IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)
e-ISSN: 2278-1684,p-ISSN: 2320-334X, Volume 14, Issue 6 Ver. IV (Nov. - Dec. 2017), PP 30-43
www.iosrjournals.org

A Study of Climate Variability on Water Resources of Some Hydrological Units of Hydrological Area I: Northwest Nigeria.

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Abstract: *Average annual temperature (1949 – 1976) and (1976 – 2008) and average annual rainfall (1949 – 1976) and (1976 – 2008); for Hydrological Area I {North – Western Nigeria} were analysed by moving averages and trend analysis to determine the trends and impacts of climate variability on water resources of some selected hydrological units of hydrological area I. Time series were performed and the irregular patterns characterised. The observed temperature values have shown an increase of 1.8% while that of the rainfall has increased by 1.2%. The observed maximum values of stream flow discharge in the area were in the year 1989 which coincides with the rise of 1.5% in temperature. The stream flow reflects multiple climatic factors, which makes it an important indicator of climatic variability and change. However, the rise in temperature is an indication of climate change, which impact negatively on water resources of the hydrological area I; there are other human influences, such as the flow diversion for irrigation and municipal use, natural stream regulation and reservoirs, and base flow reduction by groundwater pumping.*
More meteorological stations especially in the mountainous areas (in Kebbi and Zamfara States) should be established and extend climate change analysis to decadal level instead of a 30-year interval.

Key words: *temperature, rainfall, moving averages (MA), trend analysis, climate, Autocorrelation Function (ACF), Partial Autocorrelation Function (PACF).*

Date of Submission: 19 -12-2017 Date of acceptance: 05-01-2018

I. Introduction

A. General

Climate is generally defined as average weather, and as such, climate change and weather are intertwined. Observations can show that there have been changes in weather, and it is the statistics of changes in weather over time that identifies climate change. While weather and climate are closely related, there are important differences. A common confusion arises when scientists are asked how they can predict climate 50 years from now when they cannot predict the weather a few weeks from now (King, 2004).

Climate is the description of the long-term averages of weather, usually taken over a 30-year period. It describes not only the long period averages of temperature, rainfall and other climate quantities in different months or seasons, but also the variability from one year to the next (Stockton, 2006) .

Climate change affects the function and operation of existing water infrastructure – including hydropower, structural flood defences, drainage and irrigation systems– as well as water management practices. Adverse effects of climate change on freshwater systems aggravate the impacts of other stresses, such as population growth, changing economic activity, land-use change and urbanisation (*very high confidence*).

Globally, water demand will grow in the coming decades, primarily due to population growth and increasing affluence; regionally, large changes in irrigation water demand as a result of climate change are expected**.** Consequently, floods cause tremendous losses to infrastructure and industry and result in the spread of diseases that sometimes result in epidemics. However, the losses to agriculture caused both be floods and droughts are staggering and affect a vast majority of the population who depend on agriculture for their livelihood.

B. Objectives of Study

This work studies the climate variability as it affects water resources of Hydrological Area I; (HA I). To achieve this, the following objectives have to be met;

- Analysis of meteorological data to establish climate variability and extreme events
- Determination of impacts of climate variability on water availability.
- Evaluation of AR and MA models using ACF and PACF of the time series.
- To make recommendations on possible approach to climate variability as it affects water resources and irrigation of Hydrological area I.

C. Justification

Current water management practices may not be robust enough to cope with the impacts of climate change on water supply reliability, flood risk, health, agriculture, energy and aquatic ecosystems. In many locations, water management cannot satisfactorily cope even with current climate variability, so that large flood and drought damages occur.

Indeed, population, technology, economic conditions, social and political factors, and the values society places on alternative water uses are likely to have more of an impact on the future availability and use of water than changes in the climate. Even in the absence of human-induced changes in the climate and hydrological cycle, there is cause for concern over the adequacy of water supplies.

D. Scope

The scope of the study was restricted to only some hydrological units of hydrological area I, northwest Nigeria. The meteorological data of the study area were analyzed to establish climate variability within the years under study (1949 – 1976) and (1976 – 2008).

E. Study Area

The study area comprises of four states in the north-western region i.e. (Sokoto, Kebbi, Zamfara and Katsina). It lies roughly between latitudes 10^o and 14^oN and longitudes 4^o and 9^oE.

The climate of the Hydrological Area under study is divided into two: a rainy season from May to September and a dry season from October to April of the following year. The mean monthly rainfall is rich in August, showing 240 mm at Gusau. There is no rainfall from November to February every year and a very small amount of rainfall is recorded in October, March and April.

The average annual rainfall in Sokoto city is 632 mm, which showed a decreasing tendency from the end of the 1970s through the 1980s (JICA, 2001).

Judging from the distribution of rainfall north of Sokoto state, moving towards the Nigerian border, there is a decrease to below 600 mm/year. However, moving towards the southern portion of the state, the rainfall gradually increases exceeding 900 mm south of the line connecting Talata –Mafara (Zamfara) and Bunza (Kebbi).

The daily maximum and minimum temperature average yearly values are 34.8^oC and 21.2^oC, respectively. The daily maximum temperature by monthly average value is the highest in April at 40.1^oC. In addition, the daily minimum temperature by monthly average is lowest in August at 30.5^oC (JICA, 2001). There is no great difference in the area distribution for temperature.

The Rima river, the Sokoto river and the Zamfara river flow in to the Sokoto-Rima river basin. These rivers are tributaries of the Niger river, which flows into Nigeria from the Republic of Niger, through the south-western part of Sokoto state and flows out to Niger state. The flowing distance within Sokoto state is about 150 km. The Rima River originates from the basement rock area in the north-eastern part of Sokoto state. This river flows north to north-west up to Sabon –Birni and south –west up to Wamakko, where it meets the Sokoto River, which flows north-west through the basement rock area.

