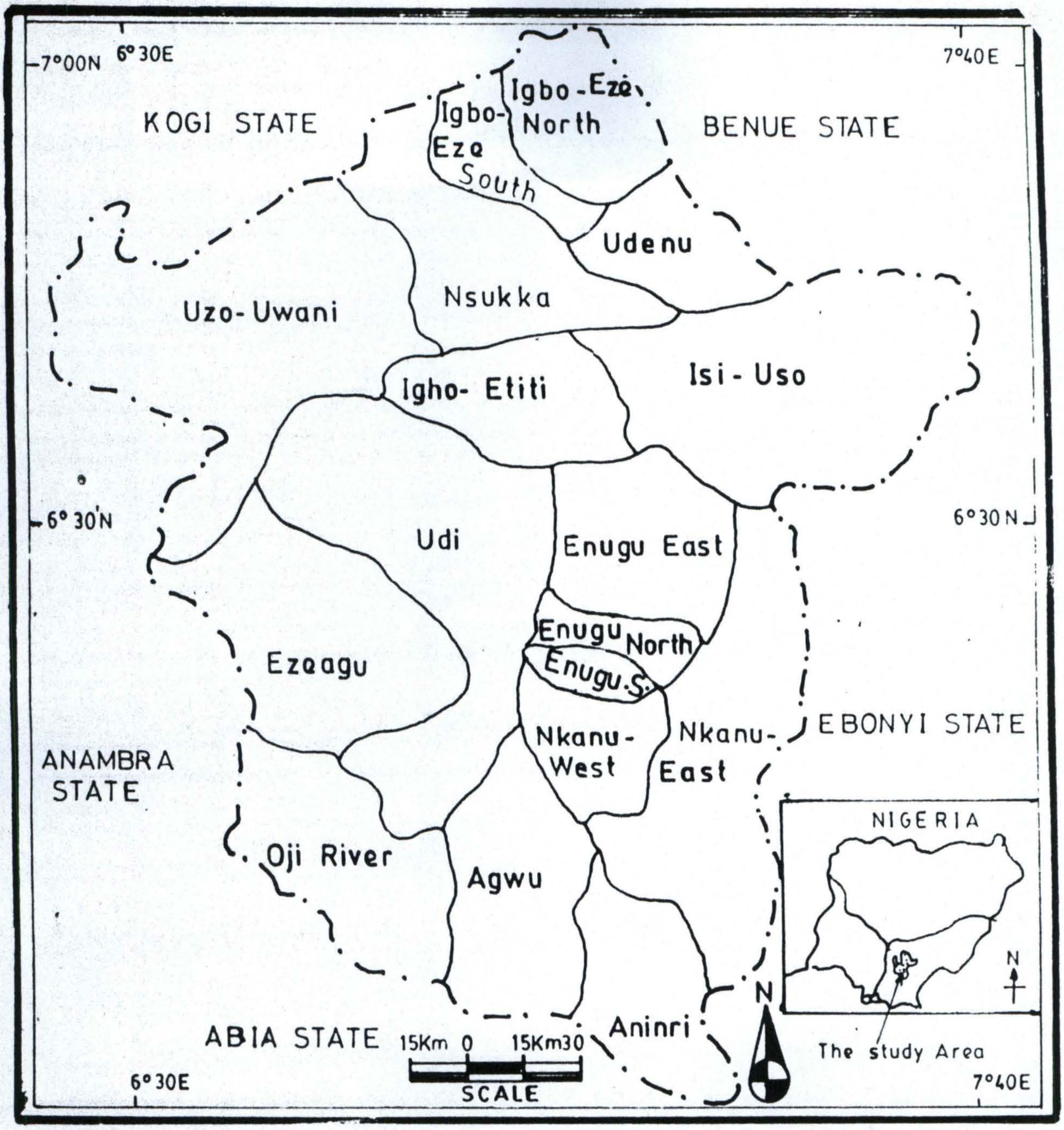


Fig.1.1: The study area and its 17 Local Government Areas.

The drainage system of the state has been divided into two major sub-catchment basins of the Ebonyi in the East and Oji River in the West. The surface drainage is very spare in the central area of the state. The Adada River crosses the Nsukka plateau near Nsukka. There are other numerous and rivulets in the State (Fig 1.3).

1.7.4 Climate:

Enugu State like other part of Nigeria is characterized by a marked dry and wet seasons which is always under the influence of two air masses. These are the tropical continental and tropical maritime air masses. Apart from the most northerly town of Nsukka which has no rain at all in December and January, every other station has rain every month of the year. Nsukka is again singular in having July as the wettest month. The double maximum is clearly visible in each station; and so is the so called August Break. Yam cultivators in Enugu state always take advantage of this period to carry out the first harvesting. In the stations shown in Fig 1.6, there are at least three months and at most six in which rainfall is greater than the potential evapovranspiration. These are the months which provide surplus water for underground storage. They may be regarded as months of effective precipitation for Enugu state.

Rainfall is seasonal in character (Barry et al. 1990) with a low annual totals ranging between 1247.8 to 1994.8mm (Table 1.6). Rainfall is bimodal (Griffiths. 1972)(Table 1.6). In other words, there are two identifiable wet seasons each year with alternating dry periods. Under these conditions, it is very useful to study rainfall and other climatic parameters so that irrigation

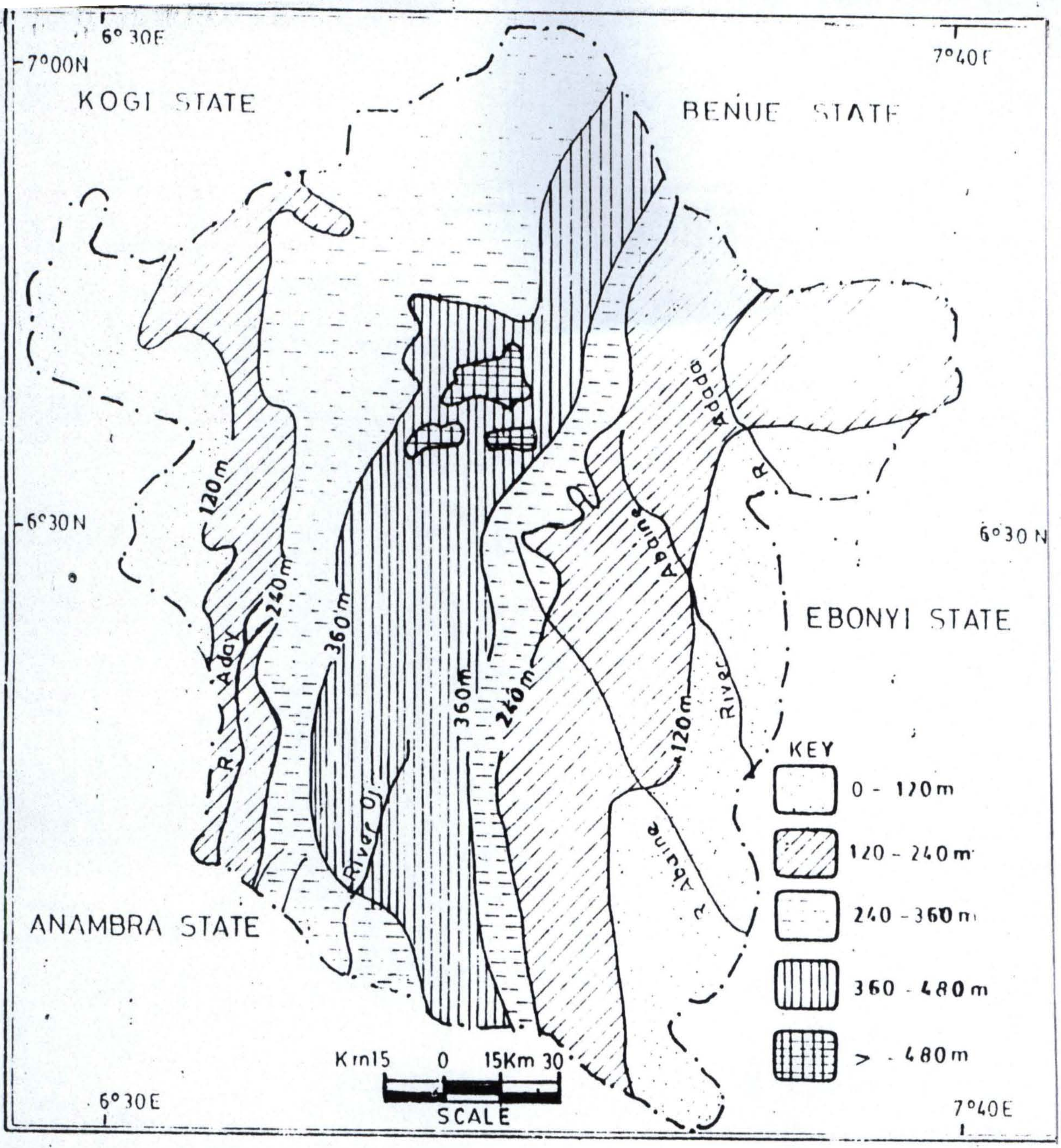


Fig.1.2 The Topographic features of the study Area
(Ofomata 1978)

cropping patterns can be planned to make the best of the climate in the area. Temperature in the State is high throughout the year with mean minimum temperature of about 25.9 and mean maximum of about 33.4

The relative humidity in the state depends on the two air masses the South West (tropical Maritime) air mass and the North East (Tropical continental) air mass prevails. Sunshine is abundantly received in the State. The maximum warmth in the state in a day may be experienced between 1 pm and 3.30pm. The amount of sunshine ranges from a minimum of 2000 hours to over 2250 hours/day in the State (Oguntoyinbo, 1978).

1.7.5 Soils and Vegetation:

The soils and vegetation communities of Enugu State occupy an important position in her development. The soils in the state varied and consist of lithosols, hydromorphic, ferrallitic as well as young soils derived from recently deposited materials (Igbozurike, 1993) (Fig.1.4). The Nsukka – Nkpologwu soil Association is developed in the red sands formed by the weathering and ferniginization of the False-bedded sandstones. These sands are mixed with colluvium derived from the upper coal measures and the upper part of the false – bedded sandstones, which form the steep hills. It is deep, well drained red soil with a texture which changes from loamy sand to sandy loan with depth. The soils occur partially under savanna, but as they are easy to work, farms have replaced savanna in many sectors.

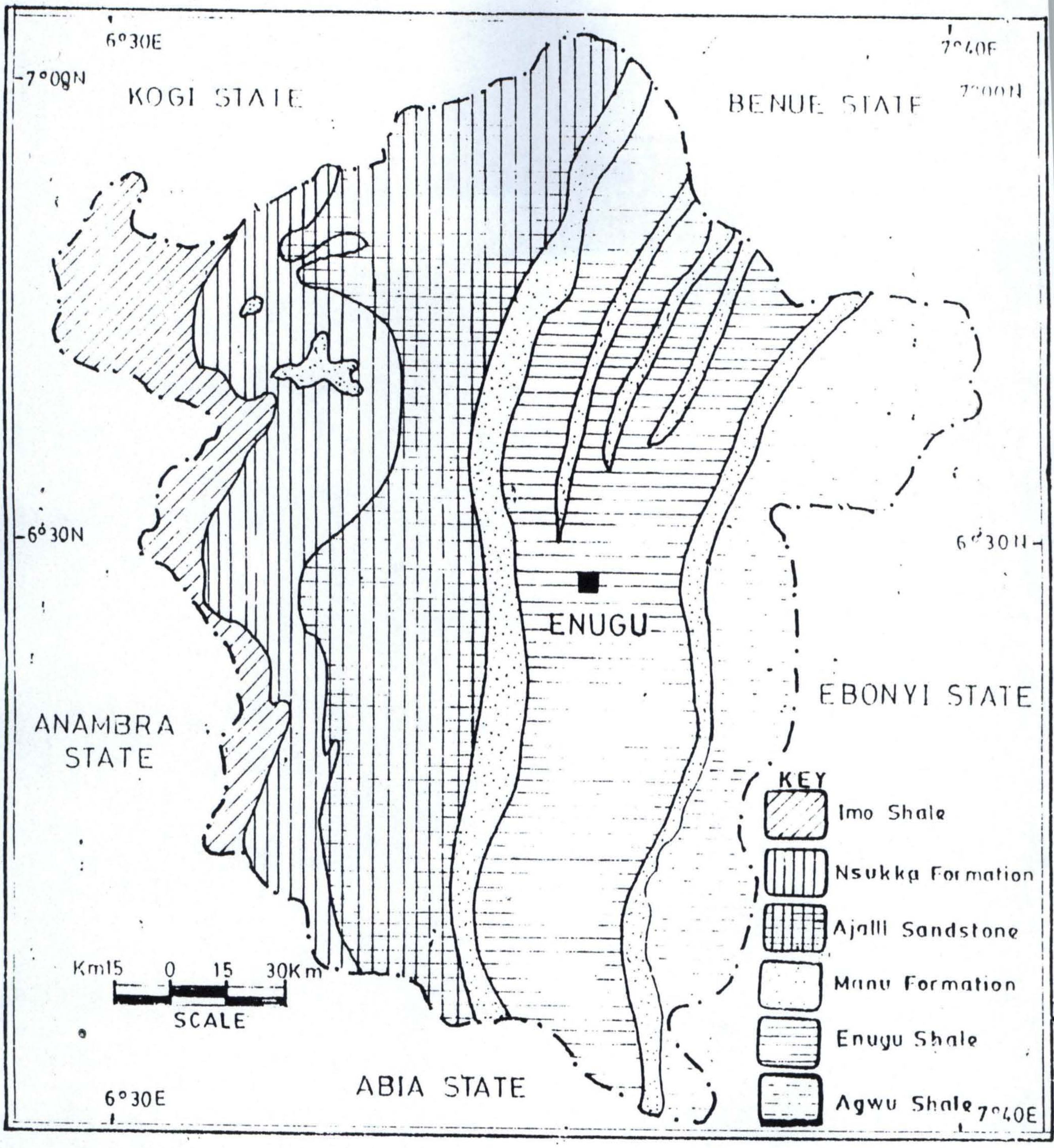


Fig. 1.1 : Geomorphological and Geological Map of Enugu State
(Ofomata 1978)

The Ururu, Amokwu and Ukpatta series are mainly developed from the shales of the upper coal measures formation. The Imo clay shales are overlain by clayey weathering products. The zone of weathering is brightly mottled red and white due to periodic water-logging. Soils developed over labaku sandstones are found on the ridges along the Anambra and Imo rivers. The greater part of this association is covered by the well-drained, deep, red sandy clayey Iga series. These well-drained, easily worked soils attract a lot of settlement and human use, and the ridge along the Anambra is intensively farmed.

Soils developed from terrace materials are found along the lower courses of the rivers. Their texture ranges from loan, to clay, the sand fraction being mainly derived from the false – bedded sandstones. The soils are extensively farmed, especially for yams. Some rubber and oil palm plantations are also established on these soils in the Enugu State.

Soil developed from alluvium are found on the flood plains along the rivers. These soils are generally loamy and mottled. Like nearly all alluvial soils, it is seasonally flooded, farming is difficulty as the soils are under swamp grassland and forest. However, some sections are used for intensive farming.

The vegetation is dominated by two physiognomic and structural forms: (a) broad leaved three types and (b) herbaceous grammoids. The complex of trees and grasses which makes up- the state has led to it being termed the forest savanna mosaic (Fig. 1.5). However, there are substantial amounts of other physiognomic forms, particularly bryoids. Further, there are small land

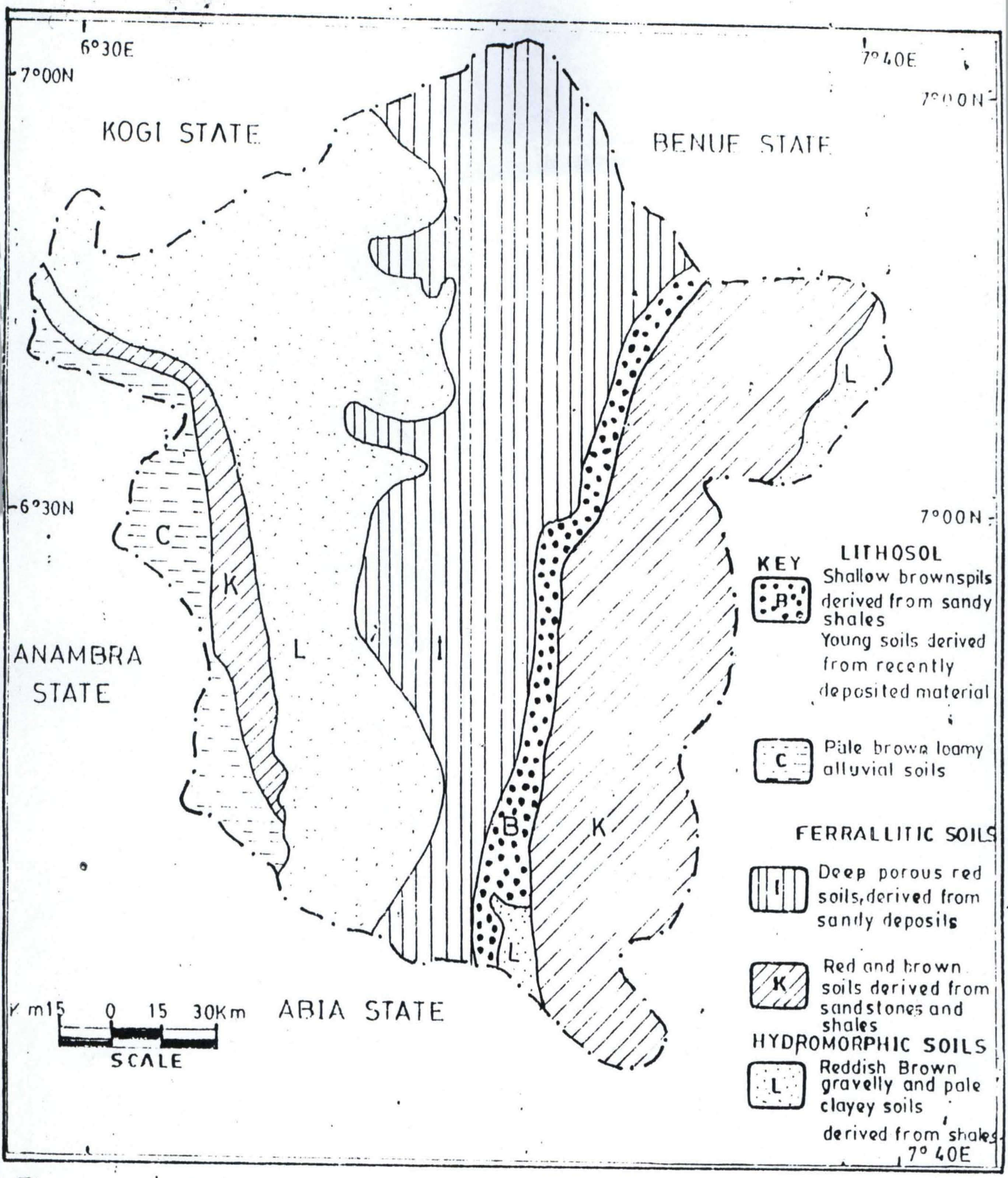


Fig.1.4 : Soil types of Enugu State

areas which the only conspicuous vegetation form is the bamboo (Bambuseae family) which in fact, is a woody grass, as well as small reparian regions, water bodies, or waterlogged sites where non-graminoid but grass like reeds and sedges, and also water ferns (ceratopoteris spp.), water lettuse (Pistia Stratiotes), water plantain (Sagittaria Sagittifolia and Alisma spp.) and water lilies (Nyamphaea odorata) are found in the state (Fig. 1.5).

Four broad categories of vegetation according to the species composition, site requirements and phytocommunal relationships are recognised in Enugu State (Igbozurike, 1974). The sub-divisions are:

(i) Open elevated and lowland stands

(ii) Closed, elevated and lowland stands

(iii) Riparaian stands

(iv) Graminoid vegetation.

The open, elevated and lowland stands are characterized by dry land species, fore-resistant trees like Parkia clappetoniara, a locally – famous food crop species, Daniellia Oliveri, Vetex doniana and lophira lanceotata. The closed, elevated and lowland stands consists of ceiba, Afzelia African as well as the close relative of some of those in the terminalia superba and lophira alata.

Riparian stands: Among the tree genera and species which characterize the Riverine areas, particularly the extensive seasonally inudated plains of the Adada, Ebonyi, Oji and Okpo Rivers are Alstonia Congensis, Mitragyna Ciliata, Nauclea ailletii, spondianthus preussxi symphonia globulifera and Raphia palms.

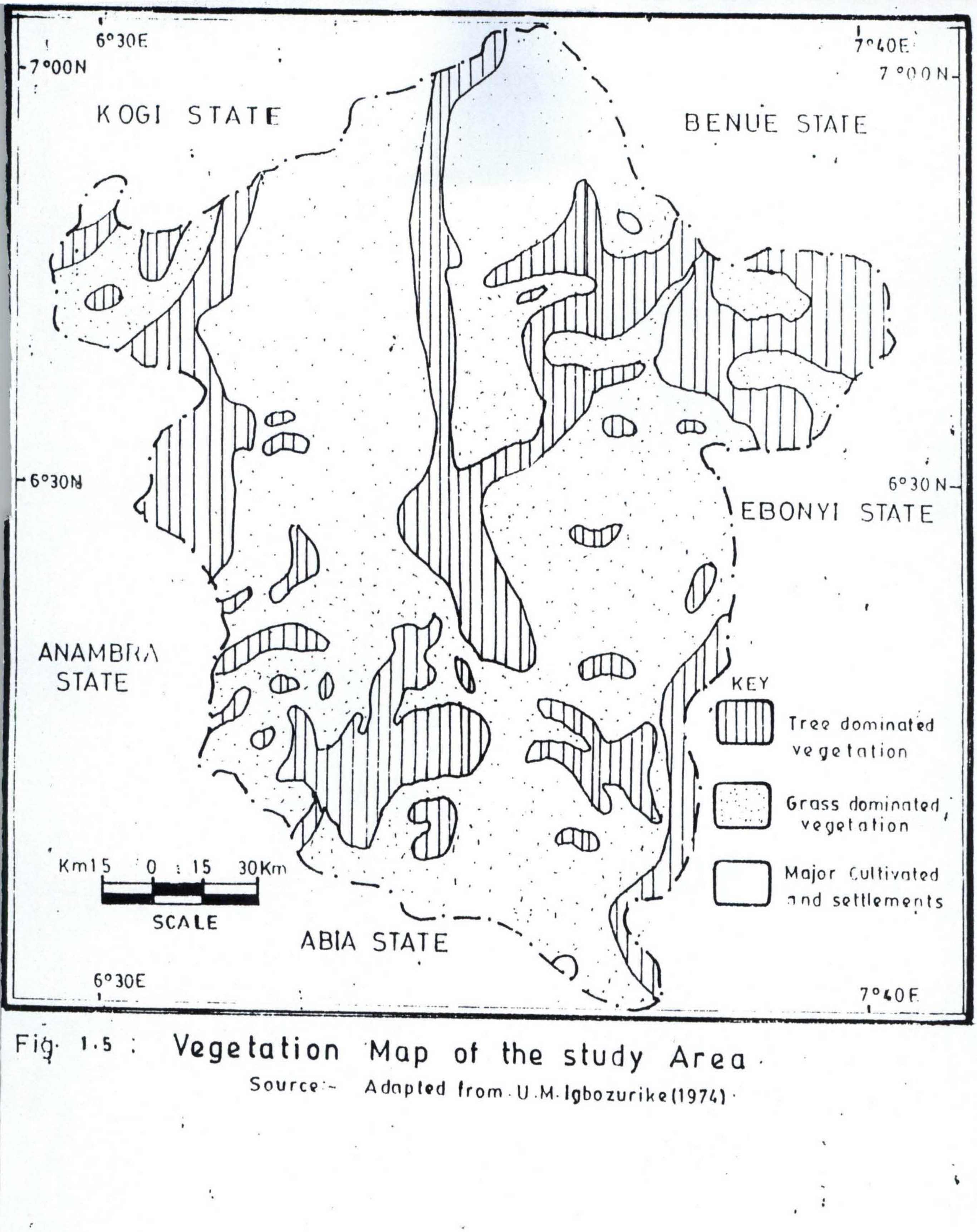


Fig. 1.5 : Vegetation Map of the study Area

Source:- Adapted from U.M. Igbozurike (1974)

The graminoid vegetation are made up of grasses, Grass dominance as well as purity of stand becomes more pronounced as one move south to north across the state, with the most elevated sections of the terrain and hillspots being covered with grass much more frequently and greater in density than are in the lower parts. Among the most important grass are *Hyparrhenia* spp, *Andropogon tectorum* (elephant grass) and other *Andropogon species, pennisetum polystachion* and *pennisetum purpureum.*

1.7.6 Man's Activities

Enugu State lies within the agricultural profic zone of Nigeria. Agriculture therefore, is the most dominant form of economic activity in the area. The cropping patterns reflect strongly the influence of the physical, human and economic environments.

Oil palm is a very important tree crop in the agricultural economy of Enugu State. It is the chief cash crop providing not only oil and kernels but also palm wine for which Enugu state is justly famous. Enugu state is favourably located with respect to the oil palm industry. Oil palm is therefore indigenous to Enugu State and it grows wild over most of the area. It is very important both as a source of food and as an export crop. Although a substantial proportion of the total output is used domestically, Enugu State is able to meet the demand for palm oils by other states of the federation as well as the industrial countries in Western European.

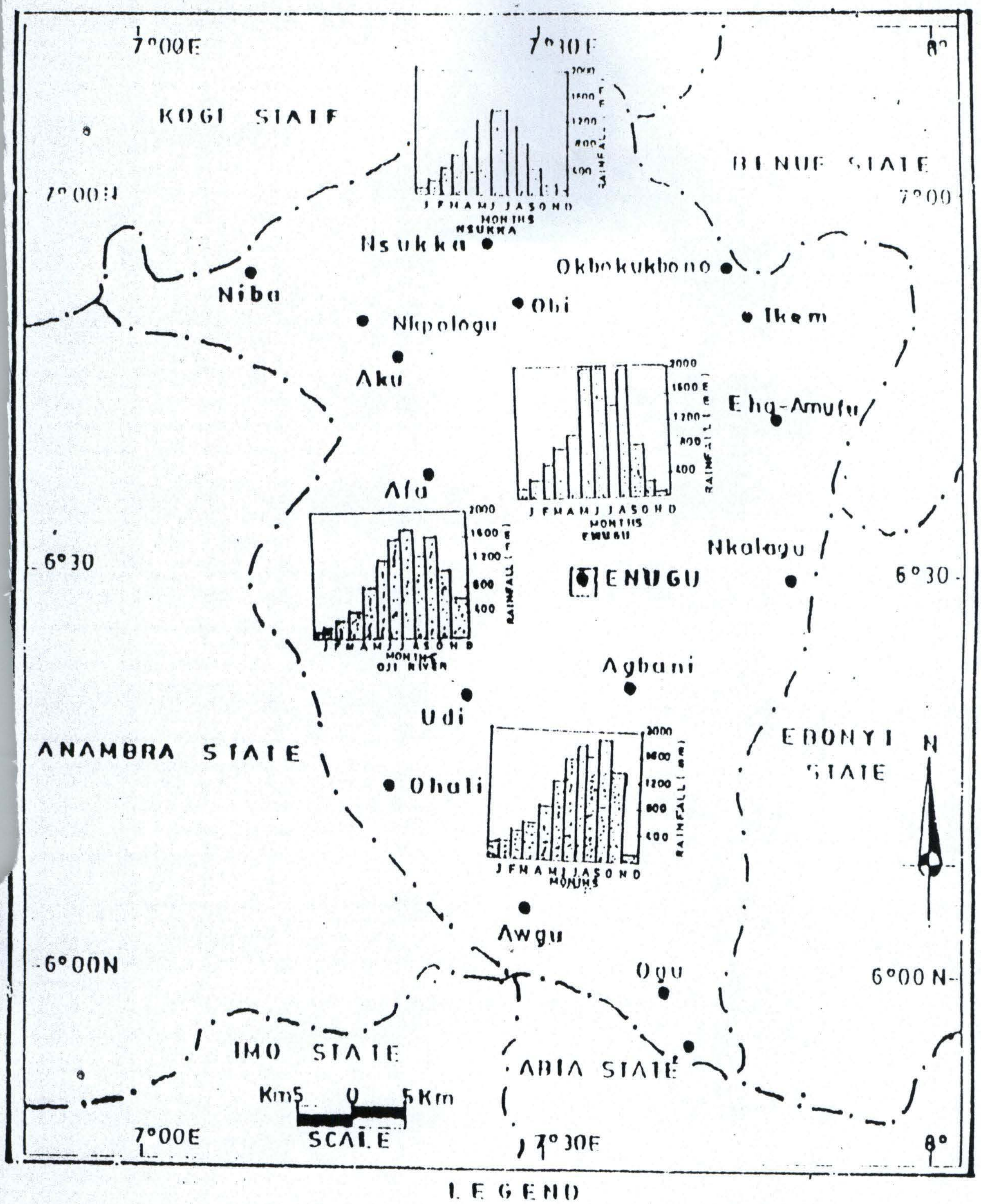


Fig.1.6: Climatic Zones of Enugu State

The traditional method of extraction produces good quality domestic oil which, though classified as technical grade by the produce marketing Board, fetches more money per tonne in the local market than special grade oil sold to the marketing Board. Inspite of the rising demand for palm oil and kernel, the peasants have for long depended on wild and semi-wild low yielding and often very tall and overcrowded species. The oil palm Grove Rehabilitation Scheme was, introduced by the government for the benefits of the peasant cultivators in Enugu state. The quality has improved considerably since the introduction and used of oil mills. Increase in palm oil production has resulted largely from government – sponsored plantations and improved processing methods.

Crops produced include Yam (Dysconia spp), Cassava (Manihot esculentus), Cocoyam (Colocasia esculents), Potato (Solanum tuberous). Tomatoes (Lycoperson esculetum), Pepper (Capsicum spp). Oranges, grapefruits, lemon, Okro (Hibiscus esculentus), Pumpkin (Teleferia). Green (Amaranths). Garden Egg (Solanum melongena), Coconut (Cocus nucifera), oil palm, cashew, Cowpea (Vignia umguiculate), Kolanut (Fig. 1.7). Fadamas are practiced along the river banks and in the period of dry season (Ifere, 1971). The production of these crops takes place under the traditional system without the use of mechanical power. Holdings are small and the main tools consist of hoes and cutlasses. Some farmers own some cows, goats and other domestic animals. Fishing is also practiced in the State.

