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Full Length Research Paper

Adapting to changing rainfall patterns: The case of flood management in Benin City, Nigeria

Godwin O. Atedhor[1]*, Peter A. O. Odjugo[2] and Alex E. Uriri[1]

[1]Department of Geography, University of Lagos, Akoka, Lagos, Nigeria. [2]Department of Geography and Regional Planning, University of Benin, Benin City, Edo State, Nigeria.

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Monthly air temperature and rainfall data of Benin City for 69 years (1941-2009) were collected from the archives of the Nigerian Meteorological Agency, Lagos. Mean annual temperatures, rainfall and standardized anomalies were computed and graphically depicted. A total of 200 structured questionnaires and field observation were designed to collect data on the causal factors and impacts of flooding as well as the adaptation strategies by people in 5 selected flood areas in the city. The results show evidence of global warming around 1978 with a corresponding above normal rainfall, particularly since 1988. The perceived causes of flooding in the selected flood areas are mainly increasing rainstorms, obstruction and absence of drainage systems, disruption of socio-economic activities, loss of properties, inaccessibility and reduction of the aesthetic quality of the environment largely form the impacts of flooding. The adaptive measures in place include emigration, construction of wooden bridges and elevated shops, embankments, construction of raised pedestrian ways with old vehicle tires filled with sand, use of netted doors, windows and rubber footwear. The need for appropriate drainage channels in Benin City is recommended as more lasting solution.

Key words: Rainfall intensity, flooding, impacts, adaptation, Benin City, Nigeria.

INTRODUCTION

Climate change refers to any change in climate over time, whether due to natural variability or as a result of human activity (IPCC, 2001). One of the consequences of global warming in humid environments is increase and alteration of rainfall patterns (O'Hare, 2002). This alteration will lead to flooding with adverse consequences on lives, properties and socio-economic activities. Although climate change is a global phenomenon, its threat and vulnerability differ not only from one continent to another, but also among sub-region, countries, and even communities. While risks from flooding are greatly reduced by a well-maintained flood control and sanitation infrastructure and public health measures (IPCC, 2007), in developing countries there is lack/inadequate infrastructural provisions to curb flooding. Consequently, the creation of floods has been identified as the worst effect of rainstorms hazard (Adelekan, 2000). While Benin City has witnessed rapid territorial expansion over the years, successive administrations until recent times failed to match this growth with infrastructural developments, particularly the expansion of drainage network (Atedhor, 2009).

With urbanization rate of 5.5% yearly which is the highest rate in the world, Nigerian cities of today face numerous problems which include rapid urbanization, deteriorating environment, urban decay, un-cleared refuse, flooding, erosion and pollution (Babanyara et al., 2010). In an urbanizing environment, the infiltration capacity is reduced by the replacement of ground cover with impervious urban surfaces (Odemerho, 1988). The severity and the duration of storm is important because a drizzle over many days will not cause the same reaction as an intense storm lasting few hours that exceeds infiltration rate of the soil (Hugget et al., 2004). Although flood hazard is natural, human modification and alteration of nature's right of way can accentuate the problem, while the disastrous consequences are dependent on the degree of human activities and occupancy in vulnerable areas (Ogba and Utang, 2008).

*Corresponding author. E-mail: gatedhor@unilag.edu.ng. Tel: +2348136446117.

While Odemerho (1988) examined flood problems in Benin City mainly from the geomorphologic perspective in relation to surface alteration, Omiunu (1988) examined flooding in relation to traffic management using ten years monthly rainfall data (1975 to 1984). Land use changes alone do not account for flood and the prevailing trend of climate change cannot be sufficiently explained using ten years rainfall data Furthermore, the unprecedented rate of flooding in recent years implicates increasing rainstorms due to the on-going global warming and climate change.

Therefore, acknowledging the fact that the causal factors of urban flooding are multifarious, this study is designed to examine the implications of the on-going climate change and anthropogenic factors on flooding in Benin City.