The Rima River then flows south, joining the Zamfara River at Bunza and meeting the Niger River at the southern boundary of the state. The catchment area of the Rima river is about 57,000 km^2 at Wamakko and its annual volume of runoff is about 1.7 billion m^3. On the other hand, the catchment of the Sokoto River is about 12,000 km^2 and its annual volume of runoff is about 0.73 billion m^3 at Gidan Doka (JICA, 2001).

The rivers in the Sokoto-Rima river basin are intermittent rivers in the basement rock area. In addition, they become perennial rivers in the middle and lower reaches of the Sokoto and Rima rivers in the sedimentary rock area.

II. Methodology

A. Data Collection and Management

The basic secondary data (rainfall, temperature and stream flow) for the project relating to climate variability and water resources of the Hydrological Area I including the occurrence of extreme events in the past was obtained from the climate records of the meteorological Department and the Central Water Resources Department Authority (Sokoto Rima Basin Development Authority) of the Hydrological Area I.

The historical climate records for 1949-1976 and 1976-2008 were compared and analysed (correlation) to determine the trends in change in various climate parameters relating to temperature, precipitation and stream flow Stream flow records of three major river stations in the hydrological area were considered in the analysis; they are as follows; at Wamakko on river Rima, at gidan Doka on river Zamfara, and at Jega on river Sokoto. However, for temperature and precipitation records; Sokoto new airport, Katsina and Gusau aerodromes were considered. These stations were chosen as a basis for the general climate conditions of the area.

B. Climate Change Analysis

River flows are affected by climate changes. Study of river flows over time is important especially to determine the sustainability of irrigation system and ground water recharge. The impacts in climate change include changes in temperature and precipitation, which in turn have varying consequences in water availability. Therefore; trend analysis was carried out to define climate change with respect to stream flow/ discharge of the rivers in the hydrological area using statistical packages (statistica, EViews, minitab).

However, long term trend curve or line was constructed so as to obtain appropriate trend values by using moving averages method. This study deals with the analysis of discharge, temperature and rainfall time series in the hydrological area. First, an analysis of the systematic components (trends, seasonality, periodicity and residual components) was performed. The models tested were the linear AR & MA models using partial and autocorrelation functions (PACF & ACF).

III. Results And Discussion.

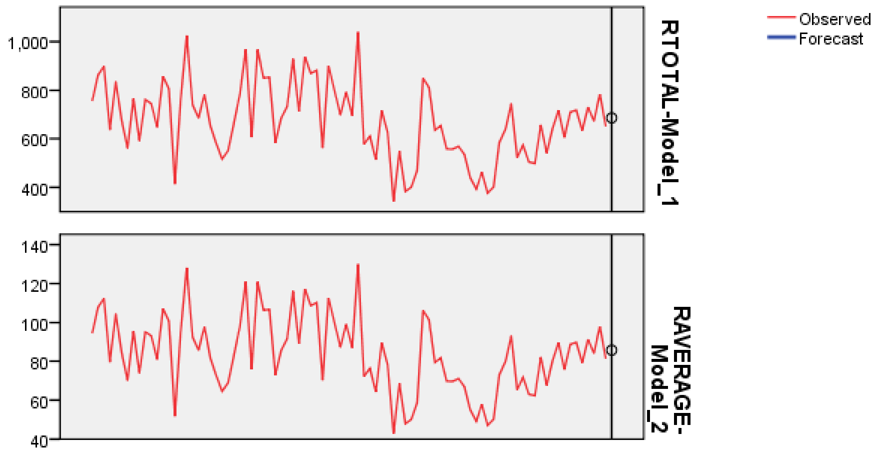
To determine whether there is a trend in the stream flow data sequences from Wamakko, Gidan Doka and Jega stations; the stream flow at Gidan Doka on river Rima from 1949 –1976 and 1976 - 2008 reveals an increase between 1961 - 1981 of 3.78% (fig. 1 and 7).

The ARMA model has been tested using the partial autocorrelation and auto correlation functions (figure 3 and 4). The plots of the auto-correlation function (ACF) and the partial auto-correlation function (PACF) for data sequences (total rainfall) were drawn to gather information about the seasonal and non seasonal operators concerning with the yearly series for the model.

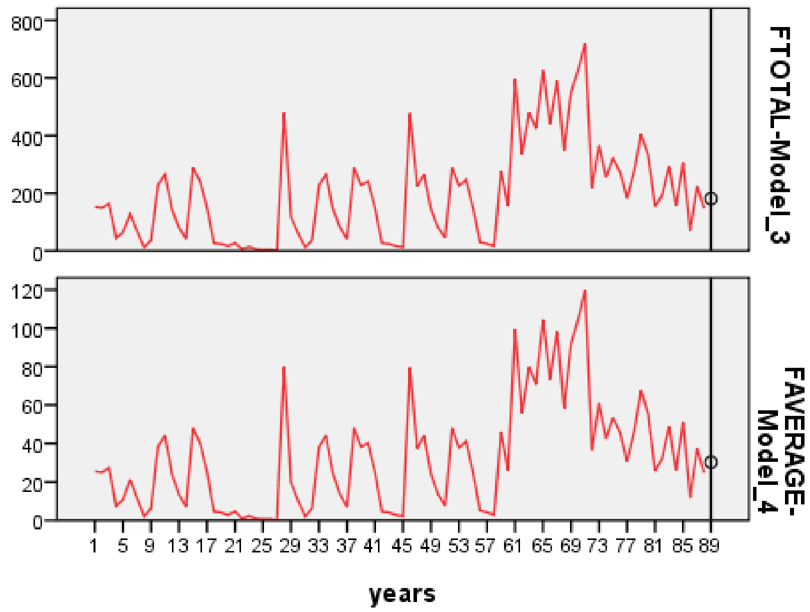
The ACFs for yearly data follow an attenuating sine wave pattern that reflects the random periodicity of the data and possibly indicates the need for non-seasonal and/or seasonal AR terms in the model (fig.2).
All the ACF plots of yearly data sequences were significantly different from zero. This implies the existence of linear dependence between amounts of yearly data sequences. However, the values of temperature from 1949 – 1976 and between 1976 – 2008 (table 1) has shown a decrease of 1.8 % while that of the average rainfall from the period 1949 – 1976 to 1976 – 2008 has decreased by 1.2 %.