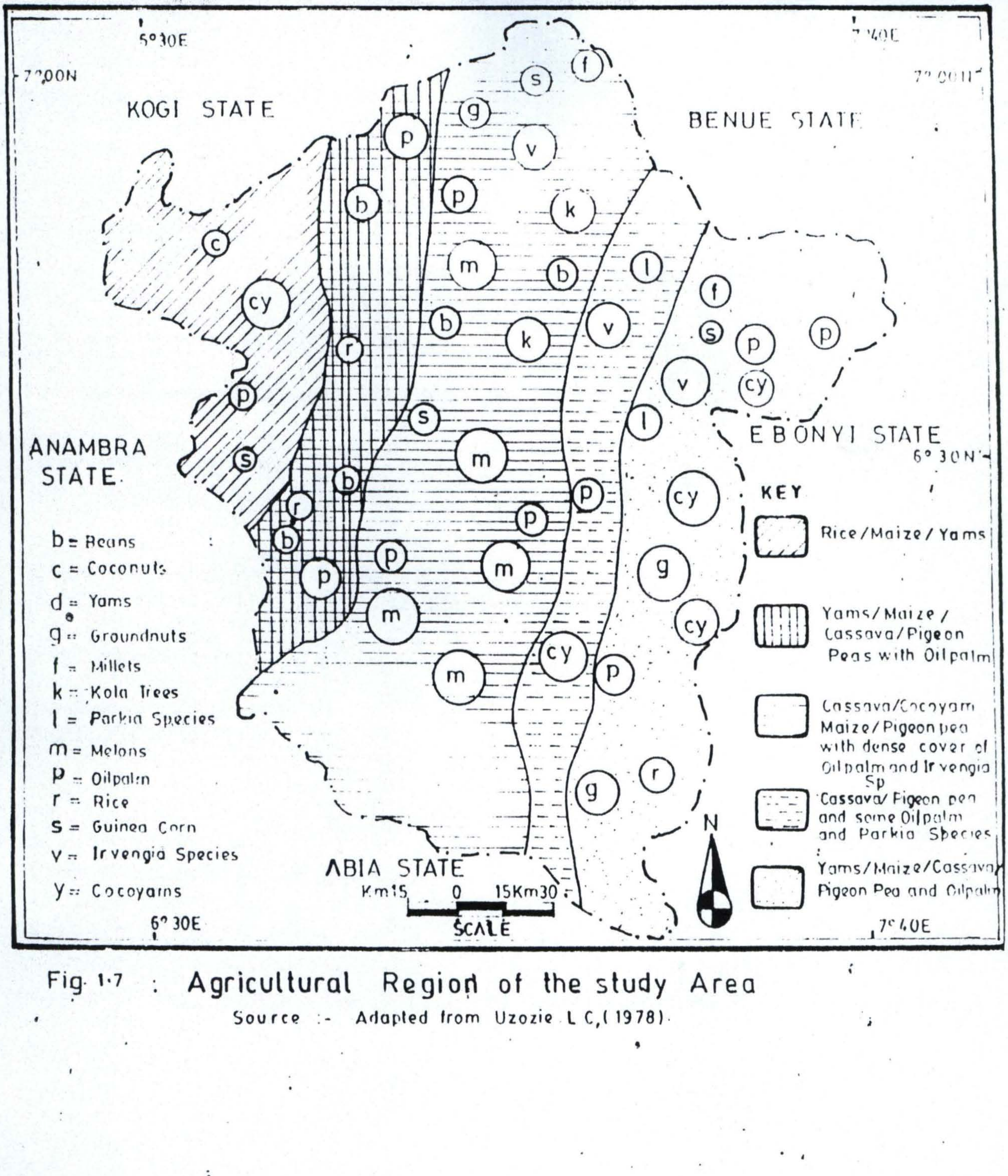


Fig. 1.7 : Agricultural Region of the study Area

Source :- Adapted from Uzozie L C,(1978).

1.8 Some Basic Soil-Water-Plant Interactions Management Concept

Plant-soil-atmosphere relationship can be summarized as follows: The plant needs water, the soil stores the water needed by the plant, and the atmosphere provides the energy needed by the plant to withdraw water from the soil. This is the water balance, which is the distributional climatic water budgeting need of agricultural crops, plants and animals in a region that relates closely to the relationship between the soil water and atmospheric water demand. This is interactive product of the following parameters:

(i) Precipitation

(ii) Evaporation

(iii) Transpiration

(iv) Evapotranspiration

(v) Potential Evapotranspiration

(vi) Actual Evapotranspiration

(vii) Water surplus

(viii) Water deficit

(ix) Soil moisture storage

(x) Soil moisture deficit

(xi) Field capacity

(xii) Infiltration

(xiii) Permeability

(xiv) Permanent wilting point

(xv) Drought

Precipitation: Ayoade (1988) defined precipitation as any aqueous deposit in liquid or solid form derived from the atmosphere. Precipitation is very important in determining the effective use of soil and water. Water, whether too much, too little or poorly distributed is one of the major limitations in agricultural production.

Precipitation may occur in any of a number of forms and may change from one form to another during its descent. The forms of precipitation consisting of falling water droplets may be classified as drizzle or rains. Precipitation may also occur as frozen water particles including snow, sleet and hail. Of the forms of precipitation, rain and snow make the greatest contribution to our water supply.

Evaporation: The term is used to describe water loss from water surfaces and bare grounds. It is a process whereby liquid water is transferred into the atmosphere through the tissue of living plants. Ayoade (1988) defined evaporation as a process by which moisture is converted into water vapour and removed and transported upwards into the atmosphere. In areas of growing plants, water passes into the atmosphere by evaporation from soil surfaces.

Transpiration: This is the process whereby water vapour escapes from living plats, principally the leaves. It is the process through which water vapours passes into the atmosphere through the tissue of living plants. Rawls et al, (1982) observed that there is a continuous movement of water from the soil into roots, up stems and out of leaves of the plants during the growing period of a crop. They concluded that, the velocity of water flowing through plant varies widely from 25 to 175 centimeters per hour; but under conditions of unusually high temperature, dry atmosphere and wind, velocity of the stream may be greatly increased.

Evapotranspiration (ET): This is combined process of evaporation and transpiration (Ayoade, 1988). This is often referred to as consumptive use of water which involves the problems of water supply, both surface and underground, as well as problems of management and economics of irrigation projects.

Water deposited by dew, rainfall or sprinkler irrigation and subsequently evaporating without entering the plant system is part of consumptive use. Consumptive use can apply to water requirements of crop, a field, a farm, a project, or a valley. This is influenced by temperature, irrigation practices, length of growing season, precipitation and other factors. Ayoade (1988) noted that evapotranspiration is controlled by two major factors: the first is the availability of moisture at the given surface, while the second is the ability of the atmosphere to vapourize the water, remove and transported the vapour upward. If moisture is always available in sufficient quantities at the evaporating or evapotranspiration will occur at the maximum rate possible for that environment.

Potential Evapotranspiration (PET):

When plants transpire at the maximum rate, which is when the soil is completely saturated the term potential evapotranspiration is used (Thornthwaite 1944, Budyko, 1978; Penman 1948). The joint relationship between potential evapotranspiration with precipitation provide the basis of climatic water budgeting.

Actual Evapotranspiration:

Bockokov (1965), William (1970) and Acheampong (1982) have made contributions on the derivation of this concept. William noted that the generalization of the observed values of actual evapotranspiration is rather a complicated matter since observed values are not free from accidental and systematic errors.

Actual evapotranspiration is a term that defines the rate of evaporation and transpiration, which occurs over a vegetated basin under the prevalent climatic conditions. It has been established that if the water supply in the soil plant sanction is limited, plants have difficulty in extracting water and evapotranspiration rate (ET) falls short of its maximum value of potential evapotranspiration (PE). Values of actual evapotranspiration can be determined from known values of potential evapotranspiration. The difference between the rate of actual and potential evapotranspiration produce a measure of the irrigation needs of crops. The concept of actual and potential evapotranspiration is important in agricultural planning, as well as climatic classification (Thornthwaite and Mathe, 1955: Ayoade, 1988).

Water Surplus

The amount of water available for runoff and ground water recharge is known as water surplus. In other words, it is the excess water after the field capacity has been met. It is given as precipitation amount less the amount of water evaporated and transpired (Thornthwaite 1948; Ayoade 1972).

Water deficit:

According to Ayoade (1972), this is the difference between potential evapotranpiration and actual evapotranspiration

Soil moisture storage:

This is the amount of water stored in the soil. It is the difference between water that infiltrates into the soil through evapotranspiration process (Thornthwaite 1948 and Ayoade 1972). The demand for potential evapotranspiration must be reached before any water can be stored in the ground. In other words, there can be no water storage when there is deficiency or deficit.

Soil Moisture Deficit

This is the difference between the amount of water in the soil when saturated and the amount of water actually contained in the soil at a given time (Thornthwaite, 1948). This is based on insufficient rainfall amount which is not enough to meet the subsequent water needs of the crops.

Field capacity

When gravitational water has been removed, the moisture content of soil is called field capacity. The concept of field capacity is extremely useful in arriving at the amount of water available in the soil for plant use. In other words, the maximum amount of water that can be held in the grains of soil against the force of gravity is known as the field capacity. In practice, field capacity is usually determine 2 days after an irrigation. Therefore, field capacity defines a specific point on the moisture content time curve. This can be without modification to estimate the water remaining in the soil in the dry season following fall irrigation.

Different soils have different field capacity (FC), which varies between 50 to 450mm. On the average, Nigeria uses 300mm for Nigerian soils. Recent work on Thornthwaite water balance was done by (Cooheme 1967) and Anyadike (1990). The principal credit of their work is that they have proved that the figure 300mm is too high for savanna and sahel regions of Nigeria. Consequently Anyadike (1990) suggests 150mm for the savanna and 300mm for the Southern region of Nigerian.

Anyadike work (1990) on:

(i) The water balance of the lake Chad and

(ii) Analysis of the moisture situation in the Benue River Basin.

Infiltration: This is one of the three phase of the hydrologic cycle of particular interest in agriculture. Like other phases such as evaporation and transpiration, the term infiltration refers specially to entry of water into the soil surface. Infiltration is the sole source of soil water to sustain the growth of vegetation and of the ground water supply of wells, springs and streams.

The most important items influencing the rate of infiltration have to do with the physical characteristics of the soil and the cover on the soil surface, but such other factors as soil water, temperature, and rainfall intensity are also involved (Duley, 1939).

Permeability: One of the important properties of the soil is the ability to convey water flow through the pore spaces caused by a given force. The permeability of soil is defined as the velocity of flow caused by a unit gradient. Permeability is used for designating flow through soil in any direction. It is influenced most by the physical properties of the soil.

Permanent Willing point:

The soil-moisture content when plants permanently wilt is called the permanent wilting point or the wilting coefficient. A plant will wilt when it is no longer able to extract sufficient moisture from the soil to meet its water needs. "Temporary Wilting" will occur in many crops on a hot windy day, but the plants recover in the cooler portion of the day.

Permanent wilting, as well as temporary wilting, depends upon the rate of water used by the plant, the depth of the root zone and the water holding capacity of the soil. The difference in moisture content of the soil between field capacity and permanent wilting is termed the available moisture. This represents the moisture, which can be stored in the soil for subsequent use by plants.

Drought: It means the non-availability of adequate amount of water for man, animals and plants for growth, development and yield or maturity as and when needed Adefolalu (1983a). It is the deficit that result when moisture is insufficient to meet the demand of potential evapotranspiration.

Basically drought is composed of three types: meteorological, agricultural and hydrological droughts. Meteorological drought refers specifically to lower the normal rainfall amounts over a specific period of time. Agricultural drought deals with insufficient soil moisture surplus at times of maximum demand due to either late onset of the rains or earlier than normal cessation dates of the rains or both thus resulting in a shorter than usual length of the rainy season. It has been found that, these characteristics of the rainy season may be more stressful for plants than storage of absolute amount of rainfall (Adefolalu, 1986). They are more injurious to seasonal plants with short near surface taproots. Hydrological droughts relate more to declining underground water amounts and hence lowering of the water table. A drawn down effect is often postulated to the combination of prolonged tapping by man with simultaneous aggravating effects of meteorological and agricultural droughts. It effects lead to the starvation, famine, economy depressions and so on.

Droughts occur as a result of low relative humidity, strong wind and high temperatures because they lead to increase evapotranspiration, shifting of normal cyclone, abnormally low sea – surface temperatures as well as variation in annual rainfall.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

The moisture content of the soil, solar radiation as well as the temperature of the environment are the most crucial meteorological variables which have significance influence on agricultural production in any area. The influence of these climatic elements on man's activities particularly on agriculture has been noticed (Obasi, 1991). According to Ojo (1991) and Corfold (1997), extreme weather events have brought benefits as well as setback in the area. Their significance in bringing about swift and wide spread consequences is neglected in the widespread damages and sometimes destruction done to man and environment. The weather hazards especially those related to flooding, drought, desertification, erosion, pollution etc have significant impacts globally, nationally, regionally and locally on man as well as on the socio-economic resources.

Man's socio – economic activities are functions of the environment. Weather can be beneficial to man through its elements if obtained at the appropriate time and quality (resources) but if otherwise it constitutes a hazards (Ayoade, 1988). For example, heavy rains with strong wind and thunder with lightening (rainstorms) becomes a hazard to man and his activities (Miller, 1965).

Although weather occurs and affect man and his socio-economic activities universally not all places have their weather experience and impact studied and documented. Extreme weather events and impacts on human interest appears to be a "rara avis" in most part of technologically developing countries. This is the experience of the study area. Though full of interesting weather phenomena, sufficient efforts have not been made to study the relationship between the observed weather and agricultural production in the area. This study therefore addresses itself to this knowledge gap. The study is based on the application of agroclimatology to small scale irrigation in Enugu State of Nigeria with the conviction that the state can still readjust and not totally submissive to weather's dictates.

2.2 Historical Perspective of Irrigation

The need for agroclimatological services for farmers and growers has long been recognized by the meteorological offices universally. As far back as 1924, Sir, Napier Shaw started the crop weather scheme to provide a record and advisory service to farmers on crop development and associated weather phenomena. The advisory tool followed the development of irrigation scheme. Advice on irrigation is normally sought for one or two reasons. The first concerns the probable long term irrigation needs of a given crop on given farm, in order to assess the adequacy of the water supply. The second concerns the frequency and the amount of application in an individual growing season. With the increasing tendency to restrict the use of water for irrigation and to charge for surface abstraction the requests becomes increasing important in economic terms.

Irrigation is therefore an age- old art. Human dependence on irrigation can be traced to earliest biblical references. Genesis mentions Amraphel, king of Shinar, a contemporary of Abraham, who is probably identical with Hammurabi, sixth king of the first dynasty of Babylon. He developed laws, bearing the name of Hummural indicating that the people had to depend upon irrigation for existence. One of the laws of Hammurabi states that is a man neglects to strengthen his bank of the canal and water carry away the meadow, the man in whose bank the breach is opened shall render back the corn which he has caused to be lost.

The letters of Hummurabi about 200 B.C. reveal a busy, governmental administrator who wastes no words when instructing his officials: "To Sid-Indiannam, Hammurabi speaks as follows: Gather the men that have fields along the Damanum Canal to clear out the Damanum Canal, within this month, let them complete the digging of the Damanum Canal". Further mention of irrigation is found in Second Kings 3:16-17. And he said; "thus saith the Lord, make this valley full of ditches. For thus saith the Lord, Ye shall not see wind, neither shall Ye see rain, yet that valley shall be filled with water, that Ye may drink, both Ye and your cattle, and your beasts".

An ancient Assyrian Queen, supposed to have lived before 2000 B.C. is credited with directing her government to divert the water of the Nile to irrigate the desert lands of Egypt. The inscription on her tomb is:

"I constrained the mighty water to flow according to my will and led its water to fertilize lands that had before been barren and without inhabitants".

Fukuda (1976) summarized irrigation history. He emphasized the development of the technical aspects of irrigation and drainage. He oldest civilization developed along the Nile, Tigris, Euphrates, Indus and Yellow rivers and in Latin America. Cultivation along the Nile began about 6000 B.C. Practices to keep canals free of sediment were in effect in Mesopotamia in 4,000 B.C. Shallow wells and flooding from the Indus River were used about 2500 B.C. Records show that, irrigation was practiced along the Yellow River in 2627 B.C. Peru about 1000 B.C., and Jordan valley in 1948. A major project to develop the history of irrigation throughout the world has been initiated by the International Commission on Irrigation and Drainage (ICDI).

2.3 Irrigation Needs as Against Rainfed Agriculture with Added Attributes

The crop yields under irrigation are higher than those obtained under rainfed conditions. The difference in yield between irrigated and non-irrigated lands is greatest during seasons that have periods of drought and above normal evaporative demands. As observed by Matanga et al, (1979a) yields on irrigated land are higher and more consistent. Faniran (1980) found that, the marked increase in crop yield is as result of combination of ameliorative effect on soil including:

(1) Providing crop insurance against drought

(2) Cooling the soil atmosphere to make it more favourable for plant growth

(3) Reducing the hazard of soil piping

(4) Softening the soil

(5) Watching out deleterious substances in the soil and

(6) Facilitating the process of osmosis

2.4 Irrigation Development in Nigeria

The formal irrigation schemes has their beginning in the establishment of Nigeria's first irrigation division in the Northern Regional Government Department of Agriculture in 1949. This was followed in 1952 by the opening of a number of rice irrigation schemes in the middle belt near Bida in Niger State. The gradual growth of formal irrigation in the 1950's and 1960's led to the establishment of schemes mainly for rice and wheat and mostly in the North – Western and North – Eastern parts of the country. The 1970's was a decade marked by far more ambitions plans than before. The major hydro-electrical dam at Kainji had been opened in 1968 and a number of big dams and water resources development projects for irrigation were soon under construction. Tiga dam was completed in 1974, construction for the take-off from lake Chad for south Chad project began in 1975, and Bakolori Dam was completed in 1978.

Between 1973 and 1977, eleven River Basin Development Authorities (RBDA'S) were established with responsibility for the multipurpose development of water and land resources in their respective catchment areas. The 1980's saw even more rapid escalation of plan and intensions for formal irrigation development.

In Nigeria, the phenomenal development of water resources started in Kano in 1967 which has since resulted in marked economic development especially in the field of agriculture. Part of the water from Bagauda Dam reservoir is being used for irrigation of nearly 1000 hectares of land in Kadawa pilot farm which involves many farmers. The Tiga Dam project located 70km South of Kano is multi-purpose benefiting irrigation, flood control and reclamation of the Hadejia valley.

On 15 June, 1976 the Federal Government established by a decree eleven River basin development authorities in the country. The decree also established the National River Basin Development Co-ordinating Committee to ensure integrated development of each basin and even development of the different basins. The river basin development authorities in their respective catchment areas are empowered to acquire land or take over projects or lease land with the agreement of the state governments concerned and to exercise several functions among which are:

(i) Developing irrigation schemes for the production of crops and livestock

(ii) Undertake comprehensive development of ground water resources for multipurpose use:

(iii) Construct and maintain dams, dykes, wells or boreholes, irrigation and drainage systems and so on.

2.5 Irrigation Development in the South East Geo- Political Zone-The case of the Study Area

Unlike in the Northern regional government where the formal irrigation schemes has their beginning in the establishment of first irrigation division in the Department of Agriculture in 1949. There was no such establishment in the south-east geo-political zone including the study area until 1973 to 1977 when eleven River Basin Development Authorities were established and charged with the responsibility for the multipurpose development of water and land resources in the zone. Agriculture to a large extend was rainfed.

However, Fadama all year round agriculture was in practice in the area before the establishment of the Imo-Anambra River Basin Development Authority in the Zone. This was carried out in flood plains or fadamas of river Adada, crosses the Nsukka Plateau near Nsukka in the North, Oji River in the West and Ebonyi river in east till date (Enugu state Agricultural Development Project, 2003).

In all forms of irrigation practices, the basic advice on most problems of irrigation is the water balance sheet. The technique is based on the assumption that, all green-cover crops which are freely supplied with water transpire at about the same rate. This rate is known as the potential evapotranspiration and can be closely estimated from weather data over periods of about week or more. Water balance is defined as the distributional climatic water budgeting needs of agricultural crops, plants and animals in a region that relates closely to the relationship between soil water and atmospheric water demand. It is made up the moisture in the upper layers of the soil profile. Apart from the actual study of water balance over river basins, territories and the world, a lot of work has been done in terms of defining the elements relevant to water balance analysis of crops and the evaluation of data involved in the study of water balance in order to determine the total irrigation need for the growing season.

Blaney and Criddle (1950) developed an empirical method that is widely used for determining evapotranspiration from climatological and irrigation data. They correlated the existing evapotranspiration data for different crops with the monthly temperature, percent of daytime hours, and length of growing season. The correlation co-efficient are then applied to determine the evapotranspiration for other areas where only climatological data are available. The evapotranspiration is used to predict soil water deficits for irrigation. Analyzing records and estimating evapotranspiration rates, drought frequencies and excess water periods can show potential needs for irrigation and drainage. The Blaney Criddle method does not use ET crop coefficients, rather the estimations of crop ET are made in one step.

Doorenbos and Pruitt (1977) revised the method to provide an estimate of Eto smaller zone for grass so that appropriate crop coefficients could be used to estimate ET for specific crop. They outlined a three stage procedure involving:

(i) a reference crop ET

(ii) a crop coefficient and

(iii) the effects of local conditions and agricultural practices

The problems of estimating evaporanspiration have been documented elaborately by Thornthwaite (1948), Penman (1948), Ture (1958), Chang (1964), WMO (1966), Ayoade (1971). With regards to Nigeria, local problems have been highlighted in the studies by Garnier (1952, 1956), Gilchrist (1961). Stanhill (1963), Chappers and Rees (1976), Davis (1966) and Ayoade (1976).

All these workers have used one type of empirical formula or another to calculate potential evapotranspiration in Nigeria, thus yielding varying results. Here evaporation was computed through direct means using evaporation pans and transpirometers. Penman (1948, 1956) approached the problem of estimating the evaporation from a free water surface by examining the energy balance at the surface water. He reasoned that, energy used in heating the water and its container could be neglected and that the evaporation of water could be predicted from the equation

$$E = R - A \quad \text{.....................} \; 2.1$$

Where E = Energy used in evaporating water.

Rn = Net radiant energy available at the earth's surface

A = Energy used in heating air.

According to Thornthwaite (1948) formula, the values of potential evapotranspiration are higher in the north than in the south. The highest values of over 1886mm are found in the lower Niger trough. The effects of relief are illustrated by the low values in the Jos Plateau and hilly areas in the east. Based on Thornthwaite (1948) method, the highest annual actual evapotranspiration values are found in the south-eastern parts of Nigeria where the highest amounts of rainfall are also recorded. The values decrease steadily northwards with the northern extremities recording less value. He also observed that the distribution of actual evapotranstiration is inversely linked to that of precipitation. Based on these, he concluded that, while the potential evaporanspiration tends to increase northward, actual evapotranspiration like rainfall decreases northwards. Gariner (1960) observed that, Thornthwaite's method works well in the moist forested southern part of Nigeria while the Penman's methods works well both in the dry northern Nigeria and wet southern Nigeria.

The degree of wetness or dryness of the soil is determined by the hydrologic ratio (λ). This is the ratio of precipitation (P) to the evapotranspiration (PE). This index of wetness or dryness is most useful in decision making in agriculture because it can provide a guide on the best choice of area where a particular type of plant will not only strive but equally have a yield, or reach optimum growth level. From the global investigation in climate change on plant growth and development, the hydro-natural zone is where the hydrologic ratio (λ) is 1.0 for optimum crop yield in areas where not only potential evapotranspiration (PE) is equal to annual precipitation (P), but also effective. As a measure of the amount of water available to plant in a particular physical environment, this is an equal to the natural resources evaluation and hydrologic ratio is given by

$$\lambda = \frac{R}{PE} \qquad \text{.............................. 2.2}$$

Where R = mean annual rainfall

PE = mean potential evapotranspiration which is determined by the concept

PE = f (p. E Pan)

Where f = Convention factor to reflect the vegetal cover.

P = Pan factor (lower case 'p')

E Pan = Total evapotranspiration from a class pan evaporimeter

Where p = Eo/E pan

Eo = Total evaporation for hypothetical open water surface at field conditions.

For Nigeria, the values adopted for f = 0.90

PE = (1.31) (Eo after Adefolalu yr).

Adefolalu (1988) gave a formulation based on earlier works of Penman (1954) and Igeleke (1961) that may be restructured as follows: if

$$\lambda = \frac{RR}{f.\ PEo}$$

Where RR = rainfall; f=a constant and Eo = total evaporation (open water body). He concluded that hydrologic ratio values of less than $0.5 > \lambda > 0.3$ are said to signify semi arid conditions which must be redressed. Thus, for a dam designed to hold water at a certain level, provision must be made to counter the 4 percent loss below hydrologic ratio of 0.60.

According to Duckham (1974), this index helps with decision making on agriculture because it can provide a guide on the best choice of area where a particular type of plant will not thrive, but will equally have high yield or reach optimum growth level. From a global investigation by Duckham (1974) and Masefield (1970) on plant response to changes of climatic condition and hence available precipitation, it was found that in the hydro-neutral zone, where λ = 1.0. optimum crop yields exists, not only because PE is equal to mean annual precipitation (p), but also because the effective actual evapotranspiration is high.

In most semi arid environment, where irrigation is used to supplement the received rainfall in order to ensure good growth of plants, there is no other yardstick for determining where and when to expect the rainfall deficit. The water equivalent to avert drought which is a drought indicator can be used to determine the exact amount of water that will be required to irrigate a field for effective plant growth and development. The techniques of Flohn et al (1974) and Adefolalu (1990) are adopted for studies in Nigeria particularly from the estimate in semi and sahel belt of West Africa.

Adefolalu (1983) observed that both observed and derived parameters of precipitation effectiveness such as: Onset and cessation dates of rains, length of the rainy season (LRS) ie water availability as a function of onset dates (ϕ) and the effective end (¢-cessation date of the rains which control the hydrologic season usually referred to as the length of the rainy season (LRS), spatial and temporal distribution pattern of point rainfall; intensity of precipitation in relation to flash and seasonal flood and erosion problems, degree of wetness or dryness (Hydrologic Ratio) for rainfall and irrigated agriculture, water equivalent to avert drought, which has provides very useful in determining the exact amount of water that will be required to irrigate a field for effective plant growth and development; breaks in the course of a normal rainy season (drought spells) and frequency of precipitation types (rain, shower, line squalls etc.) for estimation or precipitation related hazards) could enhance sustainable development, especially in the agricultural production sector and guarantee a balanced eco-system.

He noted that on the precipitation regime. Nigeria has never takes into account any rainfall characteristics apart from the total annual amounts in the planning process to date. But phonologically, it is not so much the amount that matters, it is how it is available. He confirmed that such a situation arises when precipitation distribution (in time and space) is abnormal. For instance the onset (ie the beginning) of rains may result in poor seasonal distribution even when the total rainfall received in the season is normal or above average. Similarly premature cessation (i.e. rain stop before the normal period) constitute a major problem. The worst situation is to be expected when both onset is delayed and cessation is premature or advanced resulting in a shortened rainy season that may curtail the Hydrologic Growing season (HGS).

As noted by various researches including. Ayoade (1970); Ojo (1977) and Olaniram (1983), 1987a and 1987b) among others, the relationship between water availability and precipitation effectiveness is best illustrated by parameters on onset, cessation and length of rainy season and FALSE starts of the rains equally important as prolonged dry spells are injurious to plant life (Adefolalu, 1991). Infact these characteristics of summer rains may cause more damage than what 50% reduction of actual rainfall may creates (Odingo, 1976).

Consumptive use of water involves problems of water supply, both surface and underground, as well as problems of management and economics of irrigation projects. Consumptive use, or evapotransporation, is the sum of two terms: (1) transpiration, which is water entering plant roots and used to build plant tissue or being passed through leaves of the plant into the atmosphere (2) evaporation which is water evaporating from adjacent soil, water surfaces, or from the surfaces of leaves of the plant. Consumptive use of water is influenced by temperature, irrigation practices, length of growing season, precipitation, humidity, wind velocity, vapour pressure and solar radiation. These climatic observations as an index to consumptive use has been studied by several researchers.

Jensen and Haise (1963) used observations of consumptive use from the western United States to develop a linear relationship for estimating a reference crop (alfalfa) potential evapotranspiration (Etp) (consumptive use). Although the Jensen – Haise equation has been used to calculate Etp on a day – to – day basis, it should be considered as reliably representing values for longer time periods (5 to 7 days), when effects of fluctuations in wind and humidity level are averaged out. The method has been widely used. However, there is some evidence that the elevation adjustments may be excessive and should be used with caution, particularly higher elevations (1500 to 2000-meters and above).

Bello (1987) used humidity reference number such as rainfall, actual and potential evapotranspiration data to assess water supply for Agriculture in the Niger River Basin development Authority area of Nigeria. From the humidity reference number, lengths of the periods of effective water availability and water deficiencies were determined. He observed that the southern parts of the basin area have a higher potential for agriculture because of longer periods of effective moisture availability compared with the northern parts. The lengths of the periods of effective moisture availability and average rainfall during these periods were respectively related to the length of the growing season and the moisture requirements of some selected crops. The study also showed that irrigation development is necessary in the basin area as a whole, but there is a much higher need for irrigation in the north.

Rainfall variability is not limited to seasonal fluctuations but also includes year – to – year variability in the onset, cessation and duration of the rains which are also characterized by dry spells of unpredictable magnitude. Among those who have stressed the effects of phenomena on food crops grown in Nigeria are Dagg (1965); Krammer (1963), Kowal and Andrews (1973); Olaniran (1983); and Bello (1983).

It is however, observed that most of these studies particularly those in Nigeria, were carried out based on the annual agricultural calendar. Thus the basic units of data processing for the investigation of the influence of these hydrometeorological variables on crop field were based on the entire growing season. In other words, the study of the effects of these factors on the physiological growth of the crop from planting to harvesting are not usually given due attention. Consequently, cases of crop failures and poor yields, particularly in the dry sub humid climate of Nigeria have become an annual occurrence.

Kowal et. al, (1973) tried to study the pattern of water availability and water requirements for grain sorghum production at Samaru. In their work, they observed that in matching the pattern of water supply to crop water demand it is clear that during the rainy season, there is no lack of water at Samaru to limit crop production in an average year. They noted that during the period of maturity that the crop relied almost entirely on water stored in the soil profiles. Fortunately, the crop water demand during this period gradually diminishes, but they observed that even between 119 and 174mm of water are taken from the soil before the crop is harvest towards the end of November.

The study noted that, amount of available water stored in the 180cm depth of the soil profile is about 213mm and therefore sufficient to meet the crop's water requirements. In conclusion, the work showed that the crop water demand are first met from surface layers, but as these dry to near wilting point the water is absorbed from deeper layers of the soil profiles. Though, Kowal et al, (1973) did not specify the variety of sorghum that was used as it is known that, the ability of a crop to withstand drought depends partly on the variety, soil structure and rooting system among other characteristics and features.

In a study by EL Nadi (1975), he undertook an experiment to determine the best irrigation type in Sudan. He observed that, although good vegetative growth may be associated with high yields, if conditions are also favourable for experiments. Nadi found that 70mm irrigation at intervals of ten days were better than 120mm irrigation every 15 days. In another experiment, he found that the best method of rationing water for yield of dry beans was to irrigate every ten days at 60mm. In conclusion, Nadi (1975) suggested that, the best irrigation practice for haricot bean in Northern Sudan may be to apply 60mm water that is less than traditionally accepted at interval of ten days (which is rather more frequent than the usual practice).

