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RAINFALL TRENDS AND OCCURRENCE OF FLOODS IN KATSINA STATE: IMPLICATIONS FOR INFRASTRUCTURAL DEVELOPMENT

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Abstract

Increase in extreme weather events such as flooding has become an annual recurring feature in Nigeria, especially the Northern States. This study examines the recent rainfall trends and occurrence of floods in Katsina State. Annual and monthly rainfall data for Katsina from the period 1985 to 2014 were used to analyze the rainfall trends of the area. The standard deviation was then used to determine the rainfall deviation from the normal. The paper focused on the floods event of 2012 and 2013 in the State and the implications for infrastructural development. A total of 404 copies of a questionnaire were administered to flood affected communities in order to obtain information of damages on infrastructures in the area. The Relative Seasonality Index of the rainfall series revealed that the rainfall is in 3 months or less. The 5-year running mean shows annual rainfall below the long-term mean lasted from the beginning of the data up to the late 1990s and above-average afterwards. The linear trend lines also show an increase in rainfall. The recent increase in annual rainfall amount in the study area is as a result of the increase in June, July and August rainfalls which is one of the factors responsible for the frequent occurrences of floods in the months of July and August in the State. Findings also revealed that most of the flood occurrences owe their reasons not only to high torrential rainfall, but also improper physical planning and erection of structures in areas of high risk. The major implication of these finding is that infrastructures built on the perceived decreasing rainfall have to be reviewed. The study recommends that, planning and designing of infrastructures should take into account the recent rainfall trends and occurrences of floods in the area for sustainable development.

Keywords: Climate change; Flooding; Hazard; Infrastructures; Trends

Introduction

Climate change is one of the greatest socioeconomic and biophysical challenges confronting the world in the 21st century. Human activity, particularly deforestation and the burning of fossil fuels, is driving this change by increasing atmospheric concentrations of carbon dioxide and other greenhouse gases (GHGs). As a result, the world is experiencing greater weather extremes, changes in rainfall patterns, heat and cold waves, and increasing droughts and floods. These phenomena have a negative impact on the environment and on people's lives and livelihoods. Marginalized groups in the poorest regions are particularly affected, even as they are least responsible for these changes (UNDP, 2009).

Flood disasters which are always the result of both natural phenomena and human actions have increased in number and magnitude in many regions of the world over recent years thereby demanding attention and actions. According to UNDP (2009), flooding is the outcome of natural hazard and human vulnerability coming together. Indeed, flood disaster does not only happen in a physical environment, it also occurs in a social and political context. This implies that flood disaster not only reveals the underlying social, economic, political and environment problems, but unfortunately contributes to worsening them, hindering economic and social progress. There is increasing evidence that pre-existing social, economic, political and environmental conditions determine the impact of flood disaster, thus, the weaker the pre-existing conditions are, the higher the impact of a flood disaster will be. In other words, the more vulnerable, and thus less resilient, are the social context in which a disaster occurs, the bigger the impact and the damage. As the flood disaster occurred, the pre-existing structure and social condition actually determined the impact it had on the people and social structure.

The severity of the impacts of the flood disaster is seen in the displacement of over 21million people; destruction of 597,476 houses; death of 363 people and estimated loss of USD 19.6 billion (NEMA, 2013) thereby raising security issues as it broadens security concerns away from exclusive military threats to state to include non-military threats like poverty, hunger, diseases, environmental degradation, thus the concept of human security.

Traditionally, flood disaster is conceived as environmental or humanitarian issue, but they now constitute security concerns. So in today's world, and because of their probable relationship to climate change, flood disaster must essentially be understood as a human security issue. They represent not only a threat to people's survival, but also constitute a vulnerability factor for people and communities and even nations.

Flooding as witnessed in some parts of Katsina State in the years under study (2012 and 2013) severely impacted the human security of areas hit by the disaster. On an individual or household level, the flood brought about death, injuries and trauma. By massively devastating farmland, farm produce and social infrastructure, the flood destroyed people's livelihoods and ability to their assured food and economic security on a daily basis thereby becoming dependent on relief assistance from government, NGOs and other organization to survive.

In Katsina State, limited studies have been conducted on occurrence of flood and its implications for infrastructural development. The objectives of this study, therefore, are to:

i) examine the rainfall characteristics of the study area;

ii) examine the causes of floods in the area with particular reference to the 2012 and 2013 flood disasters; and

iii) examine the implications for infrastructural development.

Study Area

Katsina State (Figure 1) is located between latitude 11o 00′N and 13o 20′N and longitude 7o 00′E and 8o 55′E. It shares boarder with Niger Republic to the North, Kaduna State to the South, Jigawa and Kano States to the East, and Zamfara State to the West. Katsina State has a land size of about 24,971.215km2 with a population of 5,801,584 as at 2006 national census (Federal Republic of Nigeria, 2010).

The climate of Katsina State is the tropical wet and dry type, classified by Koppen as Aw climate. Rainfall is between May and September with very high intensity between the months of July and August. (Abaje et al, 2014). The average annual rainfall varies from 550 mm in the northern part to about 1000 mm in the southern part of the state. The pattern of rainfall in the state is highly variable. As a result, the state is subject to frequent floods that can impose serious socio-economic constraints (Abaje et al, 2012).