Table 1: Descriptive statistics of average temperature and average rainfall of the study area.

	DIVIDER	N	Mean	Std. Deviation	Std. Error Mean
AVE TEMP	1949-1976	28	33.182°C	.7449	.1408
	1976-2008	32	33.988°C	1.7004	.3006
AVE RAINFALL	1949-1976	28	414.176 mm	.0931107	.0175963
	1976-2008	32	445.989 mm	.2162139	.0382216



(a, b)



(c, d)

Fig.1: (a – d) Rainfall (average & total) and Flow (average & total) at Sokoto new airport and Gidan Doka

The figures 1: (a –d) are the plots of the total rainfall, average rainfall, total flow and average flow of the hydrologic systems in the hydrological area over the period; 1949 – 2008.

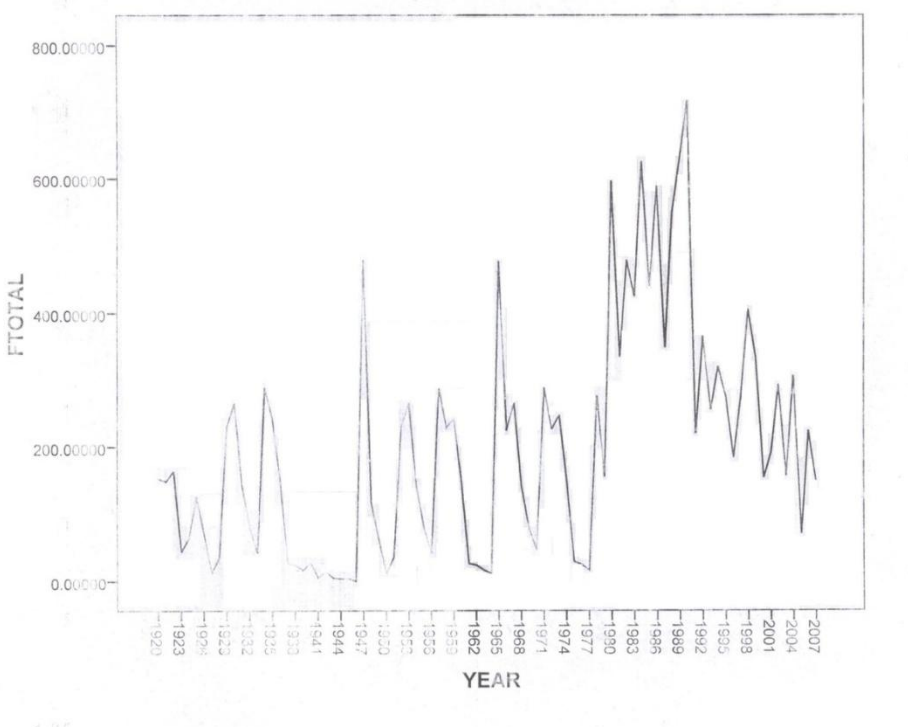


Figure 2: Time series of total flow, 1920 – 2007 at Wamakko.

The ARMA model has been tested using the partial autocorrelation and auto correlation functions (Fig. 1 and 2). The plots of the auto-correlation function (ACF) and the partial auto-correlation function (PACF) for data sequences (total rainfall) were drawn to gather information about the seasonal and non seasonal operators concerning the yearly series for the model.

The autocorrelation function (Fig.1) shows a significant peak at a lag of 1 with a long exponential tail—a typical pattern for time series

The significant peak at a lag of 1 suggests the presence of an annual seasonal component in the data. Examination of the partial autocorrelation function allows for a more definitive conclusion.

Table 2: Partial Auto Correlations for Average Rainfall at Gusau Aerodrome.

Partial Autocorrelations

Series:RAVERAGE

Lag	Partial Autocorrelation	Std. Error
1	0.398	0.107
2	0.208	0.107
3	0.123	0.107
4	0.086	0.107
5	-0.059	0.107
6	-0.04	0.107
7	0.163	0.107
8	0.114	0.107
9	0.066	0.107
10	-0.066	0.107
11	0.022	0.107
12	0.116	0.107
13	0.034	0.107
14	0	0.107
15	-0.011	0.107
16	-0.084	0.107