Arkedy (1963) in the study of irrigation water management found out that, strong correlation usually occurs between cumulative seasonal dry matter and cumulative seasonal transpiration. These relationships normally originate at or near the origin and rise in early to some yield maximum to transpiration maximum level. The attained transpiration maximum may equal the potential seasonal transpiration if adequate soil water levels were maintained by rainfall and or applied irrigation water.

Steward et al (1977) in the study of yield and field water supply demonstrated that, crop yields are typically related to seasonal evaporation and seasonal irrigation. They found out that, in a given season, the available soil water at planting (ASWP) and the effective growing season rainfall (Re) components of the seasonal field water supply make possible a yield level that is common to both functions. The evapotranspiration component associated with successive application of irrigation defines the yield and evapotranspiration function, which may rise to a yield maximum to evapotranspiration maximum level when the seasonal crop water requirement is fully satisfied. The evapotranspiration to non-evapotranspiration components of irrigation define a yield and irrigation function of conveys form.

This relationship typifies results of many experiments (Miller et al; 1965, Gerard and Namken, 1972: Stewart and Hagan 1969 and 1972: Huszer et al, 1970: Yaron, 1971, Steward et al; 1974, Shipley and Regier, 1975 and 1976; and Grimes (1977). That is non-evapotranspiration losses increase as water is applied to achieve evapotranspiration maximum levels due to the inefficiencies of irrigation methods and the exactness of water scheduling. The amount of water not used in evapotranspiration therefore represents runoff, deep percolation and or residual extractable water in the soil when the crop is harvested. They concluded that, it is by this quantity of water that the yield and irrigation function is bent away from the yield and evapotranspiration functions.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Data Collection Procedure: In order to assess the crop water requirement in relation to the climate related problems, relevant data were obtained and investigated to understand and examine the impacts of climatic change on agricultural products in Enugu State. The primary data involves the participatory observation by the researcher with the aid of field assistant (trained agricultural extension staff) i.e enumerators who were instructed on how best to administer the questionnaires on the farmers. The questions were meant to appraise their crop performance in relation to water availability in the area. The research instruments used include a 14 points questionnaire on the use of irrigation techniques by the contact farmers for increased crop yield.

For effective gathering of information number of questions were reduced to as few as possible to ensure that only relevant questions were asked. Simple random sampling technique of the farmers was adopted in the three agricultural zones of the South, Central and North in Enugu State. A copy of the questionnaire on the contact farmers is attached to the study as shown in appendix 1.

The secondary data for this study were obtained from the Centre for Climate Change and Freshwater Resources (CCCFR), Federal University of Technology Minna and 17 agricultural stations in Enugu State and its neighbouring states of Abia, Anambra, Benue, Delta, Ebonyi, Imo and Kogi covering a total of 382 station years selected on the bases of length of records as shown in Table 3.1, and Appendix 3 and their stations used in this study.

The extracting and processing of daily rainfall data was carried out on the micro – computer system at the Centre for Climate Change and Freshwater Resources, Federal University of Technology, Minna as shown in Fig. 4.1b – 4.1dx.

Table 3.1: Distribution of Stations with Onset (A), Cessation Dates of Rain, Length of Rainy Season (C), Rainfall Distribution (D) and Their Number of Years Used for the Study.

Station	A	B	C	D	No of years
Abakaliki	518.7	1526.49	4410	33600	21
Ankpa	546	1803	5700	36000	30
Arockuwkwu	253.2	1017.6	2520	19200	12
Asaba	3930.9	3237	9750	70200	39
Awgu	302.4	1150.4	3680	25600	16
Ayangba	2739	437.8	2420	12100	11
Ayangba Agric	421.4	669.2	2940	18200	14
Enugu	468.3	1451.1	5250	37800	21
Idah (N.A.Sch)	212.3	369.6	2420	14300	11
Idah Ofukolo	1210.4	1669.4	7480	37400	34
Nsukka	700	1668.8	5880	30800	28
Okene	222	681.6	2520	15600	12
Okigwe	551.6	1971.2	6720	44800	28
Onitsha	1404.9	4491.9	15750	100800	63
Otukpo	165.6	639.6	2880	15600	12
Oji River	233.6	513.6	4000	25600	16
Owerri	400.12	1257.2	3360	23800	14

Source: Centre for Climate Change and Freshwater Resources, (CCCFR) Federal University of Technology, Minna(2003)

The crop yield data were obtained from the Enugu State Agricultural Development Project (ESADP) Department. The raw data or transformation pass were proceeded to bring the variables to the same magnitude for better results. Information on the physical environment of the study area were obtained from the Department of Geography and Meteorology, Enugu State University of Science and Technology, Ministry of Lands and Urban development, Survey Division Enugu and Nigerian Meteorological Agency, Enugu.

Other sources of data includes textbooks, journals, newsletter, newspapers, periodicals, seminar, workshop, television and radio programmes.

3.2 Methods of Data Analysis

Considering the objectives of the study the methods of analysis involve the use of the following statistical tools as well as both observed and derived parameters of precipitation effectiveness.

3.2.1 Mean: This statistical tool is one of the simplest average whose purpose is to represent a group of individual values in a simple and concise manner so that the mind can get a quick understanding of the general size of the individuals in the group, undistracted by fortuitous and irrelevant variations (Osuala, 2001). It is one of the measures of central tendency. It tells the point about which the several different values cluster. The mean of a set of numbers is calculated by totally the items in a set and dividing the total by the number of individuals in a set.

The mean of a set of number X_1, X_2, X_3.................... Xn is denoted by $\overline{X}$ (read 'X' bar). In algebras notation, this tool is represented with a formula:

$$\overline{X} = \frac{X_l + X_2 + X_3 + \ldots\ldots\ldots\ldots\ldots\ldots + Xn}{N} \qquad \ldots\ldots\ldots\ldots\ldots\ldots 3.1$$

This statistical tool is employed to analysis the rainfall distribution pattern in the area during the period so as to determine the maximum rainfall for irrigation planning.

3.2.2 Deviation from Mean Value: This is defined as the arithmetic mean of the absolute differences of each score from the mean.

In symbols,

$$\overline{X}_1 \quad \text{Mean deviation} = \frac{\sum_{i=I}^{N}\left(X_1 - \bar{X}\right)}{N} \qquad \ldots\ldots\ldots\ldots\ldots\ldots 3.2$$

Where $\sum$ = Summation of the length of records in a station

No. of years in

N = No of years in length of records in a station.

X_1 = is the arithmetic mean of the length in a station.

$\overline{X}$ = Deviation from the arithmetic mean of the station.

3.2.3 The Standard Deviation

This is defined as the square root of the deviations from the mean.

In symbols

$$\sigma = \sqrt{\frac{\sum (X - \overline{X})^2}{N}} \qquad \ldots\ldots\ldots\ldots\ldots\ldots 3.3$$

Where, X represents the deviations of each of the numbers. Xj from the mean $\bar{X}$

Thus the root square of the deviation of each of the numbers Xj from the mean. This statistical tool is employed to estimate the values of length of the rainy season (LRS) in the Enugu State in relation to irrigation needs of the crops.

3.2.4 The Variance: This is defined as the square of the standard deviations and is given by:

$$\sigma^2 S = \frac{\sum_{i=I}^{N}\left(X_1 - \bar{X}\right)}{N} \quad \text{.......................} \quad 3.4$$

3.2.5 Percentage: This is a quantitative term whereby 'n' product of a number is 'n' one hundredths of the number. It is symbolized by %. It is the result obtained by taking a given percentage of a given quantity (Encyclopedia Britannia Macropedia knowledge in depth).

3.2.6. OGIVES: This statistical tool is used in summarizing and presenting the digital precipitation effectiveness for the total of 382 station years used for the studies. The technique involves the successive addition and plotting the rainfall amount on the graph and the curve so obtained is called an ogive or a cumulative frequency curves Figures 4.1b – 4.1dx This tested statistical tool is adopted in this case study to analyze rainfall amount so as to estimate the positive water balance (Obasi, 1972) as failures of water in the area suggest that there is something missing in the planning process and needs to be addressed through irrigation.

It utilizes 5 – day pentade rainfall (RR) cumulative frequency values, which is given in the form (Adefolalu, 1990):

$$PR\ (s, p = n) = PR\ (s, p = n - {}_1) + \sum_{t = (n-1)+1}^{t = (n-1)+5} RR\ (t) \qquad \ldots\ldots 3.5$$

Where:

PR (t.s) = recorded rainfall for a particular day (day = t) at location (station = s)

p = each 5 – day pentade ascribed values.

1,2,3 .... 73 (since there are approximately 365 days in a given year.

365/5 = 73.

3.2.7 Measures of Precipitation Effectiveness:

Both observed and derived parameters of precipitation effectiveness that are crucial to proper understanding of climate change, its impact on agricultural production and how best to tackle it is adopted in this case study. These includes onset dates of rains, cessation dates of rains and length of the Rainy season (LRS), breaks (drought spells) during the course of normal rainy season, degree of wetness or dryness (Hydrologic Ratio, λ) and water equivalent technique to avert drought in an area (Adefolalu, 1988).

The onset and cessation dates of the rains is employed in the estimation of the effective length of the rainy season (LRS) as discussed by Ndagi et al (1989) and Adefolalu (1990) expressed in the form:

$$LRS = ¢_{(s)} - \phi_{(s)}. \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3.6$$

Where LRS represents length of rainy season

¢ represents cessation date while

ϕ represents the onset date of the rains at location, S.

The application of the length of rainy season in Enugu State is to determine its dry monsoon regime characteristics when soil moisture surplus occurs.

Onset dates of the rains is the beginning of rainfall. This is the accumulated amount of rainfall that can sustain crop production for growth and development and not the first day of the rainfall. The cessation dates of the rains is the time in which the place experienced termination of the effective rainfall and not the dates that the rain lasts. The length of rainy season is the duration between the onset dates and cessation dates of rains.

The length of the rainy season (LRS) is employed to determine the time of sowing, growth or development and maturity of plants and the harvest period. It is also used to determine the soil carrying capacity. It is be used to determine the period of surplus soil moisture when rainfall exceed evapotranspiration.

3.2.8 Hydrologic Ratio: This is a drought indicator expressed as the ratio of mean annual rainfall to the potential evapotranspiration

$$\lambda = \frac{P}{PE} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots 3.7$$

Where RR is mean annual precipitation amount and

PE is the potential evapotranspiration.

The technique is adopted in the case study to determine the irrigation needs where seasonal rainfall is below average and required additional water to achieve a balance sheet to ensure good development of plants for maximum crop-yield. This involve using a simple algebraic equation as shown below to derive a quantitative index of hydrologic ratio (λ) as expressed in Fig 3.1 using the expression:

$$|\lambda| = \sum \Delta_s - \sum \Delta_{D1} + \sum \Delta_{D2} \quad \text{.......................} 3.8$$

where Δs = Excess Rainfall Over ET or PE

ΔD_1, ΔD_2 = Deficit of Rainfall below ET or PE

3.2.9 Water Equivalent to Avert Drought

This technique is adopted in estimating the time of greatest need of water by plants. The empirical relation of Flohn et al (1974) and Adefolalu (1990) is used to estimate the water equivalent to avert drought which is a criterion for satisfying the potential evapotranspiration condition in each location in the area.

It is given by the expression:

W/F = [D wet (Q wet – P wet) + D Dry (QDry – Pdry)] 3.9

W/F = Specific water consumption per unit area of land

D wet = Length of wet period in days

Q wet = Water demand equivalent of PE during wet period (in mm day $^{-1}$

P wet = Average daily precipitation total during wet period (in mm day^{-1})

D dry = Length of Dry period in days

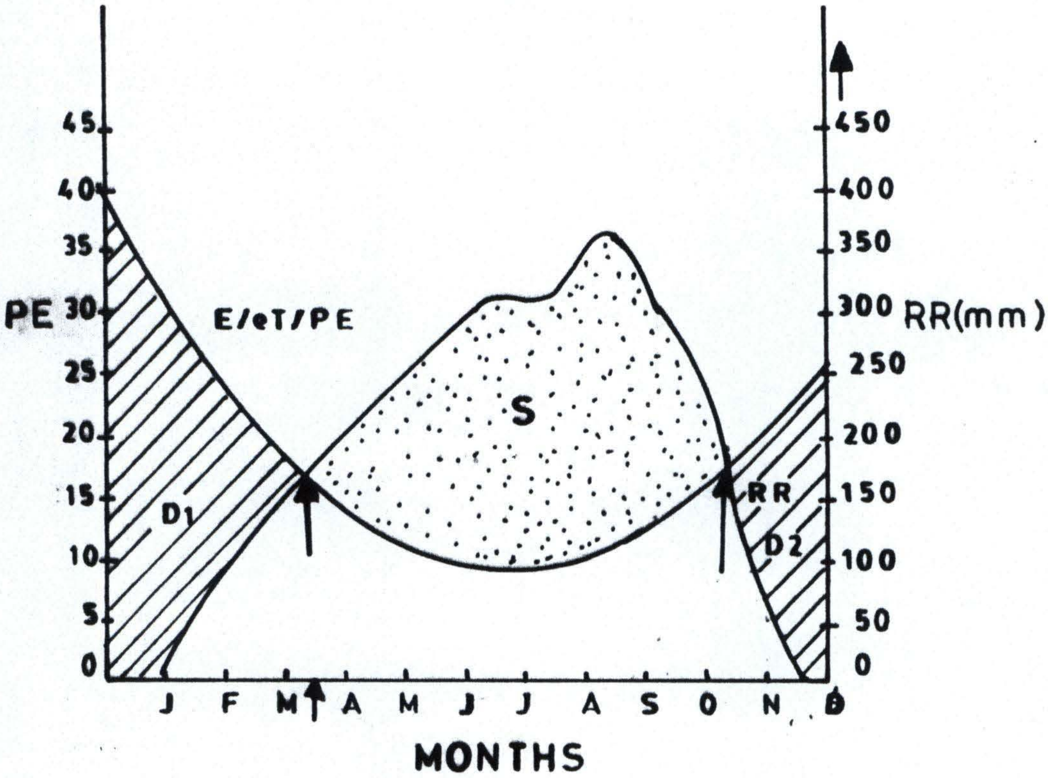


Fig.3·1: Hypothetical case showing seasonal trends of mean annual rainfall and Evapotranspiration

Q dry = Maximum water demand equivalent of PE during dry period (in mm day).

P dry = Average daily precipitation total during Dry period (in mm day^{-1})

PE = Potential Evapotranspiration

In Nigeria values for Qwet and Qdry are adapted for semi arid environment in the case of Niger state case study (Adefolalu, 1990) but can be apply in the study area as formulated by Flohn and others.

Where Qwet = 3.98mm day^{-1}

Qdry = 3.23mm day^{-1}

$$Pwet = \frac{\text{Total rainfall in (mm) during the wet months}}{\text{No. of days during wet months}}$$

$$Pdry = \frac{\text{Total rainfall in (mm) during the dry months}}{\text{No. of days during dry months}}$$

The technique suggests the amount of water to be pumped into a cropped field so that hydrologic ratio values greater than 1.0 (the ideal Hydro-neutral condition) is not exceeded.

3.2.10 Correlation Analysis:

This is concerned with the analysis of the mutual variation of variables. The technique is employed to determine the degree of relationship between special derived agroclimatic variables and the crop yield. The appropriate statistical tool used for this hypothesis testing is Pearson's product moment correlation (PPMC) and is represented by:

$$r = \frac{\sum xy}{\sqrt{\sum (X^2)(Y^2)}} \quad \text{..3.10}$$

where	r	=	Pearson Product Moment Correlation Coefficient.
	$\sum$	=	Summation of all items
	X	=	Independent variables (special derived agroclimatic variables)
	Y	=	Dependent variable (Crop yield).

3.2.11 Chi – Square Distribution Analysis

It rarely happens that an effect is brought about a single cause – rather do we find that a certain combination of circumstances is necessary and the absence of even one of them is enough to prevent the occurrence of the event. For example, the low crop yield in the area is attributed to the climatic variabilities. If we assume that the variabilities is the specific cause of the low agricultural production, we must also acknowledge that, the variabilities must find in some crops but not all the crops in all the year around. It implies that some crops will be more likely to succumb the influence of climate change while others will not. To determine this the test of association will be employed in analyzing data which is given by the expression:

$$X^2 = \sum \frac{(\theta - E)^2}{E} \quad \text{...................................... 3.11}$$

Where X is the Greek letter

X^2 is read chi-square

Σ = Summation

θ = observed frequency of agroclimatic variables

E = expected frequency of agroclimatic variables

This is the one of the most versatile statistical tool used to analyse those crops that are threatened by climate change if irrigation on small scale is not practiced. Graphs, chats and tables are employed to depict the distribution for better understanding.

The expected frequencies is computed using this statistical tool to test for the Null hypothesis (Ho). The computed value of X^2 is compared under some critical value such as X^2 0.95 or X^2 0.99) which are the critical values of the 0.05 and 0.01 significance levels respectively). This statistical tool is used to draw inference on the observed frequencies to see whether they differs significantly from expected or accepted frequencies and Ho rejected or accepted at the corresponding level of significance. The result is decided at the appropriate number of degrees of freedom with which the tables for X^2 is entered and given by expression:

$$df = (n - I)(K - I)$$

This is obtained as the number of classes whose frequency is assigned arbitrarily.

CHAPTER FOUR

AGROCLIMATOLOGICAL CONDITIONS IN ENUGU STATE

4.0 Introduction

Daily rainfall data for the study were analysed using both observed and derived parameters of precipitation effectiveness such as onset and cessation dates of rains as the main source of available water as a resource for estimating the effective length of rainy season so as to determine the dry monsoon regime characteristic when occurs and exceeds evapotranspiration for optimum crop growth and development (Adefolalu, 1986b, Olaniran, 1984, Duckham, 1974). Other parameters include breaks or length of dry spell, hydrologic ratio (λ) and specific water consumption techniques. Chi-squares test (X^2) was used in analyzing the crops that are mostly threatened by the variations in climate. Other descriptive statistics like mean, standard deviations, percentages and graphs were also employed in analyzing the data.

The application of these techniques in analyzing data is very important in the study area where environmental stress in relation to plant growth and development is becoming severe due largely to less water (in the form of soil moisture) being available from the most occurring natural source precipitation. As noted by Adefolalu (1988), by harnessing water in dams and reservoirs for irrigation and provision of water for "herded" cattle has been pursued vigorously in Nigeria in response to droughts in the northern parts of the country. These parameters gave better indication in the management and utilization of available water resources for increased crop production. This is because rainfall as a discontinuous quantity cannot obey atmospheric principles applicable to large scale motion characteristics such as wind, temperature and pressure. It is therefore logical to define the aspects of lack of precipitation that qualify as stress-inducing factors in the agricultural economy sector.

4.1 Onset Dates of the Rains

On the contradicting nature of the precipitation effectiveness in the area, Figures 4.1 series, 4.2, and Tables 4.1, and 4.2 illustrates the onset dates of rains (ϕ) in Enugu state (Appendix 3).

Table 4.1: Station Mean And Standard Deviations of Onset (ϕ), Cessation (¢) Dates, Length Of Rainy Season (LRS), Rainfall Distribution and Their Number of Years.

Station	$\overline{\phi}$	σϕ	$\overline{¢}$	σ¢	$\overline{LRS}$ (Days)	$\overline{RR}$ (mm)	No. of years
Abakaliki	24.7	7.2	72.9	10.5	210	1600	21
Ankpa	18.2	4.2	60.1	6.4	190	1200	30
Arochukwu	21.1	5.5	84.8	15.4	210	1600	12
Asaba	10.1	2.2	83.0	17.6	250	1800	39
Awgu	18.9	4.6	71.9	13.5	230	1600	16
Ayangba	24.9	8.8	39.8	12.7	220	1100	11
Ayangba Agric	30.1	8.6	47.8	9.5	210	1300	14
Enugu	22.3	6.6	69.1	11.88	250	1800	21
Idah (N.Sch)	19.3	4.4	33.6	11.2	220	1300	11
Idah Ofukolo	35.6	9.0	49.1	24.1	220	1100	34
Nsukka	25.0	7.4	59.6	12.4	210	1100	28
Okene	18.5	4.2	56.8	5.2	210	1300	12
Okigwe	19.3	6.9	70.4	10.9	240	1600	28
Onitsha	22.3	9.9	71.3	11.3	250	1600	63
Oturkpo	13.8	4.5	53.3	13.5	240	1300	12
Oji River	14.6	4.4	32.1	6.5	250	1600	16
Owerri	28.58	6.2	89.8	11.0	240	1700	14

Source: Centre for Climate Change and Freshwater Resources, Federal University of Technology, Minna (2003)

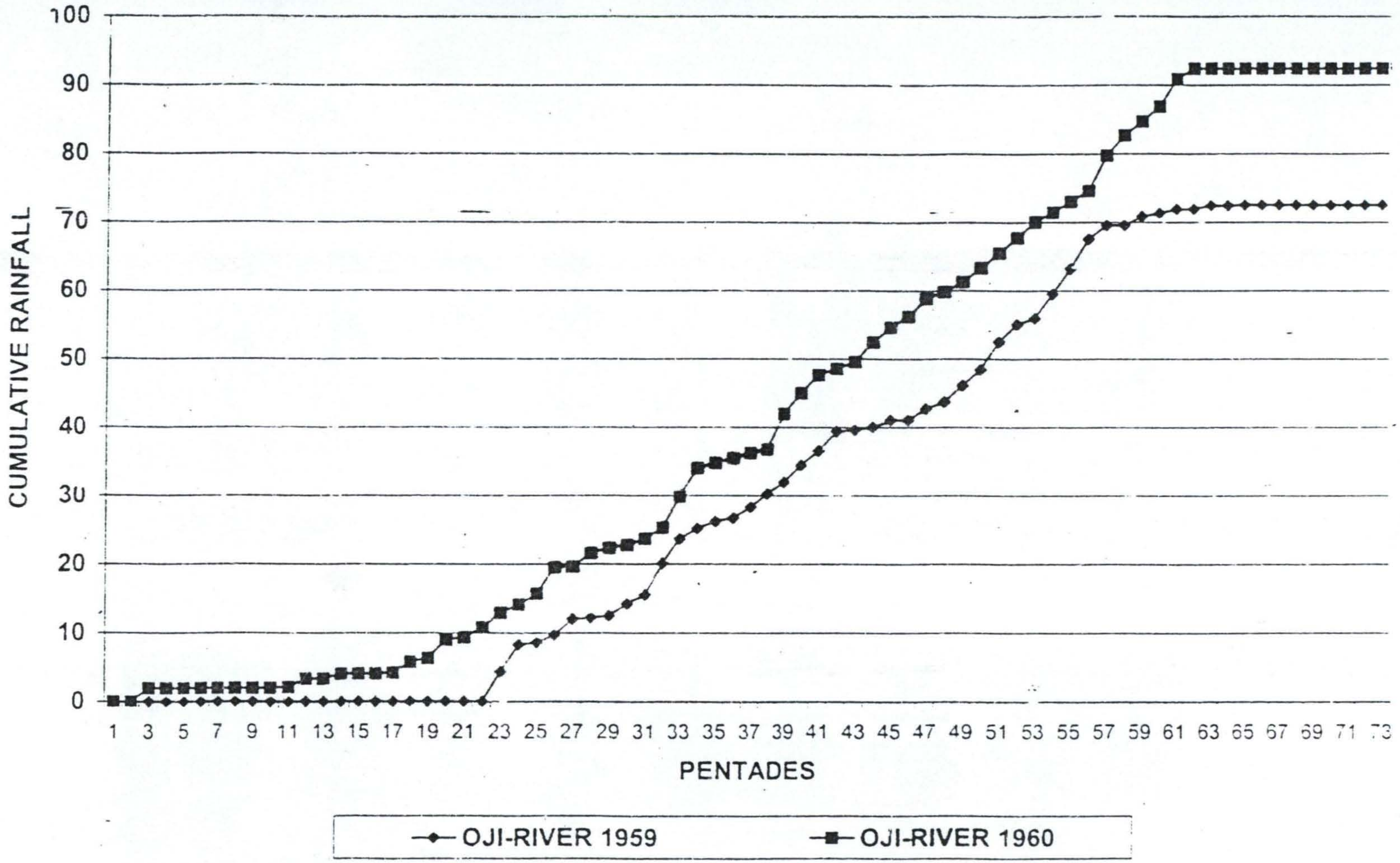


Fig. 4.1 : Ogive Graph of the study Area

The beginning of the onset date of rain is taken at a point of inflexion. This is the maximum and minimum value of the curve as shown in Figure 4.1 series, thus thereby transforming the actual point rainfall from a discontinuous to a continuous derived parameter. As previously noted by Adefolalu (1988), normal onset dates of rains extend from March 21 to April 10 in Nsukka in the north to Enugu, Agbani and Agwu local government areas in the central and southern parts of the state. In Udi and Enugu catchment areas, the onset dates extend between March 21 to March 31. At Enugu Ejike catchment areas the onset dates occur after April 10 covering areas bordering Eha – Amugu, Ikem, Obolo in the north and Nkalagu in the eastern parts of the state.

Table 4.2: Mean Onset Dates of the Rains in Enugu State

(a) Earliest	**(b) Normal**	**(c) Delayed**
Before March 16	Before March 21	Before March 26
March 16 – March 26	March 21- March 31	March 26 – April
March 26 – April 5	March 31 – April 10	April 10 – April 17
After April 5	After April 10	After April 17

In addition to the normal onset dates of rains, two other sets of onset dates of rains namely earliest and delayed dates were also examined so as to determine whether irrigation is absolutely needed in the area or not with respect to the false onset. The mean onset and their respective standard deviations using the expression:

$$\phi \text{ Earliest} = \underline{\phi} - \sigma \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots 4.1$$

$$\phi \text{ Delayed} = \overline{\phi} + \sigma \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots 4.2$$

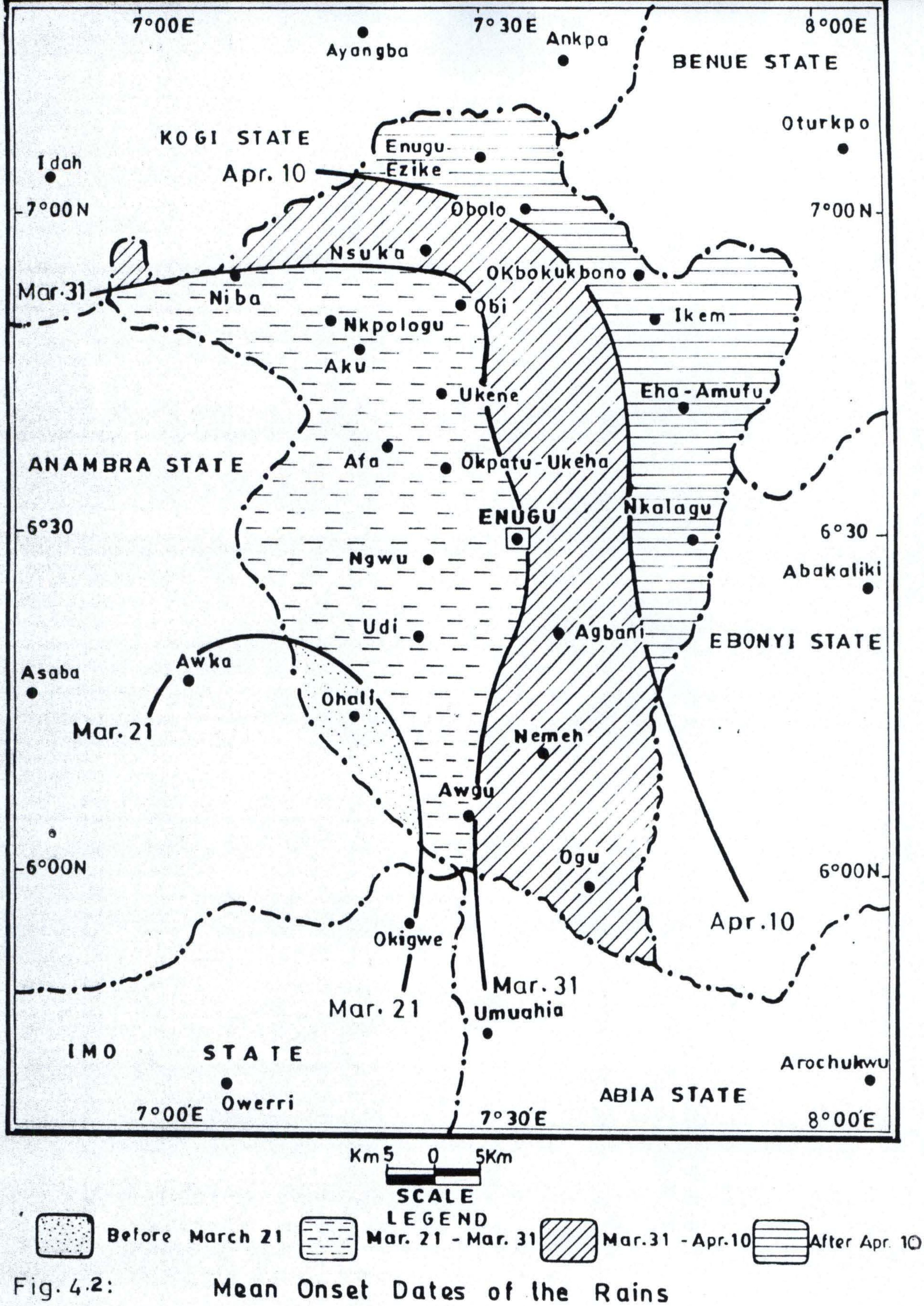


Fig. 4.2: Mean Onset Dates of the Rains

The results are presented in Figure 4.2a – b below:-

The following significant features with regards to the onset dates of rains are observed in the Enugu state.

i. Reliable onset dates are found in Niba, Nsukka, Opi, Nkpologu, Aku, Ukene in the north; Afa, Okpetu, Ukeha, Enugu, Udi and Agbani in the central sector; Agwu, Ogu and Nemeh in the southern fringes of the Enugu state.

ii. There is delayed onset of rain in Enugu Ejike, Obolo, Ikem, Okbobuone, Eha – Amugu, Nkalagu and Ogu as steady rain may not start until April 17 as shown in Figure 4.2 (b). Therefore, supplementary irrigation is absolutely necessary for increased crop yield in the area.