The study area

Benin City is located at latitude 06°19^{l}E to 6°21^{l}E and longitude 5°34^{l}E to 5°44^{l}E with an average elevation of 77.8 m above sea-level. Benin City is a pre- colonial city, the capital of defunct Bendel State and the present day Edo State. Benin City is underlain by sedimentary formation of the miocene- Pleistocene- age often referred to as the Benin formation (Odemerho, 1988) . The city is located in the humid tropical rainforest belt of Nigeria with a population of 762,717 according to the 1991 national population census with a projected population of 1.3 million by 2010 at 2.9% growth rate. Benin City belongs to Af category of Koppen's climatic classification. The rainy season in Benin begins in March/April and ends in October/November. Rainfalls are of high intensity and usually double maxima with a dry little spell in August usually referred to as 'August Break'. Apart from demographic transmutation, Benin City has witnessed, rapid territorial expansion mainly due to rapid rural- urban migration. The desire to own private properties, have made private property developers to erect structures in different parts of the city and often without strict adherence to town planning regulations.

Conceptual framework

The geographical location, size and shape of Nigeria make it to experience most of the weather prevalent in West Africa (Oguntoyinbo, 1978). According to Ojo et al. (2003), the location of West Africa between two heterogeneous surfaces- land and water causes two airmasses to develop, one over the Sahara (Tropical Continental Airmass, cT) and the other over the Atlantic Ocean (Tropical Maritime Airmass, mT). The zone of convergence of the two airmasses at the surface is the zone of moisture discontinuity known as the Inter-Tropical Discontinuity (ITD). Variations in the weather condition (particularly rainfall) in Nigeria and by extension West Africa sub-region are explained in line with the north-south migration and pulsation of the ITD (Oguntoyinbo, 1978).

Apart from large scale processes that influence the pattern of climate, the climate is also conditioned by several meso and local scale factors (Fasona et al., 2010). Urban areas may help to increase thunderstorm activity because their built-up surfaces attain higher temperatures than surrounding areas and create a local air circulation that produces an 'urban heat island' and dust particles caught up in that circulation act as nuclei on which moisture in clouds condenses, forming rain droplets that eventually may develop into the large rain drops of a major thunderstorm (ActionAid, 2006). Consequently, the drying effects of global warming coupled with the phenomenon of 'urban heat island' create favourable condition for the formation of nuclei on which rain droplets form. Furthermore, the ITD and other weather systems are embedded in the general circulation of the atmosphere. Thus, changes in the general circulation of the atmosphere as a result of the on-going global warming and climate change will have corresponding effect on the weather patterns in Nigeria. Global warming and climate change are expected to lead to extreme weather events with a tendency for increase in the incidences of rainstorms and floods in humid environments. This resultant changes in weather patterns coupled with intensive urbanization and decaying facilities will further deepen the vulnerability of lives and properties (Atedhor, 2009) with the evolving of different adaptation strategies. Adaptation is place-based and sometimes contextual and requires place-specific strategies (Fasona et al., 2010) due to variations in vulnerability.

MATERIALS AND METHODS

Monthly temperature (minimum and maximum) and rainfall data of Benin City for 69 years (1941-2009) were collected from the archives of the Nigerian Meteorological Agency, Lagos. The mean annual temperatures for Benin City were computed from the minimum and maximum temperature data. The mean annual rainfalls for Benin City were computed from the monthly rainfall data. Time series analysis was used to depict the temporal trend of mean temperatures and rainfall for Benin City. The standardized anomalies of average temperatures and rainfall for Benin City were computed using 1941-2009 normals. The standardized mean temperature and rainfall anomalies are depicted using graphical method.

Five flood areas (Teachers' House axis of Siluko Road, Uwelu Road by Ogida Primary School, Uselu Lagos Road by Tom Line Building, Five Junction by TV Road Junction and Adolor Junction along New Lagos Road) in Benin City were selected for this study. The selection of these sites is based on the perennial occurrence and severity of flood damages. Structured questionnaires were used to collect data on impacts and adaptation of flooding in the selected flood areas of Benin City. A total of 200 questionnaires (40 per selected flood area) were administered on randomly selected household heads.

