# VARIABILITY OF FLOW REGIMES OF OGBESE AND OWENA RIVERS IN SOUTH WESTERN NIGERIA.

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# VARIABILITY OF FLOW REGIMES OF OGBESE AND OWENA RIVERS IN SOUTH WESTERN NIGERIA.

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AT

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## CERTIFICATION

This is to certify that this work was carried out by OMOTAYO, Kayode Foluso (AGE/97/0124) in the Department of Agricultural Engineering, Federal University of Technology, Akure, in partial fulfillment of the requirements for the award of Master of Engineering in Soil and Water Resources Engineering option, Department of Agricultural Engineering, Federal University of Technology, Akure. It has not been submitted elsewhere for the award of any other degree or diploma

Engr (Dr) A.A. Olufayo
Supervisor

2/2/2002
Date

# DEDICATION

This project work is dedicated to God Almighty, my wife and loving children. Thanks so much for your concern always.

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# LIST OF SYMBOLS

| SYMBOL | UNIT | NUMECLATURE |
| --- | --- | --- |
| ET | mm/day | Evapotranspiration |
| T | °C | Air Temperature |
| ARIMA | - | Auto Regressive Integrated Moving Average |
| $R_v$ | mm of water | Mean rainfall |
| A | $km^2$ | Drainage Area or Catchment Area |
| Q | $m^3/s$ | River discharge |
| STG | cm | staff gauge |

**ABSTRACT**

The scarce water resources of Southwestern Nigeria could be better managed, if reliable forecast of river discharge through rainfall variability data over a long period are available. The study was aimed at carrying out analysis of rainfall data, river data of Ogbese and Owena rivers measured at Ago Aduloju and Owena respectively, on short and long term modeling forecast; using river discharge and stage of those two rivers. The data were analysed to obtain a general river discharge pattern that can be adapted for effective agricultural production planning as an index to increase food production in the study area.

The data was modelled using the Box-Jenkins forecasting procedure for short and long term forecasting which was analysed using Microsoft Excel version 5.0 software package. The result obtained for short term modeling forecast for river Owena shows a correlation coefficient of 0.65 at $0 \leq r^2 \leq 1.0$ for the month of January to July and 0.8 to 1.0 for the month of August to December. The long-term model forecast for the same river gave a correlation coefficient of 0.8. The second river, Ogbese on short-term model had a correlation coefficient of 0.9 and 0.75 for long-term model forecast, for the same period of the year.

The average value of river discharge obtained from modeled value compared with forecasted value for river Owena shows 91.62 $m^3/s$ against 126.10 $m^3/s$, while for river Ogbese, 324.36 $m^3/s$ against 307.44 $m^3/s$, respectively. This conservative estimate means that at any time in the forecasted year ahead, above 126.10 $m^3/s$ and 307.44 $m^3/s$ in water volume will be available for Rivers Owena and Ogbese, at their respective gauging stations. The crop grown in the study area was analysed, it was seen that the forecasted

values for the two rivers (Ogbese and Owena) could be channeled or used in irrigation planning for increased agricultural production through dry-season farming in the catchment area.

# CHAPTER ONE

## 1.0 INTRODUCTION

## 1.1 BACKGROUND TO THE STUDY

Water resources development in Nigeria started a long time ago but in an uncoordinated manner, and without any serious attempt to evolve a sound plan to orient it until barely 1960's when the Lake Chad Basin Commission and the River Niger Commission were established in collaboration with other West African countries. These commissions were established to promote coordinated and cooperative water resources assessment, monitoring, development and utilization in these areas of West Africa (Oyebade and Balogun, 1997).

Somehow, the establishment of these commissions encouraged the Nigerian government to create 11 (eleven) River Basin Development Authorities (RBDA's) in the 1970's as a follow-up, which were charged with the responsibility of imparting effective regional coordination of water resources, planning and development of this resource in the delineated areas of their jurisdiction (Oyebade and Balogun, 1997). Recent evidence indicates that much however remains to be done by these basin authorities in the country to ensure the effective implementation of the water resourses programmes to achieve a truly sustainable development of their jurisdictions. As a result of this inadequacy, water shortages have become so acute that it has constituted an increasing constraint to the economic growth and development of the country. Due to this shortfall, and a number of pressing needs, which include: the expansion of agricultural, domestic and industrial activities, owing to ever-increasing population of the country estimated at 88.5 million people with an annual growth rate of 2.83% in the 1991 population census (Federal

Office of Statistics, 1996). Hence, the awareness to develop water resources based on a sound environmental principle. To compliment this effort therefore, there is need to develop the data set necessary to model and forecast the potential of water resources available in the Southwestern region of the country upon which a sustainable planning could be built. Therefore, the study was aimed at analyzing the existing rainfall data set of the region (Ondo State as a case study), hydrological information of rivers Ogbese and Owena discharge and stage, and the present utilization patterns of those rivers under the present Authority of the Benin-Owena River Basin. Information from here will also serve to examine the potential of these Rivers for irrigation purposes in order to meet the food production requirement of the study area.

## 1.2 OBJECTIVES OF THE STUDY

The major objectives of this study are, to:

(i) Evaluate the water resources potential and utilization of rivers Ogbese and Owena in the Benin-Owena River Basin.

(ii) Model and forecast the rivers' discharge on both short and long term basis.

## 1.3 JUSTIFICATION OF THIS STUDY

Since there is the urgent need to shift from the unsustainable and inadequate rain-fed agriculture that characterized the major economic activities of the Southwestern Nigerian people, to a more sustainable irrigation-supplemented one; there is therefore, the need to model and forecast the future water resources potential of the two prominent rivers in the Benin-Owena Basin as a tool to assessing their agricultural usage in the region while taking into consideration their current utilization.

# CHAPTER TWO

## 2.0 LITERATURE REVIEW

### 2.1 Historical Background of River Basin Development Authority in Nigeria.

Water resources development in Nigeria started indirectly in 1908 when a water level gauge was erected in Jebba in connection with the planned railway bridge across the River Niger. This was followed in 1914 by gauges along the Niger at Baro, Lokoja, Idda and Onitsha and along the Benue at Yola, Ibbi and Makurdi. (Federal Ministry of Water Resources, 1994). Major work on water resources-related projects made in some shipping companies and the inland water way division of the then Federal Ministry of Transport and Power to install gauges at various locations along major rivers and maintain such by collecting relevant water data for further works.

Climatologically, data were also collected by the meteorological services of the Federal Ministry of Communication. The Department of Geological Survey started work in 1928 when the department undertook the actual exploitation of ground water through wells and boreholes. It was further reported by Popoola (1974) that furnishing of important information and advice on water supply became one of the important functions of the department. This effort was collaborated by the Federal Ministry of Water Resources (1986). The first irrigation division in Nigeria was established in 1949 in the Ministry of Agriculture of Northern Nigeria. Nwa (1976) reported that the activities of this division was limited to small irrigation schemes in which small hectarage of farmland are irrigated with pocket irrigation channel from the water sources. In 1959 however, Hydrological section of the Irrigation Division of the Northern Region was fully set up to develop a network of hydrological stations and to organize an in-house training services for staffers of the Ministry of the need to harness water resources potential of the region for agricultural development.

The importance of dependable and safe water supply for domestic, municipal and industrial purposes cannot be over-emphasized. Other non-agricultural benefits of water resources development include hydroelectricity generation and navigation improvement. Nwa, (1976) explained the role of agriculture in economic development in a developing nation like Nigeria. It is estimated that 75 % to 80 % of Nigerian population is employed in agriculture at one level, or the other. If the standard of living of the general populace in Nigeria must rise, if the food requirement of the ever-growing population is to be met domestically, if adequate supply of raw materials for Agro-based industries (Textile, paper mill, leather, timber, etc) will be generated locally to combat unemployment problems, modernization of Nigerian agriculture is imperative.

Water resources development will provide an inevitable background for irrigation development, fish farming and processing of agricultural produces where a lot of water is often needed. Popoola (1974) said that the climate of Nigeria makes year round cultivation possible in most parts of the country if adequate water supply is guaranteed. With proper/ efficient planning and management, farm labour requirement will become uniformly distributed and farm income more stable. Water resources in any country constitute tremendous assets that must be developed, harnessed and managed in the economic development process.

The Niger Delta Development Board, set up in 1960 by the Federal Government, was charged with the responsibility of preparing plans for the economic development and physical development of the Niger Delta area. As its contributions to water resources development, the board embarked upon flood protection schemes and made a start at the collection of hydrologic data. The FAO report (FAO 1966), commissioned by the Federal Government, which deals with the perspective for agricultural development in Nigeria up to 1980, can be considered the watershed in water resources development for agriculture in Nigeria. This report recommends a more active involvement of the Federal Government in planned water resources development for the country.

The rolling plan of 1975-80 focused on the establishment of a federal ministry of Water Resources, which has a broad and coherent water resources development plan in Nigeria, coupled with the establishment of an institute for water resources based in Kaduna. The eleven (11) River Basin Development Authorities created by the Federal Government marked the milestone in water resources development processes in Nigeria. These river basins are charged with the following objectives:

1. To undertake comprehensive development of underground water resources for multi-purpose use.
2. To undertake schemes for the control of floods and erosion and for watershed management.
3. To construct and maintain dams, dykes, wells, polders, bore holes, irrigation and drainage systems and other works, necessary for the achievement of the authority's functions.
4. To develop irrigation schemes for the production of crops and livestock and to lease the irrigated land to farmer (s) and/or recognized associations in the locality of the area concerned.

5. To provide water from reservoirs, wells and bore holes under the control of the authority concerned for urban and rural water supply schemes.

## 2.2 CLIMATIC VARIABILITY

Nigeria lies wholly within the tropics along the Gulf of Guinea on the western coast of Africa. Its climate varies from tropical at the coast to sub-tropical further inland. Temperature is generally very high (about 28°C) and increases as one moves Northward from the coast resulting in a wide geographical variety in physical features (FOS, 1996).

The diversified geographical regions provide the country with an almost inexhaustible variety. There are two well-marked seasons- the dry season lasting from November to March and the rainy season from the month of April to October. Temperatures at the coast seldom rise above 32°C but humidity can be as high as 95% (FOS, 1996). The climate is drier further north where extremities of temperature are common. The climate of Nigeria is controlled by the dynamics of the south-westerlies wind emanating from the Atlantic Ocean that moves from the south to north and the North easterlies wind from Northeast moving from the North down South. These two major winds are responsible for the two main seasons in Nigeria, rainy season and dry season. However, large-scale atmospheric circulation over the southwestern Nigeria had resulted in a positive gradient of annual rainfall 2 mm $km^{-1}$ in the vicinity of Ondo and Ekiti States (Agboola, 1985). Penetration of moisture from the Gulf of Guinea initiates the rainy season where 80% fall between the periods of July-September (Lamb and Peppler, 1991). As we move towards upland from the Gulf of Guinea, annual rainfall is the composite of convective storms of three main types identified by Desbois et al; (1988): local convective systems, moving organised convective systems, and squall limes which move in the opposite directions of the tropical North Easterlies. As we move from the regional area South Western Nigeria, where annual rainfall gradients are well defined, to the spatial and temporal variability of the north rainfall pattern is more pronounced. At the catchment point of major rivers in south-western Nigeria the annual rainfall depends largely on the chance of a storm passing over its location. This had made it possible for some catchments to have slight hydrological extremes of drought, flood that is in opposition to regional climatological conditions.

However, a dominant factor in the rainfall reduction of about 20% has been responsible for decrease in the number of storm events observed during the intense period of July-October (Label & Barbe, 1997; Lebels et al., 1997). But Le Barbe and Lebel, (1997) suggest that the rainy season length and mean event are relatively constant over the region which indicates that the spatial distribution of rainfall was due to decrease in the mean number of rainfall events between the peak seasons. However, Olufayo and Ajayi (1998) argued that there was a general decline in rainfall amount over the years in the Southwestern zone of Nigeria. However, there were indications that show that there were fewer rainfall days with high intensities resulting into flooding and other drainage problems. It must be noted that Ondo and Ekiti States, although located within south western Nigeria, the effect of climatic variability will equally have an effect on the performance of the surface water system of the region. The assessment of the surface water resources in the basin for planning and development of water projects is always carried out in basin for long-term flow characteristics (Ankomah-Opoku and Amisigo, 1998). Long term data sets that incorporate low and high flow inherent in natural hydrological series are able to depict the true characteristics of flow in the river basin. Smaklin et al; (1998) further reported that daily stream flow information is required in the design of runoff-river regimes, water quality calculation, assessment of catchment development impact on river ecology which are important parameters for development of water scheme. Hughes and Smaklin (1996) described the pragmatic techniques of spatial interpolation of observed flow data which was initially designed to extend daily flow records at the site of interest. This technique allows a time series of daily flow from one riverside to be transferred to another using a Flow Duration Curve (FDC) as a key transfer function. FDC is a relationship between a flow value and a percentage of time this flow is equaled or exceeded and it therefore gives a summary of the hydrological regime at a site displaying the complete range of river discharge from low flows to flood events.