As stated earlier, onset dates of rains is not the beginning of rainfall. It is the accumulated amount of rain that can sustain crop growth and development and not the first day of the rain. Figures 4.2, a, b and Table 4.2 gives summary of the onset dates of rains in Enugu state. The isolines shows north-south orientation dominating the entire Enugu state. It implies that Enugu state received their prevailing winds from the north-south direction with its origins over the ocean. The isobars are closer to each other, indicating that the wind is stronger in the area. The rains comes in torrential form with intensive violent showers of short duration accompany with flood and soil erosion in the field as a common feature especially at the beginning of (March/April) and the end of (October/November) of the rainy seasons. Cereal crops like maize and millet

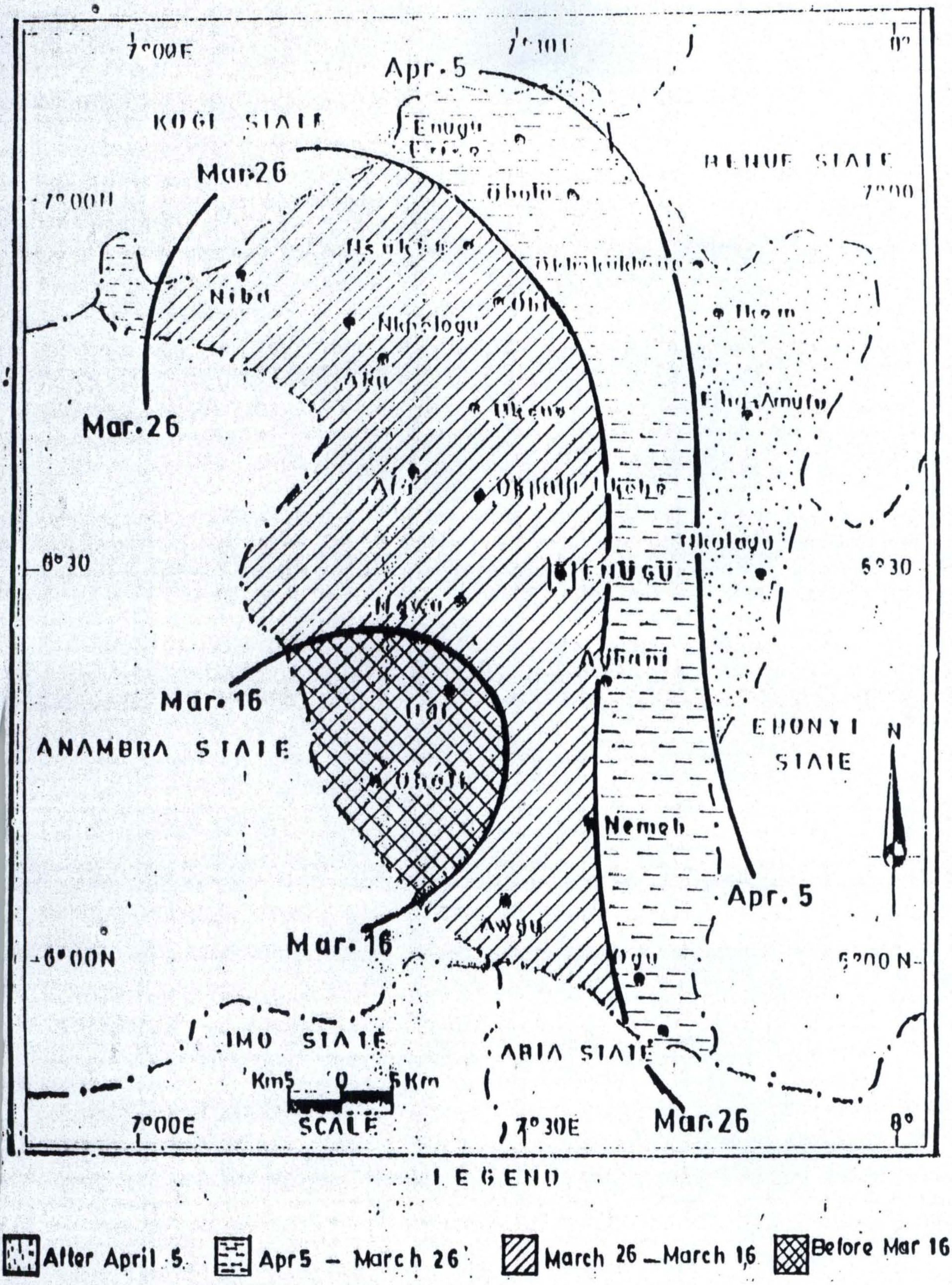


Fig. 4.2(a) : Early Onset Dates of Rains (Earliest)

are destroyed by the combine effects of floods and strong winds. These crops are ready victims of strong winds which often break their stems.

A summary of the onset dates in Figures 4.2, a, b and Table 4.2 gives the overall picture across the entire state. In the three groups of onset dates, the rains will start earlier in the south western parts before March 16 and may be delayed till March 26. In the north central, east and its extreme south west rains will not start until March 26 and may delayed till April 10, while the areas covering the north east and the entire eastern parts of the state, the rain will not start until after April 5 and may delayed till April 17 (Figures 4.2a – b).

Figure 4.2 further reveals the mean onset dates of the rains. The rain will start in the south west in March 21, while in the central parts, the mean onset dates of rains will start between March 21 to 31. The onset dates of rains occurs between March 31 to April 10 in the north extending to the east and south east (Figure 4.2).

It implies that rains start at least weeks earlier in the south west than other parts of Enugu state and may delayed until March 26. In other words, the earliest dates of rain extend between 1 – 11 days, the rainfall scenario is therefore characterized by false and delayed onset dates of rain in terms of timing, intensity and duration. Therefore farmers who are eager to take the advantage of the earliest onset dates of rains stands the high risks of crop failure leading to poor response of crops due to unsteady onset dates of rains. They will be forced to plant twice or carry out multiple sowing. This often lead to delayed maturity thus, resulting in increased overhead cost as more man-

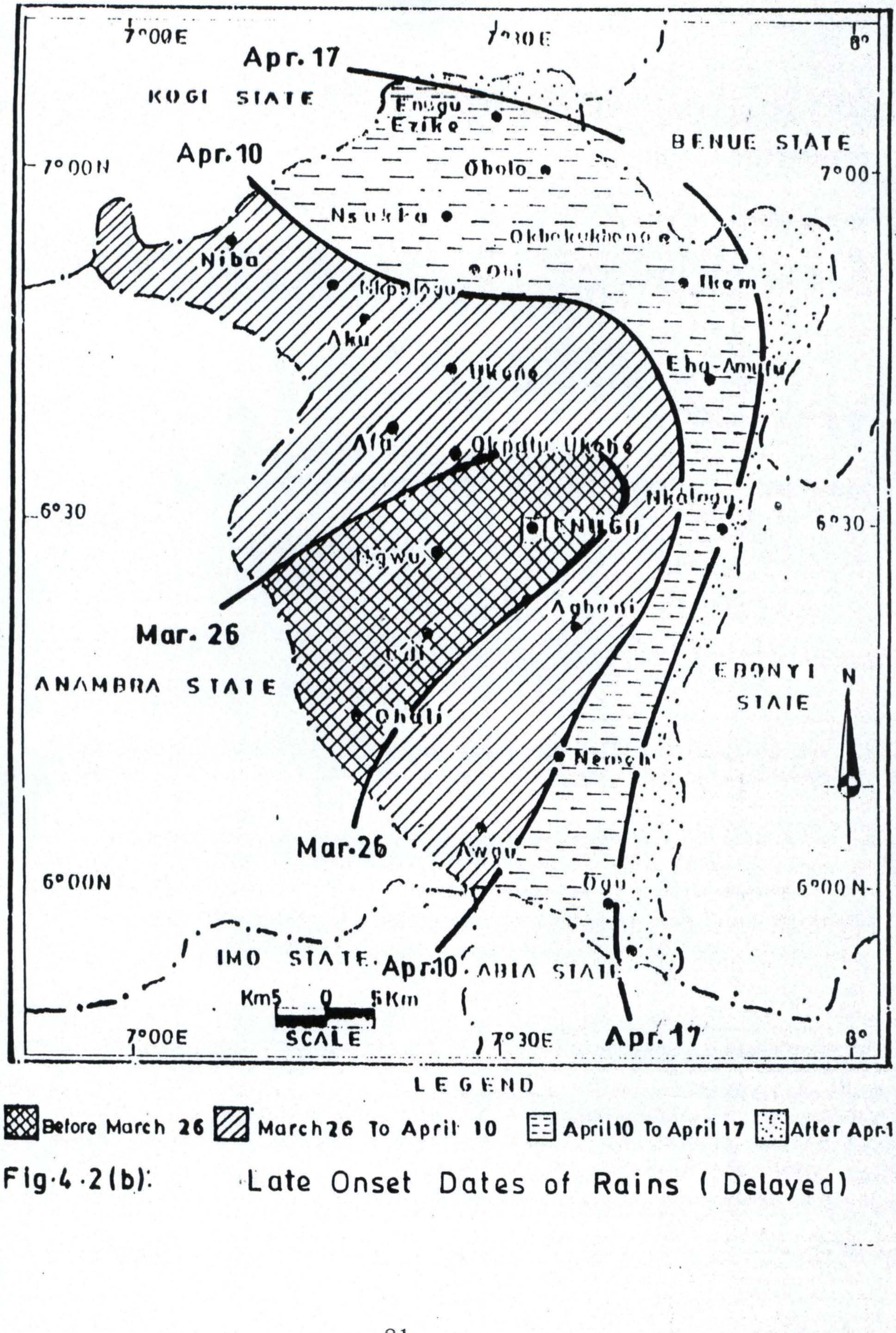


Fig. 4.2(b): Late Onset Dates of Rains (Delayed)

days and resources are spent in a single growing season. Also, the crops may never grow to maturity before the rain ceases, thus resulting in total or near total loss or crop failure. Thus, irrigation is absolutely necessary in the area and planning cannot be based onset dates of rains alone.

4.2 Cessation Dates of the Rains and Irrigation Scheduling

Figures 4.1 series, 4.3 and Table, 4.1 and 4.3. depict the pattern of cessation dates of the rains (¢) in Enugu state. The overall pattern of the isolines of equal cessation dates of the rains appears to follow the same pattern as the onset date (Appendix 3)

TABLE 4.3: Cessation Dates of the Rains in Enugu State.

(a) Premature	(b)Normal	(c)Delayed
Before Oct.12	Before Oct.27	Before Oct.28
Oct. 12 –Oct. 22	Oct. 27-Nov 5	Oct 28-Nov.11
Oct. 22 – Oct.27	Nov. 5 – Nov. 25	Nov 11 – Nov. 22
After October 27	After Nov.25	After Nov. 22

In order to determine the premature and delayed cessation dates of rains in the area, the station mean cessation dates of rains and their respective standard deviations were computed using the expression:-

$$¢\ \text{Premature} = \bar{¢} - \sigma \qquad \ldots\ldots\ldots\ldots 4.3$$

$$¢\ \text{Delayed} = \bar{¢} + \sigma \qquad \ldots\ldots\ldots\ldots 4.4$$

The results are presented in Figures 4.3a – b below:-

The following significant features are observed.

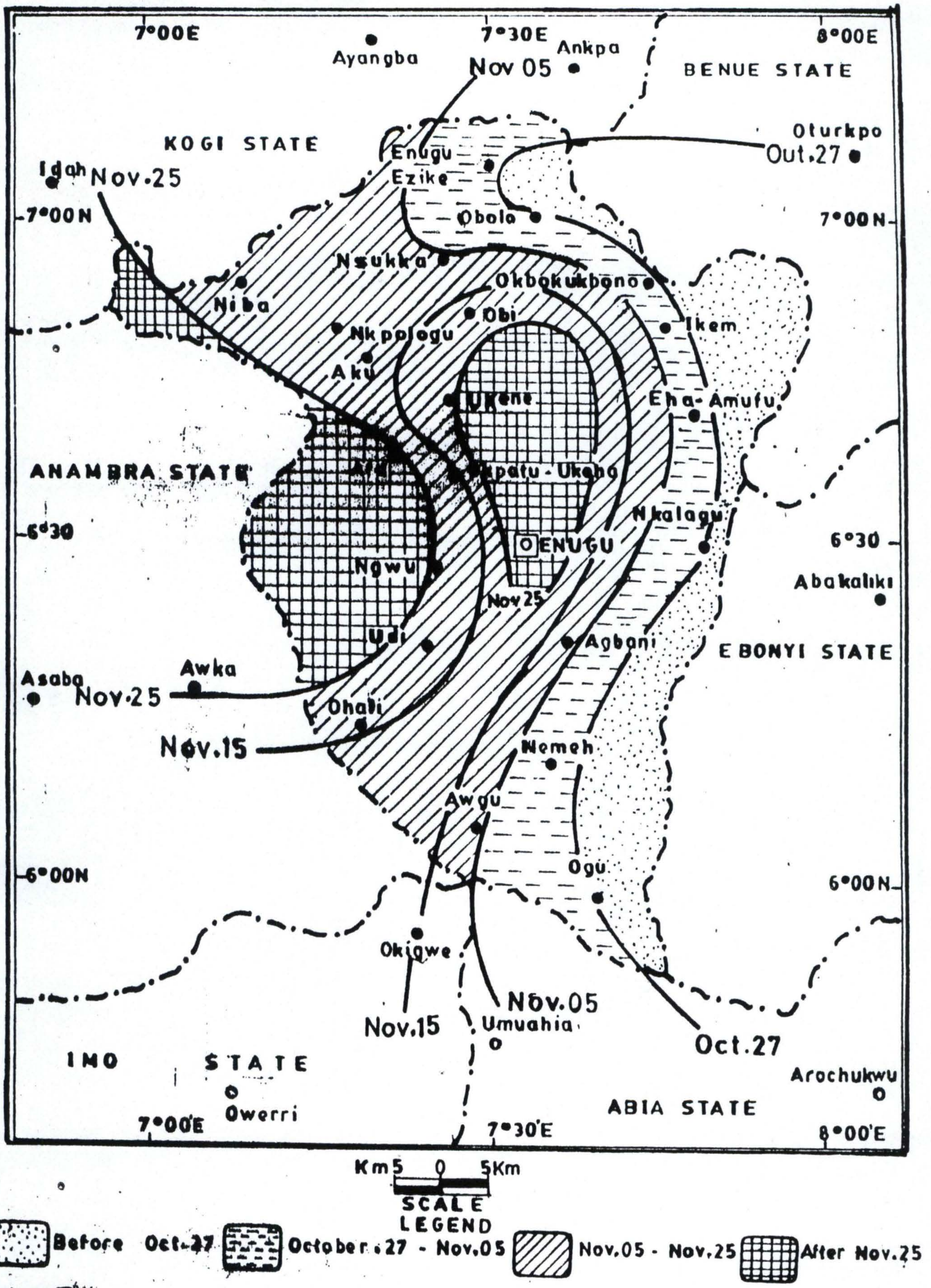


Fig.4.3 Cessation Dates of the Rains

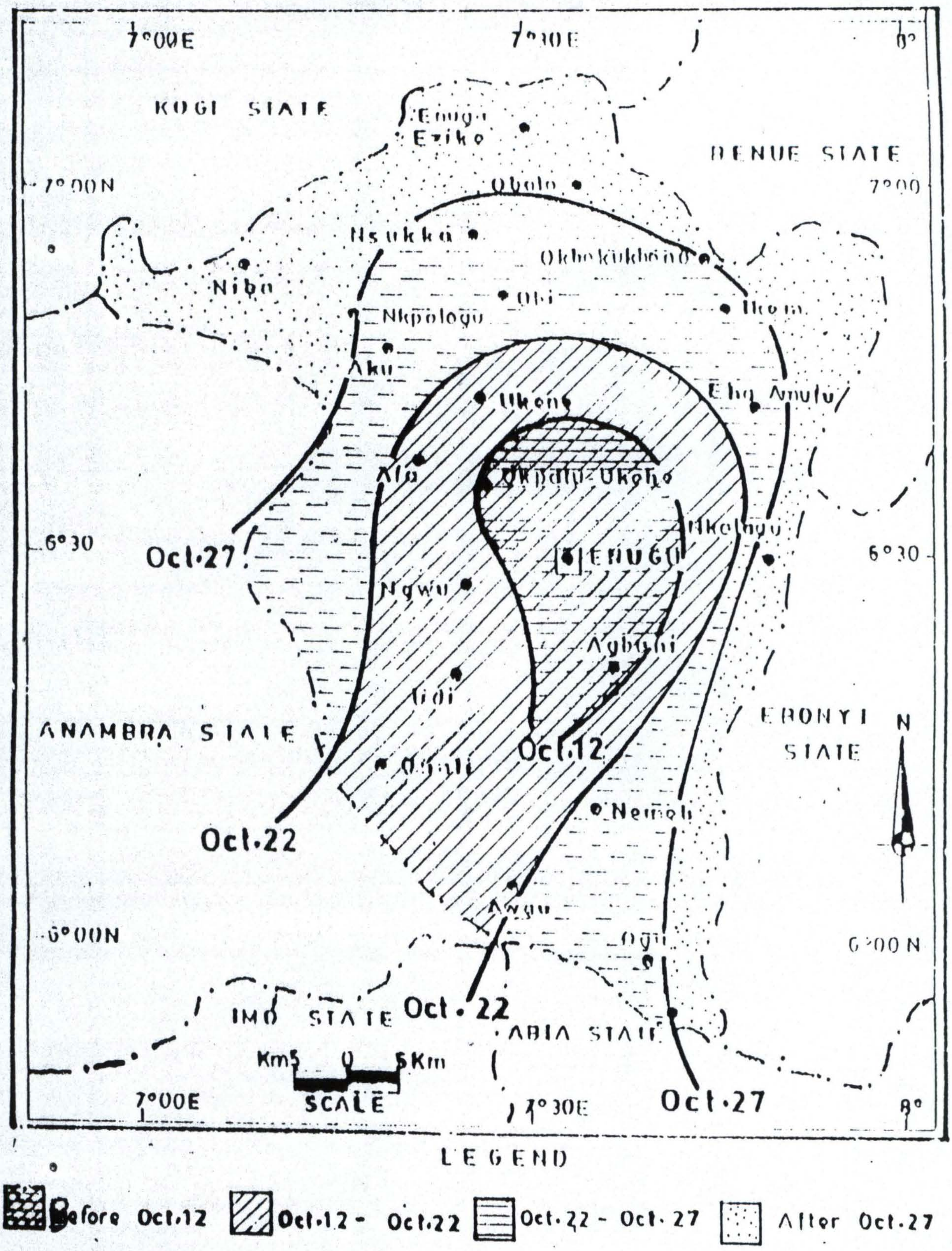


Fig.4.3(a): Premature Cessation Dates of Rains

i. The rains will stop after November 25 in any given year

ii. Areas in the eastern fringes of the central parts to the south bordering Ebonyi state in the east shows that rains terminates there earlier than other places in the state.

iii. Premature cessation indicates harms to crops such as poor development, lack of maturity, low yield and low quality of crops, therefore irrigation is needed for implied crop yield in the area.

Termination date of rains is not the last day of rains but the period when soil moisture deficit must commence due to gradual or rapid withdrawal of infiltration from rainfall received. The pattern of cessation dates of the rains in Enugu state is illustrated in Figures 4.3, 4.3a, 4.3b and Table 4.3. showing the mean, premature and delayed cessation dates of rains. The termination date of effective rainfall is taken at the highest point on the cumulative frequency curve. In the entire Enugu state, rain terminates earlier in the north east, extreme east and south east than other parts of the state. Table 4.3 shows that the range (in days of this termination is between 1 – 10 days). It was also observed that the maximum range (in days) of 10 – 20 days is recorded in the entire state. This suggest a decisive or sharp termination of the rains in the state where the last rains may fall as before October 27 but not November 25 in the Enugu Ezike, Obolo, Ikem and Ogu in the north bordering Ebonyi state in the eastern parts of the Enugu state (Figure 4.3). Figure 4.3a shows the premature cessation dates of rains. Rains terminates as early as October 12 in the central parts of the state. The isolines shows north south orientation dominating the entire Enugu

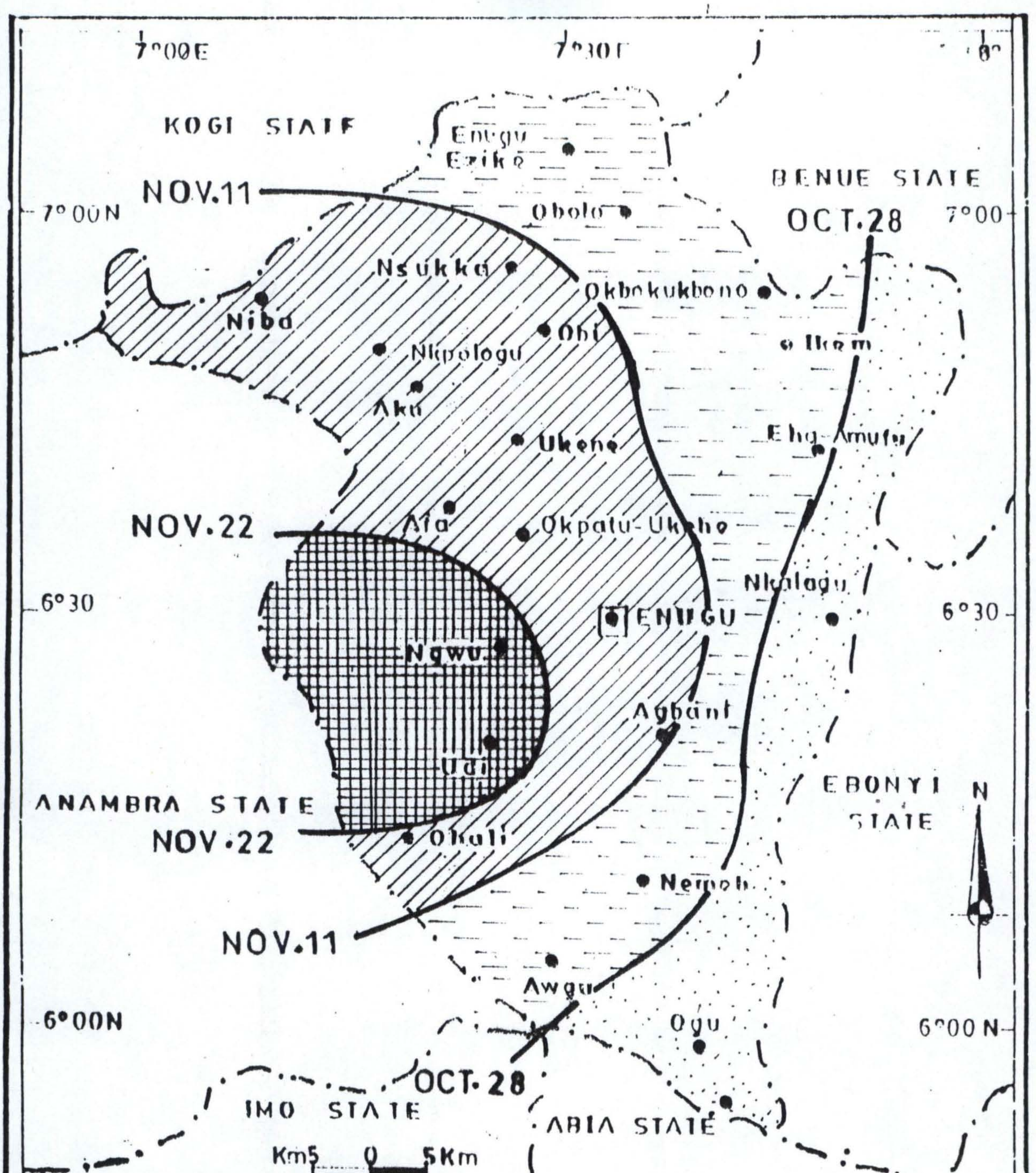


Fig 4 3(b): Delayed Cessation Dates of Rains state. The isobars are closer to each other, indicating that the wind is stronger at the end of the rains. Figure 4.3(b) shows the delayed cessation dates of rains. The rain will terminate in November 22 in the west and in the extreme eastern part of the state with a sharp termination before October 28.

The results in Figures 4.3a and 4.3b indicates that crops may not reach maturity before the respective dates in any sector of Enugu state under ranifed agriculture. It may cause harms to crops leading to poor developments, lack of maturity, low yield and low quality. It is therefore necessary to irrigate if for instance legumes are just flowering, grains have not formed pods and tubers have not developed. This option will be most advisable in the northern sector if river Adada is properly harnessed for that purpose (Adefalalu, 1988).

4.3 Length of the Rainy Season (LRS)

Table 4.1 and appendix 3 depicts the normal length of the rainy season (LRS) during the period in Enugu state. One of the most importance applications of the length of the rainy season (LRS) in the area is to determining the dry monsoon regime characteristics when soil moisture surplus occurs and exceeds evapotranspiration (Duckham, 1974). Figure 4.1 series shows the cumulative rainfall frequency curves or ogives, the onset and cessation dates of rains. The length of rainy season have been determined as discussed by Ndaji et, al (1989) and the computation is shown below:-

$$LRS\ (s) = \overline{\not{c}}(s) - \overline{\phi}(s) \qquad \text{................................4.5}$$

Where $\not{c}$ = represents cessation date while

ϕ = Represents the onset date of the rains at station.

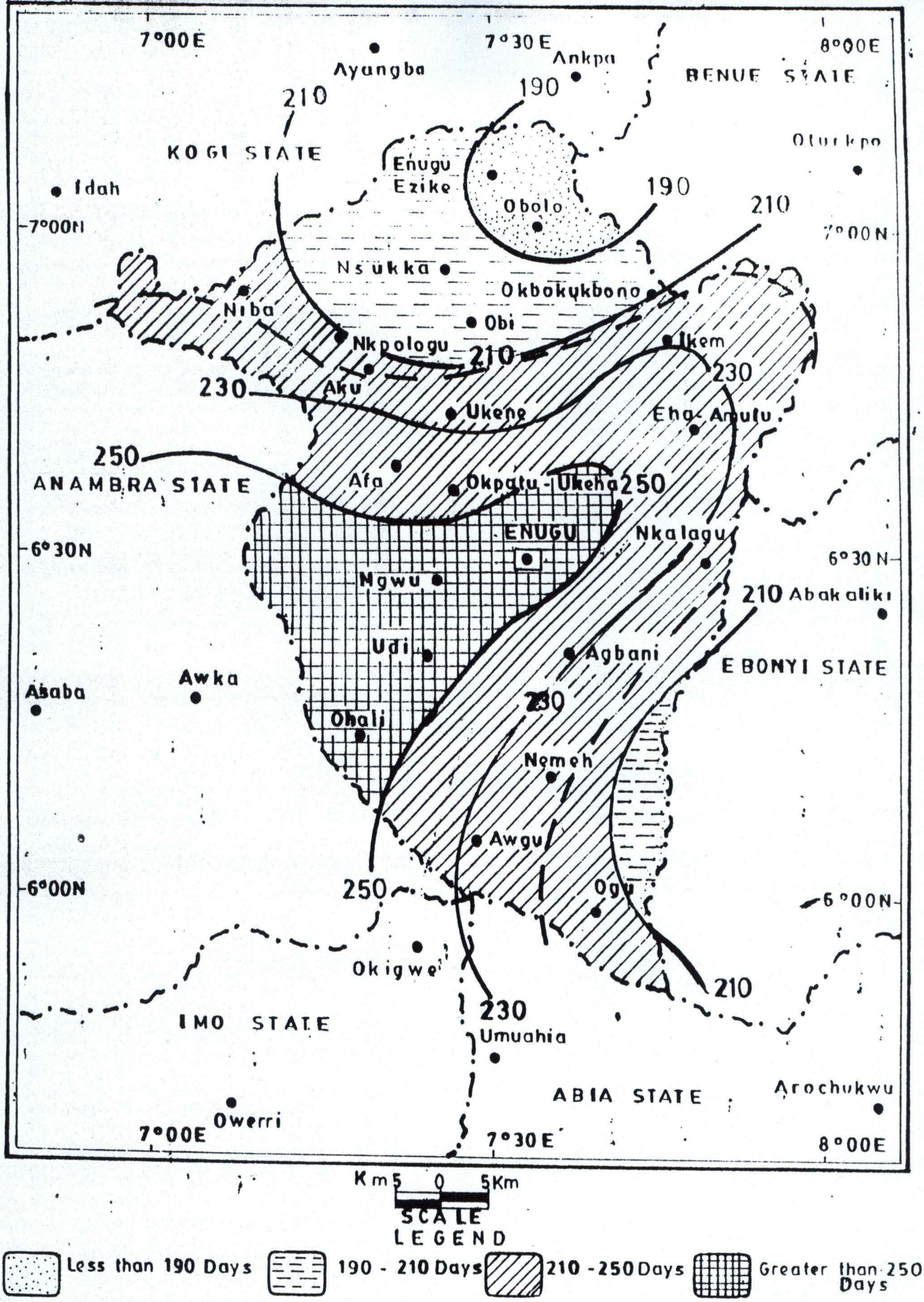
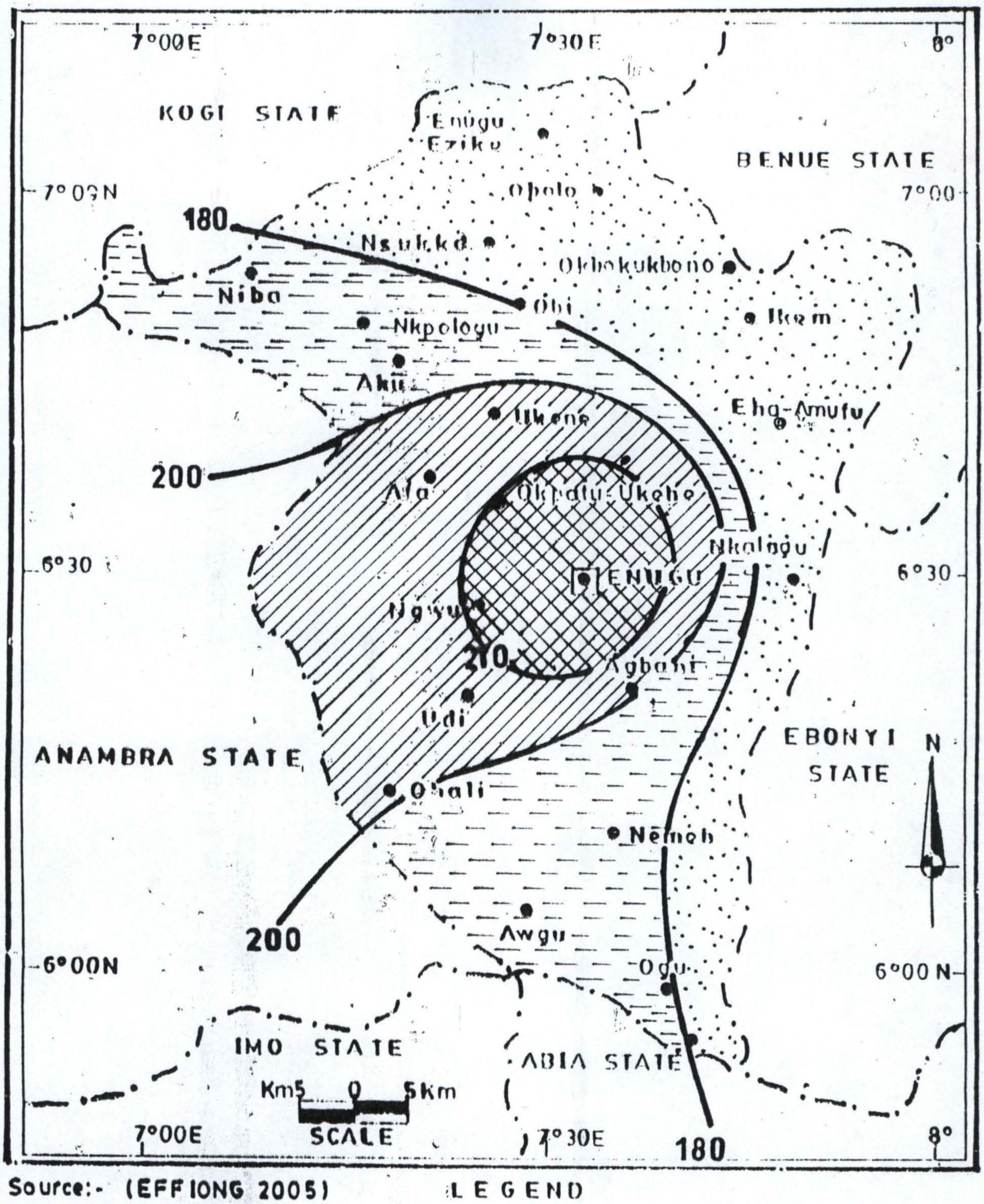


Fig. 4.4: Length of the Rainy Season (L.R.S.) in Days



Source:- (EFFIONG 2005)

LEGEND

< 180 Days; 180 - 200 Days; 200 - 210 Days; > 210 Days

Fig. 4.4(a): Low length of the Rainy Season (1)

The results shows that Obolo in the northern parts of the state have the range which is less than 190 days while Enugu Ejike, Nsukka and Opi in the same northern zone have the range of 190 – 210 days. Similarly, Awgu, Agbani, Oji River. Nkalagu, Eha, Amuta, Ukene and Niba from the south to the north have the range of 230 days with Enugu and its environs having the range of 250 days. The overall patterns are similar to those on the onset and cessation dates as shown in Figure 4.4. and appendix 3.