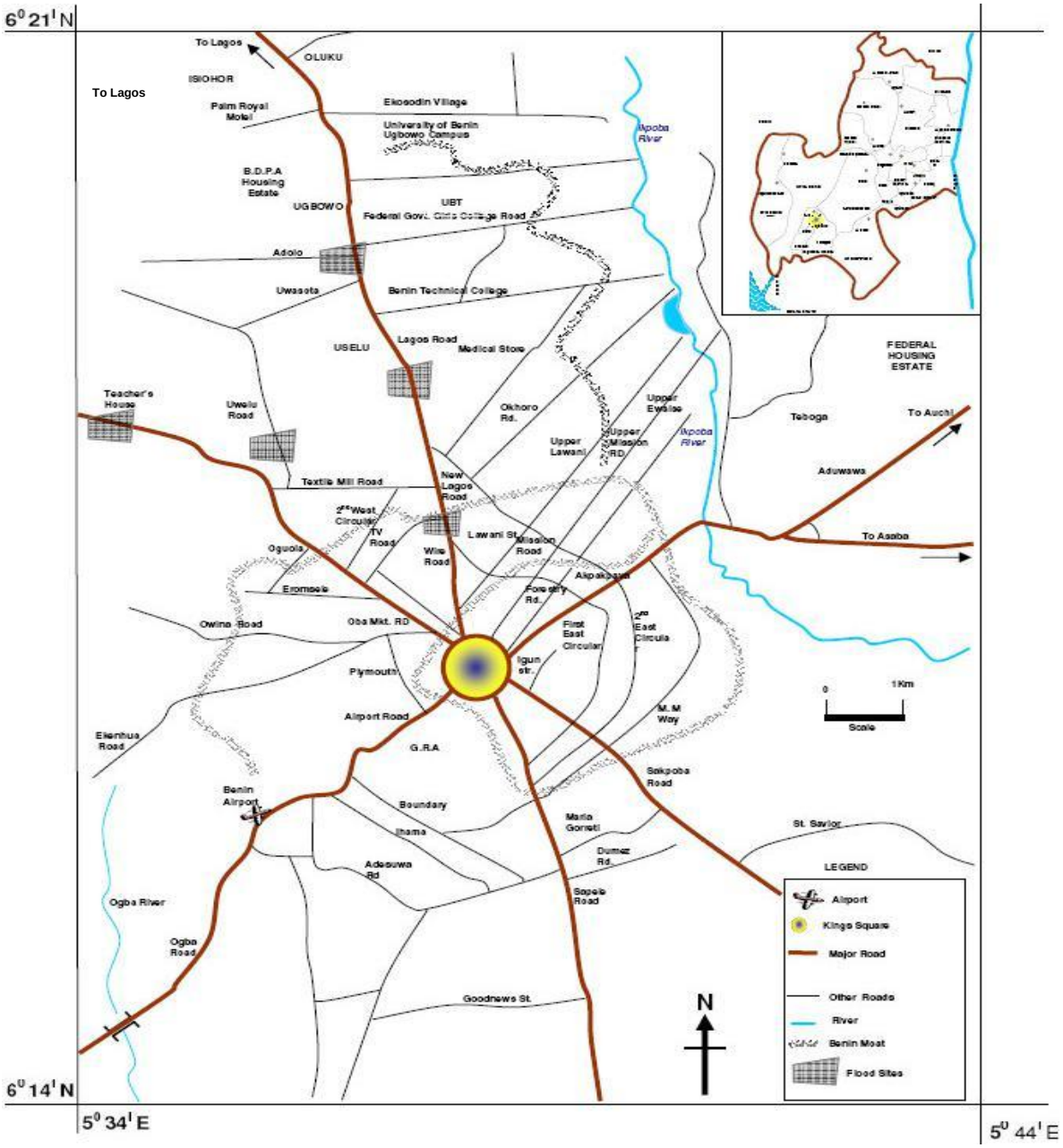

Figure 1. Benin City (Insert: Edo State).

RESULTS AND DISCUSSION

The results show a clear indication of warming since late 1960s with 2003 being the warmest year followed by 1998 (Figures 2 and 3). The period 1942 to 1968 was characterized by cool episode with below average temperature while the period 1976 to 2009 witnessed warming with few years of negative departures using the 1941 to 2009 normal. Mean temperatures between 1941 to 1975 and 1976 to 2009 are 26.5 and 27.3°C respectively. This represents 0.8°C warming which corresponds with 2.93% increase in temperature. The positive departures of average temperatures from the 1941 to 2009 particularly since 1978 as against the negative departures prior to 1969, are clear evidences of global warming. This warming trend agrees with Odjugo (2009, 2010). Overall, 2003 was warmest followed by 1998 with average temperatures of 28.8 and 28.1°C respectively while 1943 and 1950 were the coolest with average temperatures of 25.7 and 25.9°C, respectively.