## 2.3 VARIABILITY OF STREAM FLOW

Nigeria is blessed with a reasonably large networks of rivers and streams. There is ample evidence that the persistence of the drought as a phrase of the climatic fluctuation or change has taken its toll on the water availability particularly on the reliability of river Niger and Benue. According to Oyebade and Balogun, (1997), nigerian surface water system has continued to be on a decline in volume. The total annual yield of Niger into the Kanji dam reservoir steadily decreases from 51 x $10^9m^3$ in 1969/70 through the low 24.5 x $10^9m^3$ at the height of the drought in 1973 to a new more or less stable level of below 35 x $10^9m^3$ in 1989/90, this was attributed to changes in global climates. Oke, (1984) reported that surface water system in Ondo State has witnessed a large degree of variability despite having similar relief and drainage pattern in such that almost all the stream/rivers have their sources from within the state and drain in either a northward or southward drainage.

Owena catchment area stretches southwards from Ilawe Ekiti through Akure, Idanre, Owena village and terminates at the Ondo Edo State boundary. The drainage area is about 2390 square kilometer, Owena river measures about 102 kilometres from its source to the hydrological station at kilometre 90 Benin Ore expressway.

River Ogbese drains the largest portion of the two states extending to Edo State border. The river spans over 140 km length and the drainage area of about of about 850 $km^2$.

## 2.4 DRAINAGE DENSITY

Drainage density is an expression of the closeness of spacing of channels. It is ratio of the total length of streams and rivers to the drains (Farquharson and Sutcliffe, 1998). This can be expressed mathematically as:

$$D = \frac{\sum_{1}^{K} \sum_{1}^{n} LU}{Au} \quad \text{.......................................(1)}$$

where D = Drainage density

$\sum_{1}^{K} \sum_{1}^{n} LU$ = Channel segment length cumulated for all the orders within a basin

Au = Basin area (Projected to the horizontal)

## 2.4 POTENTIAL UTILIZATION OF WATER RESOURCES

Like all other natural resources, the proper management of water resources either for agricultural or municipal use is vitally needed for its effective conservation and use. The potential utilization of water resources was according to Egbuniwe, (1976) needs to be well understood. Water resources planning involves many choices among physically feasible alternative; each choice among the alternative should be made on economic grounds. Linsley et al, (1987) says that the above statement does not imply that tangible factors should not be considered.

### 2.4.1 Water demand and supply

Okeke (1983) as reported in Oke (1984) that the present water supply level in Ondo State is generally poor (30 litres per capital per day) when compared to Kano and Kaduna with about 140 litres per capital per day. Considering the abundant surface water system in Ondo and Ekiti States there should be adequate planning and effective utilization of leading to increase in water supply.

### 2.4.2 How much water is needed?

Water demand and consumption may be divided into domestic, industrial and agricultural. The volume of water required in the three categories above will depend solely on the population and level of industrial and agricultural activities respectively. Domestic water demand according to Ondo State Water Corporation, (1988) was put at

180 lpcpd in the ratio of 1:2.5 rural to urban growth rate (U.N.O. 1981). Linsley et al; (1987) noted that development of an efficient water supply system capable of supplying a sufficient quantity of potable water is a necessity for most town and village dwellers so as to live above poverty level. Industrial water demand he explained further includes water used by commercial establishment and industries.

2.4.3 **Hydroelectric - power and navigational facilities**

There are two types of power developed in used by mankind (1) hydro plant and (2) thermal plant. Hydroelectric generators are driven by water turbines while thermal (or steam) plant derive energy from combustion of fuel. The initial cost of hydroelectric power plant is generally high while the cost of maintaining and running the plant is relatively low. Surface water system when dam can be put into use for power generation navigational purpose and fish farming.

2.4.4. **Irrigation purpose**

According to Linsley et al. (1987) irrigation is the application of water to soil to supplement deficient rainfall to provide moisture for plant growth. The ability of any surface water system to support irrigation schemes depends on how much water that can be made available during the dry season when there is little or no recharge from precipitation. Crop water requirement comes into focus when water resources under study is to supply water for irrigation purpose. Loucks et al. (1991) explained that annual variation of stream flow is a key factor bearing the degree of regulation required on any particular surface water system to meet the demand for agricultural and industrial uses. They said most variation in annual stream flow occur from year to year and over a long period of years as a result of variation in climate. This statement was collaborated by

Lebel et al; (1997). The critical period of planning irrigation schemes on surface water system are the sequences necessary to supplement natural flow to meet agricultural water demand. Popoola, (1974) explained that the mean annual runoff of major streams in Nigeria at pre-determined point is estimated on the average for a specific period of year which can be used to design and construct reservoir for storage of stream runoff.

The Federal Ministry of Water Resources (1990) suggested to the Benin-Owena River Basin Development Authority that rivers Owena and Ogbese have potentials for irrigation purposes, which should be developed through the construction of small-scale dams, water reservoirs and other water intake structures that can store excess water during the pick flow for use during the dry season. Crops with short duration to maturity can be nurtured to increase the agricultural activities of this catchment area.

2.5.0 **Forecasting Tools:**

Univariate procedures involve using extrapolation of trend curves, for long term forecasting. It is often useful to fit a trend curve (or growth curve) to successive yearly/monthly tools and extrapolate. This was discussed by Harrison and Pearce, (1972) and Gilchrist (1976). A variety of curves may be tried including polynomial, exponential, and Gompertz curves. At least 7-10 years historical data are required, but Harrison and Pearce suggested that one should not make forecast for a longer period than halve of period of years for which data are available. The method is suited for long term forecasting especially in the case of a complicated model. Some of the forecasting tools are enumerated below:

Exponential Smoothening: This forecasting procedure was first suggested by Holt, in 1958, Gardner (1985), It should only be used in its basic form for non-seasonal time-series showing no systematic trend. There are many time-series, which arise in practice, which do contain a trend or seasonal pattern. In other cases this effect can be measured and removed to produce a stationary series. In other words, the adaptation of the exponential smoothening can be used for many types of series. Gradner, (1985) are a general review given a non-seasonal time-series with no systematic trend, as follows, for *a series of observations,*

$X_1, X_2, \ldots\ldots\ldots\ldots X_n$, it is natural to take as an estimate of $X_{n+1}$ a weighted sum of the past observations.

$$X(N,1) = C_o X_N + C_1 X_{N-1} + C_2 X_{N-2} + \ldots\ldots\ldots \quad (2)$$

Where the (Ci) are weights. It seems sensible to give more weight to recent observation and less weight to past observation.

An intuitively appealing sets of weights are geometric weights, which decreases by a constant ratio. In order that the weight sum to one, we take:

$$C_i = \alpha(1-\alpha)^i \qquad i = 0, 1, 2, \ldots\ldots$$

Where $\alpha$ is a constant such that $0<\alpha<1$. Then equation 1 becomes:

$$X(N,1) = \alpha X_N + \alpha(1-\alpha)X_{N-1} + \alpha(1-\alpha)^2 X_{N-2} + \ldots\ldots \quad (3)$$

Equation 2 therefore becomes an infinite number of past observations. It is therefore customarily rewritten in finite number form as:

$$X(N,1) = \alpha X_N + (1-\alpha)[\alpha X_{N-1} + \alpha(1-\alpha)X_{N-2} + \ldots] = \alpha X_N + (1-\alpha)X(N-1, 1) \ldots\ldots (4)$$

If we set X (1,1) = X1, then equation (3) can be recursively to compute forecast. This reduces the amount of arithmetic involved since forecast can easily be updated using only the latest observation and the previous forecast. Then the procedure is defined as exponential smoothening.

Equation 3 is sometimes rewritten as :

$X(N,1) \quad = \alpha[X_N - X(N-1,1)] + X(N-1,1) = \alpha\epsilon_N + X(N-1,1)$ ........................(5)

Where $\epsilon_N$ = XN-X(N-1,1) is the prediction error at time N. It can be shown that exponential smoothening is optimal if the underlying model for the time series is give by

$$X_t \quad = \quad \mu + \alpha \sum_{j<t} Z_j + Z_t \quad \text{.......................... (6)}$$

This infinite moving average process is non-stationary, but the first differences $(X_{t+1} - X_t)$ form a first-order moving average process so that $X_t$ is an Auto Regressive Integrated Moving Average (ARIMA) (0, 1, 1) process

Holt-Winter forecasting procedures: Exponential smoothening may readily generalized to deal with time series containing trend and seasonal variations. The resulting procedures of Winters, (1960) as reported by Chatfield and Yar, (1988) involve trend and seasonal term smoothening based on past data. He explained that the observations were monthly. Let $L_t$, $T_t$, $I_t$ denote level, trend and seasonal index respectively at time t. Thus $T_t$ is the expected increase or decrease per month in the current level. Let α, γ and σ denote the three smoothening parameters for updating the level, trend and seasonal index respectively. The smoothening parameters are usually chosen in the range (0,1). Then, when a new observation $X_t$ is available, the value of $L_t$, $T_t$ and $I_t$ are all updates. If the seasonal variation is multiplicative, then the recurrent forms of updating equation are:

$$L_t \quad = \quad \alpha(X_t/I_{t-12}) + (1-\alpha)(L_{t-1}+T_{t-1}) \quad \text{.......................(7)}$$

$$T_t \quad = \gamma(L_t - L_{t-1}) + (1-\gamma)T_{t-1} \quad \text{.......................(8)}$$

$$I_t \quad = \sigma(X_t/L_t) + (1-\sigma)I_{t-12} \quad \text{.......................(9)}$$

And the forecast from time t are then given as:

$X(t,k) = (L_t + kT_t)I_{t-12+k}$ ..........................................................(10)

For k = 1,2, ..........12. There are analogous formulae for the additives seasonal case.

The Box-Jenkins Procedure: Studies has shown that Box-Jenkins gives a more accurate forecast than univariate methods. Box and Jenkins (1976) base their forecasting procedures on Auto Regressive Integrated Moving Average (ARIMA) models, which is usually known as Box-Jenkins approach. The main stages in setting Box-Jenkins forecasting models are based on the following: model identification, estimation, diagnostic checking and considered alternative model if necessary. Box-Jenkins has been useful for both seasonal and non-seasonal data, the adequacy of the fitted model has been provided for by the diagnostic checking.

Other Methods:

Several other forecasting methods have been proposed. Brown, (1963) called general exponential smoothening that consists of fitting polynomial sinusoidal or exponential function to the data and finding appropriate updating formulae. Harrison, (1965) has proposed a modification of seasonal exponential smoothening that consists essentially of performing a Fourier series analysis of the seasonal factor and replacing them by smoothed factor. Also, Harrison and Steven, (1976) proposed a technique called Bayesian Forecasting, which depends on a model called the Dynamic Linear Model. The Bayesian approach also enable analyst to consider the case where several different models were entertained and if is required to choose a single model to represent the process, or alternatively, to compute forecast which are based on several alternative possible models.

Another proposed technique called Adaptive Filtering. Makridakis and Wheelwright, (1977) appears technically unfit for most engineering projects. The Box-Jenkins procedure was fully adopted and reported in the materials and method of this work. Moreover, computer programmes have been developed which can handle forecasting assignment in variability studies. The computer package Microsoft Excel was used for analyzing the data for this research work.

# CHAPTER THREE

## 3.0 RESEARCH METHODOLOGY

## 3.1 DESCRIPTION OF THE STUDY AREA AND INSTRUMENTATION

Ekiti and Ondo States constitute the area under study and are both located in the South-western part of Nigeria. The two rivers under study are rivers Ogbese and River Owena which lie within latitude 7°36'N and longitude 5°20'E and latitude 7°12'N and longitude 5°01'E respectively. The mean annual rainfalls for both areas are 1200 mm and 1350 mm; Ekiti state is classified under the sub humid zone while Ondo State is classified in the humid tropical zone. (Jagtag and Alabi, 1997).

The total drainage area of river Ogbese and Owena for this study is given as 850.00 $km^2$ and 783.00 $km^2$ respectively. The hydrological features, readings and accuracies of instrument used for the hydrological data measurement for the two rivers are presented in Tables (3.1) and (3.2).

Table 3.1 Summary of Hydrological and weather characteristic of river Ogbese and river Owena.

| Agroecological features | River Ogbese area | River Owena area |
|---|---|---|
| Longitude | 5°20'E | 5°01'E |
| Latitude | 7°36'N | 7°12'N |
| Climatic zonation | Sub humid | Humid tropical |
| Rainfall pattern | Bimodal | Bimodal |
| Drainage area | 850.00 $km^2$ | 783.00 $km^2$ |
| Name of gauging station | Ago-Aduloju | Owena |
| Mean Rainfall | 1200 mm | 1350 mm |
| Installation | S.G. & A.R. | S.G. & A.R. |

Source: Benin Owena Hydrological year book vol. III 1994

Table 3.2 Instrumentation on both Rivers

| Parameter | Instrument | Accuracy | Unit |
|---|---|---|---|
| River discharge | Automatic recorder | 0.1 | $m^3s^{-1}$ |
| River stage | Staff gauge | 0.1 | M |
| Rainfall | Universal self recording rain gauge | 0.2 | mm |
| Solar radiation | L1200X Pyranometer | 3% | M |
| Evaporation | US class A pan | 0.01 | mm |
| Temperature | Casella min & max. Thermometer | 0.1 | °C |

Source: Benin Owena Hydrological Year Book Vol. III 1994

## 3.2 DATA COLLECTION

3.2.1 The meterological data for this study were obtained from Benin-Owena River Basin Development Authority and Federal Ministry of Water Resources. The two agencies are renowned for accurate water resources data in Nigeria. Preliminary analysis of the data has been published in the hydrological yearbook and is available in various volumes. The data for all the major rivers in the Benin-Owena catchment of the Authority were collected by well-trained personnel of the agencies and data and computation unit of the agencies and hence can be considered reliable. This is essential because reliable river data for long period of about 10 years and above are not easy to come by. The hydrological and meterological parameters collected on daily basis include: river discharge, river stage, run off volume, while meterological parameters include rainfall, pan evapotranspiration, temperature, wind speed and solar radiation. All the parameters were found to be consistent although there were few instances of instrument failure with missing data.