Seasonal variation in rainfall is directly influenced by the interaction of two air masses: the relative warm and moist tropical maritime (mT) air mass, which originates from the Atlantic Ocean associated with southwest winds in Nigeria; and the relatively cool, dry and stable tropical continental (cT) air mass that originates from the Sahara Desert and is associated with northeast trade winds. The boundary zone between these two air streams is called the Inter-tropical Discontinuity (ITD). The movement of the ITD northwards across the state in August marks the height of the rainy season in the whole State while its movement to the southernmost part around February marks the peak of the dry season in the State (Odekunle, 2006; Abaje et al, 2012; Abaje et al, 2014). The annual mean temperature is about 27oC. The highest air temperature normally occurs in April/May and the lowest in December through February (NIMET, 2015). The soil is the tropical ferruginous type while the vegetation is the Sudan Savanna type which combines the characteristics and species of both the Guinea and Sahel Savanna (Abaje, 2007)

Materials and Methods

Rainfall data for thirty (30) years (1985-2014) were used to analyze the recent rainfall characteristics of the study area. The data were sourced from the archive of Nigerian Meteorological Agency

(NIMET). Only rainfall totals for the monthly growing season (May-September) and the annual were used in this study. The main reason is that 85% of the total annual rainfall received in the study area are within these months.

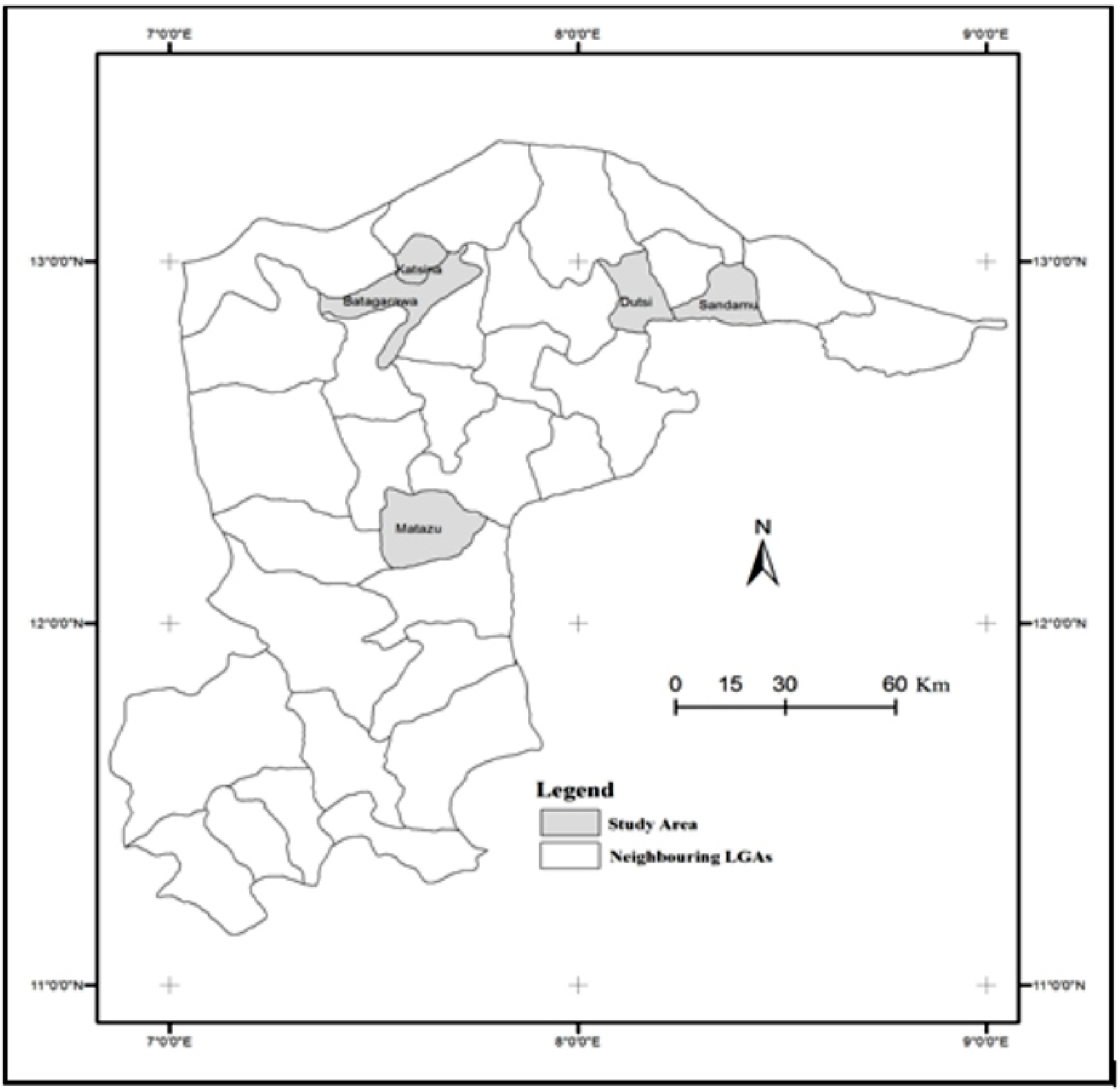

Figure 1: Map of Katsina State Showing the Study Area

The standardized coefficients of Skewness (Z_1) and Kurtosis (Z_2) statistics as defined by Brazel and Balling (1986) were used to test for the normality in the rainfall series for the study area. The standardized coefficient of Skewness (Z_1) was calculated as:

$$Z_1 = \left[\left(\sum_{i=1}^{N} (x_i - \bar{x})^3 / N \right) \Big/ \left(\sum_{i=1}^{N} (x_i - \bar{x})^2 / N \right)^{3/2} \right] \Big/ \left(6/N \right)^{1/2} \quad \text{eq. 1}$$

and the standardized coefficient of Kurtosis (Z_2) was determined as:

$$Z_2 = \left[\left(\sum_{i=1}^{N} (x_i - \bar{x})^4 / N \right) \Big/ \left(\sum_{i=1}^{N} (x_i - \bar{x})^2 / N \right)^2 \right] - 3 \Big/ \left(24/N \right)^{1/2} \quad \text{eq. 2}$$

where $\bar{x}$ is the long term mean of x_i values, and N is the number of years in the sample. These statistics were used to test the null hypothesis that the individual temporal samples came from a population with a normal (Gaussian) distribution. If the absolute value of Z_1 or Z_2 is greater than 1.96, a significant deviation from the normal curve is indicated at the 95% confidence level. If the data are not found to be normally distributed, various transformation models could be used to normalize the series such as Log transformation and Lambda transformations of Box and Cox (1964), and Square and Cube Root transformations (Stidd, 1970) amongst others.

The Relative Seasonality Index (SI) of the rainfall series was calculated using the Walsh and Lawler (1981) statistic. This was done in order to show the class into which the climate of Katsina State can be classified. This index is calculated as:

$$SI = \frac{1}{\overline{R}} \sum_{n=1}^{n=12} \left| \overline{x}_n - \frac{\overline{R}}{12} \right| \qquad \text{eq. 3}$$

where is the mean rainfall for month n and is the mean annual rainfall. This index can vary from zero (if all the months have equal rainfall) to 1.83 (if all the rainfall occurs in a single month). Table 1 shows the seasonality index classes as proposed by Walsh and Lawler (1981).

Table 1: Seasonality index classes

Rainfall Regime	***SI* Class Limits**
Very equable	⩽ 0.19
Equable but with a definite wetter season	0.20-0.39
Rather seasonal with a short drier season	0.40-0.59
Seasonal	0.60-0.79
Markedly seasonal with a long drier season	0.80-0.99
Most rain in 3 months or less	1.00-1.19
Extreme, almost all rain in 1-2 months	⩾1.20

Source: Walsh and Lawler (1981)

To examine the nature of the trends, linear regression was used to determine the linear trends of the rainfall series and changes in rainfall were also calculated using Microsoft Excel Tool (2013) for both the monthly (May to September) and annual rainfall totals (mm) for the station. In this work, the 5-year moving mean was used in order to smoothing the time series, thereby reducing the irregular fluctuations and highlighting those that are regular. The formula for the linear regression is given as:

$$y = a + bx \qquad \text{eq. 4}$$

where a the intercept of the regression line on the y-axis; b is the slope of the regression line. The values of a and b can be obtained from the following equations:

$$a = \frac{\sum y - b\left(\sum x\right)}{n} \qquad \text{eq. 5}$$

$$b = \frac{n\left(\sum xy\right) - \left(\sum x\right)\left(\sum y\right)}{n\left(\sum x^2\right) - \left(\sum x\right)^2} \qquad \text{eq. 6}$$

In ascertaining the nature of trends and measurement of variability of the rainfall, the standard deviation, which provides the deviation from normal (average) was equally determined and plotted using Microsoft Excel Statistical Tool (2013). From the plotted charts, extreme conditions were then detected. The standard deviation is given by the formula:

$$\delta = \sqrt{\frac{\sum (x - \overline{x})^2}{n}} \qquad \text{eq. 7}$$

where:

x= value of rainfall observations;

$\overline{x}$= mean value of rainfall observations;

n= number of rainfall observations of sample; and

δ= standard deviation.

Eighteen (18) LGAs were affected in the 2012 flood disaster while the 2013 flood disaster affected twenty (20) LGAs (Table 2).