In addition to the normal length of the rainy season, six other sets of rainy season values were estimated using mean length of the rainy season and their respective standard deviations to determine the shortest lengths 1, 2 and 3, the longest lengths 1, 2 and 3 of the rainy season respectively in the area during the period. The computations were obtained using the expressions below and the results are presented in Figures 4.4a -f

i. Low length of the rainy season (shortest $^{-1}$)

$$\overline{LRS^{1}}_{Low} = [\, \bar{¢} - (\bar{\phi} + \sigma)] \quad \ldots\ldots\ldots\ldots\ldots 4.6$$

ii. Low length of the rainy season (shortest $^{-2}$)

$$\overline{LRS^{2}}_{Lower} = [(\bar{¢} - \sigma) - \bar{\phi}\,] \quad \ldots\ldots\ldots\ldots\ldots 4.7$$

iii. Low length of the rainy season(shortest $^{-3}$)

$$\overline{LRS^{3}}_{Lowest} = [(\bar{¢} - \sigma) - (\bar{\phi} + \sigma)] \quad \ldots\ldots\ldots\ldots\ldots 4.8$$

iv. High length of the rainy season (Highest $^{-1}$)

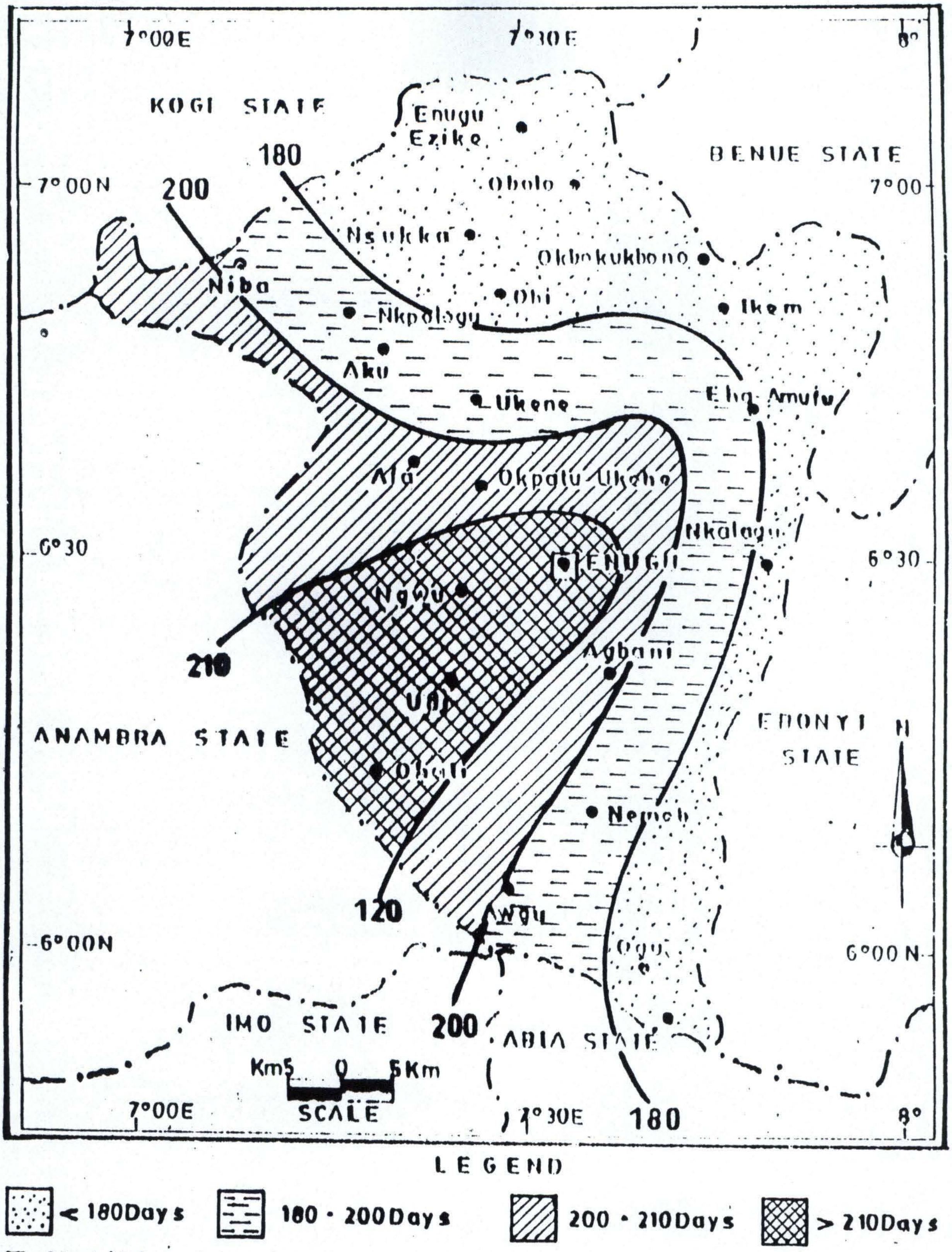


Fig:4.4(b): Low length of the Rainy Season (2)

$$\overline{LRS^1_{High}} = [(\overline{¢} + \sigma) - \overline{\phi})] \quad \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots \; 4.9$$

v. High length of the rainy season (Highest $^{-2}$)

$$\overline{LRS^2_{Higher}} = [(\overline{¢} - \sigma) - (\overline{\phi} - \sigma)] \quad \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots \; 4.10$$

vii. High length of the rainy season (Highest $^{-3}$)

$$\overline{LRS^3_{Highest}} = [(\overline{¢} + \sigma) - (\overline{\phi} - \sigma)] \quad \dots\dots\dots\dots\dots\dots\dots\dots\dots \; 4.11$$

The variations in the length of the rainy season was also estimated to determine the seriousness of the situation in Enugu state using the expression:-

vii. $$\overline{LRS} = [(\overline{¢} + \sigma) - (\overline{\phi} - \sigma)] - [(\overline{¢} - \sigma) - (\overline{\phi} + \sigma)] \quad \dots\dots\dots\dots 4.12$$

Where LRS = Length of Rainy season

¢ = Mean cessation dates of rain

ϕ = Mean onset dates of rain

σ = Standard deviation

The summaries of these computations are presented in Figure 4.4a -g. The overall patterns are similar as may be expected to those on the onset and cessation dates. The northern parts have the shortest length of rainy season of less than 180 to 200 days and longest length of less than 250 days to 270 days while the central and southern parts of Enugu state have the ranges of 200 to 210 days for shortest lengths and 270 to 290 days for longest lengths and 180 to 200 days as the shortest lengths for southern parts, while the same sector reaches the maximum of 250 to 290 days respectively but in both the central and southern sectors, very high values of greater than 290 days may be

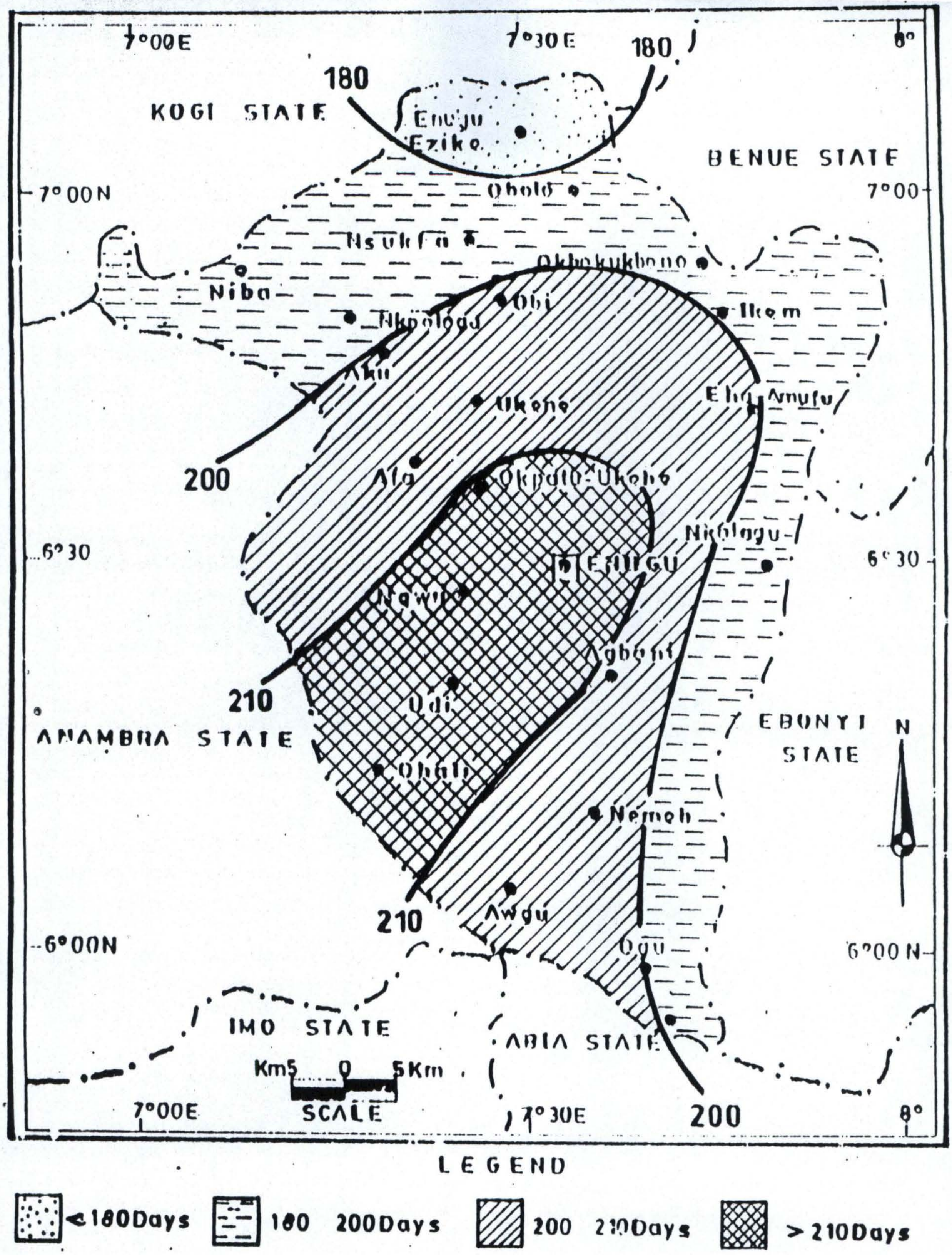
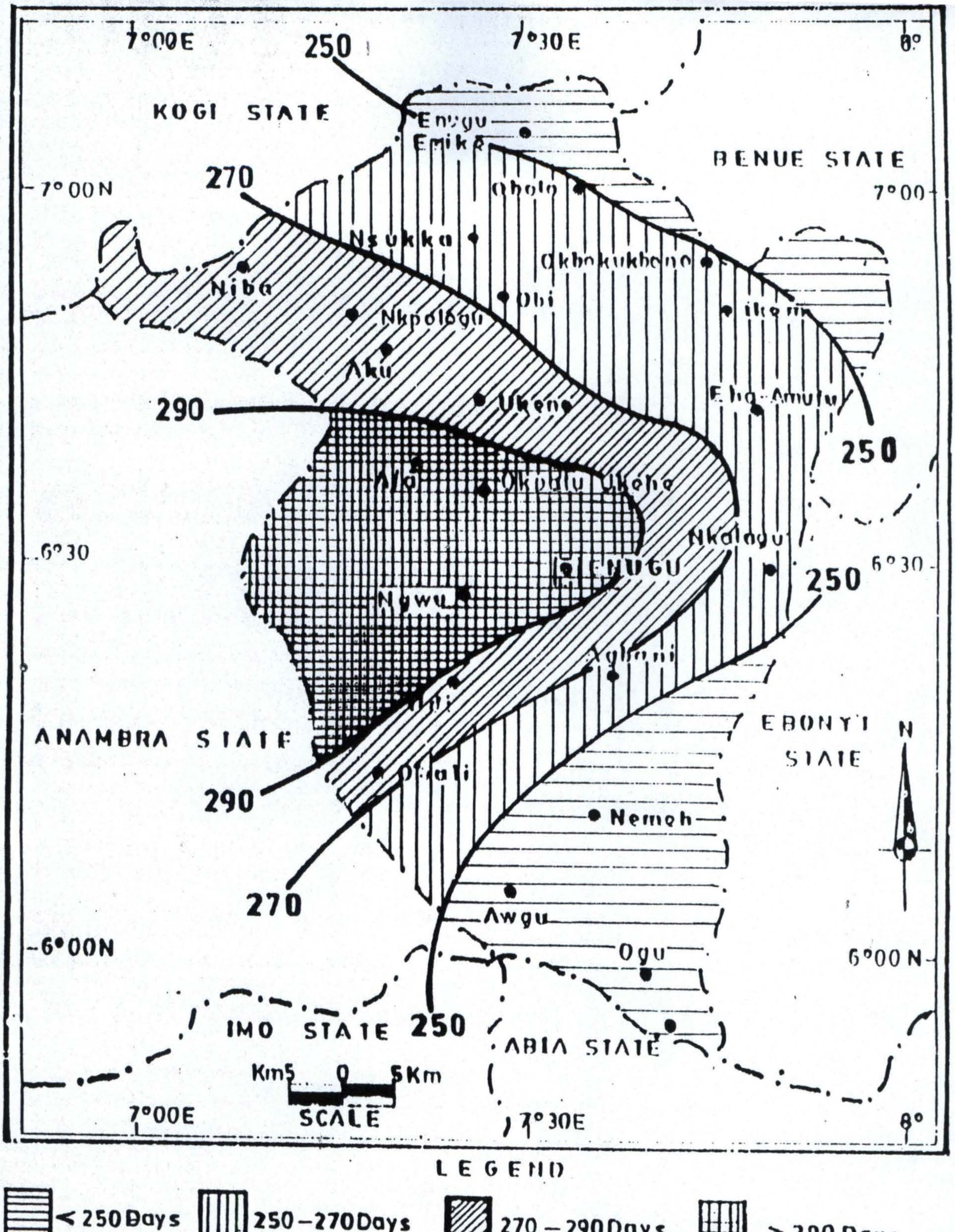


Fig.4.4(c): Lowest length of the Rainy Season (3).



LEGEND

< 250 Days | 250–270 Days | 270 – 290 Days | > 290 Days

Fig. 4 · 4(d): High length of the Rainy Season (1) expected under extremely favourable monsoon seasons. The same northern sector has lowest values of less than 180 to 200 days.

Figure 4. 4 (g) depicts the variations in the length of the rainy season. One interesting feature to be noted is the relatively shorter length in the area. In the northern parts of Enugu state bordering Kogi and Benue States, the values range from less than 50 to 70 days, while the central and southern parts of the Enugu state have the ranges of 70 to more than 90 days and 70 to 90 days respectively. This shows that irrigation is required in the area in order to satisfy soil moisture requirements of crops.

As noted earlier, length of the rainy season (LRS) is employed to determine the duration between the onset dates and a cessation dates of rains. In order words, it determine the time of sowing, growth or development and maturity of plants and the harvest period.

Figure 4.4 depicts the normal length of the rainy season (LRS) in Enugu state. From the results the northern and south – eastern fringes of the state have lowest values of between 190 and 210 days maximum. But in the central and southern sectors, very high values of 230 to 250 days are recorded. The axis of the length of rainy season band in the northern sector which rains parallel to the channel of rivers Adada in the north and Ebonyi River in the south eastern fringes of the state coincides almost exactly with the pocket of lower than normal rainfall amount for the area.

It is of interest also to note that Oji River is situated in the zone of high rainfall values and longest length of rainy season in the sector which if properly

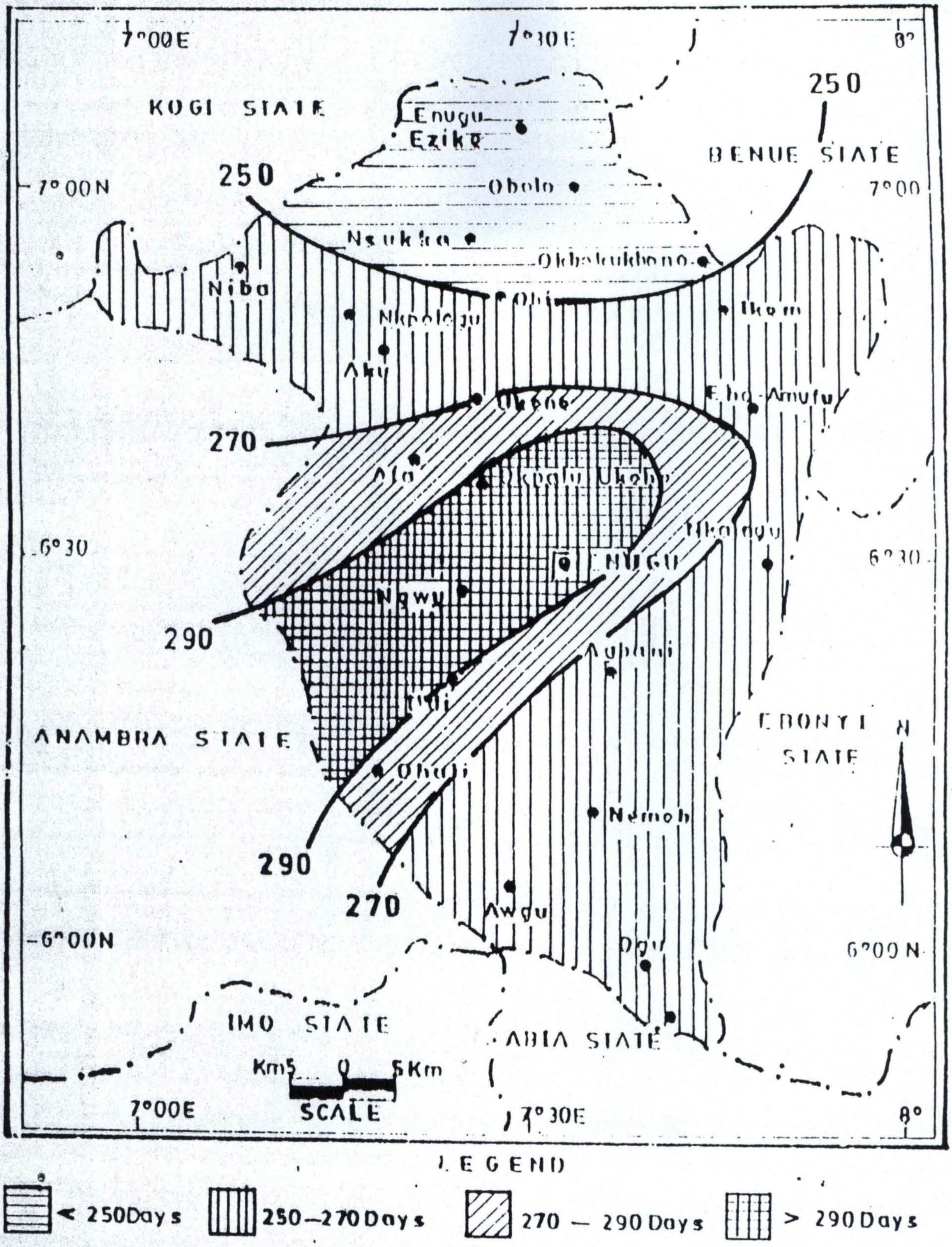
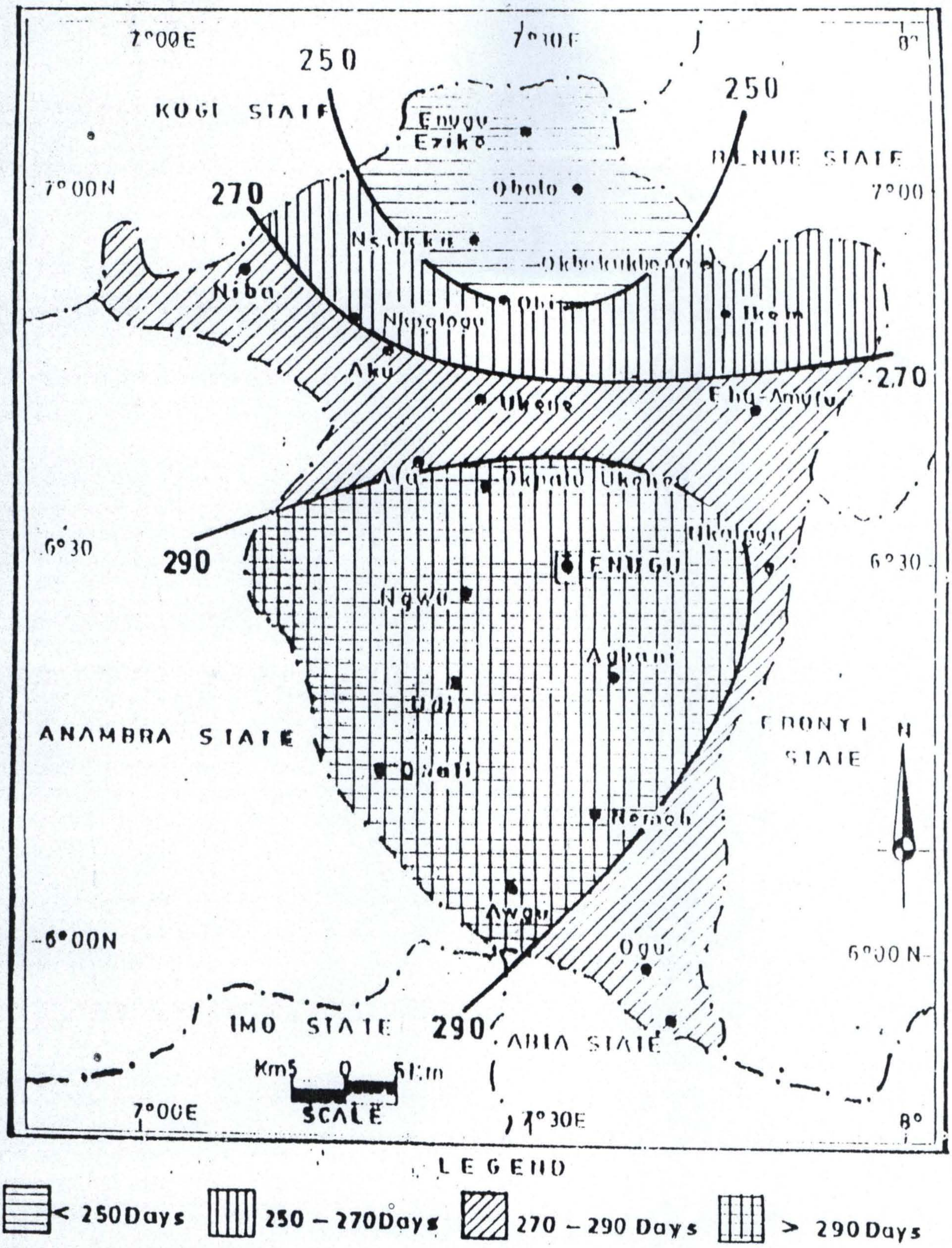


Fig.4.4(a): High length of the Rainy Season (2)



Fig·4·4(f): Highest length of the Rainy Season (3) harness into dams and reservoirs for irrigation will be an essential variable for food production (Adefolalu, 1988).

Figures 4.4a – f illustrates the various values of low and high length of the rainy season. The overall patterns are similar (as may be expected to those already discussed on the onset and cessation dates. Figures 4.4a – c depicts the values of low length – 1, 2 and 3. From the results the central parts of the state have the ranges of 200–210 days for (low length – 1), (low length–2) and (lowest length – 3) respectively, the same central parts has longest values of between 270 – 290 days maximum (Figures 4.4 (d)– f). But in the south west, north east, extreme east and south eastern sectors, lowest values of between 180 – 200 days maximum are recorded for (low length – 1), (low length – 2) and low length – 3) respectively, the same sectors has longest values of between 250 – 270 days maximum (Figures 4.4d –f). Figure 4.4g shows the variations in the length of the rainy season. The same central parts have the longest period of 90 days, while other sectors in the state have the values of between 50 – 70 days. Apart from the absolute values given above, other interesting features to be noted include:-

The symmetry of north west and south west orientation of the inter-changing values of low, high and low length rainy season (LRS) centres in all the seven maps.

- the relatively shorter length of the rainy season in north east and extreme east extending to the extreme south east where values are at least 50 days

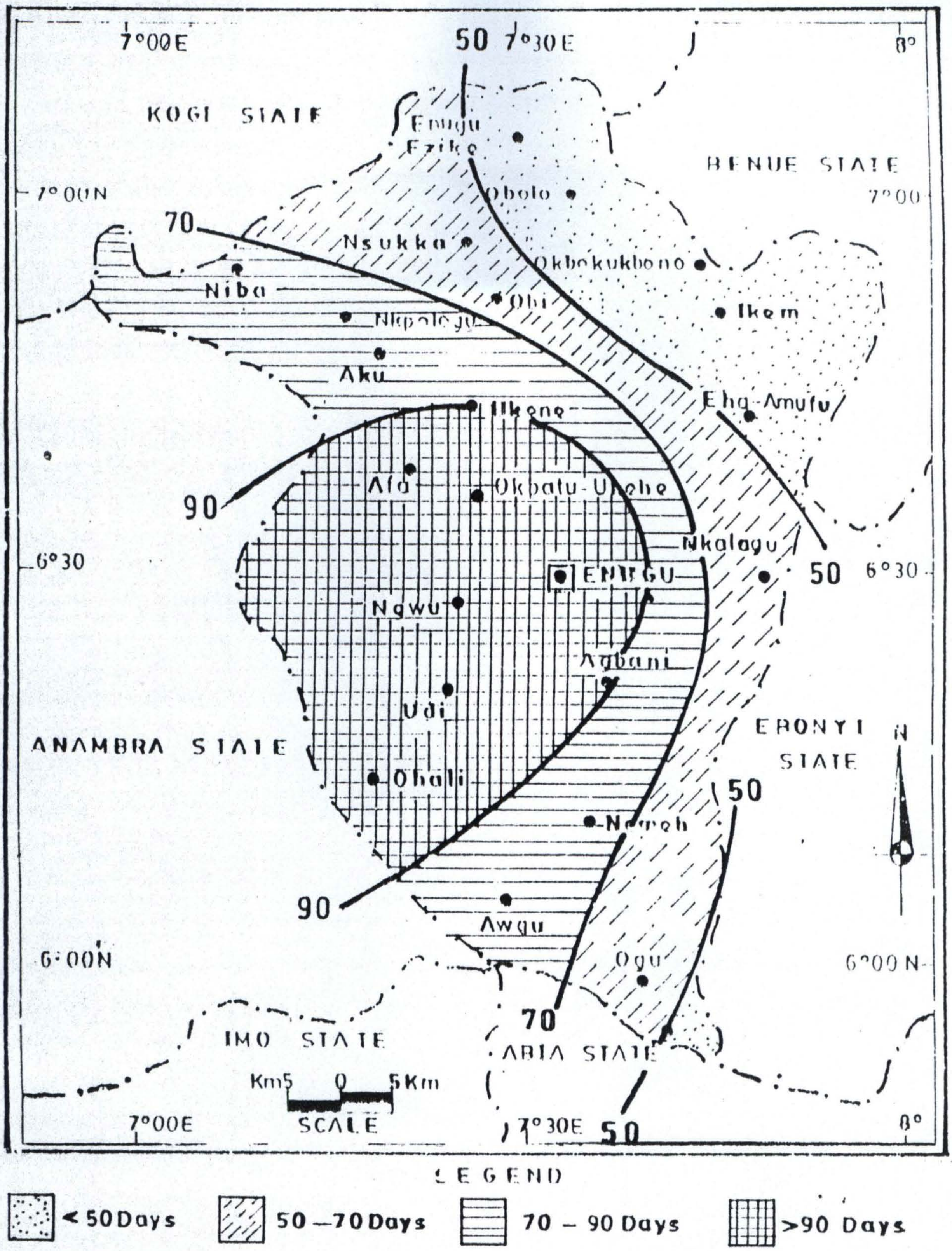


Fig.4.4(g) Variations in the Length of the Rainy Season.

less than expected values (Figure 4.4.g). This gives indication of the seriousness of the drought situation in Enugu state.

- The axis of the low length rainy season (LRS) band in the north east and extreme south east sectors, which runs parallel to the channel of river Adada and Ebonyi River in the East.

Irrigation development in the area must be based on the impoundment of these rivers to satisfy soil moisture requirement of crops.