## 3.3. VALIDATION OF DATA

On the data validation, missing data was constituted by weighing the surrounding reading and nearest year data and the use of regression method Mollar and Cook (1996). Data analysis was carried out using Microsoft Excel version 5.0 software package. The software was used to plot the graphs of most of these parameters in order to see the trends of these data and to verify the extent of consistency for forecasting.

KUR

## 3.4 DATA COLLECTED ON YIELD UNDER RAINFED AGRICULTURE

The yield data used in this study was collected from FOS (1998). The data was inputs on the food production for estimating the amount of water needed for improved agricultural production from irrigation planning. The rivers were found to possess potential to irrigate farmland between the months of January to April, and also November to December a calculated length of 180 days of every year.

## 3.5 COMPUTATIONAL AND STATISTICAL METHODS

Specific statistical procedure used in the study include regression, analysis of variance, standard deviation and the forecasting tools on both short and long term basis are described below.

## 3.6 BOX AND JENKINS FORECASTING PROCEDURES

Box and Jenkins developed three concepts of identification, estimation and diagnostic checking for arriving at a forecasting model for a specific time series. The procedure was adopted to forecast the water resources availability of the rivers under study. Forecasting equation was developed from the model. This forecasting equation used historical data up to 10 years and including the near current time period T. It used both the derivation of the forecasting equation and the use of past data in modeling forecast; using standard error of the log K into correlation is

$$S_{rk} = \sqrt{1/n}\,(1 + 2\sum_{j=1}^{k=1} r_j^2 \qquad \text{.....(11)}$$

where $S_{rk}$ = standard error of the auto correlation for lag k

n = number of auto correlations

rj = sample auto correlation at lag j

The data were modeled as follows

$$(1 - \varnothing_1 B - \varnothing_2 B^2)(1 - B)^1 Z_t = a_t (1 - \theta B) \quad \text{.........} \quad (12)$$

Using Box Jenkins examples as model coefficient

$\varnothing_1 = 0.5$

$\varnothing_2 = 0.3$

$\theta_1 = 0.25$

Rearrange equation 3.2 above as:

$$(1 - 0.5B - 0.3B^2)(1 - B)Z_t = a_t (1 - 0.25B) \quad \text{.........} \quad (13)$$

$$(1 - 0.5B - 0.3B^2 - B + 0.5B^2 + 0.3B^3) Z_t = a_t (1 - 0.25B) \quad \text{.........} \quad (14)$$

$$(1 - 1.5B + 0.2B^2 + 0.3B^3) Z_t = a_t (1 - 0.25B) \quad \text{.........} \quad (15)$$

$$Z_t - 1.5Z_{t-1} + 0.2Z_{t-2} + 03Z_{t-3} = a_t - 0.25a_{t-1} \quad \text{.........} \quad (16)$$

$$Z_t = 1.5Z_{t-1} - 0.2Z_{t-2} - 0.3Z_{t-3} + a_t - 0.25a_{t-1} \quad \text{.........} \quad (17)$$

Where:

B = Back shift operator (polynomial)

$Z_t$ = Difference between observed value in period t and t-1

$a_t$ = normally distributed random variables of data sets

To forecast the ith period in the future at the end of the current period, the forecasting equation becomes

$$Z_T(l) = 1.5Z_{T+l-1} - 0.2Z_{T+l-2} - 0.3Z_{T+l-3} + a_{T+l} - 0.25a_{T+l-1} \quad \text{.........} \quad (18)$$

where T is the forecast origin, which can be shown as our data origin.

The confidence limit for the forecast were calculated using both past data and the model coefficient ($\varnothing$ and $\theta$) which are used to determine a series of weight ($\psi_1$) applied to the past time series data in determining the confidence limit.

To calculate the weight, the coefficient of the data identifies in the ARIMA model is equated in powers of B.

$$\varnothing_p (B)\psi(B) = \theta_p (B) \qquad (19)$$

$$(1 - \varnothing_1 B^1 \ldots\ldots - \varnothing_p B^p)(1 + \psi_1 B + \psi_2 B^2 \ldots\ldots) = (1 - \theta_1 B - \theta_2 B^2 \ldots\ldots - \theta_q B^q) \qquad (20)$$

knowing the values of the $\varnothing$'s and $\theta$'s in a particular model the weight $\psi$'s are calculated as follows:

$$\psi_1 = 1 - \theta_1$$

$$\psi_2 = \varnothing_1 \psi_1 + \varnothing_2 - \theta_2$$

$$\psi_j = \varnothing_1 \psi_{j-1} + \ldots\ldots + \varnothing_p \psi_{j-p} - \theta_q \qquad (21)$$

Both the $\psi_i$ weights and the forecast error are the combined to calculate the variance of the forecast error for the ith period in the future v(p) using

$$V(R) = \{1 + \sum_{j=1}^{l=1} \psi_j^2\}^2 Sa \qquad (22)$$

Once a statistical significance level u is specified a confidence limit can be determined for the ith period in the future using:

$$Z_{T+1}(\pm) = Z_T(l) \pm u1 + \left\{ \sum_{j=1}^{e=1} \psi_j^2 \right\}^{1/2} Sa \qquad (23)$$

$$\text{where } S^2_a = \frac{\sum_{t=b+1}^{N} a_t^2}{N-b-p-pl-q-ql-m} \quad \text{--------------------- (24)}$$

where N = the total number of observation

$b = p+pl+d+(dl.s)$

p1, pl, q, ql are parameter of the ARMA model.

$$M = \begin{cases} 1 & \text{if } d = 0 \text{ and } dl = 0 \\ 0 & \text{otherwise} \end{cases}$$

$a_t^2 = (Z_t - z_t)^2$

The sequence of the confidence limit can be considered for all future periods.

3.7 Forecast Model Development

An analysis of data collected were plotted to show the trend of its time series for rivers Ogbese and Owena, as compiled and published in the Hydrological yearbook of Benin-Owena River Basin Development Authority. The data were processed and divided into two parts vis-à-vis river stage and river discharge. The plotted data shows a near identical trend when compared with rainfall pattern of the same period. Due to lack of sufficient data, five years record data were selected and used as a model for forecasting on short term forecast (i.e. 1989-1993), while the available ten year data set were adapted as model for the long term forecast (1989-1999). This is to ensure equal variance throughout the time series. The time series event for the River discharge is a non-stationary time series. The mean value increases over time as rainfall increases, indicating differencing is needed to achieve the result.

## 3.8 Limitation For the Study

The forecasting tool available for any forecasting study when adapted manually can be very rigorous and tedious. Also, the available data for the two rivers were those supplied by the authorized Federal Government agency which are very limited in years of record. The Box-Jenkins forecasting tool was adopted for this work through the use of a computer software (Microsoft Excel 5 package).

# CHAPTER FOUR

## 4.0 RESULTS AND DISCUSSION

### 4.1 Annual Rainfall Variability

There are wide ranges of rainfall fluctuation for some period of time which lead to inconsistency in the expected volumes in steam flow through the catchments area of rivers Ogbese and Owena at their respective gauging station.

Table 4.1 shows the annual rainfall total in Akure, which was adapted for the study because of non-availability of good and accurate rain data in the villages where the river studies were located. The mean annual rainfall for the 10 years record for Akure was 1346 mm. Detailed examination of rainfall amounts revealed that annual rainfall amount for 5 years was above the annual average for the 10-year record for Akure. The maximum amount of rainfall recorded at Akure (1855 mm) 1991 while the lowest value was recorded at Akure in 1993 (968 mm). Using 5 years each for basis of comparism, annual rainfall total value during the first 5 years (1993) was greater than the total value during the second 5 years average (1994-1998). This is a sharp contrast to the prevailing condition of declining rainfall in many part of the world (IITA, 1994).

Table 4.1: Annual Rainfall Summary for Akure in mm.

| YEAR | SUM (mm) | Mean Monthly Average (mm) | STDEV |
|---|---|---|---|
| 1989 | 1456 | 121.3 | ±112.2 |
| 1990 | 1591.5 | 132.6 | ±115.8 |
| 1991 | 1855.9 | 154.7 | ±125.9 |
| 1992 | 1438.8 | 119.9 | ±116.4 |
| 1993 | 968.2 | 80.7 | ±74.2 |
| 1994 | 966.4 | 80.5 | ±82.8 |
| 1995 | 1447.6 | 120.6 | ±107.2 |
| 1996 | 1200.1 | 100.0 | ±84.8 |
| 1997 | 1257.6 | 104.8 | ±85.8 |
| 1998 | 1280.7 | 106.7 | ±83.1 |

Source: Federal Airport Authority of Nigeria Akure

## 4.2 Annual Flow Regimes Variability

Most rivers in Southwestern Nigeria are recharged mainly from rainfall. It was observed that the pattern of rainfall in the study area and the behaviour of the river parameters used for the study follow a simple trend, Fig 1a and b indicate that inflows through into the main body of these rivers are from the rainfall occurring at their respective catchment areas.

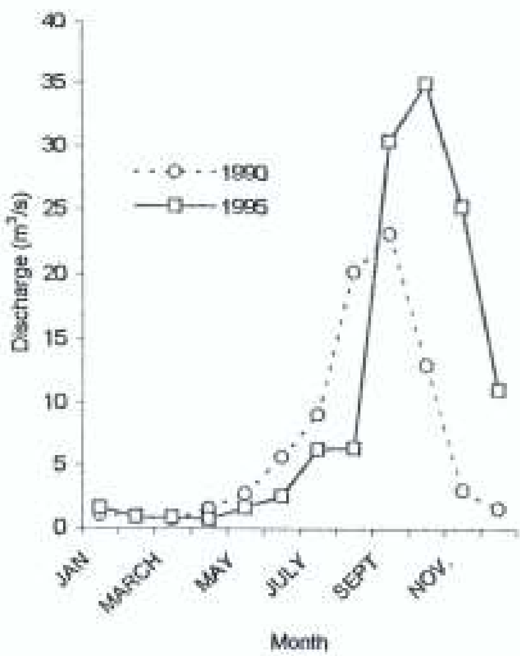


Fig. 1b: The Trend of River Discharge of River Owena

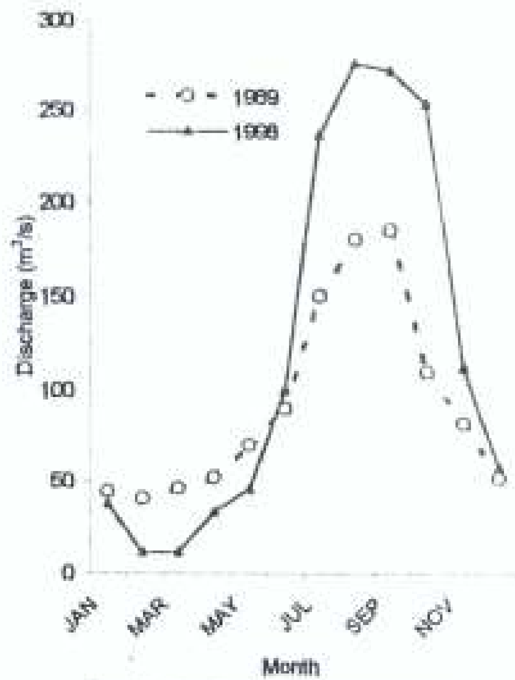


Fig. 1a: The Trend of River Dicharge of River Ogbese

Table 4.2 shows the summary of the annual flow regimes variability of the two rivers Ogbese and Owena, used for this study. For the two rivers Ogbese and Owena the river discharge and stage were analysed for the ten-year period. The average/ mean annual discharge, standard deviation and coefficient of variation were found to be 325.0 $m^3/s$, 170.3 and 1.9 respectively for river Ogbese and 105.7 $m^3/s$, 48.63, 2.2 respectively for Owena. The river stages for the two rivers show an average stage value of 1218.7 cm and 997.5 cm for Ogbese and Owena respectively. The year 1993 shows a remarkable lowest discharge value of 63.7 $m^3/s$ and 53.2 $m^3/s$ for Ogbese and Owena respectively. Also there was a corresponding lower rainfall value in the corresponding period for the study area. This shows there is a high correlation between rainfall and streams flows in the study area.

