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RAINFALL VARIABILITY AND SUSTAINABLE ENVIRONMENT IN JIGAWA STATE, NIGERIA

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ABSTRACT
Climate is naturally dynamic, subject to change either through natural or man induced forces. Jigawa State is situated at the fringe area of Sahara Desert. It is in one of the fragile climatic zone where rainfall variability is of fundamental value, being defends on nature for agricultural activities. This paper examines the spatial and temporal variability of rainfall vis-à-vis the environmental sustainability. Daily rainfall records for twenty years of the sixteen metrological stations in the state were obtained. Global Positioning System (GPS) was used to measure the coordinates (latitude and longitude) of the station. Rainfall variability Maps of the area were also generated from long term annual values for each station using ArcGIS 9.3 Geographic Information System (GIS) Software. The spatial analysis used is spline which is one of the interpolation methods. It is one of the GIS methods of inferences with which data for unrecorded area were generated by looking at the nearby recorded data. The result has shown significant rainfall variability between stations and within time frame. Although the sign of dryness has been noticed by the past studies, the findings have revealed no significant decrease in rainfall in most of the area. The study attributed agricultural problem in the area mostly to soi land other land degradation rather than rainfall variability. The research further recommended the need for better environmental management practices as a means of achieving environmental sustainability.
Keywords: Rainfall, Variability, Sustainability, Jigawa State, GIS

INTRODUCTION

The earth's climate is dynamic and naturally varies on seasonal, decadal, centennial, and longer timescales. Each up and down fluctuation of climate can lead to conditions which are warmer or colder, wetter, or drier, more stormy or quiescent (NOAA, 2007). These changes in climate may be due to natural internal processes or external forces or due to persistent anthropogenic effects resulting to changes in the composition of the atmosphere or in land use (Bates, 2008). Perhaps the most well understood occurrence of climate variability is natural oscillation (ENSO), an interaction between the ocean and the atmosphere over the tropical Pacific Ocean that has important consequences for weather around the globe (NOAA, 2007). Pronounced long – term trends from 1900 to 2005 have been observed in precipitation amount in some places; significantly wetter in northeast, and South America, Northern Europe and Northern and central Asia, but drier in the Sahel, southern Africa, the Mediterranean and southern Asia. Widespread increases in heavy precipitation

events have been observed, even in places where total amounts have decreased. These changes are associated with water vapour in the atmosphere arising from the warming of the world's oceans, especially in the troposphere (Tren berth, 2007). One of the most significant climatic variations in African Sahel since the late 1960s has been the persistent decline in rainfall amount. The Sahel is characterized by strong climate variations and irregular rainfall that ranges between 200mm and 600mm with coefficients of variations ranging from 15% to 30% (Fox and Rockstorm, 2003). A rainfall decrease of 29-49% has been observed in the 1968 -1997 period compared to the 1931 – 1960 baseline period within the Sahel region (Mc Carthy, 2001).

The West African region has experienced a marked decline in rainfall from 15% to 30% depending on the area. The trend was interrupted by a return of adequate rainfall conditions 1994. This was considered to be the wettest year of the past 30 years and was thought to perhaps indicate the end of the drought. Unfortunately dry condition returned after 1994(McCarthy, 2001). As a result of large inter-annual variability of rainfall, it often results in climatic hazards, especially floods and widespread droughts with their devastating effects on food production and associated calamities and sufferings (Adejuwon, 2004).

Rainfall regime is the important climate factor influencing agricultural activities. Rainfall can vary considerably even within few kilometers distance and different time scale. This implies that crop yield is exceedingly variable over space and time.It has biggest effect in determining the crops that can be grown, the farming system, the sequence and timing of farming operations (Adejuwon,2005). Rainfall can also be seen as the supplier of soil moisture for crops .The soil moisture supply, however, does not depend on rainfall alone, but also on various other factors concerns in the hydrological equation, such as evapotranspiration and surface run-off(IPCC, 2000).