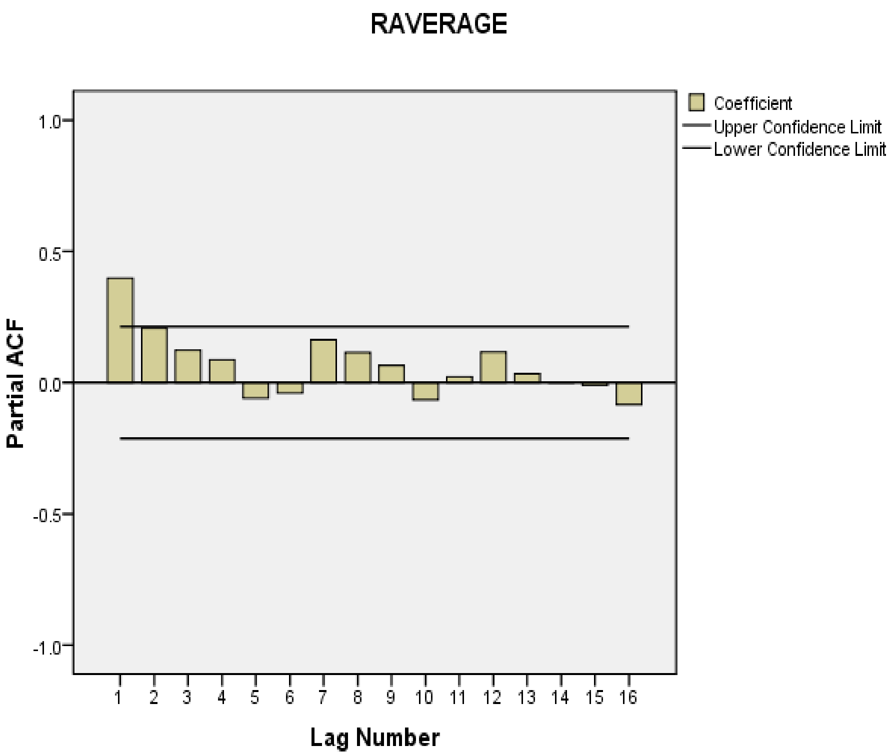


Fig. 3: Partial auto correlation function- Average rainfall at Gusau Aerodrome

Table: 3 Auto Correlations for Total Rainfall at Sokoto new Airport

Autocorrelations

Series: Rtotal

Lag	Autocorrelation	Std. Error[a]	Box-Ljung Statistic		
			Value	df	Sig.[b]
1	0.398	0.105	14.403	1	0
2	0.333	0.104	24.617	2	0
3	0.287	0.104	32.283	3	0
4	0.257	0.103	38.493	4	0
5	0.136	0.102	40.263	5	0
6	0.09	0.102	41.039	6	0
7	0.204	0.101	45.096	7	0
8	0.212	0.101	49.553	8	0
9	0.2	0.1	53.574	9	0
10	0.121	0.099	55.063	10	0
11	0.167	0.099	57.927	11	0
12	0.215	0.098	62.737	12	0
13	0.155	0.097	65.286	13	0
14	0.129	0.097	67.074	14	0
15	0.136	0.096	69.083	15	0
16	0.084	0.095	69.855	16	0

a. The underlying process assumed is independence (white noise).

b. Based on the asymptotic chi-square approximation.

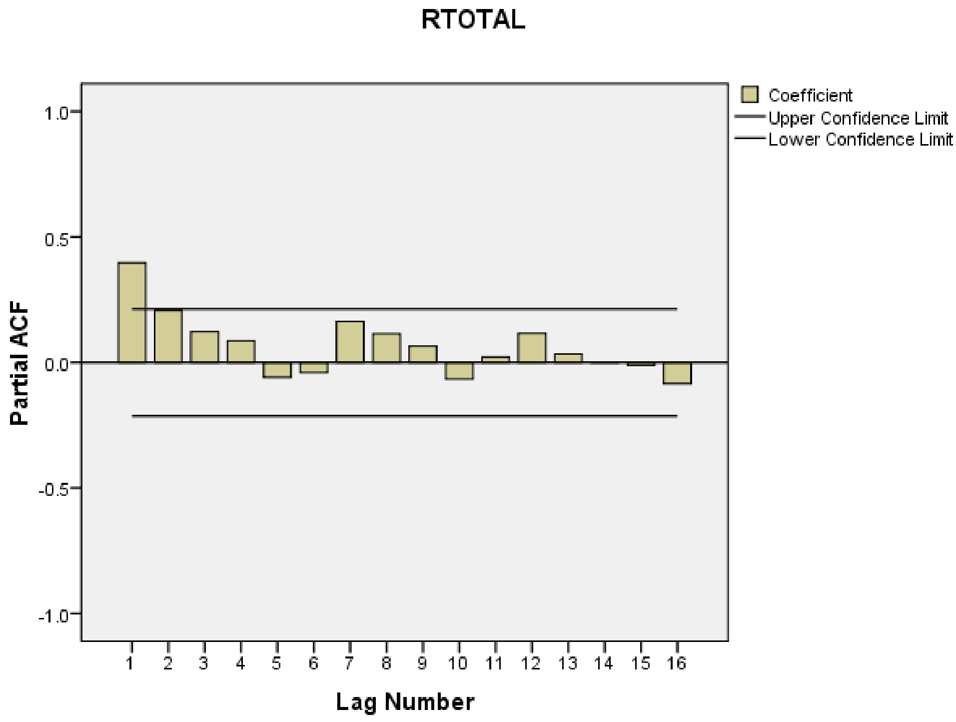


Fig.4: Partial Autocorrelation Function at Sokoto new Airport.

The plots of the auto-correlation function (ACF) and the partial auto-correlation function (PACF) for data sequences (total rainfall) were drawn to gather information about the seasonal and non seasonal operators concerning the yearly series for the model.

Table 4: Partial Auto Correlation Function for Total Rainfall at Sokoto new Airport

Partial Autocorrelations

Series:Rtotal

Lag	Partial Autocorrelation	Std. Error
1	0.398	0.107
2	0.208	0.107
3	0.123	0.107
4	0.086	0.107
5	-0.059	0.107
6	-0.04	0.107
7	0.163	0.107
8	0.114	0.107
9	0.066	0.107
10	-0.066	0.107
11	0.022	0.107
12	0.116	0.107
13	0.034	0.107
14	0	0.107
15	-0.011	0.107
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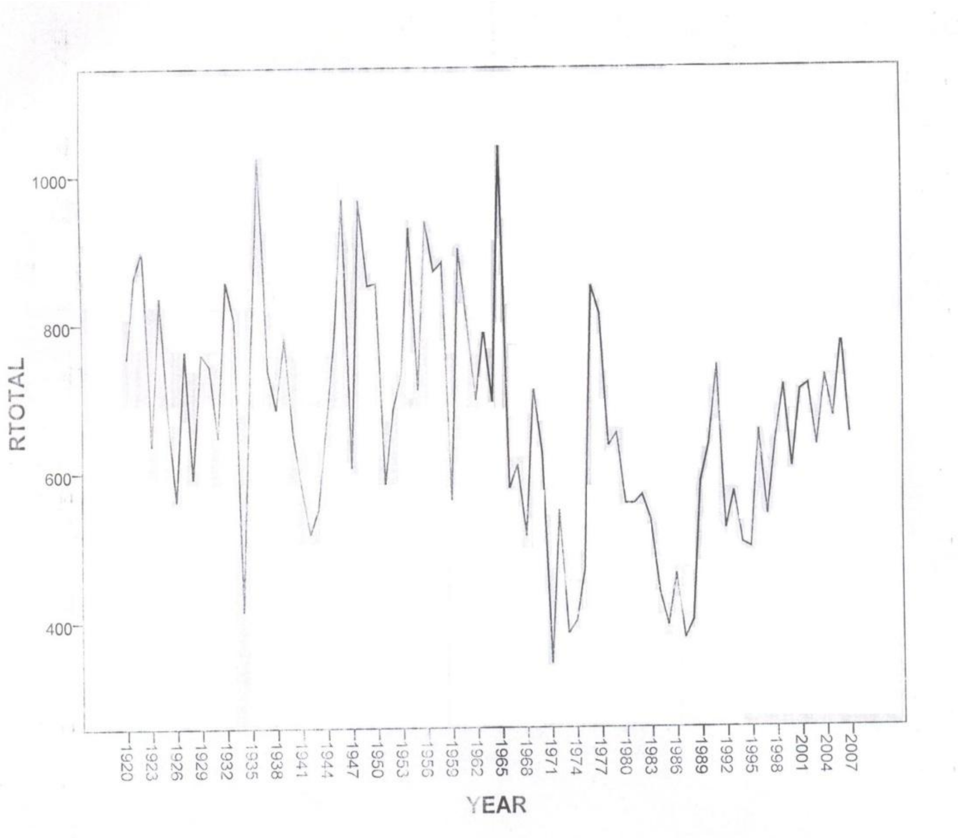