Figure 3 shows a fluctuating rainfall trend in Benin City. However, there was a near persistent departure of annual

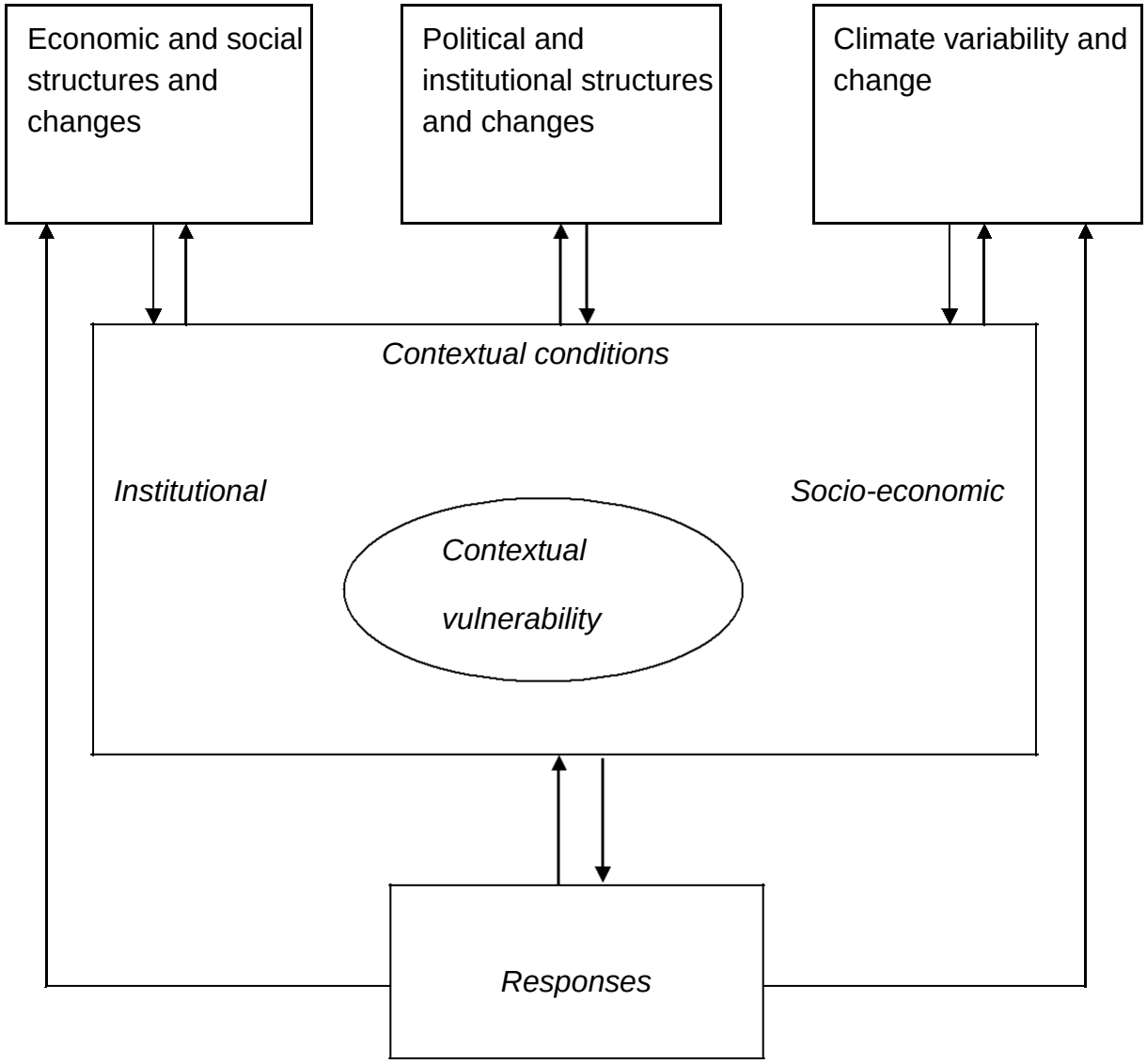

Figure 2. Contextual vulnerability framework. Source: O'Brien et al. (2007).