Table 2: Flood Disaster Affected Local Government Areas (2012 and 2013)

2012 Flood Disaster		2013 Flood Disaster	
LGA	**Affected Victims**	**LGA**	**Affected Victims**
Maiadua	721	Charanchi	129
Batsari	409	Kankia	225
Bindawa	514	Daura	281
Safana	475	Zango	257
Kurfi	244	Mashi	81
Kankia	23	Katsina	285
Jibia	17	Malumfashi	102
Katsina	535	Ingawa	32
Dutsi	949	Musawa	223
Ingawa	785	Matazu	153
Rimi	425	Danja	90
Mani	489	Dutsin-Ma	93
Daura	608	Jibia	241
Matazu	1365	Batagarawa	331
Sandamu	948	Kaita	279
Batagarawa	1232	Funtua	227
Danmusa	259	Baure	53
Kusada	515	Kurfi	186
		Maiadua	281
		Danmusa	94

Source: Katsina State Emergency Management Agency (2014)

The 2012 and 2013 floods affected LGAs were then ranked in descending order based on the affected number of victims according to their senatorial districts. In a situation where a LGA is affected in both the 2012 and 2013 flood disasters, the year with the highest number of victims was then used in the ranking. Proportional sampling method was used in selecting the five LGAs with the highest number of victims in the three senatorial districts as follows: Dutsi and Sandamu LGAs in Katsina North Senatorial District, Batagarawa and Katsina LGAs in Katsina Central Senatorial District, and Matazu LGA in Katsina South Senatorial District (Table 3). These LGAs were also chosen as an attempt to provide a representative sample of the victims' perceptual assessment of the causes and damages from the 2012 and 2013 flood disasters within the constraints of time and available resources.

Key informant survey was also carried out with field staff of the State Emergency Management Agency (SEMA) in order to obtain an in-depth information on the causes and damages of the 2012 and 2013 floods.

In order to determine the sample size and anticipated response rate of the population, Bartlett et al (2001) method was adopted. The method is computed as:

$$n_0 = \frac{(t)^2 \times (p)(q)}{(d)^2} \quad \text{eq. 8}$$

for sample size of not more than 5%.

Therefore, the required sample size for the population (N) of the study area is calculated as:

$$n_1 = \frac{n_o}{1 + {n_o}/{N}} \quad \text{eq. 9}$$

and

$$n_2 = n_0 \Big/ \left(\frac{r}{100}\right) \qquad \text{eq. 10}$$

for adjusted sample size for response rate

where:

t = value for selected alpha level of 0.025 in each tail which is 1.96

$(p)(q)$ = estimate of variance which is 0.25

d = acceptable margin of error for proportion being estimated which is 0.05

n_0= sample size of not more than 5

n_1 = required return sample size

n_2 = sample size adjusted for respond rate

N = population size

r = anticipated response rate

Based on this method, a total of 404 copies of a questionnaire were administered to flood victims of 2012 and 2013 in the affected Local Government Areas (LGAs) of the State based on simple proportion with anticipated response rate of 95% (Table 3). This was done in order to obtain information about their perceptual assessment of the causes and damages from the flood disaster.

The interview was conducted in September, 2014. Ten (10) Research Assistants (RAs) with first degree who were indigenes of the selected LGAs that understood the local dialect (Hausa) were trained to conduct the interview. Regular supervision was carried out by the authors to ensure effective administration and collation of the questionnaires.

Table 3: Selected Local Government Area in each Senatorial District

Senatorial District	LGAs	Selected LGAs	No of Affected Victims	No. Sampled
North	Dutsi, Sandamu, Ingawa, Maiadua, Daura, Kusada, Bindawa, Mani, Zango, Kankia, Mashi, and Baure.	Dutsi	949	76
		Sandamu	948	76
Central	Batagarawa, Katsina, Safana, Rimi, Batsari, Kaita, Danmusa, Kurfi, Jibia, Charanchi, and Dutsin-Ma	Batagarawa	1232	99
		Katsina	535	43
South	Matazu, Funtua, Musawa, Malumfashi, and Danja	Matazu	1365	110
Total				**404**

Source: Field Survey, 2014

Results and Discussion

Rainfall Characteristics

The calculated SI was 1.13, which means that most of the rainfall in the study area is within 3 months or less. The general statistics of the monthly (May to September) and annual rainfall of the study area (1985-2014) are presented in Table 4. The mean monthly rainfall of the study period shows a single peak in August (194.8 mm).

Figure 2 (a) shows the graphical presentation of the annual trends of the rainfall series smoothened out with the 5-year running mean. The lowest annual rainfall of about 240.6mm was experienced in 1985 while the highest annual rainfall of about 955.7mm was experienced in 2010. The 5-year running mean shows annual rainfall below the long-term mean lasted from the beginning of the data up to the late 1990s.

Table 4: General statistics of the rainfall (1985-2014)

Statistics	May	June	July	August	September	Annual
Mean	34.6	74.20	134.6	194.8	88.4	544.7
Standard Deviation	31.5	43.36	52.7	77.7	53.1	170.8
Skewness (Z_1)	0.63	0.64	0.54	0.41	1.15	0.02
Kurtosis (Z_2)	-1.03	-0.80	-0.09	-0.93	0.62	-0.23
Minimum Value	0	18.8	39.8	71,3	17.9	240.0
Maximum Value	95	157.9	264.3	359.1	216	955.2
Trend (mm/year)	1.41	2.52	2.74	3.86	0.74	11.76
Total Change (mm/30 years)	42.3	75.6	82.3	115.8	22.2	352.8

From the late 1990s to the end of the study period, the rainfall was above the long-term mean. The linear trend line generally shows an increase in rainfall in the recent years. A general examination of the monthly running means (Figure 2 (b-f)) shows that rainfall has been increasing from the year 2000 to the end of the study period.