Fig. 5: Time series of total rainfall; 1920 – 2007 at Gusau Aerodrome.

Table 5: The values of ARMA model fit.

Model Fit

Fit Statistic	Mean	SE	Minimum	Maximum	Percentile						
					5	10	25	50	75	90	
Stationary R-squared	0.278356	0.048249	0.236571	0.32014	0.236571	0.236571	0.236571	0.278356	0.32014	0.32014	
R-squared	0.273657	0.104298	0.183332	0.363982	0.183332	0.183332	0.183332	0.273657	0.363982	0.363982	
RMSE	80.16635122							80.23354	141.1847	142.3985	
MAPE	113.181	109.835	18.06106	208.3009	18.06106	18.06106	18.06106	113.181	208.3009	208.3009	
MaxAPE	3037.759	3396.519	96.28754	5979.231	96.28754	96.28754	96.28754	3037.759	5979.231	5979.231	
MAE	61.31059	53.10017	14.08676	112.6941	14.08676	14.08676	14.79584	59.23076	109.9052	112.6941	
MaxAE	237.5444	209.4972	44.20428	473.4336	44.20428	44.20428	52.87961	216.2699	443.4837	473.4336	
Normalized BIC	7.997846	2.244743	5.809255	9.968138	5.809255	5.809255	5.93575	8.106996	9.950792	9.968138	

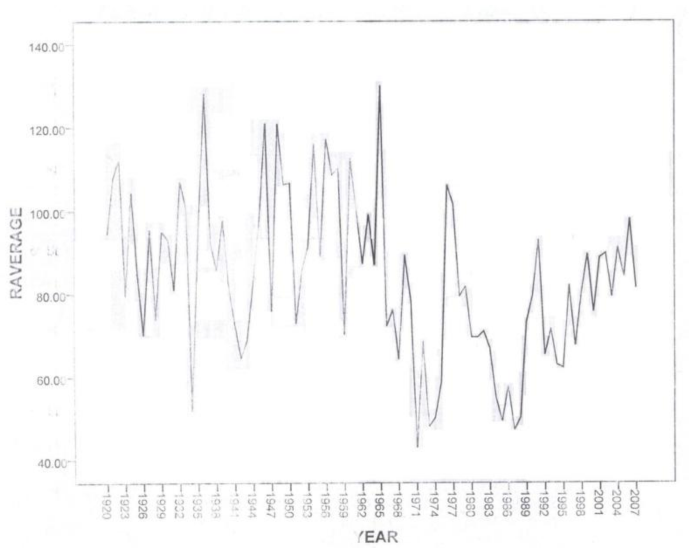

Fig. 6: Time series of average rainfall; 1920 –2007 at Katsina Aerodrome.

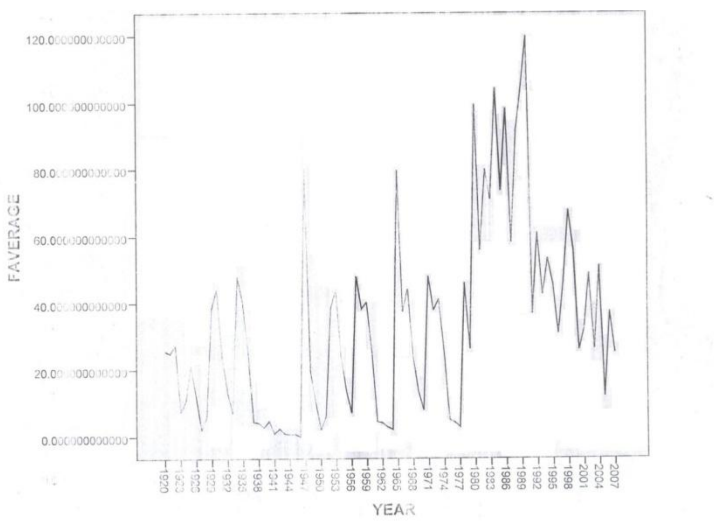

Fig. 7: Time series of Average flow, 1920 – 2007 at Jega station.