Theoretically, there are three different forms of rainfall variability are spatio-temporal, inter – annual and intra - annual variability (Nest, 2000). Spatial-temporal variability has to do with differences in total rainfall received between places structurally located within a given region over a period of time. Inter – annual rainfall variation can be defined as the annual variations from long –term averages or the differences in rainfall between years. Intra – annual rainfall variability refers to the distribution rainfall within a year (Obasi, 2003). In the last decade, inter-annual rainfall variations are causes of great stress to the farming activities, crop production and crop yield in the guinea savannah of Nigeria (Adejuwon, 2004). Previous studies such as Obasi (2003) and Adejuwon, 2004 examined inter–annual rainfall variability in Nigeria and other part of West Africa. Observations in Guinea Savannah show that rainfall variability continues to be on the increase following the increase in climate change. The total rain and distribution of rains and season in any location determines the frequency and intensity of drought and flooding as well as the length of growing season in that location. It was also discovered that rainfall variability generally results to increasing and decreasing total rainfall (Ojo, and Oni, 2001).

Study Area

Jigawa State is located between latitude $10^0$56'08.5"N to latitude $13^0$3'19"N and between longitude $8^0$7'55.8"E to longitude $10^0$36'20.8"E. The size of the area is approximately 24,057.52Km^2 with a population of 4,348,649 (census 2006). Jigawa State is bounded by the north Niger Republic, to the east Yobe states, to the west Kano state and to the south and southeast by Bauchi state. It was curved from former Kano State in 1991 by the then military regime and the capital since then remains at Dutse.