The plotted standard deviation for the monthly rainfall anomalies (Figure 2b-f) generally show that years of rainfall above the mean standard deviation were more than below the mean standard deviation from the late 1990s to the end of the study period. The annual rainfall (Figure 2a) shows 9 anomaly years (5 below the mean standard deviation and 4 above it) of the 30 years of study. All the 5 years of rainfall below the mean standard deviation occurred between 1985 and 1993. These years of rainfall below the mean standard deviation coincides with the droughts of the 1980s that ravaged the country. On the other hand, all the 4 years of rainfall above the mean standard deviation occurred between the 2005 and 2013. The findings are also in agreement with the observations made by Odekunle et al (2008), Abaje et al (2012), Abaje et al (2013) and Abaje et al (2014) that northern Nigeria has been experiencing decreasing number of dry conditions and consequently, increasing wetness from the 1990s to the recent years. The increasing wetness appears to be accounted for by significant northward shifts in the surface location of the ITD over the country.

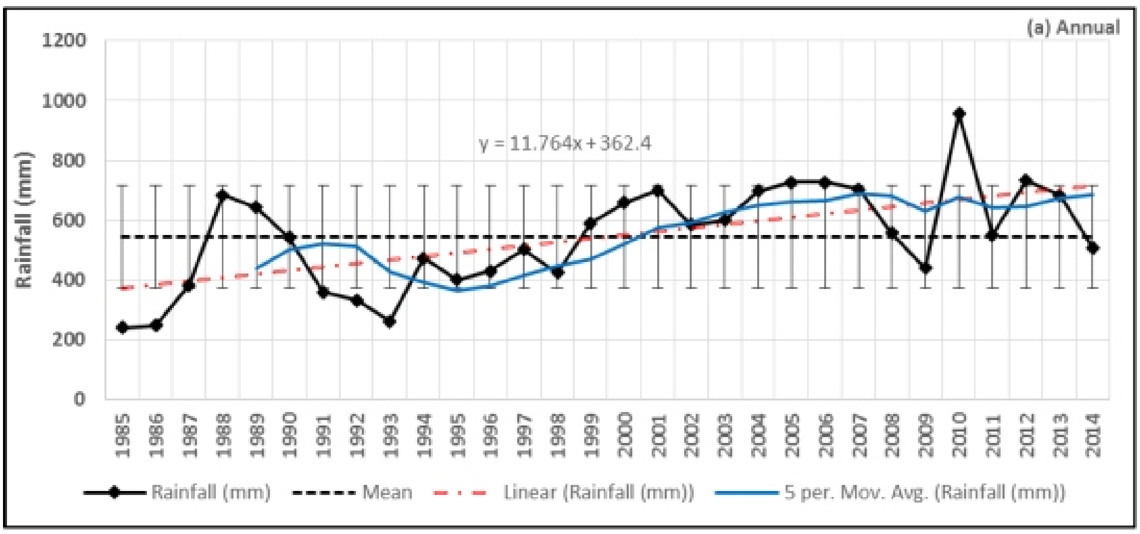

Figure 2: Rainfall Trends for Annual and Monthly Totals

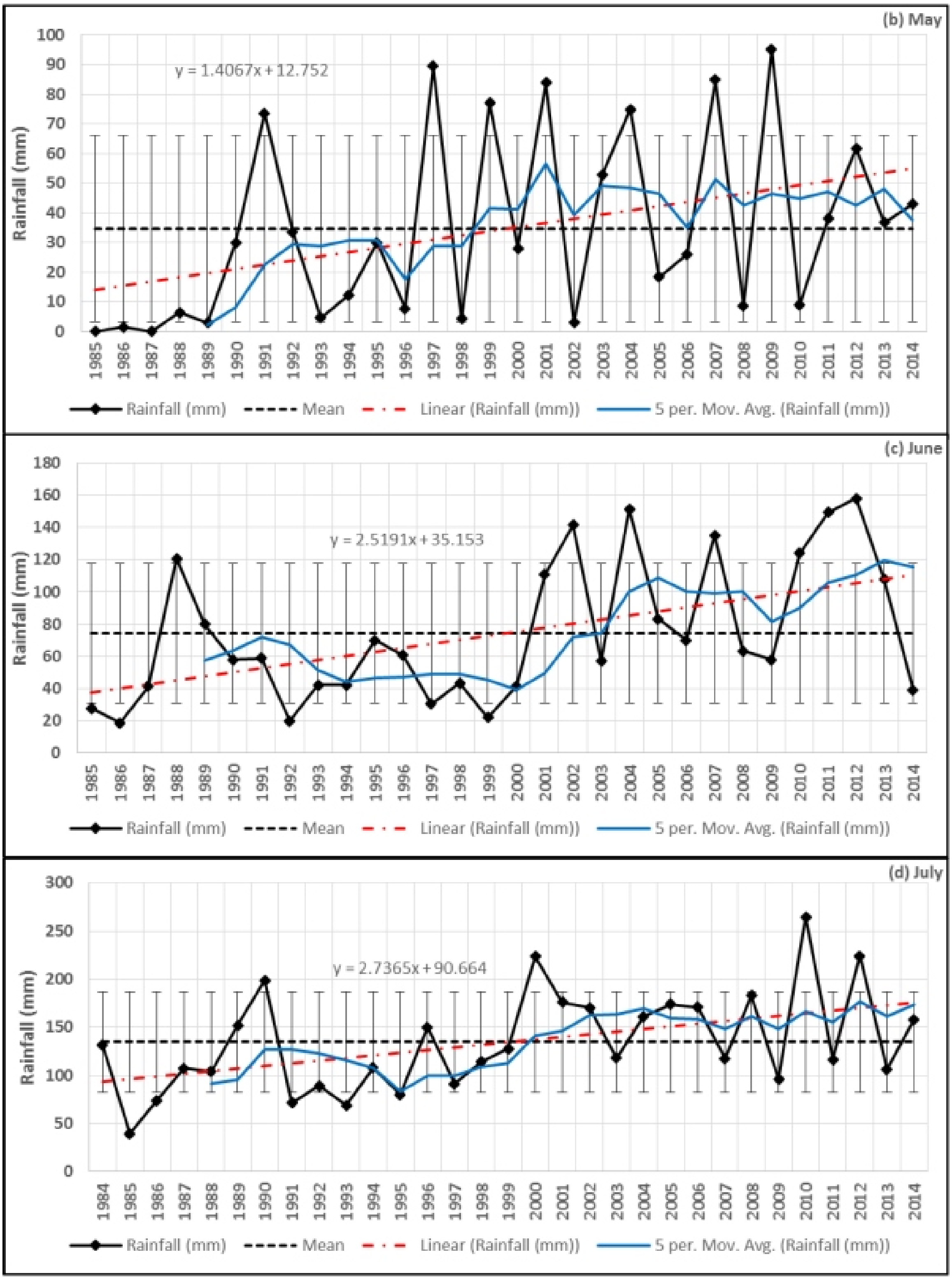

Figure 2: Continued

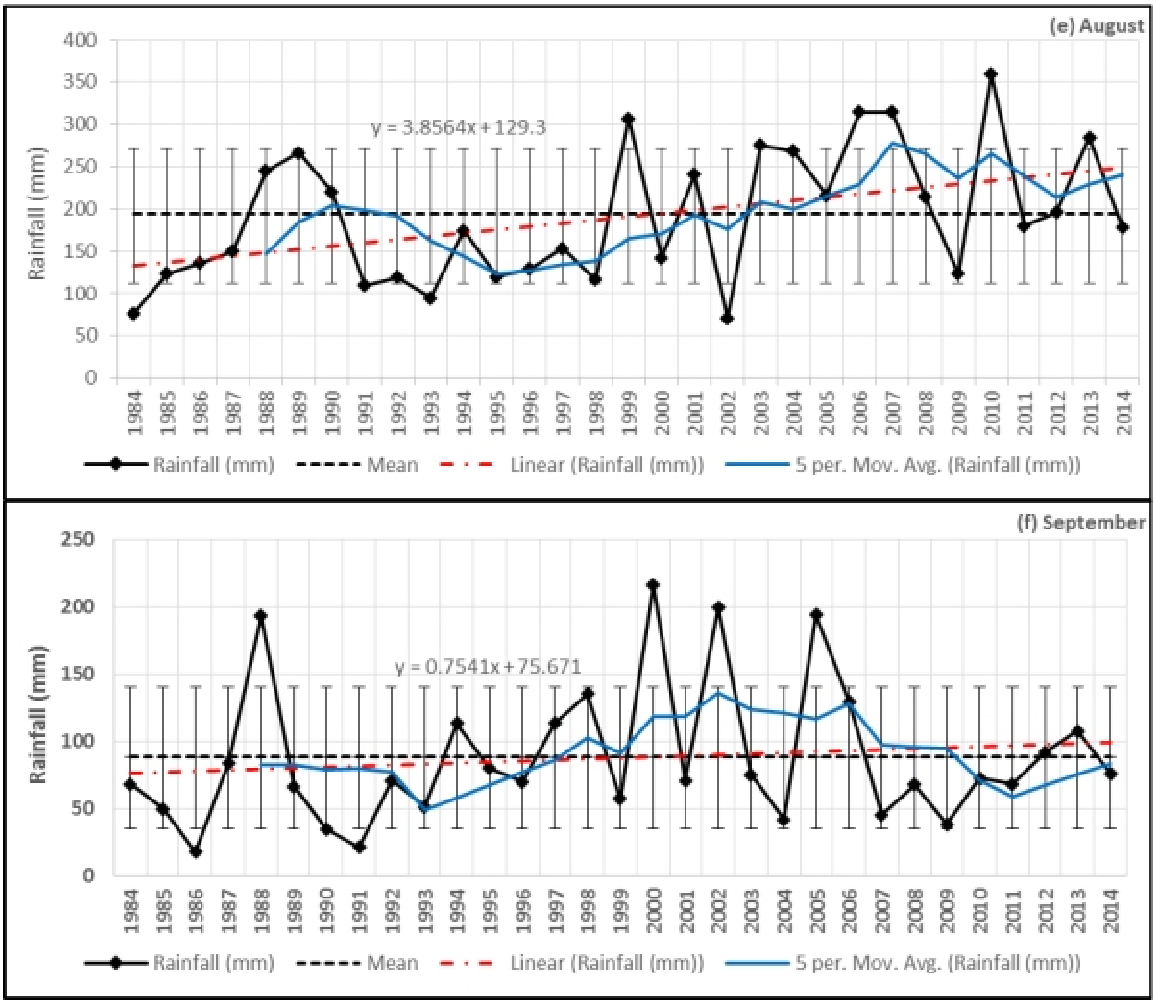

Figure 2: Continued