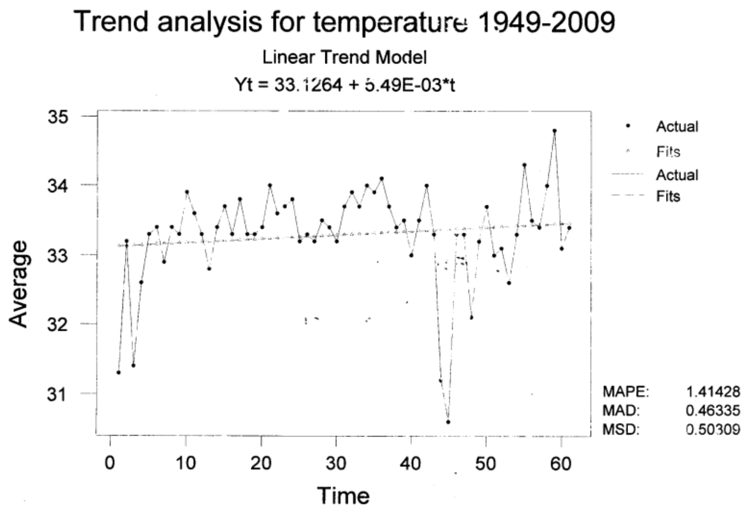

Fig. 8: The trend analysis for temperature 1949 – 2009 at Sokoto new Airport

From Figure 8, it is evident that there is a significant rise in temperature at Sokoto new airport between 1989 -2009. However, the rise might be as a result of the increase in human activities, desert encroachment, population increase and excessive emission of CO_2 and other green house gases such as CH_4, N_2O, and CFC_5 and others.

IV. Conclusion

The results of this study have clearly established the impacts of climate variability in the hydrological area I; area under study. However , all the stations considered in the analysis for stream data i.e. Wamakko on river Rima, Jega on river Sokoto and Gidan doka on river Zamfara have shown the impact of climate variability with respect to their discharges over the duration under study. Moreover, the stations selected for the analysis of temperature and precipitation i.e. Sokoto new airport, Katsina and Gusau aerodromes respectively have also shown the impacts of climate variability

- **Precipitation Trend of the Study Area**

Table (1) has shown a decreasing trend from the period 1949 – 1976 to 1976 – 2008 of 1.2%. However, figures (5 & 6) at Katsina and Gusau aerodromes have shown an increasing trend in annual rainfall at 1936 and 1965 which both attained maximum of 1025 mm and 1039.4 mm respectively with an increase of 1.4%. The average annual rainfall in Sokoto was 632mm which showed a decreasing tendency at the end of the 1970s through 1980s, with the record reading the lowest at 325mm in 1987.

- **Stream flow Trend of the Study Area**

Figures 1 (c & d) have shown a decreasing trend between the duration 1969 – 1989 at Wamakko and Gidan doka stations. In addition, there is a significant variation in the behaviour of the river flows at Jega and Wamakko stations which could be revealed in figures (2 & 7). However, from the period 1946 -1965 there was a drop in the values obtained at Jega station. The maximum value of discharge was obtained in the year 1989 which coincides with the rise of 1.5% in temperature within the same period (fig. 8).

River runoff or discharge reflects multiple climatic factors, which makes it an important indicator of climatic variability and change. Discharge also integrates numerous human influences such as flow diversions for irrigation and municipal use, natural stream flow regulation by dams and reservoirs, and base flow reduction by groundwater pumping.

- **Temperature Trend of the Study Area**

The daily maximum and minimum temperature average yearly values are 34.8^0C and 21.2^0C, respectively. The daily maximum temperature by monthly average value is the highest in April at 40.1^oC. In addition the daily minimum temperature by monthly average is lowest in August at 30.5^oC. From (fig. 8) it was evident that there was a significant rise in temperature at Sokoto new airport between 1989 -2009. A decrease of 1.8% was observed between the period 1949 – 1976 and 1976 – 2008 (table 1).

V. Recommendations.

Based on the results of this study, the following recommendations were made with respect to (i) climate change (ii) water resources and irrigation management (iii) mitigation of drought stress and water scarcity.

(i) Climate Change

• The hydrological area should be zoned on the basis of anticipated climate change. However, this information should be incorporated into zoning for efficient and sustainable land use based on soil type, topography and water availability.
• Research should be undertaken to relate climate change to land use and cover change especially large scale deforestation.
• Additional meteorological stations should be established especially in the mountainous areas (that is Kebbi and Zamfara States) and climate change analyses should be extended to decadal level instead of a 30 – year interval.

(ii) Water Resources and Irrigation Management.

• The collection and compilation of data on water resources should be entrusted to a single agency that should be the source of all agreed figures relating to water resources in the hydrological area.
• Improvement on the environmental health of the water sheds in the hydrological area for sustainable water resources development should be encouraged because of the deterioration of watersheds of most major rivers.
• A national ground water authority should be established to regulate the use of groundwater and its recharging to ensure sustainability of this precious resource.
• Rational water prices should be fixed for domestic, industrial and agricultural users to ensure that water is viewed as a precious limiting resource and used efficiently by the consumers.

(iii.) Mitigation of Drought Stress and Water Scarcity

• New crop varieties with resistance to drought stress and high temperatures should be evolved.