Table 4.2: ANNUAL FLOW REGIMES VARIABILITIES FOR RIVER DISCHARGE AND STAGE

| | | River Discharge ($m^3s^{-1}$) | | River Stage (cm) | |
|---|---|---|---|---|---|
| | YEAR | OGBESE | OWENA | OGBESE | OWENA |
| | 1989 | 427.5 | 62.1 | 1446.1 | 795.9 |
| | 1990 | 226.6 | 21.7 | 989.9 | 492.3 |
| | 1991 | 105.6 | 155.7 | 1485.3 | 1288.6 |
| | 1992 | 282.4 | 114.0 | 1306.3 | 1208.2 |
| | 1993 | 63.7 | 53.2 | 1010.8 | 608.2 |
| | 1994 | 653.8 | 77.8 | 782.1 | 999.8 |
| | 1995 | 418.8 | 124.8 | 1523.4 | 1053 |
| | 1996 | 383.5 | 158.8 | 1469.3 | 1170.7 |
| | 1997 | 3158 | 145.9 | 1071.3 | 1246.6 |
| | 1998 | 372.5 | 143.4 | 1102.9 | 1112.1 |
| Average | | 324.9 | 105.7 | 1218.7 | 997.5 |
| Standard Deviation | | 170.3 | 48.6 | 259.8 | 275.8 |
| Coefficient of Variation | | 1.9 | 2.2 | 4.7 | 3.6 |

Rainfall is undoubtedly the most important climate variable, and it has far-reaching influences on recharge to surface water system in Southwestern Nigeria and the Agricultural production. The crucial role of rainfall plays in agriculture includes the supply of moisture to the soil to activate plant growth, to replenish water in rivers to make irrigation possible and, through seepage and percolation, to build underground water reserves which are later tapped by wells in dryer areas. Fig (2) shows the mean annual rainfall distribution in Nigeria. A South-North gradation in rainfall amount is noticeable. Fig (3) shows the areas with less than 100 mm rainfall. Nigeria is marked by an alternation of wet and dry season of varying duration. In the wetter south, the dry period lasts from about three to five months and this increases to up to nine month in the sahelian zone. Fig.4 shows the analysis of average rainfall and potential evapotranspiration rate (ET) plotted against time for Akure. It indicates that, there were three district regions on the graphs, the 1st and 3rd region shows water deficit, and this necessitate the need for irrigation schemes using the water excesses from 2nd region of the analysis graphs. The available rainfall in region 1 and 3 cannot support agricultural activities,. The timing of planting operations and the number and type of food crops of the study area are influenced by the onset of rains and the region and the duration of the wet set season. (Walter, 1968). The moisture balance over Nigeria have been analyzed and commented upon in some studies (Garnier, 1960; Dvies, 1966; Ojo, 1969). Despite the differences of approach, the maps of moisture balance which emerge are similar, and they all exhibit district regional and seasonal features which compared favourably with south-western Nigeria moisture balance.

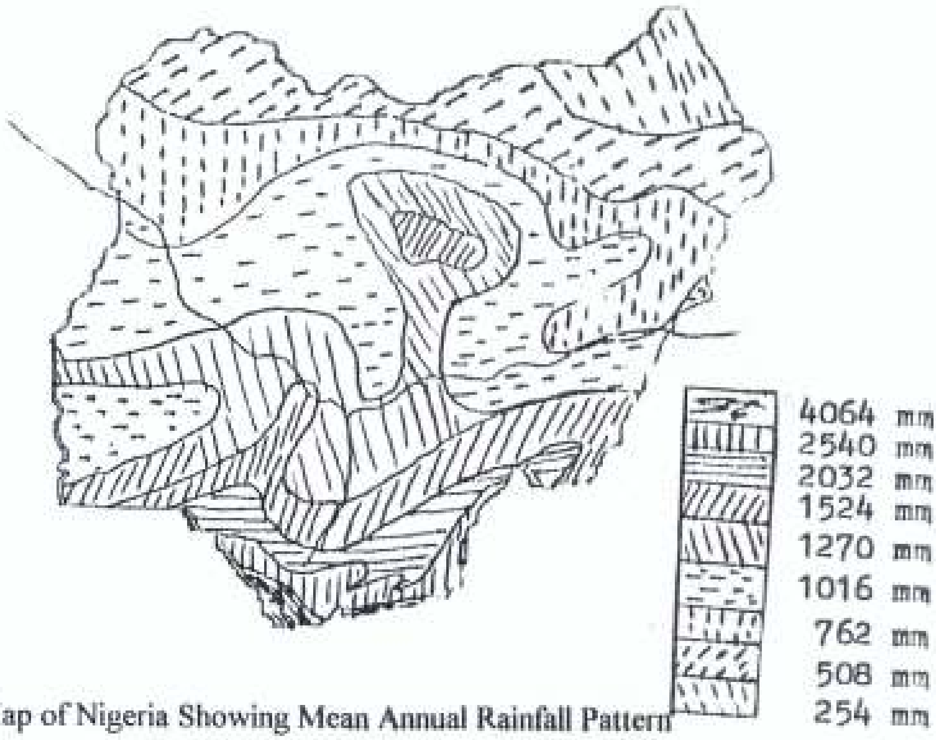


Fig. 2: Map of Nigeria Showing Mean Annual Rainfall Pattern

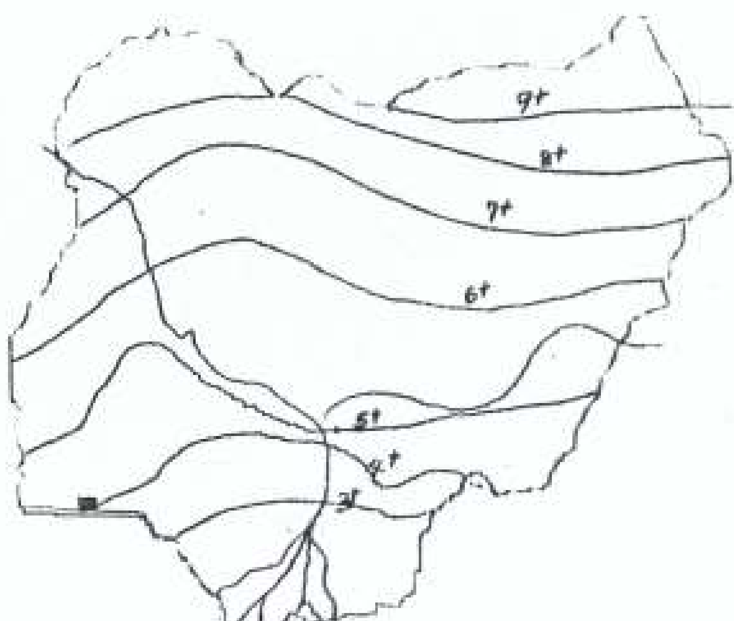


Fig. 3: Map of Nigeria Showing Area With Less Than 100 mm of Rainfall

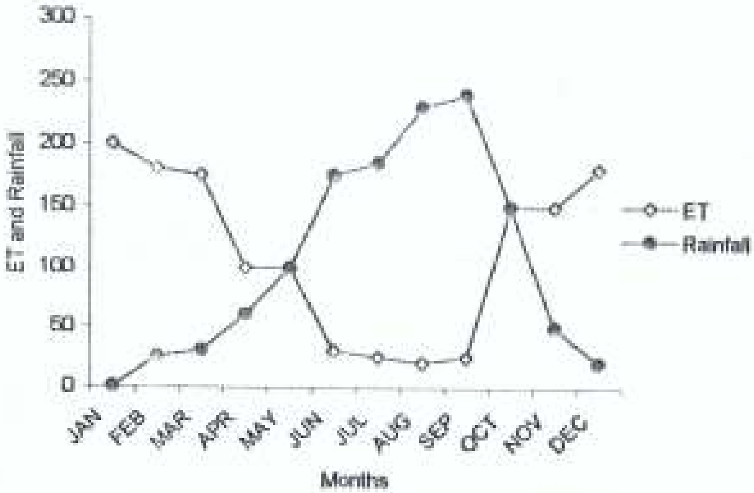


**Fig. 4: Rainfall and Evapotranspiration Rate in Akure**

River discharge and stage Analysis

The analysis of the two rivers Ogbese and Owena was done using micro-soft Excel package. Tables (2a and b) shows the average monthly data for river discharge and stage respectively for Ogbese river measured at Ago-Aduloju. Also Tables (4a and b) show data for Owena river discharge and stage respectively as measured at Owena.

**Table 4.3a** **RIVER DISCHARGE OF RIVER OBGESE (AGO ADULOJU) $m^3s^{-1}$**

| YEAR | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEPT | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1989 | 0.34 | 0.00 | 0.03 | 0.23 | 0.89 | 12.36 | 77.04 | 116.39 | 114.06 | 95.98 | 9.24 | 0.96 |
| 1990 | 0.55 | 1.57 | 0.06 | 0.54 | 4.08 | 28.29 | 102.98 | 79.10 | 56.66 | 101.07 | 16.75 | 9.41 |
| 1991 | 0.15 | 1.15 | 3.10 | 0.34 | 2.75 | 20.65 | 45.39 | 86.23 | 55.92 | 86.08 | 23.46 | 1.43 |
| 1992 | 0.47 | 0.11 | 1.70 | 0.64 | 3.28 | 6.03 | 1.54 | 63.15 | 66.16 | 121.21 | 17.56 | 0.90 |
| 1993 | 0.68 | 0.49 | 0.45 | 0.92 | 0.88 | 1.69 | 2.47 | 20.49 | 18.93 | 16.71 | 33.03 | 4.22 |
| 1994 | 0.74 | 0.51 | 0.48 | 1.02 | 1.12 | 21.85 | 130.52 | 145.74 | 60.34 | 120.35 | 60.75 | 10.34 |
| 1995 | 0.69 | 0.58 | 0.50 | 1.34 | 1.52 | 25.73 | 60.31 | 110.31 | 99.41 | 83.57 | 30.35 | 4.45 |
| 1996 | 1.00 | 0.93 | 1.05 | 1.11 | 1.93 | 12.45 | 20.23 | 83.47 | 130.13 | 101.31 | 20.42 | 9.43 |
| 1997 | 0.67 | 0.53 | 1.00 | 1.23 | 2.43 | 11.31 | 20.12 | 60.14 | 84.51 | 102.43 | 20.59 | 10.21 |
| 1998 | 0.48 | 0.21 | 0.31 | 0.74 | 1.11 | 20.75 | 51.32 | 75.31 | 95.21 | 100.25 | 25.52 | 0.46 |
| Average | 0.58 | 0.61 | 0.87 | 0.81 | 2.00 | 16.11 | 51.19 | 84.03 | 78.13 | 92.90 | 25.77 | 5.16 |

Table. 4.3b River Stage of River Ogbese (Ago Aduloju) (cm)

| YEAR | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1989 | 37.87 | 11.29 | 11.68 | 33.13 | 45.32 | 100.33 | 236.07 | 275.69 | 271.67 | 253.13 | 112.4 | 57.55 |
| 1990 | 42 | 59.93 | 20.06 | 40.77 | 83.48 | 166.9 | 264.9 | 236.58 | 0 | 0 | 0 | 75.35 |
| 1991 | 20.16 | 53.04 | 61.84 | 66.79 | 192.41 | 147.96 | 281.06 | 228.4 | 217.4 | 275.33 | 146.75 | 64.45 |
| 1992 | 45.55 | 27.97 | 0 | 58.1 | 81.71 | 104.77 | 57.43 | 222.03 | 232.37 | 280.97 | 139.2 | 56.19 |
| 1993 | 50.45 | 44.46 | 44.71 | 54.43 | 55.93 | 69 | 77.16 | 149.03 | 149.97 | 149.1 | 0 | 0 |
| 1994 | 58.41 | 48.31 | 45.38 | 60.51 | 51.21 | 60.01 | 70.31 | 120.35 | 101.35 | 65.03 | 60.75 | 40.12 |
| 1995 | 40.01 | 50.3 | 60.11 | 80.41 | 160.13 | 130.12 | 200 | 240.16 | 236.35 | 180.41 | 100.21 | 45.16 |
| 1996 | 14.14 | 40.1 | 50.46 | 80.28 | 101.72 | 110.17 | 220.17 | 20.06 | 230.17 | 170.14 | 120.78 | 48.2 |
| 1997 | 45.16 | 30.46 | 25.11 | 40.66 | 58.17 | 80.11 | 140.45 | 201.21 | 190.5 | 120.46 | 90.42 | 48.66 |
| 1998 | 44.27 | 40.52 | 46.33 | 52.17 | 70.12 | 90.19 | 150.18 | 180.12 | 185.13 | 110.14 | 82.14 | 51.55 |
| 1989 | 37.87 | 11.29 | 11.68 | 33.13 | 45.32 | 100.33 | 236.07 | 275.69 | 271.67 | 253.13 | 112.4 | 57.55 |