It is clear from the results that the annual rainfall has increased in the last 30 years. Increase in the annual rainfall yield is predominantly as a result of the increase in June, July and August rainfall. The increase in rainfall for these months is one of the factors responsible for the frequent occurrence of floods within those months.

Socioeconomic Characteristics of Respondents

The results of the field survey conducted revealed that the majority of the respondents were males (89.5%) while only 10.5% were females. 82.5% of the respondents are married; and the average household size is 9. Out of the 404 respondents, 23.5% attended Quranic School, 34% primary school, 12% have tertiary education, and 24.5% have secondary education, while 6.0% have no education at all. Majority of the respondents (43.5%) are between 41-50 years. The major occupation of the respondents is farming which represent 55.5%, while 24.5% are civil servants, 16.5% traders, and others (3.5%). This implies that, the respondents depend heavily on natural and physical resources of the environment for their livelihood.

Causes of Floods

From the surveyed questionnaires, 54.5% of the respondents opined that rainfall has been increasing in recent times. This is in agreement with the analyzed rainfall data that showed an increase in rainfall over the recent years. The result is also in agreement with the study of Abaje et al (2012) in the Sudano-Sahelian Zone of Nigeria that, at present, the climate of the region indicates a tendency towards a wetter condition rather than the increasing dryness that was a feature of the period from the 1960s to the 1980s. Heavy rainstorms according to the respondents (63.5%), do precede the occurrence of floods in the area and was suggested as the main cause of the 2012 and 2013 floods. This result is in agreement with the work of Abaje and Giwa (2010) in which 87% of the respondents said that torrential rainstorm do precede the occurrence of floods. About 65.5% of the respondents said that August rainfall is always heavy and the month marks the peak of the raining season in the study area. Only 19.5% and 15% opined that the rainfall is heavy in the months of July and September respectively.

In 2012, the highest amount of rainfall was recorded in the month of July (224mm) while August recorded 195.8mm that year; whereas in 2013, the highest amount of rainfall (284.7mm) was recorded in the month of August (Figure 3). It means that rainfall amount in the state is concentrated within two months (July and August). Coincidentally, the 2012 flood disaster occurred in the months of July and August while the 2013 flood disaster occurred in the month of August. This means that the heavy rainstorm of the months of July and August is one of the factors responsible for the occurrence of the July 2012 and August 2013 floods in the area. Climate change and global warming might be responsible for the unusual and frequent torrential rains in the area. This is in agreement with the observations made by Trenberth et al (2007) that as climate changes, changes are occurring in the amount, intensity, frequency and type of precipitation.