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APPENDIX I

Table 6: Residual Auto Correlation Function Summary at Gusau Aerodrome

Residual ACF Summary										
Lag	Mean	SE	Minimum	Maximum	Percentile					
					5	10	25	50	75	90
Lag 1	0.073306	0.001219	0.072251	0.074361	0.072251	0.072251	0.072251	0.073306	0.074361	0.074361
Lag 2	0.036251	0.017569	0.021036	0.051466	0.021036	0.021036	0.021036	0.036251	0.051466	0.051466
Lag 3							-0.150940096	-0.15094	0.002948	0.002948
Lag 4	0.001528	0.009687	-0.00686	0.009917	-0.00686	-0.00686	-0.00686	0.001528	0.009917	0.009917
Lag 5	-0.06387	0.098282	-0.14898	0.021246	-0.14898	-0.14898	-0.14898	-0.06387	0.021246	0.021246
Lag 6	0.00253	0.226582	-0.1937	0.198756	-0.1937	-0.1937	-0.1937	0.00253	0.198756	0.198756
Lag 7	-0.0508	0.055305	-0.0987	-0.0029	-0.0987	-0.0987	-0.0987	-0.0508	-0.0029	-0.0029
Lag 8	0.033432	0.002238	0.031494	0.03537	0.031494	0.031494	0.031494	0.033432	0.03537	0.03537
Lag 9	-0.03068	0.063608	-0.08577	0.024407	-0.08577	-0.08577	-0.08577	-0.03068	0.024407	0.024407
Lag 10	-0.07473	0.003531	-0.07779	-0.07167	-0.07779	-0.07779	-0.07779	-0.07473	-0.07167	-0.07167
Lag 11	-0.10522	0.136752	-0.22366	0.013206	-0.22366	-0.22366	-0.22366	-0.10522	0.013206	0.013206
Lag 12	0.076402	0.030613	0.049891	0.102914	0.049891	0.049891	0.049891	0.076402	0.102914	0.102914
Lag 13	0.061882	0.023963	0.041129	0.082634	0.041129	0.041129	0.041129	0.061882	0.082634	0.082634
Lag 14	0.00332	0.033868	-0.02601	0.032651	-0.02601	-0.02601	-0.02601	0.00332	0.032651	0.032651
Lag 15	0.00932	0.050541	-0.03445	0.053089	-0.03445	-0.03445	-0.03445	0.00932	0.053089	0.053089
Lag 16	-0.06047	0.077373	-0.12748	0.006535	-0.12748	-0.12748	-0.12748	-0.06047	0.006535	0.006535
Lag 17	0.009072	0.00849	0.001719	0.016425	0.001719	0.001719	0.001719	0.009072	0.016425	0.016425
Lag 18	0.039566	0.224568	-0.15492	0.234048	-0.15492	-0.15492	-0.15492	0.039566	0.234048	0.234048
Lag 19	0.015066	0.004879	0.010841	0.019291	0.010841	0.010841	0.010841	0.015066	0.019291	0.019291
Lag 20	-0.11012	0.036284	-0.14154	-0.0787	-0.14154	-0.14154	-0.14154	-0.11012	-0.0787	-0.0787
Lag 21	-0.01437	0.077721	-0.08168	0.052934	-0.08168	-0.08168	-0.08168	-0.01437	0.052934	0.052934
Lag 22	-0.07678	0.009811	-0.08527	-0.06828	-0.08527	-0.08527	-0.08527	-0.07678	-0.06828	-0.06828
Lag 23	-0.07262	0.115578	-0.17271	0.027475	-0.17271	-0.17271	-0.17271	-0.07262	0.027475	0.027475
Lag 24	0.066338	0.020968	0.048179	0.084497	0.048179	0.048179	0.048179	0.066338	0.084497	0.084497

Table 7: Residual Auto Correlation Functions for RT, RA, FT & FA at Sokoto new airport, Wamakko respectively.

Model				Residual ACF						
		1	2	3	4	5	6	7	8	9
RTOTAL-Model_1	ACF	0.072251	0.021036	0.002948	-0.00686	-0.14898	-0.1937	-0.0029	0.031494	0.024407
	SE		0.107155	0.107202	0.107203	0.107208	0.109536	0.113361	0.113362	0.113461
RAVERAGE-Model_2	ACF	0.072251	0.021036	0.002948	-0.00686	-0.14898	-0.1937	-0.0029	0.031494	0.024407
	SE	0.1066	0.107155	0.107202	0.107203	0.107208	0.109536	0.113361	0.113362	0.113461
FTOTAL-Model_3	ACF	0.074361	0.051466	-0.30483	0.009917	0.021246	0.198756	-0.0987	0.03537	-0.08577
	SE	0.1066	0.107188	0.107469	0.116882	0.116891	0.116935	0.120713	0.121627	0.121743
FAVERAGE-Model_4	ACF	0.074361	0.051466	-0.30483	0.009917	0.021246	0.198756	-0.0987	0.03537	-0.08577
	SE	0.1066	0.107188	0.107469	0.116882	0.116891	0.116935	0.120713	0.121627	0.121743
Model		10	11	12	13	14	15	16	17	18
RTOTAL-Model_1	ACF	-0.07779	0.013206	0.102914	0.041129	0.032651	0.053089	0.006535	0.016425	-0.15492
	SE	0.113521	0.114125	0.114142	0.115192	0.115359	0.115464	0.115741	0.115745	0.115771
RAVERAGE-Model_2	ACF	-0.07779	0.013206	0.102914	0.041129	0.032651	0.053089	0.006535	0.016425	-0.15492
	SE	0.113521	0.114125	0.114142	0.115192	0.115359	0.115464	0.115741	0.115745	0.115771
FTOTAL-Model_3	ACF	-0.07167	-0.22366	0.049891	0.082634	-0.02601	-0.03445	-0.12748	0.001719	0.234048
	SE	0.122428	0.122904	0.127445	0.127667	0.128273	0.128333	0.128438	0.129868	0.129868
FAVERAGE-Model_4	ACF	-0.07167	-0.22366	0.049891	0.082634	-0.02601	-0.03445	-0.12748	0.001719	0.234048
	SE	0.122428	0.122904	0.127445	0.127667	0.128273	0.128333	0.128438	0.129868	0.129868
Model		19	20	21	22	23				
RTOTAL-Model_1	ACF	0.010841	-0.0787	0.052934	-0.06828	-0.17271				
	SE	0.118104	0.118115	0.118709	0.118977	0.119422				
RAVERAGE-Model_2	ACF	0.010841	-0.0787	0.052934	-0.06828	-0.17271				
	SE	0.118104	0.118115	0.118709	0.118977	0.119422				
FTOTAL-Model_3	ACF	0.019291	-0.14154	-0.08168	-0.08527	0.027475				
	SE	0.134576	0.134607	0.136288	0.136844	0.137446				
FAVERAGE-Model_4	ACF	0.019291	-0.14154	-0.08168	-0.08527	0.027475				
	SE	0.134576	0.134607	0.136288	0.136844	0.137446				