In comparison with the growing period of major food crops in the state, the results show that the length of the normal rainy season satisfies the consumptive use of water by cereals, legumes, vegetables and tuber except cassava in the area as shown in Table 4.4 below:

Table 4.4: Major Food Crops and their Growing Periods in Enugu State

Major food crop	Growing periods (days)
Cassava	270 – 780
Cocoyam	180 – 270
Groundnut	90 – 140
Maize	100 – 140
Millet	90 – 120
Rice	90 – 150
Sweet potato	90 – 180
Sorghum	100 – 140
Tomatoes	60 – 175

Source: (Enugu State Agricultural Development Project(ENSADP, 2003)

4.4 Mean Annual Rainfall Distribution in Enugu State:

Figure 4.5and Table 4.1 illustrates mean annual rainfall distribution in the area. It is obvious from the detailed pattern in Figure 4.5 that the minimum rainfall distribution is less than 1100 mm in Obolo and between 1100 to 1500mm in Nsukka and Enugu Ejike in the northern fringes bordering Kogi and

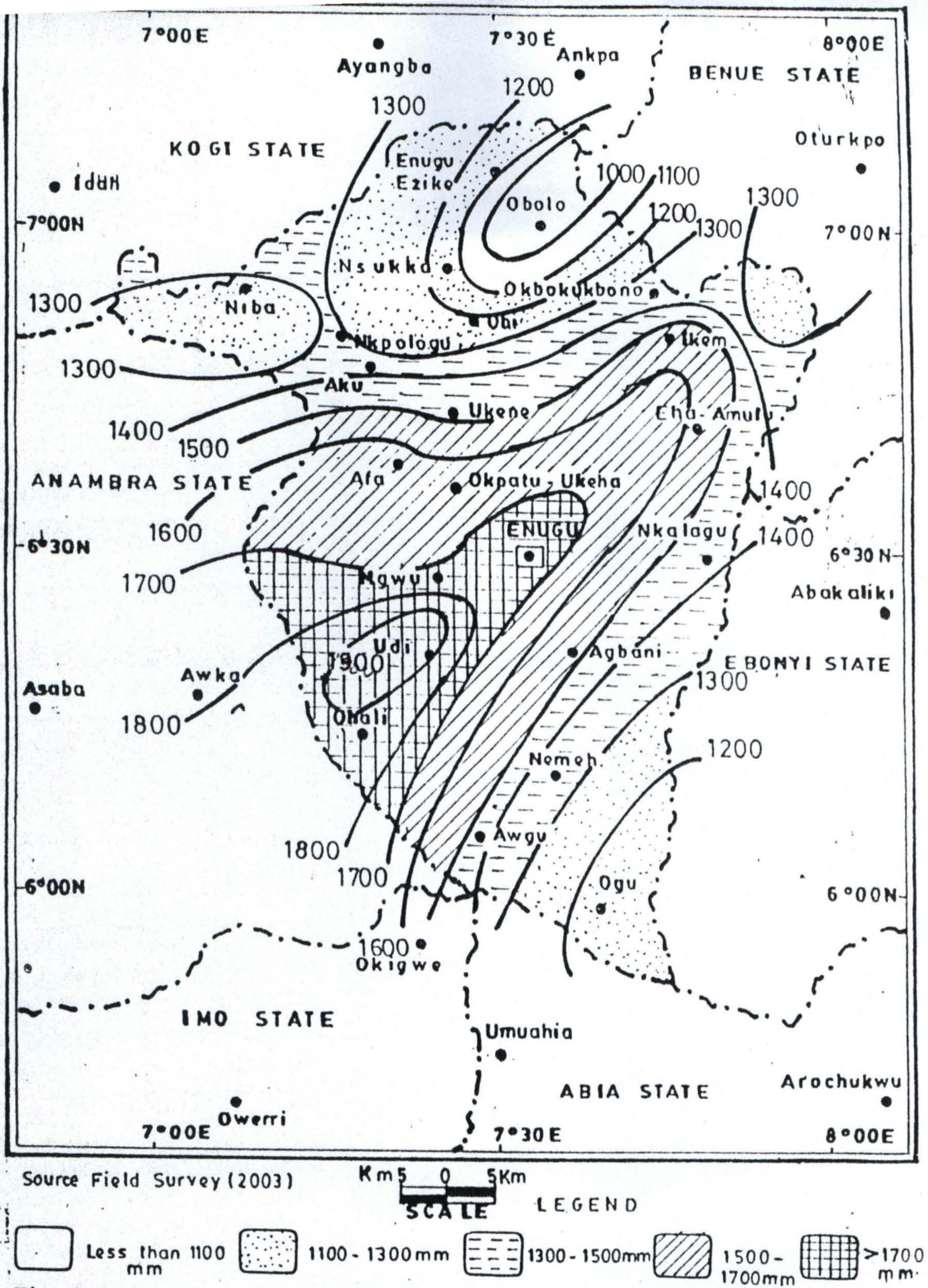


Fig. 4.5: Mean Annual Rainfall Distribution in (mm).

Benue States in the north and Ogu in the southern fringes of the state (Appendix 3).

The maximum rainfall of more than 1700mm is recorded in Enugu and Udi Local Government areas in the central parts of the state. It implies that, the total rainfall for any given year in Enugu State is usually sufficient (if not too much) for any of the annual food crops while tree crops which are native habitats can withstand the 3 – 5 months dry season between November and March in general as shown in Figure 4.5

However, the dwindling returns from agricultural production during the study shows that even with actual recorded rainfall, it still show anomalies which indicates that drought condition still affect agricultural operations with actual deficit in annual rainfall accompanied by a corresponding or proportional poor crop performance. This shows that the percentage contribution of the dry season to annual total rainfall is drastically reduced under extreme situations experience during the years in the area. This drying trend during the dry season is another significant effect of climatic variability, which tends to aggravate the water deficit during the real drought years, thus supplementary irrigation is necessary in the area.

Agricultural production in Enugu state is basically rainfed. Rainfall in most parts of the state is seasonal and variable, water availability is largely erractic as shown in Figure 4.5 and appendix 3. Therefore the assessment of the moisture factor for agriculture in Enugu state becomes paramount. The results of rainfall distribution in Enugu state shows a warm characteristics with very moist climate showing a strong rainfall peak of 1600 – 1800mm at Enugu, Agwu, Udi, Ohali in the central parts and Agwu, Nkalagu in the Southern parts of the state and reduced rainfall at Enugu Ezike, Obolo, Nsukka, Niba Ukene at the northern and southern parts around Agbani, Nemeh, Awgu and Ogu recorded between 1100- 1400 mm of rainfall. The result further revealed a small soil water shortage developing during the short dry season. The water need, that is evapotranspiration exceeds is lower in every month or the yearly total or evapotranspiration is more or both in the area with a large water supplies generated in the rainy months in Enugu state. It implies that the soil water storage is greater for the period of six to nine consecutive months. The annual cycle of soil – water need surplus is very large with soil water storage remaining for eight consecutive months (March through October). The lowest monthly values occurs in November to February which is the brief water – shortage period in the Enugu State. Therefore rainfall cannot be taken for granted in any planning for enhancement of agriculture in Enugu state and crop yield is directly related to the effectiveness of precipitation and related derived parameters of climate.

4.5 BREAKS OR DRY SPELLS DATES

Breaks during the course of the particular rainy season are injurious to plant life (Adefolalu, 1991).

Table 4.5: Breaks or Dry Spell Dates in Enugu State

(a) Earliest	(b) Normal	(c) Delayed
Before March 7	Before March 16	Before March 20
March 7 – March 21	March 16 – March 31	March 21-April 10
March 21 – April 6	April – May 4	April 11-May 10
After April 6	After May 4	After May 11

As shown in Table 4.5 and appendix 3, the breaks occurs between March 7 and May 11 in each year in the state during the growing season and could last for up to 14 – 31 days in the state with Nsukka and Enugu Ejike catchment areas in the north and Nkalagu and Eha–Amuga areas bordering the state in the east which are already victims of late onset and early cessation of the rains. This reduce the production potentials of crops as water is not available to them as soil moisture. Therefore irrigation is required to supplement the short fall during break periods for optimum plant growth and development in Enugu state.

Breaks or dry spells during the course of a normal rainy season could be injurious to plant development and consequent crop – yield (Adefolalu, 1991). Table 4.5 shows the beginning dates of breaks and length of spells respectively. The results shows that the break in Enugu state may last for more than 20 days. This is the premature or false cessation rainfall which affects the entire phenological processes of the crops. The shortened rainy season may damage plant development and consequently affects yields when onset dates of rains is delayed with premature cessation occuring simultaneously in single rainy season, thus leading to abnormally short growing periods of crops. The overall effects of this on crops at that, it tends to wilt and some times they eventually die (due to very high temperature and evaporation). As stated earlier, farmers are forced to plant twice or more. This often lead to delayed maturity, thus resulting in total or near total loss or crop failure.

The prolong break into the area implies even though the total annual rainfall amount do not change but temporal distribution means plants receive less rain at the time of maximum demand. This account for significant drop in agricultural yield in the spatial and temporal variations of precipitation patterns in the area (Adefolalu, 1988). The added advantage of this technique is that it allows for accurate estimation of the beginning and end of short breaks in Enugu state for designing dams especially in making allowance for steady flow of waters during such breaks for crops. Irrigation is therefore needed in the area to supplement the water available from rainfall which seep into the root zone as a result of breaks or dry spells.

4.6 Forecasting Irrigation Needs with Agroclimatic Variables.

On the contrasting nature of evaporative power in the area, Figures 4.6, 4.7 a-c and appendix 4 shows the values of the hydrologic ratio (λ), which is expressed as the degree of wetness or dryness in the area.Figure 4.6 illustrates the important features of evapotranspiration in relation to the precipitation in the area. The result showed that no local government area reaches the maximum crop yield potential λ=1.0. Majority of the local government areas in the state belongs to 0.4 to 0.9. It implies that potential evapotranspiration is not equal to the mean annual precipitation (p) in the state.

Figures 4.7a-c depicts the moisture budget in the three agricultural zones of Enugu state. The results defined the climate of Enugu state into a moist regions with(λ) values of 0.4 to 0.9 as shown in Figures 4.6, 4.7a-c(Appendix 3).

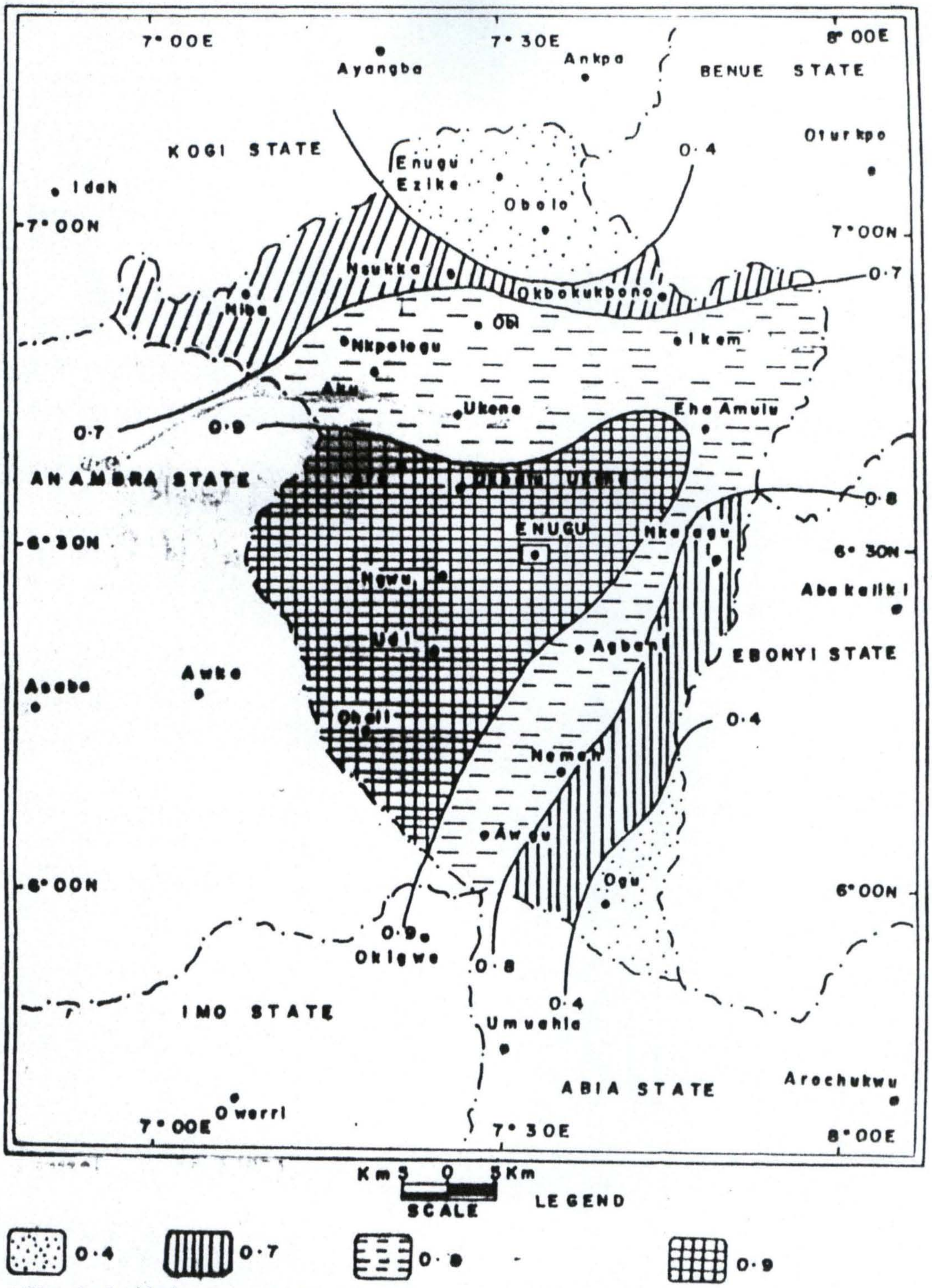


Fig. 4.6: Values of the Hydrologic Ratio (λ) the degree of Wetness or Dryness

With the surpluses shown, Enugu state does not belong to semi – arid zone. Critical areas are in the extreme northern parts of Enugu Ezike and Obolo bordering Benue and Kogi states in the north and Ogu in the extreme south east bordering Ebonyi and Abia states in the south eastern parts with lowest λ – values of 0.4 in those areas. The implication of $\lambda = 0.4$ is that the maximum soil moisture available for plant use is 40 percent of requirement before $\lambda = 1.0$ can be reached. Thus, for implied crop yield, irrigation is required to supplement the 60 percent loss below λ=0.40 In other words, to meet up crop requirements, supplementary water is required in order to meet the $\lambda = 1.0$ requirement for optimum plant growth and development in those areas.

The following interesting features are observed in Figures 4.7a – c:-

(i) the symmetry high precipitation value and low evapotranspiration orientation in the three zones.

(ii) rainfall is zonally symmetric

(iii) areas in the central and southern parts are alike

(iv) planting of crops in the central and southern zones under rainfed will do better than in the north, because the hydrologic ratio λ values are more than 0.4 except in the extreme south – east of Ogu.

(v) for favourable cropping, the extreme north of Enugu Ezike, Obolo and Ogu in the extreme south east requires irrigation.

By determining the annual moisture surplus and the annual moisture deficits from Figure 3.1 or monthly "balance sheet", an index of aridity or humidity was obtained. The result shows that there is generally a surplus in one

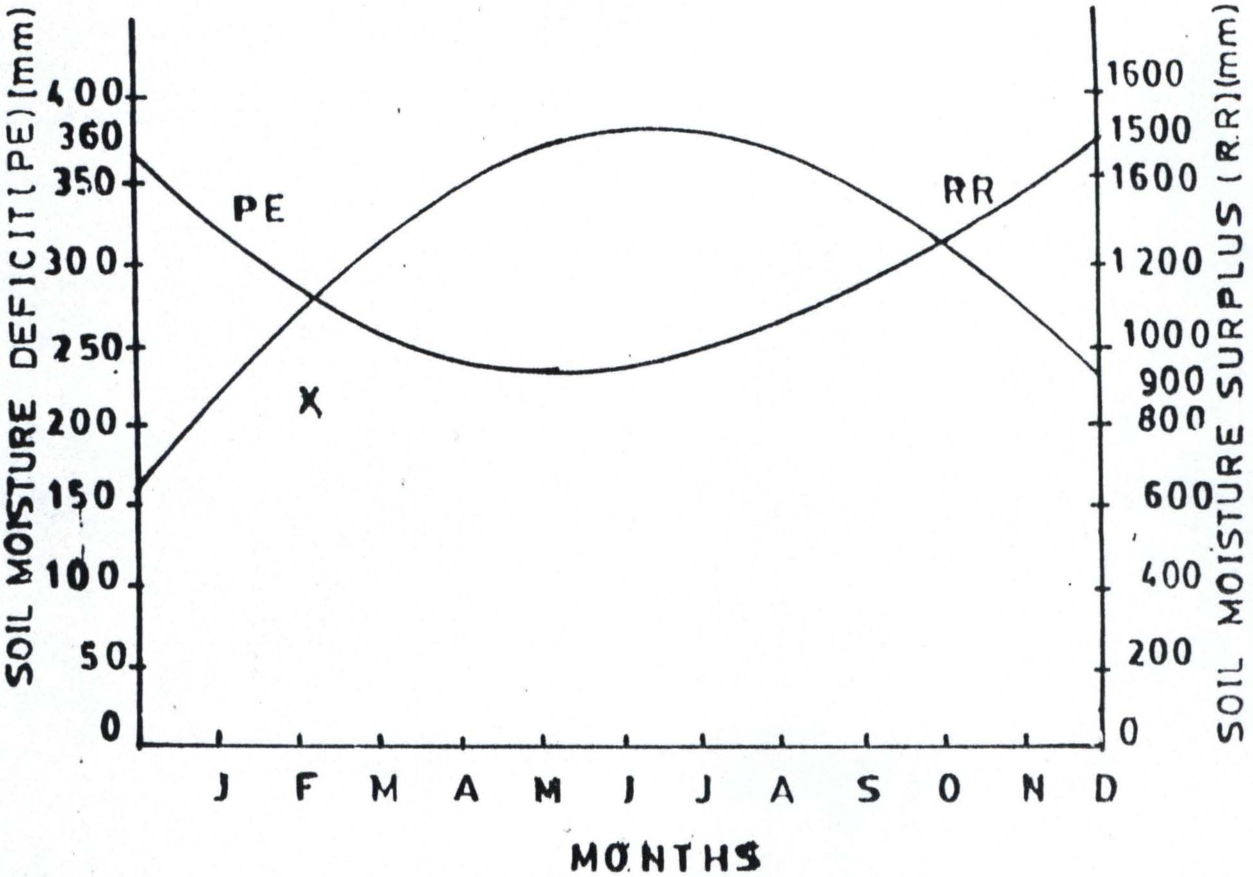


Fig. 4.7 (a) Moisture Budget in Northern Zone of Enugu State

season and a deficit in another. From the result, the deficit is given less weight as the surplus is held in the soil. The deficit therefore means that the actual evaporation rates falls below the potential value. The result also defined the climate of Enugu state into a moist regions with λ – values of 0.4 to 0.9 as shown in Figure 4.6, Figure 4.7a – c and appendix 4. The major humid areas are along central and southern parts of the state, while the extreme northern parts, northwest and the south eastern parts such a Enugu Ezike, Obolo, Niba and Agu have hudrologic ratio (λ) value of 0.4 may be defined as less humid area. These are areas bordering Benue and Kogi states in the northern fringes of Enugu state and Ebonyi state bordering the Enugu state to the east. It implies that the effective actual evapotranspiration is higher and therefore the crop yield will decrease. Thus, the fertility of soil not withstanding without water, such soil useless and plant life is nil. This is supported by the findings of Masefield (1970) and Duckham (1974) on plant response to changes of climatic conditions and hence available precipitation for optimum crop yields.

The values of hydrologic ratio (λ) computed are plotted in Fig. 4.7a – c and illustrated in Figure 4.6, Enugu state has a bioclimatic type of climate which is characterized with both tree forest and sudan savanna grasslands. This is considered to be one of the most delicately balance ecosystem in the world (Gadzama, 1990). The degree of wetness which have been defined by the hydrologic ratio (λ) shows both central and south western parts of Enugu state in Fig. 4b – c, general be classified as very humid with surplus soil moisture tendency due to lower evaporative power as indicated by low

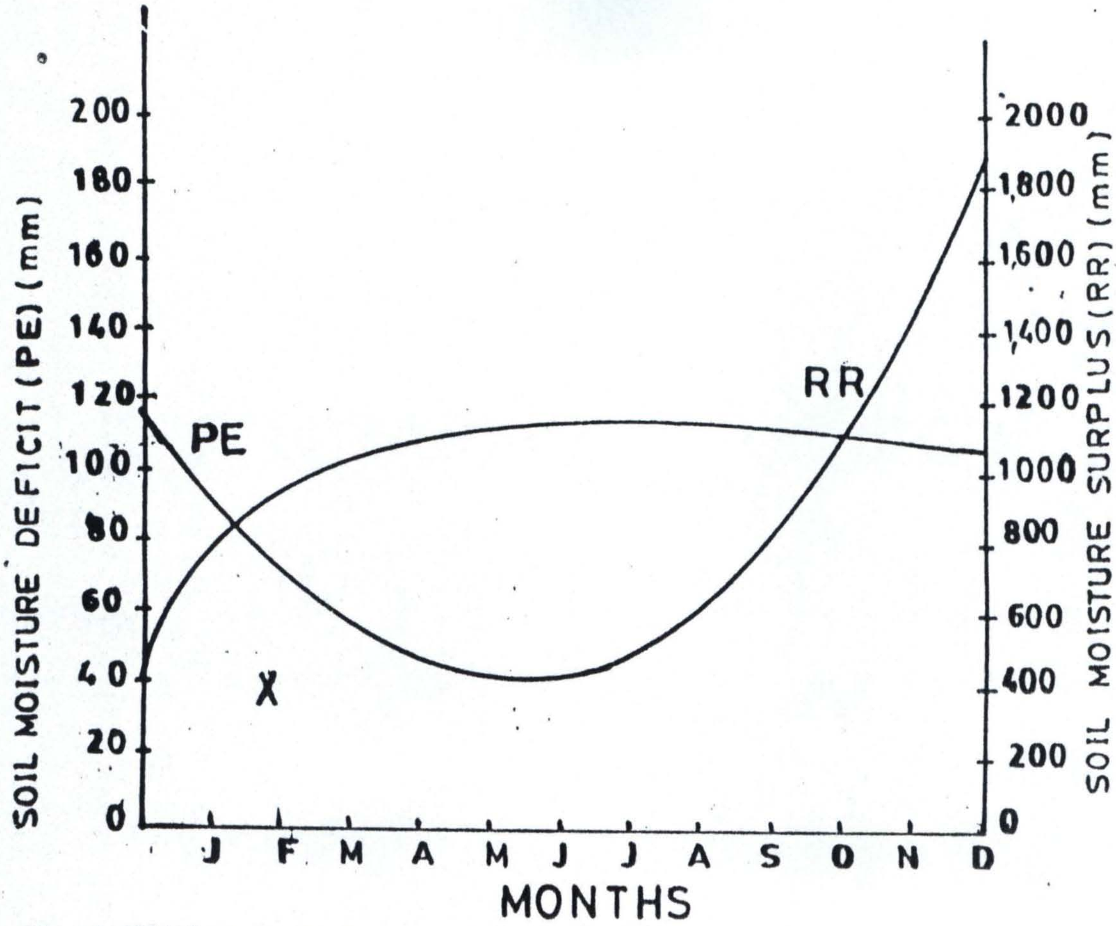


Fig.4.7(b) :Moisture Budget in Central zone of Enugu State

evapotranspiration values and high precipitation (Adefolalu, 1983) Fig 4.7(a). One the other hand depicts the degree of dryness which have also been defined by hydrologic ratio (λ) shows that both the north eastern and western parts as well as the south eastern parts of Enugu State in general be classified as relatively dry with hydrologic ratio value of the implication of $\lambda = 0.4$ is that the maximum soil moisture available for plant use is 40 percent of requirement before $\lambda = 1.0$ can be reached. Therefore, irrigation is required to supplement 60 percent loss below $\lambda = 0.4$ The situation of extreme dryness in these areas is due to both very high evaporative power and low rainfall (P<1000 – 1300mm). Here supplementary irrigation may be required during periods of high water demand by plants.

These results conformed with the FAO (1980) on agro-ecological classification which uses the concept of length of growing season with emphasizes on the period of the year when sufficient water is freely available for the crop and temperature is not limiting for plant. With the range of 0.4 average rainfall to full potential evapotrasporation makes the start of season and beginning of the presumed period in the area in which case soil moisture during the rainy season is fairly satisfactory. The hydrologic ratio value of 0.4 to 0.9 is above potential evapotransporation with satisfactory soil moisture surplus during the rainy season. Hence, normal crop germination, seedling emergence and the establishment are expected to take place with the onset dates of rains. Areas with λ - ratio value of 0.9 indicates good soil moisture surplus during rainy season as shown in Fig. 4.6.

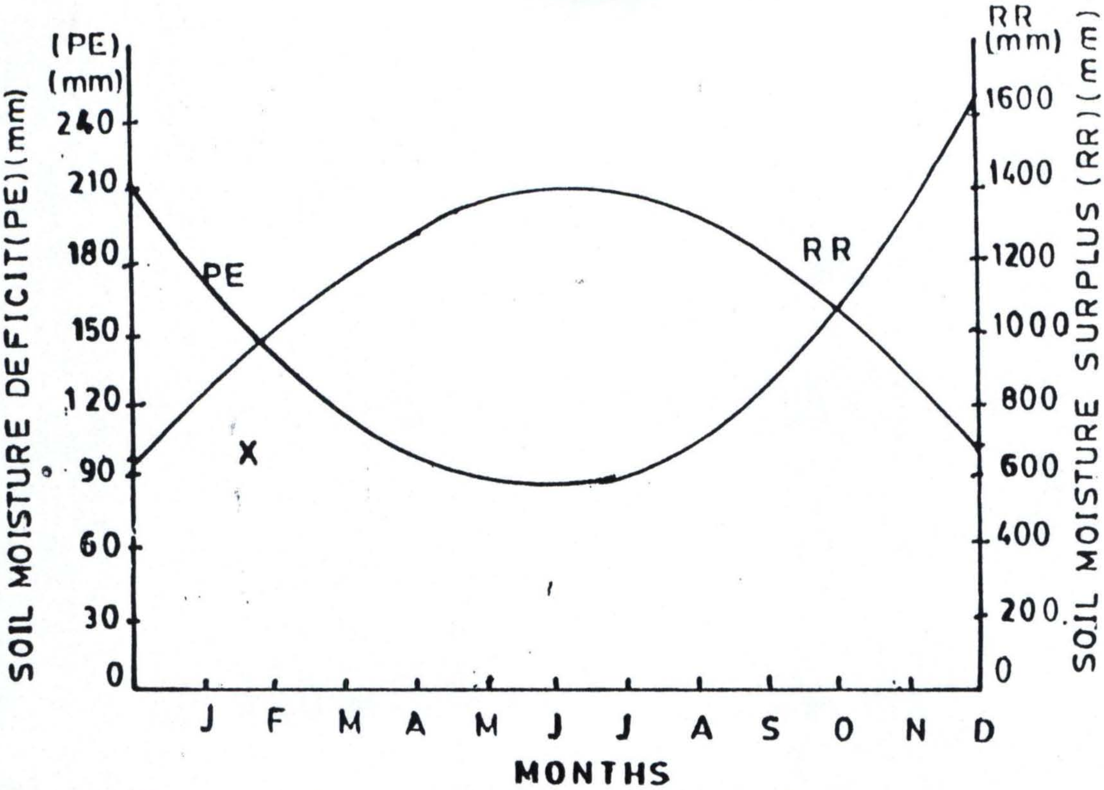


Fig.4.7(c): Moisture Budget in Southern zone of Enugu State.

However, the result showed that there is no condition whereby soil moisture content is equal to water deficit in the area. It implies that the area do experienced agricultural drought in which case supplementary irrigation is required during the periods of high water demand by plants. Thus soil moisture status is a function of precipitation and potential evapotranspiration.

4.7 Averting Drought Situation in Enugu State

Drought is the deficit that result when moisture is insufficient to meet the demand of potential evapotranspiration (Adefolalu et al. 1989). In order to avert the drought situation in the area which is a criterion for satisfying the potential evapotranspiration condition, the emipirical relation of Flohn et al (1974) and Adefolalu (1990) were adapted for the study to estimate the water equivalent to avert drought using equation 3.9 and the results are presented in Fig. 4.8 and Table 4.6 below.

Table 4.6: Total Rainfall and Number of Days in Wet Months, Total Rainfall and Number of Days in Dry Months, Specific Water Consumption and Drought Condition in Enugu State.

Agricultural zone	Total rainfall in wet season	No of days in wet season	Average daily (RR) total	Total rainfall in dry months (mm)	Average daily RR total in dry months (mm)	No of days in dry months	Specific water consumption (mm)	Drought condition
North	1819.2	133	16.0	103.1	19.31	10	+250	Serious but not severe (seasonal dry)
Central	1994.8	121	7.94	94.5	4.15	4	-360.12	Not severe (seasonal dry)
	1567.5	215	7.29	124..2	24.84	24	-340.13	Not severe (seasonal dry)
South	1587.5	214	7.42	112	22.4	22.4	-341.39	Not severe (seasonal dry)
	1998.3	115	17.37	198.9	49.7	48.7	+250	Serious but not severe

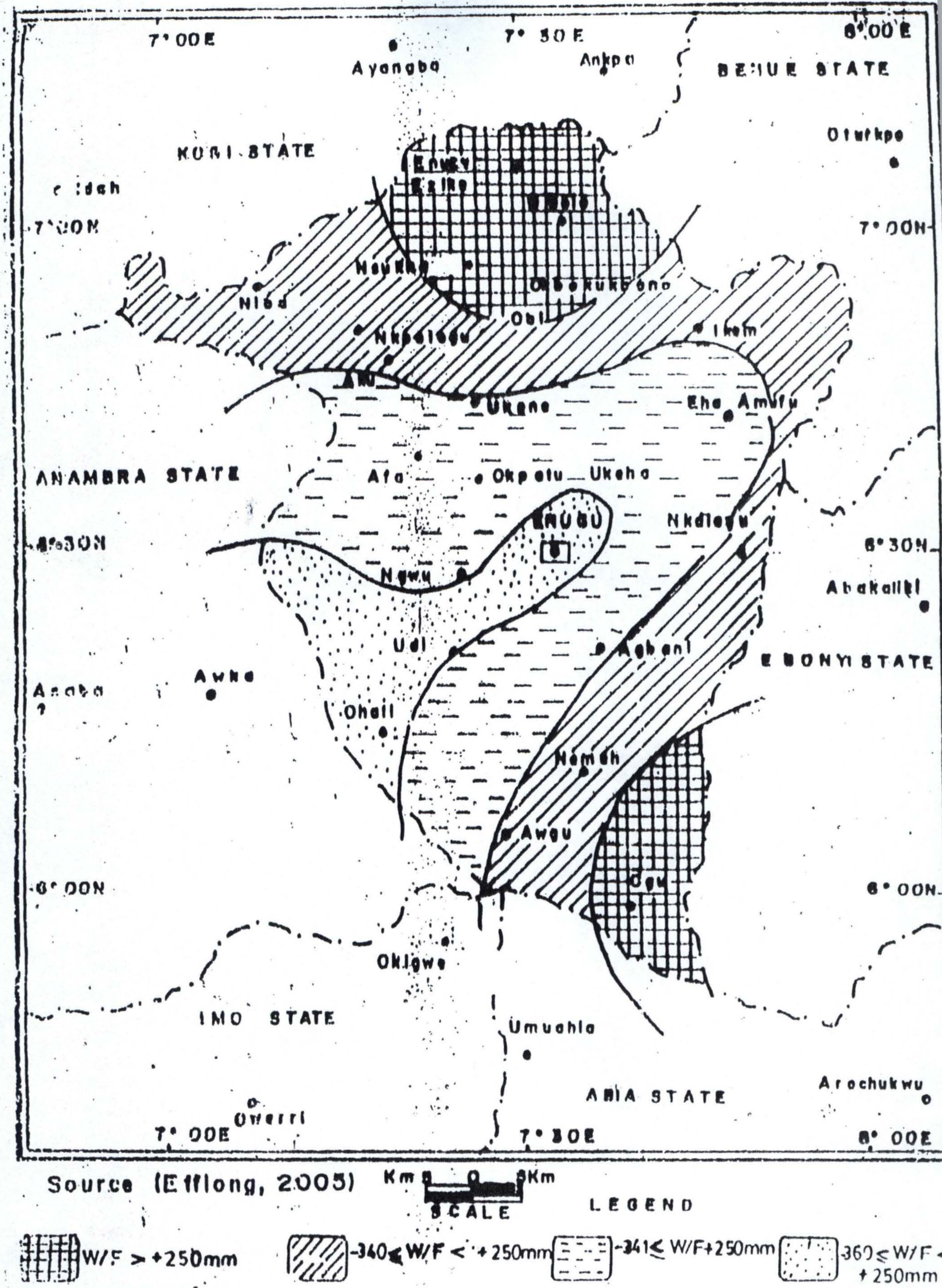


Fig- 4.8 : Water Equivalent to Avert Drought (mm)

The result shows that the specific water consumption requirement is greater than 250mm but less than 360mm. These values are less than the minimum requirement for optimum crop growth and development as shown in appendix 5. This suggest the amount of water to be pumped into a cropped field so that the hydrologic ratio values of greater than 1.0 which is the ideal hydro-neutral condition is not exceeded.