AKURE

Table 4.4a: RIVER DISCHARGE OF RIVER OWENA (STATIONED AT OWENA ) $m^3s^{-1}$

| YEAR | JAN | FEB. | MAR | APRIL | MAY | JUNE | JULY | AUG | SEPT | OCT. | NOV. | DEC. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1989 | 0.95 | 1.2 | 1.6 | 1.5 | 2.6 | 7.025 | 9.461 | 10.451 | 15.545 | 14.032 | 3.059 | 1.537 |
| 1990 | 1.014 | 0.915 | 0.652 | 1.539 | 2.736 | 5.686 | 9.136 | 20.23 | 23.21 | 13.06 | 3.01 | 1.61 |
| 1991 | 0.981 | 1.51 | 1.323 | 1.687 | 7.263 | 6.08 | 43.984 | 41.239 | 30.33 | 13.648 | 4.253 | 3.394 |
| 1992 | 2.14 | 1.5 | 1.365 | 2.341 | 3.736 | 7.213 | 10.5 | 12.606 | 45.795 | 15.533 | 7.643 | 3.601 |
| 1993 | 1.65 | 1.21 | 1.01 | 1.69 | 2.68 | 2.89 | 3.904 | 3.602 | 16.957 | 21.333 | 5.198 | 2.205 |
| 1994 | 1.207 | 0.996 | 0.934 | 0.855 | 1.188 | 1.968 | 5.512 | 6.248 | 5.218 | 33.225 | 20.458 | 5.23 |
| 1995 | 1.531 | 0.852 | 0.8 | 0.732 | 1.61 | 2.531 | 6.341 | 6.432 | 30.432 | 35.021 | 25.331 | 11.12 |
| 1996 | 8.32 | 4.025 | 2.451 | 2.551 | 3.461 | 6.3 | 15.421 | 38.211 | 42.231 | 20.003 | 12.241 | 4.612 |
| 1997 | 0.879 | 0.7251 | 0.7 | 1.253 | 3 | 12.531 | 14.331 | 33.421 | 35.337 | 30.211 | 10.303 | 3.225 |
| 1998 | 1.21 | 1.00 | 0.94 | 0.89 | 2.73 | 4.73 | 10.62 | 24.77 | 28.77 | 31.93 | 25.21 | 11.01 |
| Ave | **1.99** | **1.39** | **1.18** | **1.50** | **3.10** | **5.70** | **12.92** | **19.72** | **27.38** | **22.80** | **11.67** | **4.75** |

Table 4.4bRIVER STAGE OF RIVER OWENA (OWENA VILLAGE) (CM)

| YEAR | JAN | FEB | MARCH | APRIL | MAY | JUNE | JULY | AUG | SEPT | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1989 | 51 | 0 | 0 | 0 | 0 | 102.87 | 115.03 | 119.71 | 139.27 | 133.22 | 74.73 | 60.06 |
| 1990 | 52.13 | 50.32 | 44.61 | 59 | 74.13 | 97.93 | 114.19 | 0 | 0 | 0 | 0 | 0 |
| 1991 | 51.58 | 59.96 | 57.29 | 60.53 | 105.23 | 97.77 | 186.9 | 195.25 | 176 | 131.35 | 86.83 | 79.94 |
| 1992 | 68.42 | 59.93 | 57.1 | 69.57 | 81.16 | 105.4 | 120.32 | 128.55 | 193.63 | 136 | 106.73 | 81.39 |
| 1993 | 0 | 0 | 0 | 0 | 0 | 0 | 84.06 | 81.68 | 136.3 | 143.97 | 93.93 | 68.26 |
| 1994 | 55.39 | 51.66 | 51.29 | 48.97 | 54.77 | 66.17 | 95.03 | 100.58 | 94 | 173.97 | 147.07 | 60.71 |
| 1995 | 56.43 | 50.11 | 49.34 | 47.21 | 55.68 | 67.28 | 105.1 | 120.13 | 150.11 | 161.31 | 120.16 | 70.14 |
| 1996 | 68.31 | 60.81 | 55.11 | 52.23 | 57.66 | 98.73 | 100.15 | 151.21 | 179.69 | 148.16 | 120.11 | 68.53 |
| 1997 | 59.01 | 52.33 | 52.21 | 56.17 | 58.11 | 120.42 | 133.46 | 186.53 | 190.43 | 153.61 | 110.36 | 73.92 |
| 1998 | 57.72 | 56.13 | 54.28 | 52.31 | 61.58 | 95.11 | 100.43 | 120.14 | 161.49 | 179.13 | 105.61 | 68.14 |

Source: Benin-Owena River Basin Development Authority Hydrological Yearbook Vol. i-v

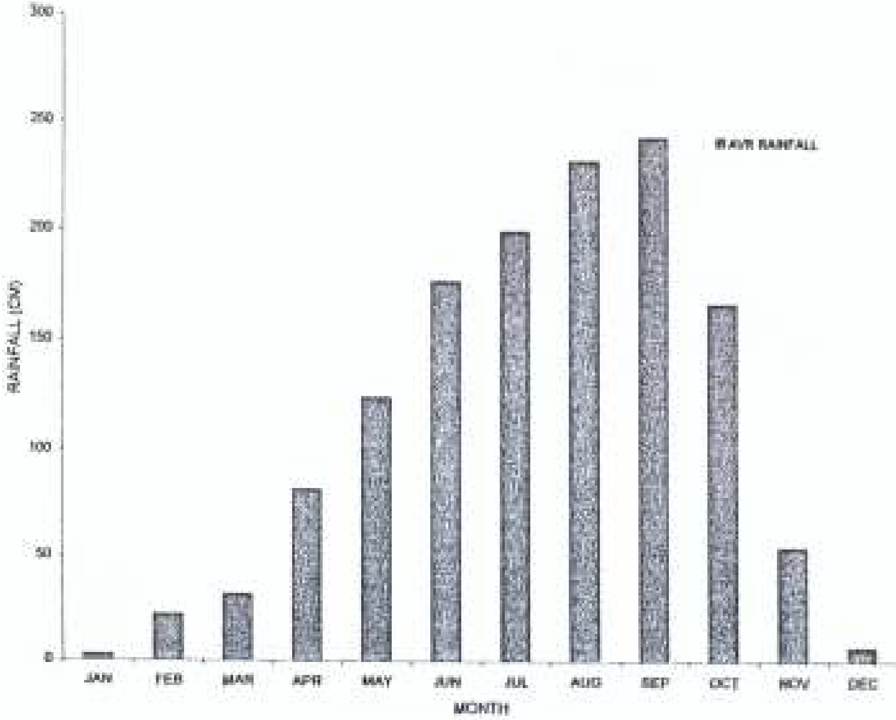


FIG. 5: AVERAGE RAINFALL DATA (1992-1996)

The average value in monthly basis was plotted to show the trends or the behaviour of the data as shown in Fig (1a and b). The trend of the river discharge of Ogbese followed the same trend of rainfall pattern as shown in Fig (4). Between Jan and April there was low level of water but it gradually increases with the onset of rainfall around Mid-May and rises until peak of rainfall in August-Sept through to Oct; then a decline follow till low level around November to December.

**Forecasting modeling Approach.**

In order to present a variable results using the available data a two way model was formulated and forecasting. The model and the forecasted value were subjected to correlation analysis. These are short and long term modeling approaches.

**Short term Modelling**

Five years river data was further subjected to analysis in which the five years data were averaged on monthly basis and fitted to a forecasting model. From the model, five years forecasted value was generated and was compared graphically and a correlation coefficient was shown. The graphs of forecasted value and the model shown in Fig. 6 indicate that there was high degree of accuracy in the forecasted value between Jan and June, from 1st week in June, Both model and forecasted value increases progressively for river Ogbese. The correlation coefficient indicate a depression in value between the month of July and August, as the graph shows a decrease in the value of model and forecasted value. The correlation was particularly lowest in the month of July and Oct, correlation values as high as 98% was recorded in the month of November.

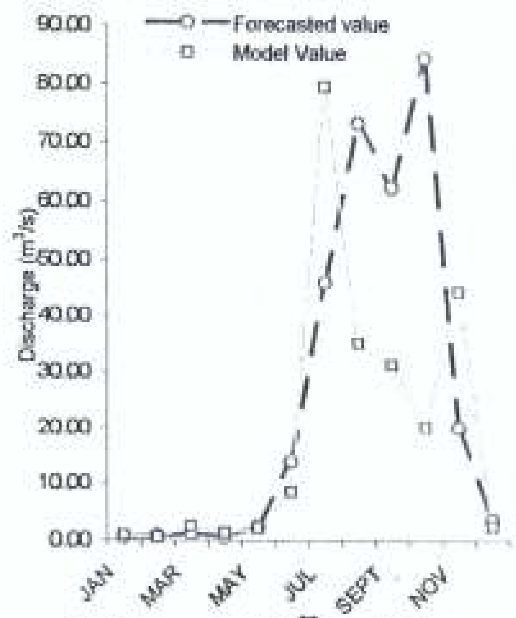


Fig. 6 :Average Model Value Against the Forecasted Value For River Ogbese on Short Term Model Approach

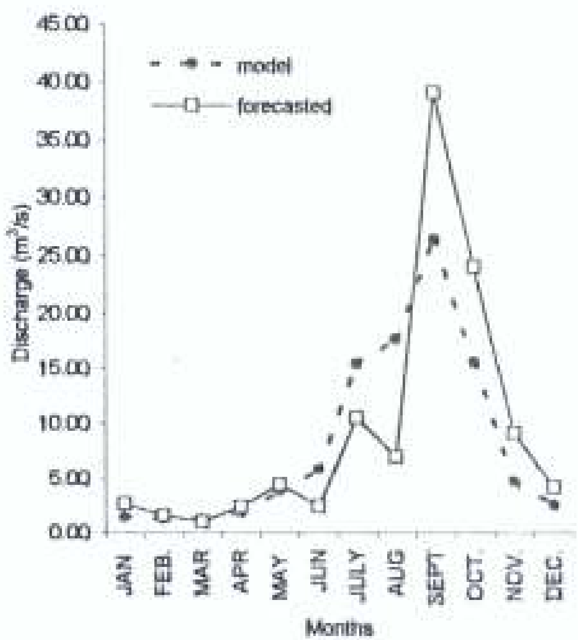


Fig. 7: Average model values and the forecasted value for river Owena on short term modelling approach

For river Owena, 1989-1993 river discharge data were used as model on short term modeling forecast. Fig.7 shows a high correlation in model and the forecasted values. The percentage of accuracy of the model and forecasted value was high when compared with the correlation coefficient, $0 \geq r \leq 1$ from Jan to July about 0.65 and from August to December. The high degree of correlation was about 0.80 to 1.0, which indicates that the model and the forecasted values are near accurate. This shows that the result is highly reliable for future use.

Understanding the reasons for this substantial change in surface water system and rainfall remain major challenges for climate scientist. Various hypothesis remain unresolved including those pertaining to large scale oceanic circulation (Rowell et al, 1995) regional land cover change (Xue, 1997) and regional atmospheric aerosol concentration (Tegen et al, 1996)

**Long Term Modelling Forecast**

The long-term model value was 1989-1998 average river discharge for the two river systems. The model and the forecasted were plotted as shown in Fig. 8. The values for 1989-1998 were used to develop the model and the forecasted values covered 1999-2010. There is high incident of great correlation for river Ogbese as shown below. A gradual increase in the available water from the river follows a similar trend of the rainfall pattern. Between the months of January to May, there is a general low water level hence the model value and the forecasted value is said to have a correlation coefficient of almost ±0.80. From June, then was rise in the volume of water available at the gauging station of river Ogbese at Ago-Aduloju. On careful observation from the graphical analysis the percentage of accuracy of the model and the forecasted value indicate that there was a high degree of accuracy when average value of long term river data were used.

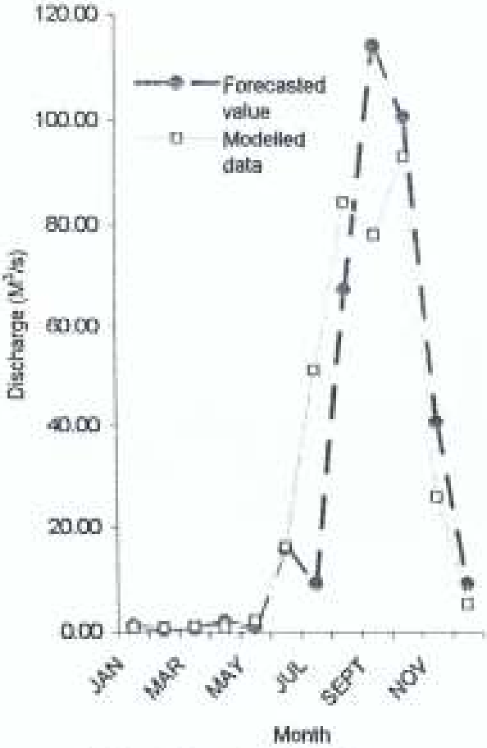


Fig. 8 : Average Model and The Forecasted Value For Long Term Approach

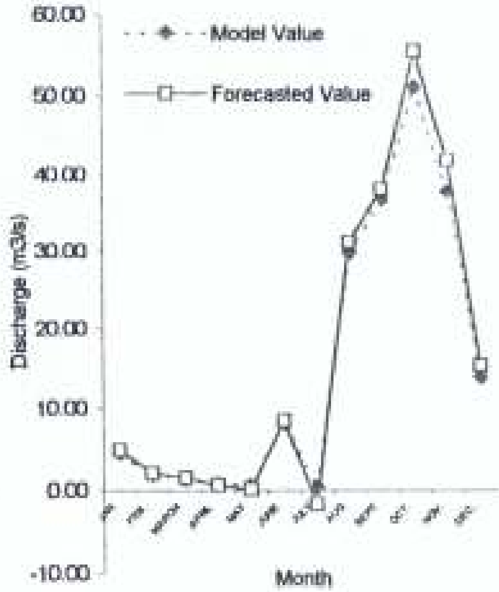


Fig. 9: River Owena River Discharge Against the Forecasted Value on Long Term Approach

The long term modeling approach for river discharge of Owena, as indicated in the Fig. 9 above for 1989-1998 years data was used for the model, the forecasted value of 1999 to 2110 was done from the 10-year river discharge data between the months of January to May. The model and the forecasted value indicate a high degree of correlation of about ±0.80;changes begin to show, from the middle of the month of May. It also shows the characteristic rainfall pattern of the study area, but the forecasted value indicate a rise to about 8.5 $m^3/s$ around mid-May to June. A decline below zero (-ve value) in the table was recorded from the forecasted value. From the month of July there was an astronomical rise in the volume of available water to reach its maximum at mid-Sept of about 55 $m^3/s$ in value. Reduction in the value of available water was recorded from mid-Oct through Dec of the year under review. The overall observation of the model value and the forecasted value of river Owena indicate that the results show a high degree of accuracy which can be attributed to the average value being plotted. Also changes in temperature and rainfall pattern might be responsible for the negative value recorded in the month of May and July. With the exception of rainfall data of 1993, rainfall records were found to demonstrate no pronounced temporal decrease or increase in the supply of runoff to the surface water system though the recharge and drainage basin of these rivers were moderately constant. The river discharge records forecasted above provide the most reliable history of water availability for the study area.