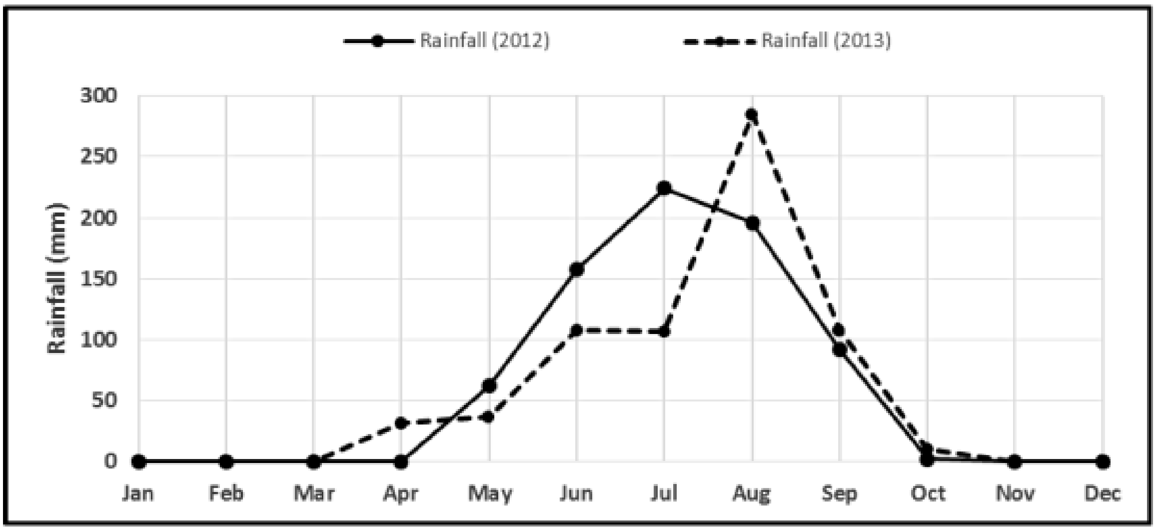

Figure 3: Monthly Rainfall for 2012 and 2013

Increasing frequency and severity of flood do not stem from torrential rainfall alone. It is noted that increasing rate of urbanization in the absence of well-articulated and comprehensive physical planning and land use planning control is one of the major factors that causes floods in the area. About 74% of the respondents in the various areas affected by the flood said that their houses plans were not approved by the relevant authority before being built.

In terms of drainage systems, 64.5% of the respondents said there are no drainages in their communities while 35.5% have drainage systems. This is in-line with the field observations that show inadequate drainage channels in most of the affected areas visited. In areas where drainages exist, these have been blocked by refuse as the communities are in the habit of dumping their wastes in the drainage channels. It was also observed that most of the houses affected were constructed on waterways. About 69% of the houses according to the respondents were built with mud. These mud houses, coupled with the sandy nature of the soil cannot easily withstand any flood disasters. About 77.5% of the respondents said that the State government through the Ministry of Environment has been enlightening them on the dangers of farming and building on areas liable to flooding, but people still construct houses (especially in urban LGAs like Katsina and Badagarawa) and farm in such areas as testified by 69% of the respondents.

Deforestation which is the deliberate destruction of the vegetation as a result of the activities of Man and his domesticated animals (Abaje, 2007), can intensify flooding by affecting the soil structure, reducing infiltration rates and reducing water storage. Evidence has shown that forests and grasses provide an intercepting layer for rainfall, which reduces the rate of overland flow. From the surveyed questionnaires, 72.5% of the respondents use firewood as their source of cooking, 5.5% (gas), and 22% (kerosene). With this, it is clear that deforestation is another factor that causes floods in the area. This is evident from the 78% of the respondents that said they have never planted any tree to replace the ones cut down.

Implications of the Flood Disasters on Infrastructural Development in the State

In 2012 and 2013, the ravaging effects of flooding in Nigeria became so drastic that it was seen as a national disaster. Katsina State was among the 34 states that had the bitter experience of the flood. Houses and other public and private properties, infrastructure and facilities were submerged and destroyed, while many residents were displaced (NEMA, 2013). Data collected and analyzed revealed that the damage caused by the flood ranges from loss of lives, livelihoods to destruction of houses and infrastructural facilities in the areas.

Infrastructures here include bridges, roads, schools, hospitals, markets, electric poles, etc. Analyzing the response of the flood disaster on infrastructural facilities shows the damage on roads were the most severely affected (46.5%) and unfortunately, roads are the largest, fastest-growing and the most heavily used transport infrastructure in the area and Nigeria at large. This is followed by bridges (20%), hospitals/health centers (13.5%), electric poles (12%), schools (5.5%) and markets (2.5%). This means increase maintenance and repair costs, public safety, interruption of critical evacuation routes and energy supplies, disruption of economic activity, and degrading of quality of lives among others.

The widespread destruction of infrastructural facilities caused by the floods exerted a huge negative impact on the health, power, social and communication sector. The damaged hospitals/health centers coupled with the damaged roads and collapsed bridges (for example, Charanchi bridge) cut off many communities, making the delivery of health services a difficult task and also making it impossible to get people and communities to assist flood victims.

Since there is interrelationship between infrastructure and other sectors of the economy, a destruction of infrastructure by flooding leads to disruption of socio-economic activities which eventually results in developmental problem in the State. For example, the 2012 flood alone affected 10,536 people in the state and a total loss of N679, 880, 580:00 (SEMA, 2014).

The implications of the increase in rainfall and the frequent occurrences of floods on infrastructure are that models built on the perceived decreasing rainfall, such as drainages, bridges among others, have to be reviewed. This will lead to increase burden of the recurrent cost of repair/replacement.

Conclusions

Flooding is the common and most costly national disaster which not only impacts but threatens people's survival thereby represents a major factor for infrastructural development today. In assessing the flood disaster in some parts of Katsina State, it was noted that most of the flood occurrences owe their reasons not only to high torrential rainfall, but also improper physical planning, blockage of drainage channels, deforestation and the erection of structures in areas of high risk. It was also noted that flood disaster triggered vulnerability factor as it left many people and communities in precarious conditions, depriving them of most basic goods.

The study recommends that:

1) the planning and designing of infrastructure should take into account the nature of rainfall variability in the areas;

2) the provision of adequate drainage facilities should be an important segment of all development planning programs in the study area;

3) capacity building to integrate climate change and its image into urban development planning involving local communities, raising public awareness and education on climate change; and

4) the establishment and improvement of early warning systems by Nigerian Meteorological Agency to monitor the occurrence of floods in these areas would help in planning of relief measures that would reduce the level of human insecurity in the study area.

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