Figure 4.8 and Table 4.6 depicts the values of specific water consumption in Enugu state. The computed values in the entire state ranges from greater than 250 to less than 360mm. These values are less than the minimum requirements for optimum crop growth and development. It implies that rainfall is not equally distributed all the year round. Therefore the soil does not retain enough moisture for good plant growth and development.

The values of greater than 250mm is indicative of the rainy season water demands to supplement soil moisture or the amount of water requires to be pumped into the cropped field for optimum crop growth and development while the values of less than 340 to 360mm gives an indication of the lowest (minimum) equivalent water to be added to the annual water received rainfall. It implies that the values of greater than 250mm is the maximum to supplement it if drought conditions are to be avoided in those areas. From the results lowest values are found in Enugu, Udi, Ngwu and Ohali, with highest values of hydrologic ratio while those with the lowest hydrologic values are found in Enugu Ezike, Obolo, Nsukka and Ogu and call for maximum specific water consumption values. The values of greater than 250mm is suggestive of the extreme dryness of both soil and immediate environment above the ground. This implies high evaporation power. For control measures shelter belts and wind-breaks will serve against excessive evaporation from open surface water bodies. Therefore dam construction may be useful in these areas as water demand is greater than 250mm though the areas does not located in the highest rainfall areas in the state, although these are subject to the initial Q wet and Q dry assumed values.

CHAPTER 5

WATER USE AND AGRICULTURE IN ENUGU STATE

5.0 INTRODUCTION

Water is one of the most important element for plant life and serves as the medium for a vast array of life sustaining processes (Morgan. et al (1980). Its availability represents one of the main controls of crop growth. Water deficiencies lead, under extreme conditions, to loss of turgidity and wilting of the plants; under less extreme conditions, growth is inhibited by lack of nutrients and by reduced assimilation of energy. It is a critical factor and input that has scarce value in agricultural usage without which no growth will occur.

5.1 Major source of water to the farm

In order to determine the major source of water to the farm, a total of 1130 questionnaire were distributed to the contact farmers in the three agricultural zones of Enugu state. Out of these, 1121 were completed and returned (Appendix 1). Percentage was employed in analyzing data and the results are presented in Table 5.1 below:- The results indicates that, 666 (59.4%) depend on rainfall as a major resource for agricultural production, followed with streams with 310 (27.7%) dew, lakes and others sources contributing 9.4, 1.2 and 2.3 percent respectively (Appendix 1). Therefore, Enugu State like other areas in the tropics, agricultural production is basically rainfed Bello, (1999). This accounts for the low performance in agricultural production in Enugu state. The study showed that people's opinion support irrigation development in Enugu state and will fight against drought that poses threats to agricultural activities.

Table 5.1 Distribution of Respondents According to the Source of Water to the Farm.

Source of water	Agricultural zone				
	South	Central	North	Total	%
Rainfall	226	225	215	666	59.4
Dew	48	34	23	105	9.4
Streams	105	95	110	310	27.7
Lakes	3	6	5	14	1.2
Others (specify)	3	10	13	26	2.3
Total	385	370	366	1121	100

Source: (Field survey, 2003)

5.2 Climate Change and Agricultural Production

The implications of climate change on agricultural production has been documented by several authors including Hogg (1964), Agu (1988), Badejo et al (1998), Adefolalu (1983), Ojo (1988) and Jackson (1977). As a means of shedding more light on the crops that are mostly threatened by the variations in climate, gross tabulations were made between various crops grown in Enugu State and the chi-square distribution analysis was employed in analyzing those crops that are threatened by variations in climate change and the results are presented in Fig 5.1.

The result shows that cereals and vegetables/fruits were mostly affected while roots, legumes and tree crops were less affected with variations in climate (Appendix6). It implies that cereals and vegetables/fruits have shorter growing periods which coincides with the length of the rainy seasons in the area.

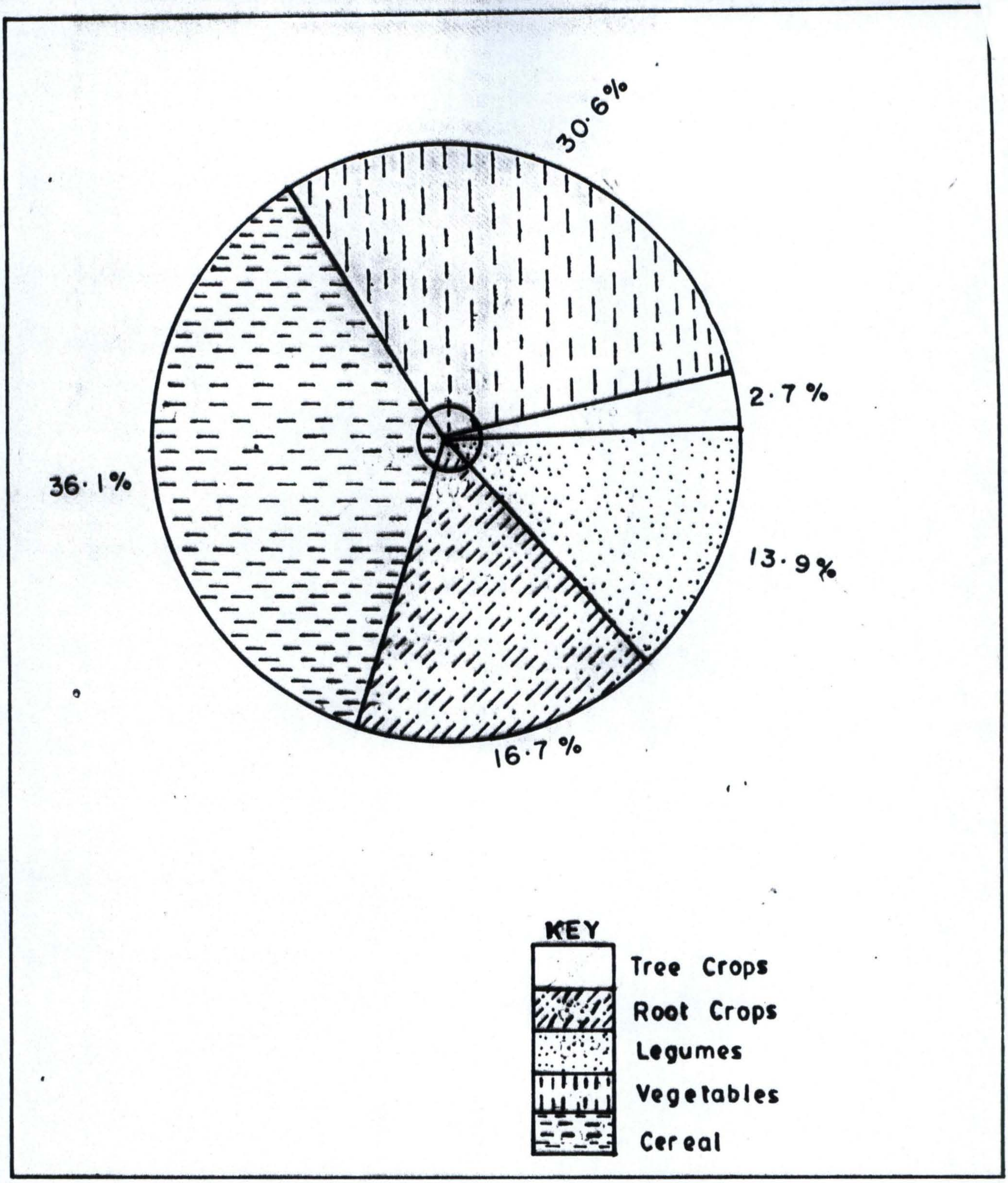


Fig.5·1: Pie chart showing frequency distribution of crops that are threatened by climate change in the study Area.

The validation test conducted to test their association between the zones and crops that are mostly threatened by the climate change gave a chi-square value of 14.305. The result indicates that there is no association between agricultural zones and crop being threatened by variations in climate.

5.3 Environmental Degradation and Its Impact on Agricultural Production

Environmental degradation have been identified as the main constraint to crop production in Enugu State (Ministry of Agricultural and Rural Development, (1999). In particular Flooding, soil erosion, drought, pollution, desertification and strong winds are significant and reduce the production potentials of crops grown in Enugu State thereby reducing the income of the farmers and others whose occupations depend upon farming (Ojo 1988). Percentage was employed in analyzing the data and the results are presented in Table 5.2 below.

Table 5.2 Distribution of the Respondents According to the Damage on Crop Due to Environmental Degradation.

Environmental degradation	Agricultural zone				
	South	North	Central	Total	%
Soil Erosion	90	65	95	250	22.3
Flood	83	78	87	248	22.1
Drought	158	194	146	496	44.2
Strong winds	48	25	26	99	8.7
Others	10	8	12	30	2.7
Total	385	370	366	1121	100

Source: (Field survey, 2003)

Table 5.2 indicates that when respondents were asked to rank the damage on crop due to soil erosion, flood, drought, strong winds and others, 496 (44.3%) attributes the damage to drought, while 250 (22.23%), 248 (22.1%) 99 (8.8%) and 30 (2.5%) of the respondents attributes the damage to soil erosion, flooding, strong winds and other factors in the area. The result showed that loss of crops due to drought account for the significant drop in agricultural yield in Enugu state. The drought may be related to the shortened rainy season which may damage plant development and consequently affect yield when onset of rains is delayed or there is premature cessation occuring simultaneously in a single rainy season, thus leading to abnormally short length of rainy season, therefore irrigation is required to improve crop yield in the area.

The erosion of crop land by runoff water is severe and accounted for 22.3 percent. This shows that 22.3 percent of Enugu state crop land is suffering soil losses at a rate too high to sustain current levels of productivity. These problems will intensify as demand for food increases. This could be prevented if the arable land were allowed to revert to forest or grasslands (fallow) to regain its fertility.

Floods accounted for 22.1 percent to the damage due to crop in all the three agricultural zones. Floods are the most damaging of our nation's natural hazards (Moran, 1980). Flood occurs whenever runoff exceeds the discharge capacity of a river channel, causing water to flow over river banks and spread out over the flood plains beyond and erodes valuable topsoil. Floods can only be prevented or reduce to its barest minimum if its cause can be understand.

Flood control efforts therefore should consist of exclusively of a variety of engineering projects aimed at excluding flood water from farmland so that valuable topsoil cannot be eroded away.

Strong winds and other factors of environmental degradation accounted for 8.8 and 2.5 percent to the damage due to crop. This shows that the annual losses from crop destruction by strong winds is 8.8 percent while the remaining 2.2. percent were accounted for by other environmental hazards to crop production. The only way to increase the crop yield is to take advantage of the kind of data input in this study as a better and more appropriate approach to the solution of environmental hazards with respect to crop production in Enugu state.

5.4 Water Use and Field Application Efficiency

Water is the essential input to crop production. The main objectives of irrigation is to provide plants with sufficient water to prevent stress that may cause reduced yield or poor quality of harvest (Haise and Hagan, 1867; Taylor, 1965). The required timing and amount of applied water is governed by prevailing climatic conditions, crop and stage of growth, soil moisture holding capacity and the extent of root development as determined by type of crop, stage of growth and soil. In order to determine when to irrigate the fields so as to avoid reduction in crop yield or quality, percentage was used in analyzing the data and the results are presented in Table 5.3 below:-

Table 5.3 Distribution of the Respondents on the frequency of water application to the field.

Frequency of water application	Agricultural zone				
	South	Central	North	Total	%
When water is available	45	61	56	162	14.5
On day light	34	37	25	96	8.6
Once a week	65	46	43	154	13.7
Fortnightly	165	154	171	490	43.7
Crops needs	76	68	75	219	19.5
Total	385	366	370	1121	100

Source: (Field survey, 2003)

Table 5.3 depicts the distribution of respondents when asked to rank on when to irrigate the field for increase crop yield. From the results, 490 (43.7%) of 1121 respondents indicates that, water to crops should be done forthnightly. Table 5.3 further revealed that 219 (19.5%), 162 (14.5%), 154 (13.7%) and 96 (8.6%) of 1121 respondents agreed that water supplement to crop should be carried out on crop needs, when water is available, once a week and on day light respectively.

From the results, people's opinion on water supplement in the field, is in fact, corroborative of the observations by (Stern, 1979). He observed that as plants cannot readily use more than half the available moisture in the soil, irrigation is needed when this half is used up. The amount of water to be applied to a particular crop in one irrigation is therefore half the available moisture in the root zone of the crop when the soil is at field capacity.

5.5 Water Lifting Devices for Irrigation

While the earliest irrigation schemes in history probably depended only on the gravity flow of water, it was not long before man became aware of the need to lift water for irrigation and many devices were developed for this purpose in different parts of the world using man or animal power (Stern, 1979).

In order to determine the type of devices used in lifting water for small – scale irrigation in Enugu State, percentage was employed in analyzing data and the results are presented in Table 5.4 below:

Table 5.4 Distribution of Respondents According to Water Lifting Devices.

Water lifting Devices	Agricultural zone				
	South	Central	North	Total	%
Watering can	55	41	44	140	12.5
Small irrigation pump	175	181	186	542	48.3
Tube well	84	74	69	227	20.2
Animal powered system	18	16	20	54	4.8
Water power	15	14	16	45	4.1
Wind power	38	40	35	113	10.1
Total	385	366	370	1121	100

Source: (Field survey, 2003)

Table 5.4 depicts the percentages of the respondents when asked to rank on the devices used in lifting water for small – scale irrigation in Enugu state. The results showed that 542 (48.3%) of 1121 respondents supported the use of small irrigation pump, while 227 (20.2%), 140 (12.5%), 113 (10.1%), 54 (4.8%) and 45 (4.1%) of 1121respectively of the respondents supported the use of tube well, watering can, wind power, animal powered system and water power respectively as a means for lifting water to the farm.

The small irrigation pumps are mechanically – powered pumps most widely used primarily for community water supply and is the answer to: the problem of lifting water in Enugu state as it account for 48.3 percent of the respondents supported its use. Tube well was rated second after small irrigation pumps. The capacity of a well or borehole for supplying irrigations water is usually not very great. Shallow wells are feasible sources than small-scale operations and tend to be too costly.

However, water power was ranked lowest with 4.1 percent. This device is used where there is a fairly constant flow in a river or large canal. The results confirms non-availability of large canal in Enugu state. Watering can is the water container, which is filled and carried to the plants to be irrigated. It is the traditional water lifting devices such as shadoof and calabash. Animal powered systems comprise a water wheel or a chain of buckets, operated by an animal harnessed to a beam which rotates in a horizontal circle to provide the motive power. The wind power device is expensive for the small – scale farmers and tend to suffer from the usual problems of mechanical equipment which is dependent upon imported materials and components; thus difficult for the farmers to operate and maintain.

5.6 Farm Size Holding and Irrigation Potential

The study area is a predominantly agricultural state with its economy relying heavily on crop production (Agu, 1988). In order to examine the irrigation potential and the farm size holdings, percentage was employed in analyzing and determining the actual hectare cultivated by individual farmers and the results are presented in Table 5.5 below:

Table 5.5 Distributions of the Respondents According to the Farm Size Holdings.

Farm size	Agricultural zone				
	South	Central	North	Total	%
Less than 1 ha.	117	143	151	411	36.7
1 – 1.99ha	90	98	82	270	24.1
2 – 2.99 ha	6	53	61	178	15.9
3 – 3.99 ha	45	33	30	108	9.6
4 – 4.99ha	41	24	25	90	8.0
5+ha	28	15	21	64	5.7
Total	385	366	370	1121	100

Source: (Field survey, 2003)

Table 5.5 depicts the farm size holdings in relation to the irrigation potentials in Enugu state. Out of 1121 contact farmers interviews, (60.8%) owned farmlands which are less than one hectare to 1.99 hectares in the area. This was followed with those having farmland between 2-4.99 hectares and accounted for 376 (33.5%). However, out of 1121 contact farmers interviewed in all the surveyed zones about 64 (5.7%) owned more than 5 hectares of farmland. This further confirms the smallness of land holdings and limit at which this study is based as small scale irrigation development in Enugu state.

The general conclusion to be drawn is that owing to the difficulty of acquiring large expand of land, and the need to involve private entrepreneurs in irrigation development, this work is embarking on small scale irrigation scheme to bridge the gap in disputing boundaries and frontiers associated with the traditional land tenure systems which is the bottleneck for increased agricultural production in Enugu State.

5.7 Water Resources Utilization and Irrigation Development in Enugu State

Scientific management of water provides the best insurance against weather– induced fluctuation in total food production. This is the only way in which we can make our agriculture competitive and profitable (Michael, 1978). An integrated policy for water resources management, in addition to efficient utilization of the resources for optimum crop production, should meet the requirements of the growing industry, human and livestock consumption and provide for flood control, hydro-electric power generation, recreation and navigation.

Some of the fundamental problems of irrigation development relate to the non availability of the facilities to the farmers in the area. In order to determine the problems encounter by the farmers in securing irrigation facilities, percentage was used in analyzing the data and the results are presented in Table 5.6 below:

5.6 Distribution of the Respondents According to the Problem Encounter in Securing Irrigation Facilities

	Problem encounter			
Agricultural zone	No +	%	No⁻	%
South	307	80.2	76	19.8
Central	320	86.7	49	13.3
North	344	93.2	25	6.8
Total	971		150	

Source: (Field survey, 2003)

Table 5.6 depicts the distribution of the respondents in relation to the problems in securing irrigation facilities in Enugu State. The result shows that the problems differ from one agricultural zone to another. Out of 1121 contact farmers interviewed, 307 (80.2%), 320 (86.7%), and 344(92.2%) indicated that the problems encountered in securing the facilities were due to its non availability at their disposed, while 76(19.8%), 49(13.1%) and 25 (6.8%) respectively disagreed in the entire Enugu State.

With the highest percentages encountered in securing irrigation facilities, it showed that there is still much to be done in the area. Presently, the relative lack of financial assistance to meet with the high cost of these facilities continues to perpetuate the absence of a built in mechanism for mutual growth stimulation between the food production and the teeming population. There is need therefore to emphasize financial assistance to the farmers to meet up with the high cost of these equipment in order to enhance agricultural production in Enugu State.

5.8 Agricultural Credit and Food Production

Agricultural credit facilities have been identified as one of the major constraints to increased food production in Enugu state (Ministry of Agriculture and Rural Development, (1999). This is due to the fact that the overwhelming proportion of food crop production in Enugu State is in the hands of peasant farmers operating within the framework of traditional system of agriculture without access to loan facilities. In order to increase food production, the contact farmers were asked to suggest on the assistance required to increase their agricultural activities. Percentage was employed in analyzing data and the results are presented in Table 5.7.

Table 5.7 Distribution of the Respondents According to Assistance needed by the farmers

Assistance needed	Agricultural zone				
	South	North	Central	Total	%
Less than ₦500,000.00	118	130	141	389	34.7
₦500 – ₦1 Million	120	111	108	339	30.3
₦1 Million – ₦5, million	80	85	65	230	20.5
Over ₦ 5million	67	44	52	163	14.5
Total	385	370	366	1121	100

Source: (Field survey, 2003)

Table 5.7 shows the distribution of the respondents in relation to loan facilities in Enugu state. Analysis of the assistance as suggested by the contact farmers reflected in lower output in the state. Table 5.7 reveals that 389 (34.7%) out of 1121 respondents suggested less than ₦500,000.00. This was closely followed with 339 respondents representing 30.3 percents, ₦500,000 to 1mmillion, while 230 (20.5%) and 163 (14.5%) suggested the amount ranging between 1₦million to ₦5million and above in the entire Enugu state. The lower values of 14.5% and 20.5% confirms the fact that the contact farmers were peasants in the traditional agriculture without exchange economy that requires large sum of money for agricultural development.

In other words, the concept of surplus farm labour and large expanse of land are not emphasized as these could be withdrawn from subsistence farming without reducing the volume of farm output, that is, the marginal productivity of labour as well as acquisition of large expanse of land are believed to be zero (or even negative in Enugu state (Abumere, 1978).

5.9 Climate Change and Strategies for Sustainable Agricultural Development

Evidence of climate change based on parameters like rainfall seasonality and replicability is the most important factor in tropical agriculture (Agu, 1998), (Ojo, 1998), Bello (1987), Adefolalu (1983) and (Adebayo, 1997). The change is a symbolic decline in agricultural production thereby pushing the famine levels even higher than the already crises proportions particularly in the sub-Saharan Africa. In recognition of the consequences of climate change in relation to the crop production various strategies and plan logistic were suggested by the contact farmers on how to overcome the problem that would enable them benefit from its positive effects. Percentage was used in analyzing data and the results are presented in Table 5.8 below:

Table 5.8: Distribution of the Respondents According to the Strategies Adapting to the Effect of Climate Change to Achieve Self – Sufficiency.

Strategies	Agricultural zone				
	South	North	Central	Total	%
Dam construction	82	93	86	261	23.3
Food preservation and conservation	76	81	65	222	19.8
Early warning and Environmental monitoring	41	28	35	104	9.3
Development and control of water Resources	72	79	75	226	20.2
Protection of arable soil	65	58	62	185	16.5
Access to information technology	46	23	38	107	9.5
Other specify	3	8	5	16	1.4
Total	385	370	366	1121	100

Source: (Field survey, 2003)

Table 5.8 depicts the distribution of the respondents on the strategies adapting for sustainable agricultural development in Enugu state. Out of 1121 contact farmers interviews, 261(23.3%) suggested the construction of dam to conserve water for agricultural production. This was closely followed with the development and control of water resources with a total of 226(20.2%), while 222 (19.8%), 182(16.5%), 107(9.5%), 104(9.3%) and 16(1.4%) suggested food preservations and conservation, protection of available soil, access to information technology, early warning and environmental monitoring and others remedies respectively as the strategies to be adapted to the effect of climate change to achieve self – sufficiency in food production in Enugu State.

The result is in fact, corroborative of the observations by Bryson (1973), Hocking and Thompson (1979), Newell and Kidson (1984). The development and control of water resources confirms the present government initiatives in Fadama all year round agriculture. The preservation and conservation of food is the confirmation of the ancient biblical strategy of storing grain in the good years to provide food for the lean. By protecting arable soil, its fertility in relation to crop production will be increased thereby pushing famine already experience in Enugu State. Access to information and technology will lead to better decision – making regarding how best to respond to potential climates change, while the environmental monitoring will be useful in predicting climate change for sustainable development.

CHAPTER SIX
SUMMARY, CONCLUSION AND RECOMMENDATION

This study was designed to give a micro level information on the climate-related problems of agriculture that have been hitherto neglected in Enugu state and trying to solve vis-à-vis the application of agroclimatology to small scale irrigation. In the agricultural sector the basic aspects of applied research have been neglected over the years resulting to low crop yields, not due to poor agricultural practices by the farmers but exacerbation of its logistic problems by climatic aberrations of which drought is the most serious; resulting in low-yield of crops. The assessment was therefore centered critically on the precipitation effectiveness as the available resource to crop. The derivable data obtained were used as a suitable mean for conserving available water resources in irrigation support system for agriculture through proper management and utilization to meet up with increasing food demand for the teaming population.

The study adopted both observed and derived parameters of precipitation effectiveness such as the onset and cessation dates of rains, length of the rainy season (LRS), breaks during the course of rainy season, hydrologic ratio, water equivalent technique, , chi-square distribution analysis and other statistical tools in modeling soil moisture requirements for optimum crop growth and development. In other words, the nerve center of this research was to design a model using derivable data as a suitable means to establish the water balance sheet and the best irrigation practice to be adopted in the area for implied crop yield through proper management of water resources in Enugu State.

In the study of the onset dates of rains in the area it was found out that the earliest dates of rains varies within Enugu state. For instance, it was found out that the earliest dates extend between 1-11 days in the south west, central as well as in the extreme eastern south parts of Enugu state, while it may extend between march 31 to April 10 in the north, east and south east. The normal dates of rains extend between 11-22 days, while the delayed dates of rains extend between 1-16 days in the same sectors of the Enugu state at the extreme north east, central and extreme south west, the delayed date of rain extend 1-8 in the area. The onset dates scenario is therefore characterized with false and delayed rainfall in terms of timing, intensity and duration leading to crop failure, thus multiple sowing with the corresponding increased in overhead cost as more man-days and resources are spent in a single growing season, hence the need for irrigation. However, the shorter length of 1 – 8 days implies available water shortage capacity of soils capable to sustain crop growth and development as the entire life span of crops hinges remarkably on the amount of moisture available in the ground before sowing is done (Olaniran, 1987).

The distribution pattern of cessation dates of rains also follows the same pattern as the onset dates with the termination dates of 1-11 days in the central and maximum range of 1-8 days recorded in other part of the Enugu state. However, the rains may delayed in the central zone till November 22 and may extend to 1 -12 days in the north west, south west, central the south west, while in the north east, extreme east to south east it may extend to maximum 1-15 days in the Enugu State. It implies sharp termination of rains in both the north eastern, east and southern parts of the state as the growing crops may not reach maturity resulting to low yield, therefore supplementary irrigation is necessary to enhance crop production.

The breaks and the length of the dry spells was also analyzed. It was found out that this could lasts till after April 10 to May 6 in the state and could last for up to 13-40 days in the entire state. It implies that Enugu state experienced late onset and early cessations of the rains in which case irrigation is therefore needed in the area to supplement the water available from rainfall which seep into the root zone.

The length of the rainy season was also investigated. The results shows that the southern parts of the state have the range of 210-230 days while the northern zones have the range of 190-210 days with its catchment areas having overall pattern similar to those on the onset and cessation dates. The low and high lengths also showed similar pattern to those of the earliest and delayed onset as well as those of premature and delayed cessation dates of rains. The comparative analysis of the length of the rainy season and growing periods of major food crops also shows that the length of the normal rainy season satisfies the consumptive use of water by these crops with drought threat to crop production greater in the eastern and northern fringes of the state.

However, while it may be possible for certain early maturing crop varieties to be cultivated twice in the central and south western parts of the state, this is not so in the north and south eastern fringes of Enugu State. There is every indication that irrigation development is necessary in every part of

Enugu state in order to increase agricultural productivity. However, irrigation need is higher in northern parts and extreme south eastern fringes than other areas of Enugu state (Figures 4.6 and 4.8). Generally, irrigation development could make possible, all year round crop production in the south west and central sectors, while in the extreme south east and northern parts, droughts threats can be minimized.

The hydrologic ratio (λ) value ranges between 0.4 to 0.9 in the area. This indicates that no local government area reaches the maximum crop-yield potential of λ = 1.0. In other words, the soil moisture content is not equal to water deficit for optimum crop growth and development. The 0.4 value indicates the maximum possible soil moisture available for plant use which is 40 percent of the requirements before hydrologic ratio (λ) = 1.0 can be reached. Therefore, irrigation is required to supplement 60 percent loss below λ = 0.4.

In order to avert the drought situation in Enugu State, specific water consumption was tested, the result gave the values range of greater than 250mm but less than 360mm. This show that crops can be grown without irrigation but low yields are common and the risk of crop failure is fairly high. Irrigation is therefore needed for short periods during the growing season.

The results of the questionnaire on the agricultural production and the use of irrigation technique by the farmers showed that people's opinion support irrigation development as a means of averting drought which has posed threats to agricultural activities in Enugu State. The results further reveals that cereals and vegetables/fruits were mostly affected by the variations in climate, therefore, water supplement to crops should be done forthnightly using small irrigation pump in the area. It implied that climate change has significant effect on the agricultural production, therefore water supplement is required for implied crop yield and soil conservation.

On the crop of socio-economic value threatened by variations in climate, the results showed that cereals and vegetables/fruits were mostly affected than other crops in the area. A validation test conducted to test the association between the zones and crops that are threatened by the climate change gave a chi-square value of 14.305. The result indicates that there is no association between agricultural zone and crop being threatened by climate change.

The farm size holdings ranges from less than 1 hectare to more than 5 hectares with majority of the farmers cultivated less than 1 hactare to 1.99 hactare representing 60.8 percent. This serves as a limit for the study. Hence the need for private entrepreneurs to embark upon small scale irrigation development schemes to bridge the gap in disputing boundaries and frontiers associated with the traditional land tenure system which is the bottleneck and assistance is required to increase agricultural production in Enugu State.

Conclusion:

Results for the Enugu State case study conclude; the presentation with specific recommendations on certain aspects which if properly applied may assist in the various amelioration programme in the drought-prone states. The most important of such programmes concern dam construction for irrigation and domestic water supply as a better and more appropriate approach than other strategies for adapting to the effect of climate change a sure short term solution but with long-term permanent problems (Adefolalu, 1982a; Barrow, 1983).

However, different areas have different climatic conditions and so it will be pertinent to extend this kind of work to other climatic environments in order to verify the results obtained. This will offer a suitable base for formulating a good model for irrigation planning in the areas.

Recommendations

This research is tailored towards providing a framework into the critical analysis of the role of impact of climate change that make irrigation the best options in the area with particular emphasis on precipitation effectiveness as the main source of available water for implied crop yield and soil conservation. The impact can be reduced or mitigated briefly through the constructions of dams to store water and check the flow of a river. This will help to regulate and augment the surface flow for flood control, irrigation and conservation of natural resources and preservation of ecological system with implied better crop yields. The wall of the dams has to be both higher and more stable than their ridges in order to store water for a longtime.

To ensure the success of irrigation provided by the mini dams there should be proper selection of crops not only to increase yield but also to keep the soil loose for infiltration. It will also ensures that pests which are active and prevalent in the dry season is almost absent during the rains as rains impacts flush them away.

The farmers should be encouraged to build barrages and dykes across river channels and can even divert the stream flooding. The can build ridges and mounds on which to plant their crops, while the soil erosion can be checked by building bunds and other structures across the hill slops. In the construction work as in all the planning stage, community participation is paramount. They should be convinced of the advantage they would enjoy from such participation since small streams flow through farmlands which are owned by families and group of families. They should be vigorously mobilized to construct and manage micro-dams for their benefits and that of their communities.

Soil water should be conserved by modified tillage and crop management techniques, level terracing, physical means of retaining precipitation on the land and reducing evaporative loses from the soil surface.