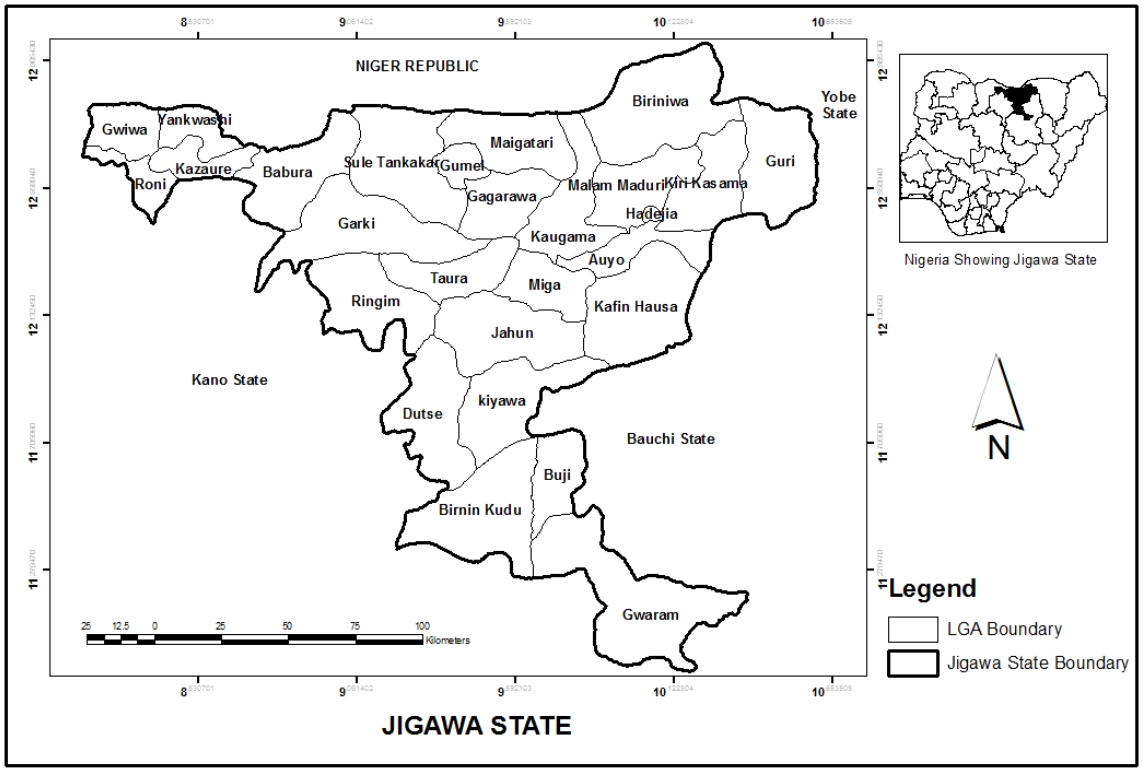


Figure 1: Map of the Study Area
Source: Dept. of Geography, BUK, 2012

The geology of the area is Chad formation consist of sedimentary rocks and gently undulating plains. Olofin (1987) identified six major landforms in Kano region of which five are found Jigawa State. The landforms found in the area are Plains with grouped hills, drift and Pedi plains, sandy plains and dune fields and alluvial channel complexes. The landforms are mostly plain and undulating lowlands with exception of dissected hilly lands. The type of soil identified in the study area is the soil on the Chad formation which is consists of the unconsolidated sediments which are sand with silt or sandy loam on the well-drained interfluves (Olofin, 1987).

The region has tropical continental types of climate with relatively wide and rapid changes of temperature and humidity (Olofin, 1987), the general type, coded Aw by Koppen"s although Climate changes are believed to have occurred in the past. The years are divided into well marked rainy season and dry season. The dry season last from October to May and rainfall is concentrated between June and September. Rainfall patterns of the study area show a distinct and fairly regular south to north gradient in which the annual rainfall in the southern part is about 800mm around Gwaram and about 400-300mm in the north and east around Babura and Birniwa. The seasonal pattern also follows north gradient in length of the wet and season. The season has one peak and generally is highest during month of August. The distance rate is 13 days per degree latitude while retract is almost twice, at rate of seventy seven days per latitude.

Temperature of the region is warm to hot throughout the year even though there is slightly cool period between November and February. The mean annual temperature is about 26^{o}C but the mean monthly value ranges between 21^{o}C in the coldest months (December-January) and 31^{o}C in the hottest month (April-may), the average temperature ranges from 22^{o}C to 28^{o}C.

There is considerable spatial and seasonal

variation in the relative humidity. The marginal spatial variations exist in the relative humidity which increases by 2% southwards. The diurnal ranges may fall from 30% at dawn to 10% in the afternoon in the Harmattan periods when the dry and dust laden northeast trade winds are blowing from the Sahara under cloudless but dusty condition. During rainy season the humidity rises as a result of southwest monsoon wind. The variation in the humidity reflects the variation in temperature. Evapotranspiration is generally high in the study area. The meant annual evapotranspiration of the area is about 2538 as determine by the used of sunken pan method. The actual evapotranspiration estimated at about 60% to 70% of the annual rainfall is not as high as the potential one (Olofin, 1987).

MATERIALS AND METHODS

Data for the purpose of this work were obtained using daily rain gauge data sets from different metrological stations in the region from Jigawa agricultural and rural Development Authority, JARDA, in Jigawa State. The stations here considered (see figure 2) adequately represents a fairly coverage of the study area.