From all indications, it is obvious that, the available water between the month of May and Oct of every year could be estimated as 324.4 $m^3/s$ for the model value and 307.4 $m^3/s$ for the forecasted value can be useed in planning extensive irrigation scheme for the catchment areas of river Ogbese at the gauging station (Ago-Aduloju areas), while 91.6 $m^3/s$ for the model value and 126.1 $m^3/s$ for the forecasted value of river Owena measured at Owena gauging station, can be extensively used also for irrigation purpose within their respective catchment area.

Yields of some major food crop produced within the two states as obtained from FOS (1996) were presented in Figures.10 and Fig.11. It indicates that under rain fed agriculture over the years there was a dramatic reduction in metric tonnes of food crops produced in the growing season of 1991/92 to 1992/93. This period was observed as low rainfall periods, which generally affected agricultural production. Also, from the study area, water resources availability of the rivers Ogbese and Owena can be used to raise the level of agricultural production marginally. The development of surface water system to support agricultural production cannot be over-emphasized in that food and water are basic necessities that man needs for survival on the planet earth.

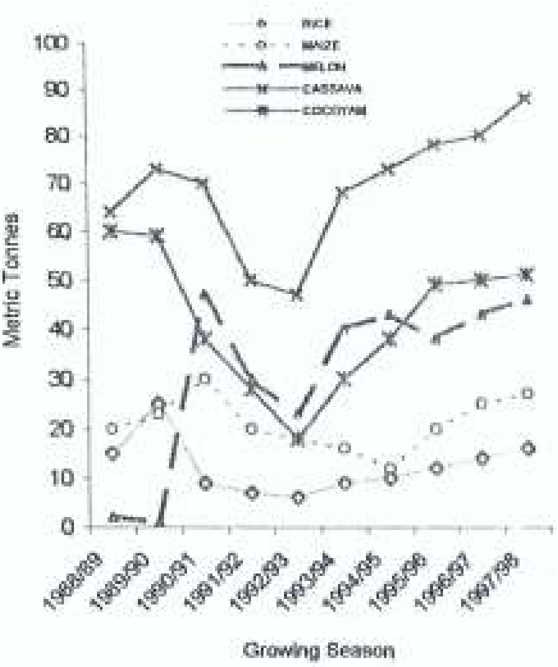


Fig. 10 : The Yield of Major Crops Grown under rain-fed condition in the Study Area

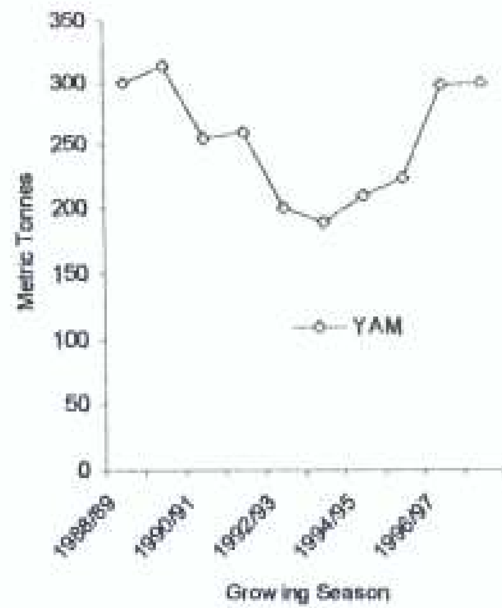


Fig. 11: Yam Yield Under Rain-fed agriculture of The Study Area

Famine and Africa seems to go together because, most developed countries always make adequate preparation for future needs. African countries including Nigeria have been experiencing drought, one of the worst natural disasters in history of mankind. Millions of dollars and many-man-hours have been spent on food relief, drought related services and research projects on drought (Payne et al., 1987). Yet fundamental properties of drought such as the frequency of occurrence and duration are not known with sufficient accuracy to all predictions (Oguntoyinbo, 1986; Kane & Trivedi, 1986). In order for Nigeria to meet her food production need, other uses of our surface water system must be put in place.

**PROSPECTS FOR WATER RESOURCES DEVELOPMENT**

The study area has been found to possess many known seasonal surface water resources, most of these rivers can be dammed through construction of earth dam/stone dam, water diversion structures, canals, channels and other forms of water conveyance structures that will assist farmers to go into irrigation farming. The water at the peak season of rainfall between the months of July and Sept, can be store in a storage reservoir, the average potential evapotranspiration ET of 5.38 mm/day, measured at Akure airport meteorological station which is adopted for the study area. Substantial quantities of water will still be available for use towards the end of the raining season. This indicates that irrigation farming can be incorporated within the months of November and March.

Forecast Error and Confidence Limit

Often forecasts are required for several periods in the future. It is obvious that as we look further into the future less reliability can be put upon these estimates. Changing weather conditions which are natural event such as sudden increase in rainfall intensities leading to greater runoff, in most cases, increase in global temperature (global warming) as a result of human activities, can either increase or decrease the water available to the catchment area and recharge of these rivers and thereby causing a serious shift in actual demands (i.e. model value) from the forecast value/result. We can represent the levels of risk that are exposed to by calculating confidence limit for the future forecast.

# CHAPTER FIVE

## 5.0 CONCLUSIONS AND RECOMMENDATIONS

## 5.1 CONCLUSIONS

Within the limits of the available data, river flow regimes throughout the study area are characterized by marked temporal variability and occasional periodicity. This variability may well be affected in part by some complex climatic parameters, although other factors such as land use changes may also be significant in some cases. However, the primary causes of inter-annual variability is caused by variation in rainfall inputs. Given that annual potential evaporation is relatively constant, a small increase or decrease in rainfall can lead to a marked changes in runoff, which is the difference between rainfall and evaporation, and which make a remarkable seasonal change over much of the drainage basin. Whilst projected climatic and other changes will undoubtedly have an impact upon future runoff, it is apparent that the long-term natural variability of flow regimes throughout the drainage area will continue to result in periods of floods and drought.

As the world moves into another millennium, the rapid increase in the population growth rate put at 3.5% annually (UN; 2000) especially in the third world, which is alarming, and the corresponding demand for water for all types of uses will far outstrip available water supply. Hence, the need for adequate planning, proper Engineering management and control of water resources in such that any water resources development strategies to be undertaken for any beneficial use whatsoever, must rely on reliable data collected on river for a relatively long period of time.

## 5.2 RECOMMENDATIONS

The methodology adopted in this study is useful in taking decision on any non-seasonal surface water system in any region of Nigeria. It can also be used for establishing future trends of river behaviour within the limit of climatic variabilities.

Thus the following are recommended:

1. The study should be adopted for other rivers within the region of study (South-Western Nigeria) to access their suitability for irrigation and other agricultural uses.
2. That further study is done, using a longer year of data above those used in this study.
3. That the model used for this study be subjected to further analysis in order to evaluate its level of accuracy in the model value and the forecast value of data

## REFERENCES

Agboola, S. A. (1985). An agricultural atlas of Nigeria Oxford University Press

Ankomah-Opoku, Y. and Amisigo, B. A. (1998). Rainfall and runoff variability in Southwestern river system in Ghana: Water resources variability in West Africa during the XXth Century (Proceeding of the Abidjan '98 conference held at Abidjan Cote D'Ivorie, Nov. 1998 IAHS Publ. No. 252, 1998.

Benin-Owena River Basin Development Authority (1994). Hydrology Yearbook vol. III.

Box, G. E. P and Jenkins, G. M. (1976). Time series analysis forecasting and control, Revised Edition. Eaglewood Cliff Publishers New Jersey. Prentice Hall

Brown, R. G. (1963). Smoothing, forecasting and prediction, Englewood Cliffs, NJ: Prentice-Hall

Chatfield, C. (1991). The analysis of time series; an introduction 4th edition Published by St. Edmundsbury press Ltd. Bury St Edmund, Suffolk.

Chatfield, C. and Yar, M (1988). Holt-Winters forecasting: some practical issues. The statistician 37, 129-140

Davies J. A. (1966). The assessment of evapotranspiration for Nigeria Geografiska Annaler, Vol. 48A PP 139-56.

Desbois, M. Kayiranga, T. Gramien, B. Guessous, S. and Picon, L. (1988). Characterization of some elements of the Sahelian climate and their inter-annual variation for July 1985 and 1985 from the analysis of METEOSAT ISCCP data. J. Climate Vol. 1(9), P 867-904

Egbuniwe, N. (1976). Public health aspect of tropical water resources development. Water Resources Bull 12(2); 393-408

Farguharson F. A. R. and Sctcliffe J. V. (1998). Water Resources variability in Africa during the XXth century: Edited by Eric Servat, Denis Hughes, Jean-Marie Fritsch and Mike Hulme. IAHS Publication no 252 P 161-109

Federal Ministry of Water Resources (1990). Bulletin on Benin Owena River Basin Development Authority. Vol. I.

Federal Ministry of Water Resources (1994). The Bulletin of the Ministry on River Basin Development Authority

FOS. Federal Office of Statistics (1996) FOS publication on Agricultural activities in Nigeria. Abuja.

FOS. Federal Office of Statistics (1998). Food Production in Nigeria; Federal Office of Statistics Abuja Nigeria

FAO. Food and Agricultural Organization (1966). Publication on water research development Rome.

Fuller, W. A. (1976). Introduction to statistical time series New York John Wiley publishers

Garnier, B. J. (1960). Maps of the water balance in West Africa Bulletin, Institute Franc Afrique Noire, vol.22, PP70-120

Gardner, E. S. Jr. (1985). Exponential smoothening: the state of the art J. Forecasting, 4, 1-28

Gilchrist, W. (1976). Statistical forecasting, London Wiley

Harrison, P. J. and Pearce, S. F. (1972). The use of trends curves as an aid to market forecasting. Industrial Marketing Management, 2 149-170

Harrison, P. J. (1965). Short-term sales forecasting Appl. Statist 14, 102-139

Harrison, P. J. and Steven, C. F. (1976). Bayesian forecasting (with Discussion) J. Royal. Statist. Soc. B, 38, 205-247.

Hughes, D. A. sand Smaklin, V. Y. (1996). Daily flow data time series patching or extension: a spatial integration approach based on flow duration curves. Hydrol. Sci. J. 41(6), 851-871.

IITA, (1994). Rainfall Changes call for shift in cropping practices; the case of Nigeria Annual Report 1994

Jagtab, S. S. and Alabi, R. T. (1997). Reliability of daily, weekly and monthly grass evapotransiration using hourly estimates by Penman method in three agro-ecological zones of West Africa Nig,. Mgt. J 2(1): 59-68

Kane, R. P. and Trivedi, N. B. (1986). Are drought predictable? Journal of Climate Change 8, 209-223

Label, T. and LeBarbe, L. (1997). Rainfall monitoring during HAPEX-Sahel .2. Point and Arial estimation at the event and seasonal scales. J. Hydrology 188-189, 87-122

Lamb P. J. and Peppler, R. A. (1991). West Africa Teleconnection linking worldwide climate anomalies (ed. M. Glantz, Rowkatz and N. Nicholls) P. 121-189 Cambridge University Press U.K.

Le Barbe, L. and Label, T (1997). Rainfall Climatology of the HAPEX Sahel region during the year 1950-1990. Journal of Hydrology 188-189. 43-73

Lebels, T. Taupin, J. D. and D'Amato, N (1997). Rainfall monitoring HAPEX-Sahel 1 General rainfall condition and climatology J. Hydrol. 188-189 74-96.

Linslay, R. K., Joseph, B. Franzini, D. L., Freyberg, G. T. (1987). Water Resources Engineering 4th Edition; McGraw Hill International Edition Civil Engineering Series

Loucks, D. P., Stedinger, J. R., Haith, D. A. (1991). Water resources systems planning and analysis; Prentice Hall International Inc. London

Makridakis, S and Wheelwright, S. C. (1977). Adaptive filtering: an integrated autoregressive/moving average filter for time series forecasting opl. Q28, 425-437.