Adequate infrastructure like good road should be put in place to ease in evacuation of the farm products to urban centers. The cost of product should be drastically reduced and their market expanded.

Food conservation and preservation should also be put in place in order to avert hunger before the first harvest of crop the following year. That is maintaining food reserves and adopting disaster response strategies. We should seriously consider the ancient biblical strategy of storing grain in the good years to provide food for the lean.

Proper water management that involves the development and control of water resources so as to reduce the occurrences, magnitude and impacts of hazards if occur like flooding and erosion should be keenly monitored for any eventuality and appropriate warning issued. A fore-knowledge of the rainfall pattern for a given year would be of great benefit to farmers and other agriculturists.

Other strategies for the consequences of climate change in the area should includes protection of arable soil, applying agrotechnology, improved land use policies, access to information and technology which can lead to better decision making regarding how best to respond to potential climate change. Examples of such strategies include the use of environmental monitoring and warning systems, the collection and use of improved data, public information and education and the transfer of technology (Ojo, 1988).

For effectiveness of all these measures, all measures must be put in place before rather than after the adverse consequences (UNDP, 1993; IDNDR, 1994). The impact of climate change on agricultural production would no doubt be significant in Enugu State. It indicate that it is necessary to plan and take reasonable steps to avoid further risks of catastrophic consequences which could result from the changes that would occur in the area.

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APPENDIX 1

QUESTIONNAIRE ON THE AGRICULTURAL PRODUCTION AND THE USE OF IRRIGATION TECHNIQUE BY THE CONTACT FARMERS.

INTRODUCTION:

Please provide appropriate answers to questions. Your candid answers will assist the researcher in evolving ways of assisting farmers to improve productivity.

GENERAL INFORMATION

(1) State LGA

(2) Types of farming

(3) Major source of water to the farm:

(a) Rainfall ☐

(b) Dew ☐

(c) Streams ☐

(d) Lakes ☐

(e) Others specify ☐

(4) Have you suffered loss of your farm crops? Main crops (Roots, cereals, vegetables/fruits, legumes).

(i) Yes ☐ (ii) No ☐

(5) If yes state the crops that are mostly affected?

(6) Damage to crop due to:

(a) Erosion ☐ (b) Flood ☐

(c) Drought ☐ (d) Strong winds ☐

(e) Others specify ☐

(7) Do you hope to supplement your crops with available water?

(a) Yes ☐ (b) No ☐

(8) If yes, how often?

(a) When it is available ☐

(a) On day light ☐

(c) Once a week ☐

(d) Fortnightly ☐

(e) Crops needs ☐

(9) Devices for lifting water for irrigation:

(a) Through watering can ☐

(b) Provision of small irrigation pumps to lift water ☐

(c) Tube well ☐

(d) Animal – powered systems ☐

(e) Water power ☐

(f) Wind power ☐

(10) Farm size holdings and irrigation potential

(a) Less than 1 ha. ☐

(b) 1-1.99 ha ☐

(c) 2-2.99 ha ☐

(d) 3-3.99 ha ☐

(e) 4-4.99 ha ☐

(f) 5^{+} ☐

(11) Do you encounter any problem in securing the irrigation facilities in your area?

(a) Yes ☐

(b) No ☐

(12) If yes, how much assistance will you require?

(a) Less than N500,00 ☐

(b) N500,00 to N1 million ☐

(c) N1million to N5 million ☐

(d) Over N5 million specify ☐

(13) Major source of financial assistance

(a) Local Government ☐

(b) Community ☐

(c) ENSADP ☐

(d) Cooperative society ☐

(e) Other specify ☐

(14) In your opinion, suggest ways or strategies of adapting to the effect of climate change to achieve self – sufficiency.

- (a) Construction of dams to store water ☐
- (b) Food conservation and preservation ☐
- (c) By early warning and environmental monitoring ☐
- (d) Development and control of water resources ☐
- (e) Protection of arable soil ☐
- (f) Access to information technology ☐
- (h) Others specify ☐

APPENDIX 2

Year	Crop yield	Annual	XY	X^2	Y^2
1991	14.614	1994.8	29152.0072	213.568998	3979227.04
1992	16.336	1699.5	27763.032	266.864896	2888300.25
1993	16.421	1713.5	28137.3835	269.649241	2936082.25
1994	19.876	1526	30330.776	395.055376	2328676
1995	22.527	1691.7	38108.9259	507.465792	2861848.89
1996	24.852	1963.1	48786.9612	617.621904	3852761.61
1997	25.555	1824	46612.32	653.058025	3326976
1998	25.168	1247.8	31404.6304	633.428224	1557004.84
1999	23.509	1392.9	1417.409	552.673081	1942957.21
2000	26.641	1562.3	41621.2343	709.742881	2440781.29
Total	214.699	16616.6	323334.6795	4819.128416	28114615.38

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

$$\frac{323334.6795}{\sqrt{(4819.128416)(28114615.38}}$$

$$\frac{323334.6795}{368086.8673}$$

=0.8784.194

=0.87

DISTRIBUTION OF STATION WITH MEAN ONSET (Φ), CESSATION (C) DATES IN PENTADE, LENGTH OF RAINY SEASON (LRS), MEAN RAINFALL DISTRIBUTION (RR), BREAK (DRY SPELLS) AND THEIR NUMBER OF YEARS USED FOR THE STUDY

S/No	Station	Period covered	Onset dates of Rains (Φ)						Cessation dates of Rains (¢)						LRS	RR	Breaks (Dry spells)		
			Earliest	Pentade No	Normal	Pentade No	Delayed	Pentade No	Premature	Pentade No	Normal	Pentade No	Delayed	Pentade No			Earliest Pentade No	Normal Pentade No	Delayed Pentade No
	Awgu	1961	10	March 7-11	15	April 1-5	18	May 11-15	56.5	Oct. 8-12	65	Oct. 18-22	76	Oct. 28-31	232	1825	May 21-25	June 5-9	July 30.3
		1962	25	Jan 31-Feb 4	30	May 1-5	38	June 20-24	80	Oct. 8-12	85	Nov 2-6	95	Nov. 1-20	275	1875	March 7-11	April 21-25	May 16-20
		1963	25	May 2-6	28	May 26-30	40	June 25-29	100	Oct 8-12	102	Oct 23-27	113	Nov 27-dec. 1st	2150	375	12-16	April 1-5	May 1-5
		1964	20	March 11-15	25	April 15-19	30	May 20-24	55	Nov. 1-5	70	Nov 6-10	80	Nov 2-6	175	1875	March 21-25	April 20-24	17-21
		1965	20	March 2-6	27	April 6-10	29	April 16-20	45	Oct. 8-12	92	Oct 13-17	94	Nov. 16-20	225	2125	Feb. 20-24	March 17-21	April 1-5
		1966	10	April 1-5	12	April 21-25	20	April 21-25	45	Oct 18-27	75	Nov 7-11	80	Nov. 2-6	225	1950	March 22-26	April 11-15	April 26-30
		1974	25	April 1-5	30	May 1-5	30	June 20-24	70	Oct 3-7	94	Oct 18-22	95	Nov. 25-30	250	200	March 27-31	April 6-10	April 6-20
		1975	15	April 1-5	17	May 6-10	22	June 1-4	60	Oct 23-27	78	Nov. 2-11	79	Oct. 28-Dec 31	225	1825	March 17-21	April 16-20	April 20-26
		1977	20	April 26-30	160	June 31- July 4	60	July 20-24	64.0	Oct 8-12	68	Oct 18-22	72	Nov 22-26	220	162	March 7-11	April 1-5	April 5-30
		1978	21.47	March 12-16	47.64	April 11-15	50.5	April 21-25	66	Oct 8-12	85.0	Oct 23-27	87.58	Oct 28-31st	225	1824	March 22-26	April 1-5	April 6-10
		1981	21.42	March 27-31	34	April 26-30	59.1	May 6-10	77.38	Sept 28-30	76.1	Oct 18-22	73	Nov. 2-6	279	1599	March 12-16	April 6-10	April 11-30
		1982	10	Feb 20-24	40	March 22-26	58.74	May 1-5	57.55	Oct 1-7	71.57	Nov 2-6	71.63	Oct 23-27	237	1447	Jan 26-30	Feb 20-24	March 7-11
		1983	12.92	April 26.30	40	May 1-5	42.9	May 1-5	50.72	Sept 23-27	62.96	Nov 27-30	76.60	Nov 7-11	189	948	March 2-3	March 6-31	March 31-April 20
		1984	29.15	April 30-May 4	54.98	May 25-29	62.1	July 4-8	75	Aug. 18-22	95.3	Sept 28-Oct 1	50.24	Dec. 12-16	233	1165	April 30- May 4	Nov 1-4	May 4-9
		1985	20.82	March 12-16	40.3	April 1-5	45-75	May 1-5	45.82	Sept 28-Oct 2	94.7	Oct 8-12	69.60	Sept 28-31	125	1418	Jan 31-Feb 4	Feb 5-25	March 1-11
		1986	23.4	March 7-11	52.1	April 1-5	105.5	May 18-20	60.98	Oct 8-12	380.76	Oct 18-22	76.48	Oct 28-Nov 1st	187	1715	Jan 26-30	Jan 30-Feb 28	March 1-April 6
			$\bar{X}$= 19.32				$\bar{X}$= 55.59								$\bar{X}$= 230	$\bar{X}$= 1600			

			Earliest	Pentade No	Normal	Pentade No	Delayed	Pentade No	Premature	Pentade No	Normal	Pentade No	Delayed	Pentade No			Pentade No	Pentade No	Pentade No
	Enugu	1933	16.3	Jan 21-25	44.8	Mar 12-16	70.5	April 16-20	76.93	Nov. 7-11	79.42	Nov. 22-26	80.47	Dec. 17-21	303	1515	Jan 26-30	Feb. 26-30	Feb. 5-Mar
		1934	9.85	Mar. 22-26	27.35	April 11-15	44.65	Mar. 6-10	81.17	Dec. 7-11	81.17	Dec. 7-11	81.17	Dec. 7-11	356	1783	Jan. 13	Feb 4-28	Mar. 1-6
		1935	11	Mar. 17-21	19.9	Mar. 27-31	47.3	April 21-25	52.04	Oct. 8-12	59.74	Oct 28-Nov.1	68.05	Dec. 2-6	205	1046	Jan. 31-Feb. 4	Feb. 4-Mar 16	After Mar. 16
		1936	13.65	Mar. 16-20	26.4	Mar. 26-30	36.05	April 25-29	56.62	Oct. 2-6	49.25	Oct. 27-31	51.61	Dec. –5	214	1233	Feb. 20-29	Mar. 1-6	Mar. 6-21
		1937	27.5	Jan. 31-feb. 4	28	April 21-25	55.05	May 21-25	67-98	Oct. 28-Nov 1	60-6	Dec. 12-16	70.47	Dec. 17-4	202	1012	Feb. 5-28	Mar 1-6	Mar 6-20
		1938	5.6	Mar. 7-11	10.65	April 1-5	28	April 26-25	69.6	Nov. 17-21	69.6	Dec. 7-11	70.47	Dec. 22-24	320	1600	Jan. 31-Feb. 28	Mar 1-6	Mar 6-20
		1939	11.7	Jan.26-30	71.55	April 6-10	75.05	April 26-30	77.91	Nov. 28-Dec. 1	78.53	Dec. 2-6	79.4	Nov. 22-26	331	1655	Jan 11-25	Mar 1-11	After Mar. 5
		1940	12.9	Feb. 5-9	40.3	Mar. 21-25	70.4	April 30-May 4	74.53	Oct. 27-31	77.5	Nov.26-30	77.5	Nov. 26-30	308	1540	Feb. 10-14	Mar. 1-15	Mar. 1-10
		1941	15.8	Mar 12-16s	21.1	May 11-15	39.28	June 15-19	81.78	Nov. 7-11	82.11	Nov. 22-76	81.11	Nov. 22-26	329	1649	Jan. 13-31	Feb. 1-28	Mar. 1-10
		1942	39.15	April 1-15	46.35	May 6-10	58	May 26-30	67-7	Oct 18-22	68.5	Nov. 22-26	68.9	Dec. 12-16	243	1215	Jan. 16-31	Feb. 1-24	After Feb. 24
		1943	38.65	April 26-30	48.15	May 2-25	52.05	June 30-July 4	58.26	Nov. 7-11	6.03	Nov. 2-16	60.03	Nov. 22-26	241	1205	Jan 16-31	Feb. 1-28	March 1-6
		1944	48.8	April 21-25	65.1	May 16-20	90.8	July 5-9	96.76	Nov. 22-26	96.79	Nov. 27-Dec 1	97.18	Dec. 12-16	239	1499	Jan. 16-31	Feb. 1-14	After 1-10
		1945	13.7	April 21-28	39.6	May 21-25	50.95	July 10-14	54.55	Oct. 3-7	59.88	Oct. 28-Nov 1	60.05	Dec. 12-16	204	1221	Mar. 7-10	Mar 1-6	March 22-31
		1946	31.65	April 6-10	47.3	June 30-July 4	49.09	Oct. 3-7	60.14	Nov. 7-11	63.98	Dec. 7-11	64	Dec. 12-16	145	2175	Feb. 15-28	March. 1-6	April 1-10
		1947	58.4	Feb. 20-24	60.5	May 21-2	63.4	June 10-14	87.21	Nov. 22-26	89.25	Dec. 7-11	89.38	Dec. 22-26	144	720	Feb. 20-28	March 1-26	April 11-25
		1948	31.45	April 1-5	45.75	April 5-9	70.1	May 20-24	74.23	Nov. 1-5	75.39	Nov. 26-30	75.7	Dec. 26-31	213	1069	Jan 21-31	Feb. 15-24	March 1-30
		1949	26.95	March2-6	49.75	May 21-25	69.05	June 10-14	74.09	Oct 23-27	74.78	Nov. 2-6	74.9	Nov. 22-26	235	1178	Feb. 5-9	Feb. 1-19	March 2-21
		1950	13.75	March 22-26	45.15	April 25-25	56.6	May 16-20	63.47	Nov. 28-Dec. 1	65.87	Nov. 22-26	65.87	After 26th Nov	248	1243	Feb. 5-28	Feb. 10-28	March 17-21
		1951	11.5	March 1-10	30-1	April 16-20	50.9	May 11-15	52.94	Oct. 18-22	55.82	Oct. 23-27	56.48	Nov. 27-30	207	1836	Feb. 5-24	March 1-6	After March 11-31
		1952	11.45	March 10-14	45.8	May 1-4	72.35	20.24	77.04	Nov. 1-5	78.47	Nov. 6-30	79.9	Dec. 21-30	327	1639	Feb. 5-24	Feb. 25-10	March 11-31
		1953	20.65	March 22-26	50.25	April 26-30	58.55	May 11-15	60.49	Nov. 7-11	61.77	Nov. 12-16	61.77	Nov. 22-26	199	1996	Feb. 1-14	March 1-11	March 10-31
			$\bar{X}$= 22.39						$\bar{X}$=69.13						$\bar{X}$= 250	$\bar{X}$= 1800			

			Earliest	No		No		No										
	Oji	1955	8	March 12-16	25	April 11-15	27	April 16 – 30	70	Oct 28 – Nov 1st	79	Nov 17 –21	80	Dec 12-16	310	1550	March 2-6	April 11-15
	River	1956	15	March 12 – 16	20	April 5 – 9	25	May 11-15	85	Nov 7 – 11	80	Oct 3-7	85	After Nov 25	350	1750	March 6-10	April 15 19
		1959	13	April 26 – 30	15.54	April 5-9	20	May 1-5	55	Nov 7 – 11	73	Nov 22-26	75	After Nov25	210	1050	April 25 – 29	April 31 May 4
		1960	10	Feb 20 – 24	12	March 12 – 16	25	April 5 – 9	40	Nov 6 – 10	52	After Nov25	58	After Nov 25	150	750	April 10 – 14	May 10 14
		1961	13	April 20 – 24	15	May 30 June 3	25	June 19 – 23	69	Oct 7 –11	70	Oct 22 – 26	75	Oct 27 – 31	280	1400	Feb 25 – 29	March 1 – 20
		1962	14	March 11-15	18	April 6 – 10	27	May 26 – 30	86	Sept 23 – 27	95	Oct 23 – 33	97	Nov 27 – Dec 1	360	1800	Feb 10 – 14	May 1 –5
		1963	10	March 21 – 25	12	April 25 – 29	20	May 25 – 29	56	Oct 7-11	58	Oct 22 – 26	60	Nov 6 – 10	230	1150	Feb 10-14	March 2[illegible] – 28
		1964	25	March 27 – 31	29	May 6 – 10	30	May 31 June 4	75	May 26 – 30	118	Aug 19 – 23	138	Oct 18 – 22	275	1375	March 17 – 21	April 1 – 5
		1965	20	Feb 5-9	23	March 27 –31	25	May 1-5	48	Sept 28 Oct 2	49	Nov 7 – 11	59	Nov 12 – 16	140	700	March 1-5	March 21 – 25
		1966	15	March 27 – 31	25	May 6-10	30	June 10 –14	70	Sept 28 Oct 2	78	Oct 3-7	79.5	Nov 12 – 16	275	1375	April 1 –5	July 5-9
		1981	14	May 1-4	20	May 16 – 20	29.6	May 31 June 2	44.6	Aug 29 June 2	51.2	Oct 8-12	54.5	Nov 2-6	152	764	May 16-29	April 26 – 30
		1982	10	Feb 28 – 24	18	March 17 – 21	40.2	April 21 – 25	56	June 1-4	58	Sept 18 – 22	60.4	Sept 18 – 22	230	1150	March 7-11	May 16-20
		1983	12	May 1-5	17	May 26 30	65	June 15 – 19	85	Sept 18-22	88.04	Aug 29 Sept 2	92.04	Sept 3 – 7	365	1825	June 1-5	May 20 – 31
		1984	14	March 21 –25	20	May 15 – 17	35	June 9-13	61.92	Aug 24 – 28	99.2	Oct 7-11	100	Oct 17-27	239	1198	March 31 April 4	June 1-19
		1985	20	March 17-21	23	April 1-5	45.2	Apri; 11-15	71.8	Sept 27 Oct 1	75	Oct 25 Nov 1	79	Nov 7-11	258	1290	April 11 – 15	March 22 – 26
		1986	20	March 17 – 21	25	March 22 – 26	48	April 11 – 15	60	Oct 13 – 17	68.4	Oct 18 – 22	85.2	Nov 28 Dec 1	200	1000	March 22-26	April; 20 –24
			233 X = 14.6						1033.08 x = 64.56						X = 250	X = 1600		

S/N	Station	Period covered	Onset Dates of Rains (Φ)						Cessation Dates of Rains (¢)						LRS	RR	BREAKS (DRY SPELL		
			Earliest	Pentade No	Normal	Pentade No	Delayed	Pentade No	Premature	Pentade No	Normal	Pentade No	Delayed	Pentade No			Earliest Pentade No	Normal Pentade No	Delayed Pentade No
		1941	22..9	March 6-10	40.65	March 16-20	51.5	March 31 April 4	63.89	Nov. 1-5	63.97	Nov. 6-10	64.43	Nov. 21-25	204	1024	March 21-31	Feb. 1-28	March 1-5
	Nsukka	1942	14.2	March 16-20	25.6	March 31-April 4	50.45	May 1-4	62.15	Nov. 1-5	62.15	Nov. 21-25	65.35	Nov. 26.30	239	1198	Jan 21-Feb 28	March 1-15	March 16-25
		1943	10.95	March 27-30	22.8	April 11.15	30.8	May 11-15	45.29	Nov. 2-6	45.29	Nov. 7-30	45.30	Dec. 1.31	171	858	Jan 26-31	Feb. 1-28	March 1-16
		1944	11.55	March 21-25	39.5	April 30-May 4	43.85	May 25-29	40.2	Nov. 1-5	40.2	Nov. 6-30	40.2	Dec. 1-31	143	716	Jan 1-31	Feb. 1-29	March 1-15
		1945	9	March 2-6	17	April1-15	49.2	May 25-15	38.77	Oct. 28 Nov. 30	38.7	Dec. 1-15	47.77	Dec. 16-31	193	969	March 7-16	March 17-26	March 27-April
		1946	11.45	April 16-20	44.4	May 26-30	67.15	May 30-Jan 5	38.59	Oct. 27-Nov. 1	60	Nov. 1-30	89.55	Dec 1-31st	135	678	Feb. 15-28	March1-31	April 1-5
		1947	17	April 6-20	17.25	April 21-30	22.75	May 1-15	63.5	Oct 28-Nov. 1st	82.32	Nov. 2-Dec 21	92.44	Dec. 22-31	232	1162	Feb. 5-19	Feb.20-March 2	March 2 April 25
		1948	15.75	March 2-21	33.5	April 6-10	43.5	May 16-20	81.17	Nov. 2-6	85.4	Nov. 7-30	86.75	Dec. 1-31	327	1635	Jan 27-31	Feb. 1-14	Feb. 1 March 2
		1949	31	April 21-30	36.5	May 6-25	64.5	May 6-30	74.1	Oct. 23-Nov 6	75.4	Nov. 6-30	80.2	Dec. 1-31	215	1077	March 2-21	March 22-31	April 6-18
		1950	15	Jan 31-March 21	37	April 26-30	40.5	June 25-29	44.36	Oct 28-Nov. 1	69.04	Nov. 2-30	71.81	Dec. 1-31	146	734	Feb 5-28	March 1-21	March 2 31
		1951	10.4	Jan 16 Feb 9	20.15	April 1-5	59.65	May 21-25	67.59	Nov. 28 Dec. 1st	68.04	Nov. 2-6	69.21	Nov. 7-Dec 31	285	1429	5Jan 21-Feb	9Feb.10-March	6March 31
		1953	30.4	Feb. 25-March 1	28.8	March 17-21	72.4	May 18-28	69.88	Oct 27-31st	70.48	Nov. 2-11	96.5	Nov. 12-Dec 31	197	987	Feb 25-March11	March 22-31	April 1-4
		1954	60	Feb 15-19	63.88	March 21-25	66.27	April 20-24	68.07	Oct. 1-6	75.17	Nov. 6.10	94.52	Nov.11-30	40	201	Feb. 15-March 5	March 6-15	March 1-6
		1955	11.75	March 7-11	59.7	April 16-20	60.75	May 11-15	75.17	Nov.7-11	75.7	Nov. 12-30	79.87	Dec. 1-31	317	1585	Jan 21-Feb. 19	Feb 25-28	March 1-6
		1956	20.4	March 12-16	35.1	April 6-10	47.9	May 21-25	58.03	Nov. 7-16	62.28	Nov. 17-26	65.40	Nov. 27-Dec. 1	188	940	March 25-Arpil 6	March 22-31	After Apr 6
		1957	21.65	March 22-31	44.8	April 16-30	49.85	June 10-14	58.7	Oct 18-22	61.2	Oct. 23-27	62.46	Nov. 28-Nov.1st	185	926	March 7-21	March 22-31	After March 31
		1958	16.65	Feb. 25-March 1st	35.85	April 16-30	43.1	May 6-15	47.2	Oct 28-Nov. 6	47.94	Nov. 7-21	56.46	Nov. 22-Dec 6	152	763	Jan 21-Feb. 19	Feb. 20-28	March 1-6
		1959	33.8	April 1-20	46.95	April 21-25	49.25	June 5-9	58.28	Nov. 21-17	59.5	Nov. 22-Dec. 1st	62.46	Dec. 2-31	122	612	Jan 31Feb. 28	March 1-6	march 17 21

														5					11
		1961	9.05	April 6-10	20.65	April 16-20	41.95	June 10-14	53.27	Nov. 2-30	53.27	Dec 1-31	55.74	After Dec. 1	221	1105	Jan 31-Feb. 28	March 1-21	March 22-31
		1962	31.3	April 1-10	48.1	April 21-25	70.75	March3 1 June 4	67.77	July 30-Aug.3	370.82	Nov. 2-16	67.77	Nov. 17-26	182	9111	Feb. 10-14	March 2-11	Marc h 12-24
		1963	19.35	April	48.8	April 26-30	57.15	May 21.30	55.04	Oct 18.22	55.61	Oct 23-27	55.94	Oct 28-31	178	892	Feb. 10-14	March 2-11	March 12-21
		1964	11.45	April 16-20	22.25	May 6-15	37.44	March 31-June	51.4	Act 3 – 12	62.48	Oct 23-27	71-55	Oct. 28-31	199	998	Feb.15-Mrach 31	April 1-5	April 6-15
		1965	12.25	Feb. 10-14	24.4	April 6-10	56.05	April 1-4	58.75	June 5-9	59.46	Oct. 13-17	59.91	Oct 18.31	232	1162	Jan 6-31	Feb. 1-5	March 1-31
		1984	60	March 17-21	69	March 27 April 5	84	April 26-May 30	87.7	Nov. 2-6	91.42	Oct 15-25	106.38	Nov. 1-30	138	692	March 18-25	Feb. 1-28	April 1-5
		1985	34.9	March 17-21	43.6	April 6-15	51.5	April 16-30	67.71	Oct.27-31	74.73	June 25-29	84.10	Oct 1-31st	164	802	March 12-21	March 22-31	April 1-5
		1986	15.5	March 21-24	139.9	April 20-24	235.5	May 10-14	53.58	Aug. 23-31	65.67	Nov-30	66.72	Nov.22-30	190	952	Jan 16-31	Feb1-24	Feb 25-Mar. 5
		1987	31.84	Feb. 1-24	33.72	Feb. 24-March 3	37.8	April 10-14	64.74	Sept. 1-30	70.81	Oct. 1-31	70.81	Oct. 1-31	74	822	Feb. 5-24	Feb. 25-29	March 1-20
			$\bar{X}$= 21.74						$\bar{X}$ = 59.91						$\bar{X}$= 190	$\bar{X}$= 1200			

APPENDIX 4

Precipitation and irrigation relationship to obtain bydrologic ratio. The summary expression for computation is of the form:

$$\frac{\sum\Delta s \quad - \quad [\sum\Delta_{DI} + \sum\Delta_{D2}]\ \mathbf{Yr.}}{\Delta RR\ (yr)}$$

where Δ_s = soil moisture surplus in a year

Δ_{DI} **and** Δ_{D2} **= soil** moisture deficiency

Δ_s = **Hydrologic ratio** (λ) is the ratio of **precipitation (P) to the evapotransporation** (PE).

Δ_s = **Amount of rainfall in the** months of **April to October (ie wetter** months)

Δ_{DI} + Δ_{D2} = Amount of rainfall in the months of **January to March and November to Decem**ber (Dry months)

$\sum\Delta_s$ = 1488.3 mm

$\sum\Delta_s$ = 146.7 mm

$\sum\Delta_s$ = 66.6 mm

$$= \frac{[\sum\Delta_s - (\sum\Delta_{DI} + \sum\Delta_{D2})]\mathbf{Yr.}}{Yr.}$$

(i) $= \frac{[1488.3mm - 146.7 + 66.6mm]}{\mathbf{1701.6}}$

$= \frac{1275}{1701.6} = 0.749294$

n 0.75

(ii) $\sum\Delta_{DI} + \sum\Delta_{D2} = 525$

= PE = 525

$RR = 195.75$

$\therefore \lambda = \frac{RR}{PE} = \frac{195.75}{525}$

$= 0.372857114$

Л 0.4

(iii) $\sum \Delta_{Ds} = 1921.2$

$\sum \Delta_{Dl} = \sum \Delta_{D2} = 41.9$

$= \frac{1921.2 - 41.9}{1963.1} = \frac{1879.3}{1963.1}$

$= 0.957312414$

$= \underline{0.96}$

(iv) $\sum \Delta_s = 1536.4$

$\sum \Delta_{D1} + \sum \Delta_{D2} = 173.1$

$= 1536.4 - 173.1 \quad = \quad 1363.3$

$1713.5 \quad\quad 1713.5$

$= 0.795622993$

$= 0.79$

(v) $\sum \Delta_s = 1238.84$

$\sum \Delta_{D1} + \sum \Delta_{D2} = 155.06$

$= \frac{1238.84 - 155.06}{= 1393.9} = \frac{1083.78}{1393.9}$

$= \underline{1083.78} =$

$1393.9 \quad\quad 0.78$

(vi) $\sum\Delta_s$ = 1189.1

$\sum\Delta_{D1} + \sum\Delta_{D2} = 58.7$

$= \frac{1189.1 - 58.7}{1247.8} = \frac{1130.4}{1247.8}$

= 0.905914409

= 0.9

APPENDIX 5

Specific water consumption (W/F). This is water equivalent to avert drought condition in the area.

The summary expression for computation is of the form:

W/F = [dwet (Qwet-Pwet) + D Dry (Q Dry – P Dry)]

Amount of rainfall in the year (ie wet months) April to October

267.1+401.0+0+233.0+281.5+247.0+230.5+199.7

No. of wet days in the months = 214 days

$= \frac{1879.8}{214} = 8.78$ mm

Dwet = 214 days

Qwet = 3.93 mm day^{-1} (constant)

Pwet = $\frac{1879.8}{214}$ = 8.78 mm

D Dry = No. of days in the dry months ie January to March and November to December of the year in the area.

= 31+28+31+30+31 = 151 days

Q Dry = 3.23mm day^{-1} = (constant)

P Dry = Average daily precipitation during the dry period.

$$= \frac{0.0+42.7+62.3+10.0+0.0}{5} = \frac{115}{5}$$

$= \quad 23mm\ day^{-1}$

(i) W/F = [214(3.98 – 8.78)+151(3.23-23)]

= [214(-4.8)+151(-19.77)]

= 209.2+131.23

= 340.43mm

(ii) [215(3.98-2.29)+45(3.28-12.84)

= 215(1.19) + 45 (19.56)

= 255.85 + 35.44

= 291.29

(iii) [1835(3.98-6.23) + 182 (3.23-17.85)]

= [183(-2.25)+182(-14.62)]

= 180.75 + 167.38

= 348.13 mm

(iv) [245(3.98-6.70)+120(3.23-18.15)]

= [245(-2.72)+120(-14.92)]

= (242.28+105.48) = 347.36mm

= 347.36mm

(v) [214 (-4.44)+150(-19.17)]

= [214(-4.44)+150(-19.17)]

= 210.56+130.83 = 341.39mm

(vi) [245(3.98-7.94) + 120(3.23-4.15)]

= [245(-3.96)+120(-0.92)]

= [241.04+119.08]

= 360.12mm

(vii) [215(3.98-6.82)+151(3.23-11.86)

= [215(-2.84)+151(-8.63)]

= (212.16 + 142.17)

= 354.33 mm

APPENDIX 6

Computer printout (from crops that are threatened by the climate change) showing the results of analysis from the questionnaire:

Agricultural zone	CROP						
		Root	Legumes	Cereal	Vegetables	Others	Row Total
Awgu	Count Exp value	10	12	16	16	1	55
		9.17	6.39	19.86	16.81	1.53	
Enugu		8	5	14	19	0	46
		7.67	6.39	16.61	14.06	1.28	
Nsukka		12	8	35	20	4	79
		13.17	10.97	28.53	24.14	2.19	
Column Total		30	25	65	55	5	180

Chi-square value = 14.305

Degree of freedom (DF) = 8

P value = **0.00000**