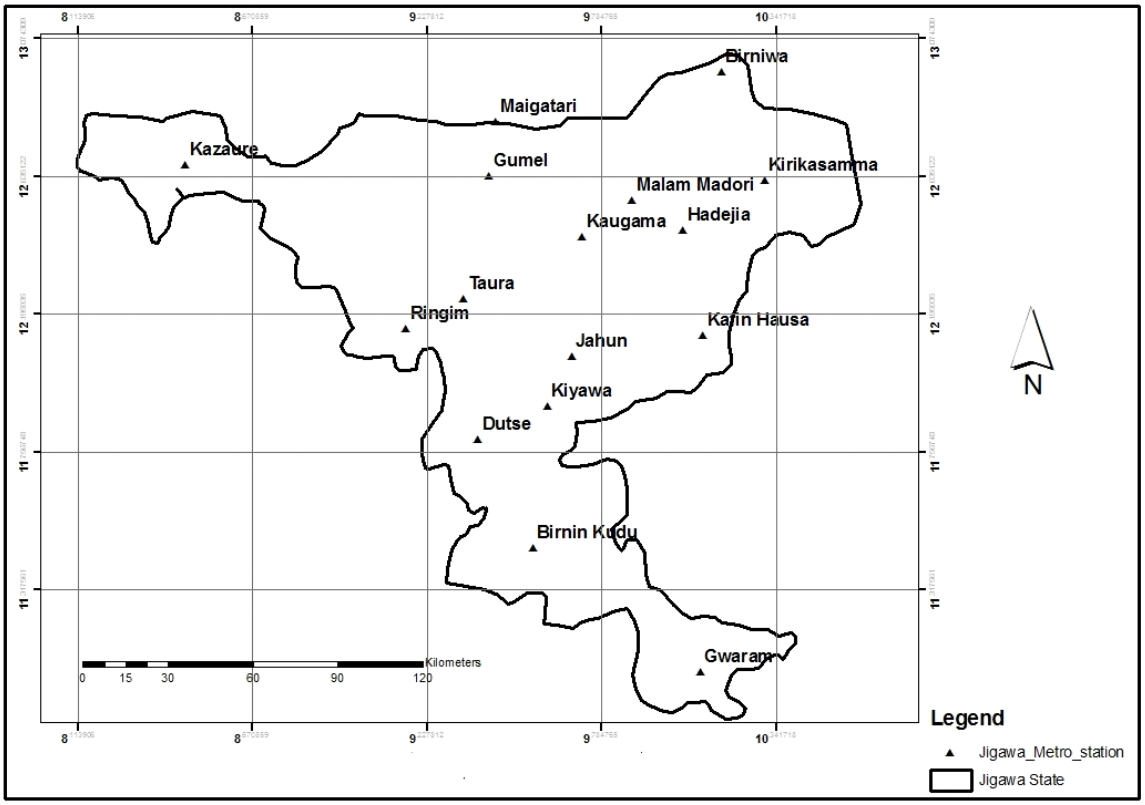


Figure 2: Jigawa State Showing Metrological Station Source: Source: Dept. of Geography, BUK, 2012 data available at the moment of study.

The station were choosing based on the fact that they used standard instrument for recording rainfall data in the region, therefore the stations here are the most reliable and available rainfall data for the region. The data used for the study ranges from 1990 to 2010 ie twenty years, less than thirty years optimum required for climatic studies. The study used the data because is only

Data Analysis

The study seeks to understand the problem of rainfall variability, the statistical analysis of rainfall pattern/trend was used, using World Metrological Organization (WHO). Descriptive statistics of the long term monthly rainfall were computed for all the stations in the study area. Long term annual

mean rainfalls were also computed for all the stations in the area measurement of dispersion (Standard deviations) and variability (coefficient of variation) for all the station were computed from mean data values. Long term annually values/minimum, maximum and mean were also used to produce a graphic map which describes the major feature of rainfall variation over the study area.

Maps of the area were also generated using long term annual values for each station using ArcGIS 9.3 Geographic Information System (GIS) Software. The spatial analysis used is spline which is one of the interpolation methods. It one of the GIS methods of inferences with which data for unrecorded areas are generated by looking at the nearby recorded data. In addition the maps were vectorized since spline is raster operation and can only produce colour map. This is to enable the map to be used in black and white format. Also the fact that vector format is closely related to traditional mapping is another reason for conversion. Bar graphs for inter-annual mean rainfall were also computed for the station to show the temporal variability of the station.

RESULTS AND DISCUSSION

Rainfall records of the area were summarized into monthly and yearly bases. For each station the total annual rainfall were computed from the year 1990 to 2010. The average rainfall for the twenty years was computed for each station.

Table 1 reveals there are a lot of variations in rainfall records between station and within station over a time in the state. The data do not show any clear of rainfall decrease or otherwise in the study area. To have a clear picture, the data above were summarized in table 2 using simple descriptive statistics.

Monthly Rainfall Variation

Monthly Rainfall of the sixteen stations were computed and the mean values were determine and presented in table 1.

Table 1: Mean Monthly Rainfall Summary in mm (1990 - 2010) For 16 stations.