Mollah, W. S. and Cook, I. M. (1996). Rainfall Variability and Agriculture in the Semi-Arid Tropics. The Northern Territory, Australia Agric and Forestry Met. Journal 79: 39-60.

Nwa, E. U. (1976). Water resources and agricultural development in Nigeria. Paper presented at the 12th Annual Conference of the Agricultural Society of Nigeria, University of Ife (O.A.U. Ile-Ife)

Oguntoyinbo, J. S. (1986). Drought prediction Climatic change 9 79-90

Ojo, O. (1969). Potential evapotranspiration and the water balance in West Africa, an alternative method of Penman, Arch. Met. Geogh Biokl Ser B.17 PP 236-60

Oke, V. A. (1984). Water Resources potential of Ondo State Nigeria: MSc. Thesis of Loughborugh University of Technology. Unpublished.

Ondo State Water Corporation (1998). Bulletin on water activities in Ondo State.

Olufayo, A. A. and Ajayi, A. E. (1998). Analysis of rainfall variability in the sub humid zone of Nigeria; Proceedings of International Conference on water variability in Africa during the XXth century held in Abidjan, 98 Cote D'Ivories.

Oyebade, Lekan and Balogun, Idowu (1997). Water Resources Development in the West Africa beyond the 2000: Problems, Needs and Priorities: Canadian Journal of Development Studies Vol 4 No2 pg 61-70.

Payne, R., Rummel, L and Glantz, M (1987). Denying famine a future: Concluding remarks In Drought and Hunger in Africa (ed by M. H. Glantz) 433-435 Cambridge University press, London U.K. 432-435

Popoola, N. O. (1974). Water Resources planning in Nigeria. In proceeding of the National Irrigation and Agricultural Engineering seminar, Zaria.

Sivakumar, M. U. K., Maidouki, H. H. and Stern, R. D. (1993). "Agroclimatology of West Africa": Niger INCRISAT bulletin 105.

Rowell, D. P., Folland, C. K., Maskell, K and Ward, M. N. (1995). Variability of summer rainfall over tropical North Africa (1906-92) Observation and modeling. Quart J. Roy. Met soc 121, 669-704.

Tegen, I. Lacis, A. A. and Fung, J. (1996). The influence on climate forcing of minerals aerosols from disturbed soil. Nature 380, 419-422

UNO (1981). Publication on population growth and water demand in Developing countries.

UNO (2000). Publication on population growth and food security in Africa

Walter, M. W. (1968). Length of the rainy season in Nigeria. Samaru Research Bulletin, No 103 (Ahmadu Bello University Zaria).

Xue, Y. (1997). Biosphere feedback on regional climate in tropical North Africa. Quart. J Roy. Met. Soc. 123, 1483-255

# APPENDIX

Table 1: RIVER DISCHARGE OF RIVER OWENA (STATIONED AT OWENA )

| YEAR | JAN | FEB. | MARCH | APRIL | MAY | JUNE | JULY | AUG | SEPT | OCT. | NOV. | DEC. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1989 | 0.95 | 1.2 | 1.6 | 1.5 | 2.6 | 7.025 | 9.461 | 10.451 | 15.545 | 14.032 | 3.059 | 1.537 |
| 1990 | 1.014 | 0.915 | 0.652 | 1.539 | 2.736 | 5.686 | 9.136 | 20.23 | 23.21 | 13.06 | 3.01 | 1.61 |
| 1991 | 0.981 | 1.51 | 1.323 | 1.687 | 7.263 | 6.08 | 43.984 | 41.239 | 30.33 | 13.648 | 4.253 | 3.394 |
| 1992 | 2.14 | 1.5 | 1.365 | 2.341 | 3.736 | 7.213 | 10.5 | 12.606 | 45.795 | 15.533 | 7.643 | 3.601 |
| 1993 | 1.65 | 1.21 | 1.01 | 1.69 | 2.68 | 2.89 | 3.904 | 3.602 | 16.957 | 21.333 | 5.198 | 2.205 |
| 1994 | 1.207 | 0.996 | 0.934 | 0.855 | 1.188 | 1.968 | 5.512 | 6.248 | 5.218 | 33.225 | 20.458 | 5.23 |
| 1995 | 1.531 | 0.852 | 0.8 | 0.732 | 1.61 | 2.531 | 6.341 | 6.432 | 30.432 | 35.021 | 25.331 | 11.12 |
| 1996 | 8.32 | 4.025 | 2.451 | 2.551 | 3.461 | 6.3 | 15.421 | 38.211 | 42.231 | 20.003 | 12.241 | 4.612 |
| 1997 | 0.879 | 0.7251 | 0.7 | 1.253 | 3 | 12.531 | 14.331 | 33.421 | 35.337 | 30.211 | 10.303 | 3.225 |
| 1998 | 1.21 | 1.00 | 0.94 | 0.89 | 2.73 | 4.73 | 10.62 | 24.77 | 28.77 | 31.93 | 25.21 | 11.01 |
| Average | 1.99 | 1.39 | 1.18 | 1.50 | 3.10 | 5.70 | 12.92 | 19.72 | 27.38 | 22.80 | 11.67 | 4.75 |

**Table 2: Forecasted value for River Owena on Long term approach**

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1999 | 3.17 | 1.64 | 1.24 | 1.13 | 1.95 | 6.66 | 7.41 | 24.81 | 32.33 | 36.09 | 23.98 | 9.12 |
| 2000 | 3.38 | 1.68 | 1.26 | 1.06 | 1.71 | 6.88 | 6.23 | 25.62 | 33.06 | 38.56 | 26.26 | 9.92 |
| 2001 | 3.59 | 1.73 | 1.28 | 0.99 | 1.47 | 7.11 | 5.05 | 26.44 | 33.78 | 41.02 | 28.53 | 10.72 |
| 2001 | 3.80 | 1.77 | 1.30 | 0.91 | 1.23 | 7.33 | 3.87 | 27.25 | 34.51 | 43.48 | 30.80 | 11.52 |
| 2002 | 4.01 | 1.82 | 1.32 | 0.84 | 0.99 | 7.55 | 2.69 | 28.06 | 35.24 | 45.95 | 33.07 | 12.32 |
| 2003 | 4.23 | 1.86 | 1.34 | 0.76 | 0.75 | 7.77 | 1.52 | 28.87 | 35.96 | 48.41 | 35.34 | 13.12 |
| 2004 | 4.44 | 1.91 | 1.36 | 0.69 | 0.51 | 8.00 | 0.34 | 29.69 | 36.69 | 50.87 | 37.61 | 13.92 |
| 2005 | 4.65 | 1.95 | 1.38 | 0.62 | 0.27 | 8.22 | -0.84 | 30.50 | 37.42 | 53.34 | 39.88 | 14.72 |
| 2006 | 4.86 | 2.00 | 1.40 | 0.54 | 0.03 | 8.44 | -2.02 | 31.31 | 38.14 | 55.80 | 42.15 | 15.52 |
| 2007 | 5.08 | 2.04 | 1.42 | 0.47 | -0.21 | 8.66 | -3.20 | 32.12 | 38.87 | 58.26 | 44.43 | 16.32 |
| 2008 | 5.29 | 2.09 | 1.44 | 0.40 | -0.45 | 8.89 | -4.38 | 32.93 | 39.60 | 60.73 | 46.70 | 17.12 |
| 2009 | 5.50 | 2.13 | 1.46 | 0.32 | -0.69 | 9.11 | -5.56 | 33.75 | 40.32 | 63.19 | 48.97 | 17.92 |
| 2010 | 5.71 | 2.18 | 1.49 | 0.25 | -0.93 | 9.33 | -6.74 | 34.56 | 41.05 | 65.65 | 51.24 | 18.72 |
| Average | 4.44 | 1.91 | 1.36 | 0.69 | 0.51 | 8.00 | 0.34 | 29.69 | 36.69 | 50.87 | 37.61 | 13.92 |
| Average | 4.82 | 1.99 | 1.40 | 0.56 | 0.08 | 8.40 | -1.79 | 31.15 | 38.00 | 55.31 | 41.70 | 15.36 |

Table 3: Model Value for River Owena Discharge on Short Term Approach

| YEAR | JAN | FEB. | MAR | APR | MAY | JUN | JULY | AUG | SEPT | OCT. | NOV. | DEC. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1989 | 0.95 | 1.20 | 1.60 | 1.50 | 2.60 | 7.03 | 9.46 | 10.45 | 15.55 | 14.03 | 3.06 | 1.54 |
| 1990 | 1.01 | 0.92 | 0.65 | 1.54 | 2.74 | 5.69 | 9.14 | 20.23 | 23.21 | 13.06 | 3.01 | 1.61 |
| 1991 | 0.98 | 1.51 | 1.32 | 1.69 | 7.26 | 6.08 | 43.98 | 41.24 | 30.33 | 13.65 | 4.25 | 3.39 |
| 1992 | 2.14 | 1.50 | 1.37 | 2.34 | 3.74 | 7.21 | 10.50 | 12.61 | 45.80 | 15.53 | 7.64 | 3.00 |
| 1993 | 1.65 | 1.21 | 1.01 | 1.69 | 2.68 | 2.89 | 3.90 | 3.60 | 16.96 | 21.33 | 5.20 | 2.21 |
| Average1 | 1.35 | 1.27 | 1.19 | 1.75 | 3.80 | 5.78 | 15.40 | 17.63 | 26.37 | 15.52 | 4.63 | 2.47 |

Table 4: Forecasted Data for year 1989-1993

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1994 | 2.10 | 1.45 | 1.05 | 2.11 | 4.15 | 3.76 | 12.47 | 11.23 | 33.99 | 20.64 | 7.31 | 3.47 |
| 1995 | 2.36 | 1.51 | 1.00 | 2.22 | 4.27 | 3.08 | 11.50 | 9.10 | 36.53 | 22.35 | 8.20 | 3.80 |
| 1996 | 2.61 | 1.57 | 0.96 | 2.34 | 4.38 | 2.41 | 10.52 | 6.96 | 39.07 | 24.06 | 9.09 | 4.13 |
| 1997 | 2.86 | 1.63 | 0.91 | 2.46 | 4.50 | 1.73 | 9.55 | 4.83 | 41.61 | 25.77 | 9.98 | 4.47 |
| 1998 | 3.12 | 1.69 | 0.86 | 2.58 | 4.62 | 1.06 | 8.57 | 2.70 | 44.15 | 27.47 | 10.87 | 4.80 |
| Average2 | 2.61 | 1.57 | 0.96 | 2.34 | 4.38 | 2.41 | 10.52 | 6.96 | 39.07 | 24.06 | 9.09 | 4.13 |

Table 5: Correlation between the model and forecasted value of owena discharge on short term approach

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1994 | 0.71 | 0.70 | 0.68 | 0.65 | 0.62 | 0.58 | 0.52 | 0.50 | 0.67 | 0.81 | 0.69 | 0.15 |
| 1995 | 0.77 | 0.77 | 0.75 | 0.73 | 0.71 | 0.68 | 0.63 | 0.62 | 0.83 | 0.81 | 0.66 | 0.01 |
| 1996 | 0.76 | 0.76 | 0.74 | 0.72 | 0.70 | 0.68 | 0.62 | 0.60 | 0.88 | 0.88 | 0.79 | 0.76 |
| 1997 | 0.77 | 0.76 | 0.75 | 0.73 | 0.71 | 0.70 | 0.65 | 0.63 | 0.86 | 0.89 | 0.77 | 0.76 |
| 1998 | 0.79 | 0.79 | 0.78 | 0.76 | 0.74 | 0.74 | 0.69 | 0.67 | 0.81 | 0.85 | 0.85 | 1.00 |

average model and forecasted values for river owena on short term modeling approach

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| average 1 | 1.35 | 1.27 | 1.19 | 1.75 | 3.80 | 5.78 | 15.40 | 17.63 | 26.37 | 15.52 | 4.632.47 |
| average 2 | 2.61 | 1.57 | 0.96 | 2.34 | 4.38 | 2.41 | 10.52 | 6.96 | 39.07 | 24.06 | 9.094.13 |

Table 6: Forecasted River discharge of Ogbese using Table 3 values as a model on long term modeling approach