Table 8: Number of Existing Meteorological Stations in the Hydrological Area 1

Station Type	Number
Rainfall Stations	27
Meteorological Stations	12
Agrometeorological Stations	8
Synoptic Stations	3

Source: (Sokoto Rima River Basin Development Authority, 2009)

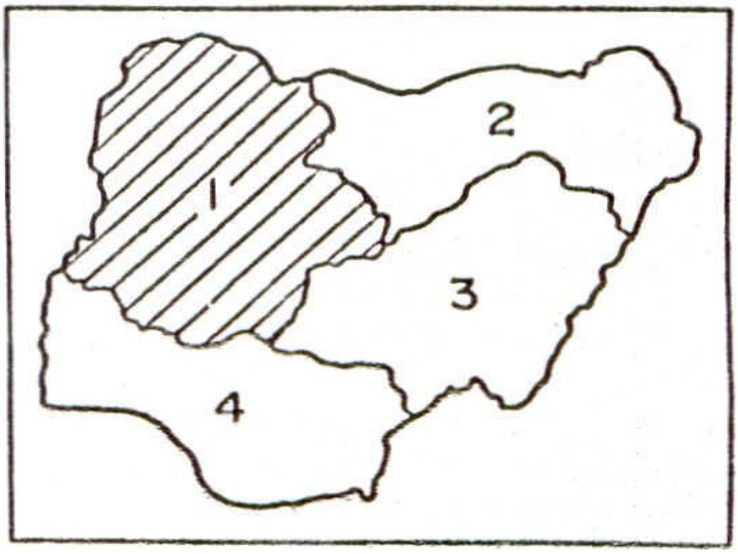

Fig. 9: Map of Nigeria showing Hydrological Area I

Source: (Sokoto Rima River Basin Development Authority, 2009)

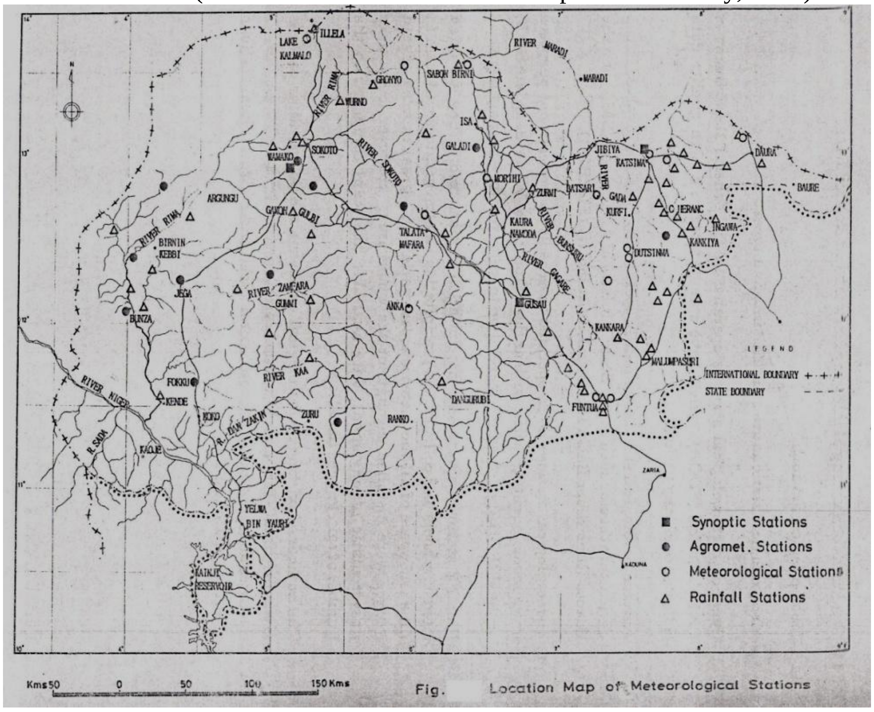

Fig. 10: Location Map of Meteorological Stations within the Hydrological Area. (Source: Sokoto Rima River Basin Development Authority, 2009)

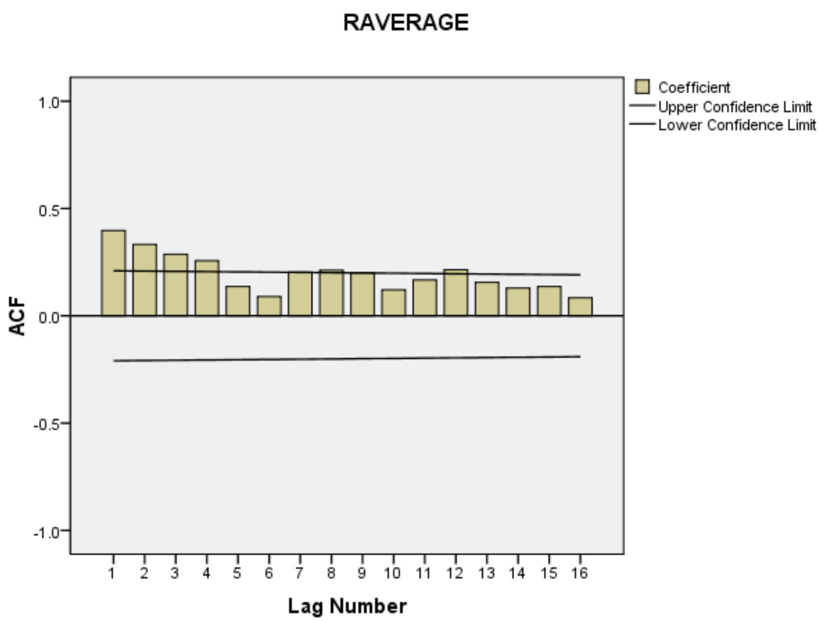

Figure 11: Residual ACF- Average Rainfalls at Gusau Aerodrome.

Adamu Y.Yunusa"A Study of Climate Variability on Water Resources of Some Hydrological Units of Hydrological Area I: Northwest Nigeria." IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE) , vol. 14, no. 6, 2017, pp. 30-43