S/N	Station	APRIL	MAY	JUNE	JULY	AUGUS	SEPT	OCT
1.	Birnin Kudu	17.52	51.31	124.51	214.45	279.19	155.86	34.39
2.	Gwaram	14.00	80.00	178.00	257.50	322.50	346.00	41.80
3.	Dutse	0.00	73.30	256.60	273.30	323.30	371.10	24.50
4.	Buji	5.00	62.36	103.32	229.99	285.18	167.81	28.90
5.	Kiyawa	30.90	50.52	82.23	157.35	265.87	118.81	47.16
6.	Jahun	16.90	39.08	118.84	159.02	216.21	142.97	26.40
7.	Gumel	12.00	38.68	57.06	144.84	203.76	98.43	25.57
8.	Maigatari	0.00	54.05	96.91	206.79	287.49	118.68	22.33
9.	Garki	6.20	53.80	101.25	177.31	212.69	156.50	30.83
10.	Ringim	10.08	48.88	105.99	256.51	262.69	128.45	38.31
11.	Taura	30.25	33.40	94.63	191.24	204.15	122.76	37.66
12.	Hadejia	1.00	32.03	52.63	167.71	191.00	136.27	24.30
13.	Kafin Hausa	5.00	38.92	104.42	228.18	244.13	133.98	190.90
14.	Kaugama	0.00	26.70	117.38	163.39	213.76	114.22	26.90
15.	Birniwa	0.00	9.28	59.96	118.20	149.84	88.87	25.07
16.	Kirikasamma	0.00	11.95	76.05	149.63	161.40	142.02	82.47

Source: JARDA, 2012

The rainfall duration is four to five month. Proper rainfall (60mm and above) began in June and lasted till December. However traces of rain are recorded in April, May and October (see table 1). On the overall rainfall is always highest in August, followed by June and September. This conforms to popular belief among the natives of the region.

Summary of Rainfall by Station

To determine the variation between the station mean values, standard deviation, kurtosis and skewness were computed and presented in table 2

Table 2: Rainfall Summary of the Sixteen Stations in Jigawa States (1991-2010)

Station	Mean Rainfall (mm)	Kurtosis	Skewness	STDV	Variance
Birnin Kudu	856.0722	3.75555	1.808367	247.2363	61125.77
Gwaram	808.4722	-0.50065	0.323122	226.2055	51168.95
Dutse	915.7412	-0.49245	0.254901	213.4053	45541.84
Buji	844.9	-0.83594	0.370926	182.832	33427.53
Kiyawa	619.9563	-0.67775	0.399795	310.4467	96377.13
Jahun	643.85	0.447018	0.01474	181.4711	32931.77
Gumel	533.5611	0.029537	0.360178	110.1798	12139.59
Maigatari	698.6	-0.09908	-0.00747	184.8196	34158.3
Garki	716.975	-0.05735	0.715553	214.9025	46183.09
Ringim	772.7611	-0.01969	0.042837	214.2853	45918.2
Taura	626.2235	1.519278	0.629507	173.5526	30120.51
Hadejia	520.9353	1.017842	0.578883	257.044	66071.64
Kafin Hausa	739.4706	1.200285	1.365092	374.03	139898.5
Kaugama	590.5357	-0.07645	-0.5896	187.7511	35250.49
Birniwa	407.9143	-1.06038	-0.01938	153.8618	23673.45
Kirikasamma	483.1776	6.193833	2.351202	333.307	111093.6

Source: JARDA, 2012

Areas around Birnin Kudu has the highest annual rainfall average (about 856mm) while Birnawa has the lowest record as can be observed from the table. The record reveals a wide variation of data around the mean value which conforms to assertion that rainfall in the drylands is highly variable. Kurtoses were computed to determine the spread of data around the modal class. Kirikasamma and Birnin Kudu have the highest variation from the modal class (6.193833 and3.75555 respectively). The values show positive skews except Maigatari, Kaugama and Birniwa which have negative skews. This implies that the data are skew to the right than to the left.

Inter Annual Rainfall Variation

The average rainfall records of the stations were used to calculate the total annual rainfall for the state for the years studied by this work and the findings are shown on figure 3.