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1999 | 0.81 | 0.44 | 0.71 | 1.33 | 1.38 | 15.94 | 30.10 | 75.72 | 96.05 | 96.72 | 33.24 | 7.11 |
| 2000 | 0.86 | 0.41 | 0.68 | 1.42 | 1.26 | 15.91 | 26.26 | 74.21 | 99.31 | 97.42 | 34.60 | 7.46 |
| 2001 | 0.90 | 0.38 | 0.66 | 1.51 | 1.15 | 15.88 | 22.42 | 72.69 | 102.57 | 98.12 | 35.96 | 7.81 |
| 2002 | 0.94 | 0.35 | 0.63 | 1.61 | 1.04 | 15.85 | 18.59 | 71.18 | 105.82 | 98.81 | 37.32 | 8.16 |
| 2003 | 0.99 | 0.32 | 0.60 | 1.70 | 0.92 | 15.82 | 14.75 | 69.67 | 109.08 | 99.51 | 38.68 | 8.51 |
| 2004 | 1.03 | 0.29 | 0.57 | 1.79 | 0.81 | 15.79 | 10.92 | 68.16 | 112.34 | 100.20 | 40.04 | 8.87 |
| 2005 | 1.07 | 0.26 | 0.54 | 1.89 | 0.70 | 15.76 | 7.08 | 66.65 | 115.60 | 100.90 | 41.40 | 9.22 |
| 2006 | 1.11 | 0.23 | 0.51 | 1.98 | 0.58 | 15.73 | 3.24 | 65.13 | 118.86 | 101.60 | 42.76 | 9.57 |
| 2007 | 1.16 | 0.20 | 0.49 | 2.07 | 0.47 | 15.70 | -0.59 | 63.62 | 122.11 | 102.29 | 44.12 | 9.92 |
| 2008 | 1.20 | 0.17 | 0.46 | 2.17 | 0.36 | 15.67 | -4.43 | 62.11 | 125.37 | 102.99 | 45.47 | 10.27 |
| 2009 | 1.24 | 0.13 | 0.43 | 2.26 | 0.24 | 15.64 | -8.26 | 60.60 | 128.63 | 103.68 | 46.83 | 10.62 |
| 2010 | 1.29 | 0.10 | 0.40 | 2.35 | 0.13 | 15.61 | -12.10 | 59.09 | 131.89 | 104.38 | 48.19 | 10.97 |
| Average | 1.05 | 0.27 | 0.56 | 1.84 | 0.75 | 15.77 | 9.00 | 67.40 | 113.97 | 100.55 | 40.72 | 9.04 |
| Average | 0.58 | 0.61 | 0.87 | 0.81 | 2.00 | 16.11 | 51.19 | 84.03 | 78.13 | 92.90 | 25.77 | 5.18 |

Table 7:River Discharge of Ogbese measured at Ago-Aduloju (for 1989-1993) on short Term Modeling

| YEAR | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEPT | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1989 | 0.34 | 0.00 | 0.03 | 0.23 | 0.89 | 12.36 | 77.04 | 116.39 | 114.06 | 95.98 | 9.24 | 0.96 |
| 1990 | 0.55 | 1.57 | 0.06 | 0.54 | 4.08 | 28.29 | 102.98 | 79.10 | 56.66 | 101.07 | 16.75 | 9.41 |
| 1991 | 0.15 | 1.15 | 3.10 | 0.34 | 2.75 | 20.65 | 45.39 | 86.23 | 55.92 | 86.08 | 23.46 | 1.43 |
| 1992 | 0.47 | 0.11 | 1.70 | 0.64 | 3.28 | 6.03 | 1.54 | 63.15 | 66.16 | 121.21 | 17.56 | 0.90 |
| 1993 | 0.68 | 0.49 | 0.45 | 0.92 | 0.88 | 1.69 | 2.47 | 20.49 | 18.93 | 16.71 | 33.03 | 4.22 |
| Average2 | 0.44 | 0.66 | 1.07 | 0.53 | 2.38 | 13.80 | 45.88 | 73.07 | 62.35 | 84.21 | 20.01 | 3.38 |
| average1 | 0.74 | 0.42 | 2.31 | 1.27 | 1.97 | 8.29 | 79.41 | 35.10 | 31.28 | 20.08 | 44.20 | 2.39 |

Table 8: Forecasted Data for 1994-1998

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1994 | 0.62 | 0.52 | 1.81 | 0.98 | 2.13 | 0.72 | 29.29 | 10.75 | 8.12 | 42.69 | 34.53 | 2.78 |
| 1995 | 0.68 | 0.47 | 2.06 | 1.12 | 2.05 | 3.64 | 54.35 | 10.03 | 9.96 | 28.85 | 39.36 | 2.59 |
| 1996 | 0.74 | 0.42 | 2.31 | 1.27 | 1.97 | 8.00 | 79.41 | 30.80 | 28.04 | 15.01 | 44.20 | 2.39 |
| 1997 | 0.80 | 0.38 | 2.56 | 1.42 | 1.89 | 12.36 | 104.46 | 51.58 | 46.11 | 1.17 | 49.04 | 2.19 |
| 1998 | 0.86 | 0.33 | 2.81 | 1.57 | 1.80 | 16.72 | 129.52 | 72.35 | 64.19 | 12.67 | 53.88 | 1.99 |
| Average1 | 0.74 | 0.42 | 2.31 | 1.27 | 1.97 | 8.29 | 79.41 | 35.10 | 31.28 | 20.08 | 44.20 | 2.39 |

Table 9:

Correlation of Model Value (1989-1993) and the forecasted value or tables

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1989 | 0.36 | 0.32 | 0.28 | 0.23 | 0.15 | 0.01 | -0.12 | 0.10 | 0.21 | 0.13 | 0.62 | 0.51 |
| 1990 | 0.39 | 0.36 | 0.32 | 0.26 | 0.17 | 0.03 | -0.10 | 0.11 | 0.12 | -0.05 | 0.90 | 0.29 |
| 1991 | 0.41 | 0.38 | 0.33 | 0.28 | 0.19 | 0.05 | -0.08 | 0.16 | 0.12 | -0.15 | 0.93 | 0.61 |
| 1992 | 0.46 | 0.43 | 0.39 | 0.34 | 0.26 | 0.12 | -0.01 | 0.21 | 0.16 | -0.15 | 0.94 | 0.48 |
| 1993 | 0.56 | 0.53 | 0.50 | 0.45 | 0.38 | 0.26 | 0.14 | 0.33 | 0.29 | 0.01 | 0.98 | 1.00 |

Table 10: River Stage Of River Ogbese (Ago Aduloju) (cm)

| YEAR | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1989 | 37.87 | 11.29 | 11.68 | 33.13 | 45.32 | 100.33 | 236.07 | 275.69 | 271.67 | 253.13 | 112.4 | 57.55 |
| 1990 | 42 | 59.93 | 20.06 | 40.77 | 83.48 | 166.9 | 264.9 | 236.58 | 0 | 0 | 0 | 75.35 |
| 1991 | 20.16 | 53.04 | 61.84 | 66.79 | 192.41 | 147.96 | 281.06 | 228.4 | 217.4 | 275.33 | 146.75 | 64.45 |
| 1992 | 45.55 | 27.97 | 0 | 58.1 | 81.71 | 104.77 | 57.43 | 222.03 | 232.37 | 280.97 | 139.2 | 56.19 |
| 1993 | 50.45 | 44.46 | 44.71 | 54.43 | 55.93 | 69 | 77.16 | 149.03 | 149.97 | 149.1 | 0 | 0 |
| 1994 | 58.41 | 48.31 | 45.38 | 60.51 | 51.21 | 60.01 | 70.31 | 120.35 | 101.35 | 65.03 | 60.75 | 40.12 |
| 1995 | 40.01 | 50.3 | 60.11 | 80.41 | 160.13 | 130.12 | 200 | 240.16 | 236.35 | 180.41 | 100.21 | 45.18 |
| 1996 | 14.14 | 40.1 | 50.46 | 80.28 | 101.72 | 110.17 | 220.17 | 20.06 | 230.17 | 170.14 | 120.78 | 48.2 |
| 1997 | 45.16 | 30.46 | 25.11 | 40.66 | 58.17 | 80.11 | 140.45 | 201.21 | 190.5 | 120.46 | 90.42 | 48.66 |
| 1998 | 44.27 | 40.52 | 46.33 | 52.17 | 70.12 | 90.19 | 150.18 | 180.12 | 185.13 | 110.14 | 82.14 | 51.55 |
| 1989 | 37.87 | 11.29 | 11.68 | 33.13 | 45.32 | 100.33 | 236.07 | 275.69 | 271.67 | 253.13 | 112.4 | 57.55 |

Table 11: Forecasted Values

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1999 | 41.17 | 42.74 | 52.28 | 67.09 | 84.12 | 78.60 | 118.85 | 116.57 | 200.88 | 115.29 | 91.08 | 38.23 |
| 2000 | 41.42 | 43.12 | 55.13 | 68.98 | 83.05 | 73.63 | 109.59 | 103.70 | 204.41 | 107.08 | 92.14 | 36.32 |
| 2001 | 41.66 | 43.50 | 57.99 | 70.86 | 81.98 | 68.65 | 100.33 | 90.83 | 207.94 | 98.86 | 93.20 | 34.41 |
| 2002 | 41.91 | 43.88 | 60.85 | 72.75 | 80.91 | 63.68 | 91.07 | 77.96 | 211.46 | 90.65 | 94.26 | 32.50 |
| 2003 | 42.16 | 44.26 | 63.70 | 74.63 | 79.84 | 58.70 | 81.81 | 65.09 | 214.99 | 82.43 | 95.31 | 30.59 |
| 2004 | 42.41 | 44.64 | 66.56 | 76.52 | 78.76 | 53.73 | 72.55 | 52.22 | 218.52 | 74.22 | 96.37 | 28.68 |
| 2005 | 42.66 | 45.02 | 69.42 | 78.40 | 77.69 | 48.76 | 63.29 | 39.35 | 222.04 | 66.00 | 97.43 | 26.77 |
| 2006 | 42.91 | 45.40 | 72.27 | 80.29 | 76.62 | 43.78 | 54.03 | 26.48 | 225.57 | 57.79 | 98.49 | 24.86 |
| 2007 | 43.15 | 45.79 | 75.13 | 82.17 | 75.55 | 38.81 | 44.78 | 13.60 | 229.09 | 49.58 | 99.54 | 22.95 |
| 2008 | 43.40 | 46.17 | 77.99 | 84.06 | 74.48 | 33.84 | 35.52 | 0.73 | 232.62 | 41.36 | 100.60 | 21.04 |
| 2009 | 43.65 | 46.55 | 80.84 | 85.94 | 73.40 | 28.86 | 26.26 | -12.14 | 236.15 | 33.15 | 101.66 | 19.14 |
| 2010 | 43.90 | 46.93 | 83.70 | 87.83 | 72.33 | 23.89 | 17.00 | -25.01 | 239.67 | 24.93 | 102.72 | 17.23 |

Table 12: Yield of Major Crops in Ondo and Ekiti States Under Rain-fed Agriculture

(Measured in Metric Tonnes)

| CROP | 1988/89 | 1989/90 | 1990/91 | 1991/92 | 1992/93 | 1993/94 | 1994/95 | 1995/96 | 1996/97 | 1997/98 |
|---|---|---|---|---|---|---|---|---|---|---|
| RICE | 15 | 25 | 9 | 7 | 6 | 9 | 10 | 12 | 14 | 16 |
| MAIZE | 20 | 23 | 30 | 20 | 18 | 16 | 12 | 20 | 25 | 27 |
| MELON | 2 | 1 | 47 | 30 | 23 | 40 | 43 | 38 | 43 | 46 |
| CASSAVA | 64 | 73 | 70 | 50 | 47 | 68 | 73 | 78 | 80 | 88 |
| COCOYAM | 60 | 59 | 38 | 28 | 18 | 30 | 38 | 49 | 50 | 51 |
| YAM | 300 | 314 | 255 | 260 | 201 | 189 | 210 | 224 | 298 | 300 |

Table 13: Rainfall Data Measured At Akure Airport Met. Station
Total Volume Of Rainfall/Month Measured in Mm Of Rainfall

| YEAR | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1989 | 0 | 0 | 123.3 | 59.1 | 183.7 | 226.8 | 199.6 | 357.4 | 175.5 | 111.5 | 19 | 0 |
| 1990 | 4.4 | 15.5 | 0 | 157.6 | 113.6 | 90.7 | 370.3 | 243.8 | 247.4 | 213.3 | 72.4 | 62.5 |
| 1991 | 1.2 | 98.7 | 136 | 223.2 | 201.7 | 163.7 | 456.3 | 203.3 | 201.8 | 159.6 | 0 | 10.4 |
| 1992 | 0 | 0 | 35.2 | 107.8 | 145.5 | 227 | 265.3 | 100.4 | 347.6 | 184.4 | 25.6 | 0 |
| 1993 | 0 | 57 | 18.8 | 81.3 | 95.1 | 108.6 | 131.8 | 274.1 | 0 | 95.8 | 84.3 | 21.4 |
| 1994 | 11.2 | 39.4 | 44.4 | 97.8 | 169.9 | 225.7 | 0 | 0 | 180.3 | 189.7 | 28 | 0 |
| 1995 | 0 | 0.6 | 34.2 | 70 | 120.7 | 180.6 | 220.4 | 310.5 | 240.2 | 200.4 | 70 | 0 |
| 1996 | 2.1 | 12.6 | 26 | 50.6 | 90.4 | 140.7 | 180.7 | 240.6 | 200.6 | 180.6 | 64.6 | 10.6 |
| 1997 | 0 | 0.1 | 43 | 70.7 | 110.3 | 160.3 | 204.2 | 220.4 | 210.3 | 175.4 | 50.2 | 12.7 |
| 1998 | 1.3 | 13 | 51 | 90.8 | 130.4 | 170.3 | 210.7 | 215.6 | 190.6 | 162.4 | 44.6 | 0 |

AKURE