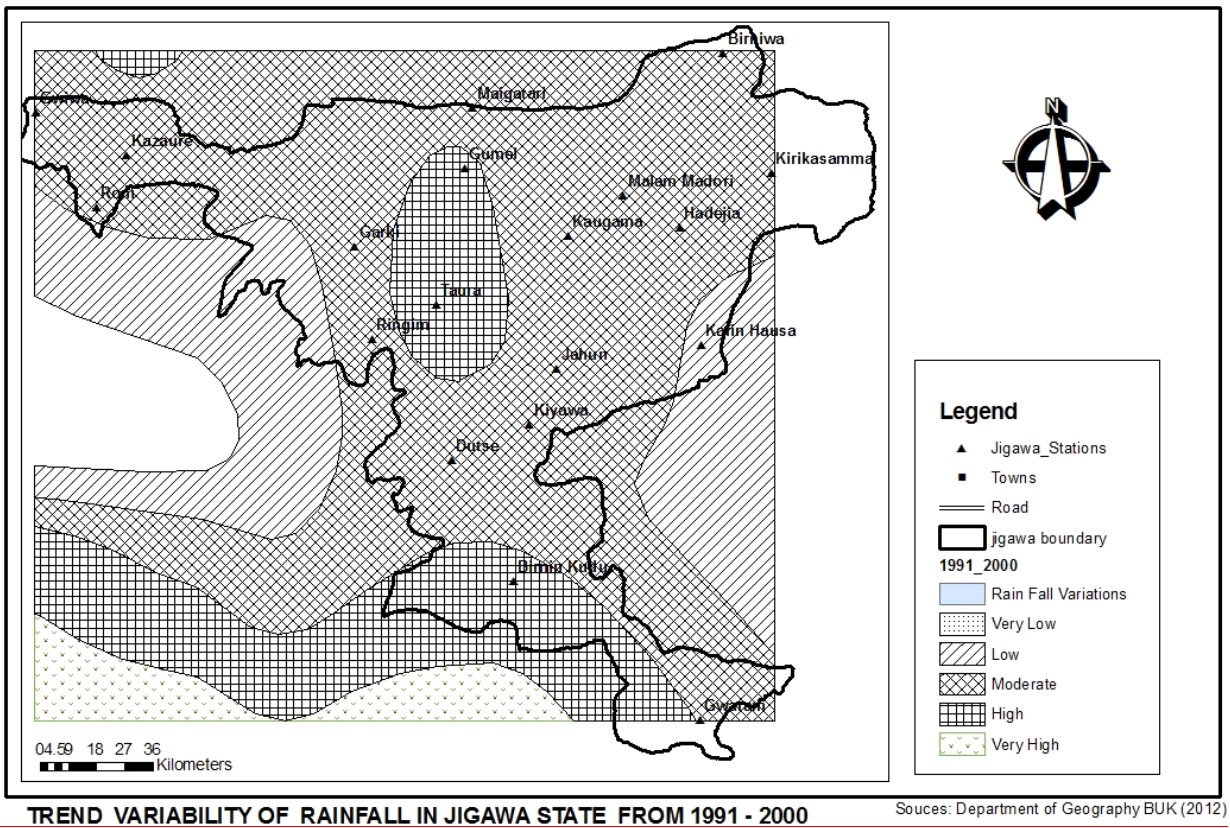
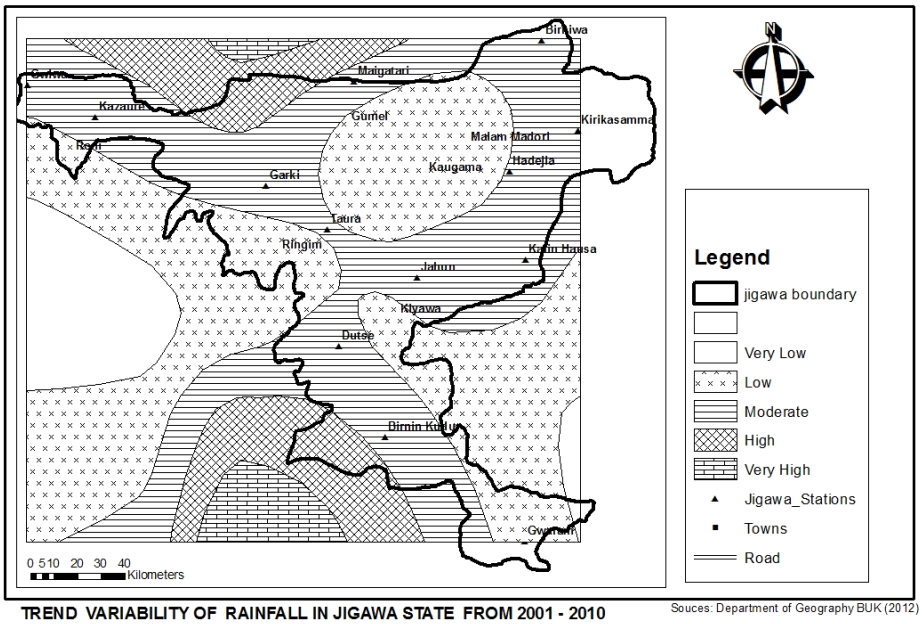


Figure 3: Annual Rainfall Variability in Jigawa State

On average there is no serious change in rainfall in the Jigawa State over the studied periods as shown by the trend line. However the two period moving averages have shown that highest rainfall amount were received between 1994 and 2000. Rainfalls below averages were recorded in the year 1991, 1992, 2004, 2005 and 2010.

The data were imported in the ArcGIS 9.3 environment to draw a choropleth maps to show the distribution rainfall of the area (figure 4). Spline method which is one of the interpolations techniques was used to generate data of unrecorded areas from the recorded stations. Jigawa state is part of the Kano region (Olofin, 1987). Therefore to create the map station within Kano region were considered to generate the rainfall distribution map of the area. From the map areas were classified into very low, low, moderate, high and very high rainfall area. Most areas in Jigawa fall within low and moderate rainfall areas.Two maps were drawn, one showing the rainfall distribution between 1991 and 2000, and another one between 2001 and 2010.



TREND VARIABILITY OF RAINFALL IN JIGAWA STATE FROM 2001 - 2010

Rainfall is low around Malam Madori, Kaugama, Gumel and Ringim. Rainfall is moderate around Birnin Kudu, Garki, Kazaure and Jahun. Only areas in south western parts and extreme north eastern parts are receive high rainfall compare to the surrounding areas.

Comparison of Rainfall Averages

Bars were drawn to show whether the rainfall increases between 1991 and 2000 and between 2001 and 2010 on average (figure 5).

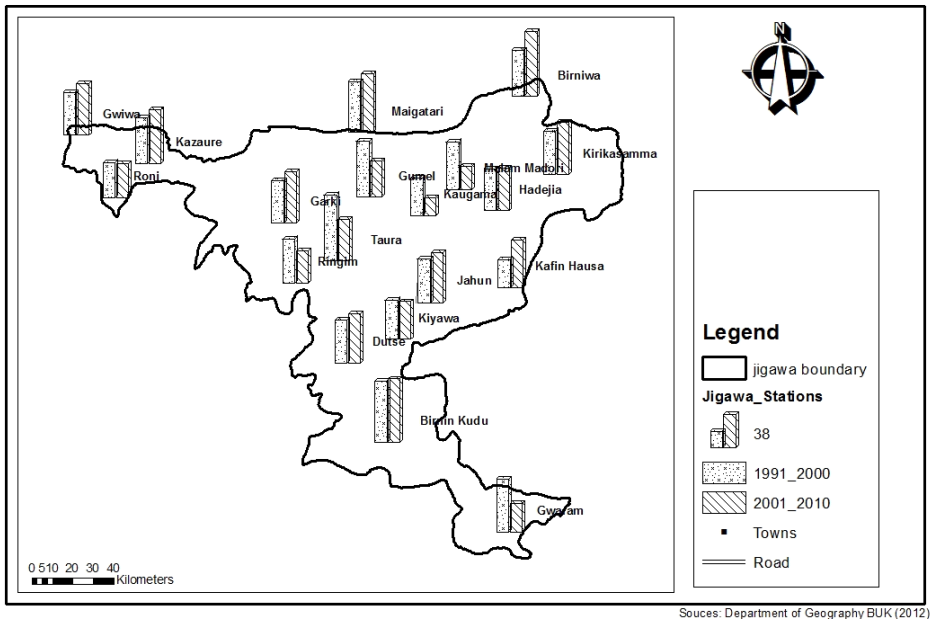


Figure 5: Comparison of Average Rainfall between 1991-2000 and 2001-2010

This reveals rainfall variability in the area and by extension Kano region is a complex phenomenon and subject to fluctuation. While rainfall on average increases between the two periods (1991-2000 and 2001-2010) in areas such Gwiwa, Kazaure, Birniwa and Kirikasamma, it decreases in areas such as Garki, Jahun and Taura.

CONCLUSION AND RECOMMENDATIONS

Rainfall is the most important climatic variable in tropical dry land areas such as Jigawa State. Its distribution is subject to wide range fluctuation and variation. So far the research cannot confirm a vivid change in rainfall distribution in the area. The findings had shown rainfall in the area is highly variable and so easy to predict. The paper further concludes by the following recommendation:

- That there is need for adequate meteorological data records in the area. As observed by the study in many areas some data were missing and this can impair the findings and conclusion of the research.
- That land degradation in the area cannot be attributed mainly to rainfall and other climatic change phenomena, but other factors like land mismanagement, poor agricultural practices among others.
- Better environmental management practices are magic wand for achieving environmental sustainability.

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Appendix 1: Total Annual Rainfall in Jigawa State (1991-2000)

Station	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Birnin Kudu	720	647.5	782.4	1584.9	686.3	730.7	901.5	802.4	883.9	733.7
Gwaram	540	586.5	490	906.7	1082.1	447.5	755.5	541.6	601.5	830.9
Dutse	632	862	610.1	1100.2	717.2	990	839	998.2	918.4	602.4
Buji										880.9
Kiyawa	650	667.6	558.7	877	330.9	1190	825.1	577.6	1135.1	457.7
Jahun	489.9	545.5	485.8	622.4	451.2	614.8	495.3	725.1	667	770.8
Gumel	478.9	417.3	560.5	529.4	562.6	466.8	431.8	779.2	572.9	437.7
Maigatari	409.8	693.4	424.7	580.3	844.6	864.5	439.2	719.5	645	368.5
Garki	690	771.1	570.3	731	1057.7	906	673.7	1148	550.9	574.6
Ringim			516	1205	351.4	772.5	789.9	835.6	768.9	445.9
Taura	568.5	522.5	314.2	629.6	540.5	589.1	813.5	702.3	653.7	486.6
Hadejia	846.5		257.8	826.9	339.9	528.1	1154.7	690	522.5	568.5
Kafin Hausa			395.9	1459	645.1	751	1270.3	631.5	539.1	1669.6
Kaugama	693.4			542.5	238.5	647.5	586.5	862	545.5	667.6
Birniwa	771.1	417.3	573.5	519.9	513.6	691.8	531	488.8	479.2	426.6
Kirikasamma	602.4	502.4	302.3	982.4	260.7	482.1	1575	685.6	602.3	370.42

JARDA, 2011

Appendix 2 Total Annual Rainfall in Jigawa State (2001-2010)

Station	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Birnin Kudu	956.5	501.4	1362.9	787.6	869.1	815.7	957.8	674.7	684.8	693
Gwaram	983.7	870.3	881	894.7	609.5	839.3	1228.2	644.5	705.7	1239.8
Dutse	874.2	661.2	906	657.5		1028.1	1307.3	1071.4	964.3	1322.1
Buji	845.5	592.5	1149.6	661	637	874		939.6	742.7	1126.2
Kiyawa	567.9	535.8	1045.3	708.3			121.3	353.6	201.2	433.8
Jahun	701	582.4	809.5	523.4	1001.1	250.7	662.9	938.2		
Gumel	601.9	442.9	660.5	485.7	576.4	590.7	337.2	376.6	486.7	704.6
Maigatari	816.3	714.5	1087.5	828.8	698		678	586	882.2	
Garki	782.4	383.8	676.3	549						
Ringim	1018.8	1008.9	664	816.5	1094	762.8	710.8	576.6	718.5	853.6
Taura	1080.2	417.3	693.4	771.1		417.5	502.8	684.4	638.1	711.5
Hadejia	846.5	393.7	590.9	385.4	28	319.1		275.9	531.5	596.5
Kafin Hausa	779.2	723.4	900.2	605.6	504.7	287.7		390.9	476.4	541.4
Kaugama	838	401.1	616.6	587.3				691.5	234.4	808.5
Birniwa	161.6	214.5	253.6					223.7	321.2	311.8
Kirikasamma	401	275.7	283.4	169	240	284.8		467.9	437.5	393.9