rainfall from the 1941 to 2009 normal since 1988 (Figure 4). Benin City like other parts of Nigeria has also witnessed recurrent drought episodes such as 1945 to 1947, 1971 to 1974 and 1983 to 1987 episodes. The wet period of 1988 to 2009 correspond with years of above normal average temperatures which confirm the impact of global warming on rainfall patterns in Benin City. Flooding in Benin City mainly occurs in the months of July and September and also in the month of October in recent years. These flood periods coincide with double peaks (July and September) which characterize rainfall in the humid tropical rainforest belt of Nigeria (Figure 6). Figure 6 also shows that the highest rainfall in the month of September occurred in this decade (2000s). This therefore partly accounts for the rising trends of rainstorms and increasing flood incidence.

Perceived causes and impacts of flooding

A combination of factors with different magnitude accounts for flooding in Benin City. The respondents identified seven causes of flooding in the selected flood areas of Benin City. Therefore, causes of flooding identified are increasing rainstorm, obstruction of drainage system, absence of drainage system, poor land use control, global warming and soil. Figure 6 shows that in decreasing order, increasing rainstorm, obstruction of drainage system, absence of drainage and poor land use control are the main causes of flooding in Benin City. The high illiteracy and the resultant low awareness on the on-going global warming and its multiplier effects may be responsible for the relatively low responses it attracted. Warming in moist environment will increase the

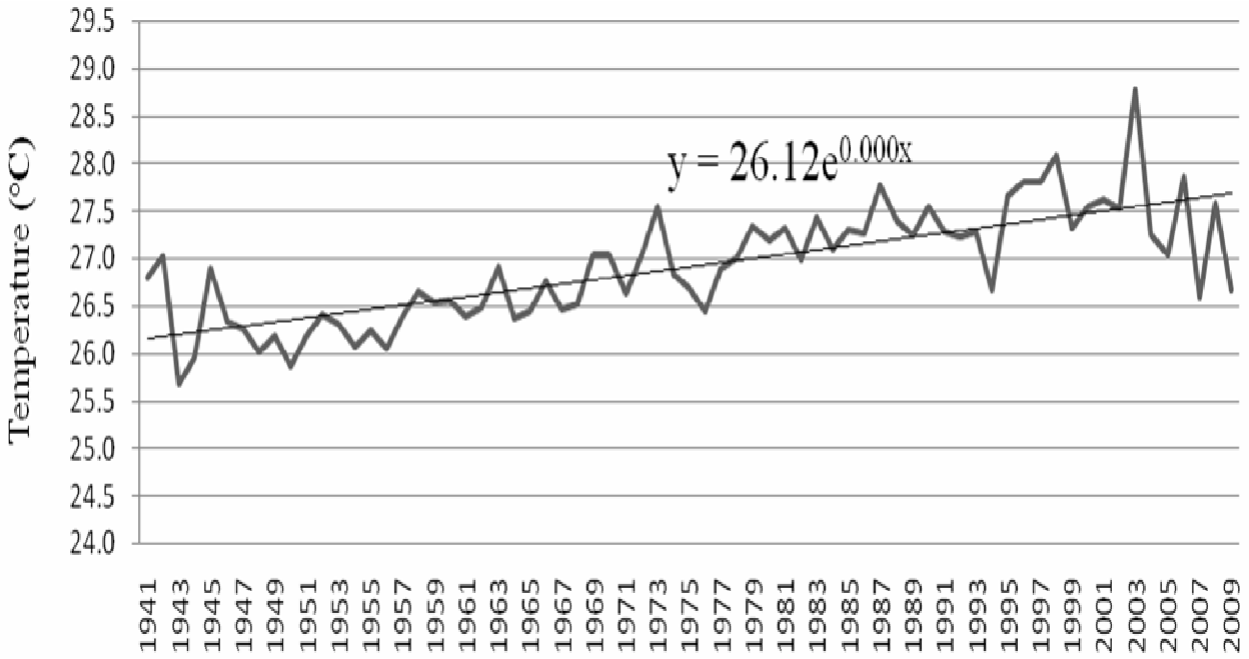

Figure 3. Mean temperature trend in Benin City (1941-2009).

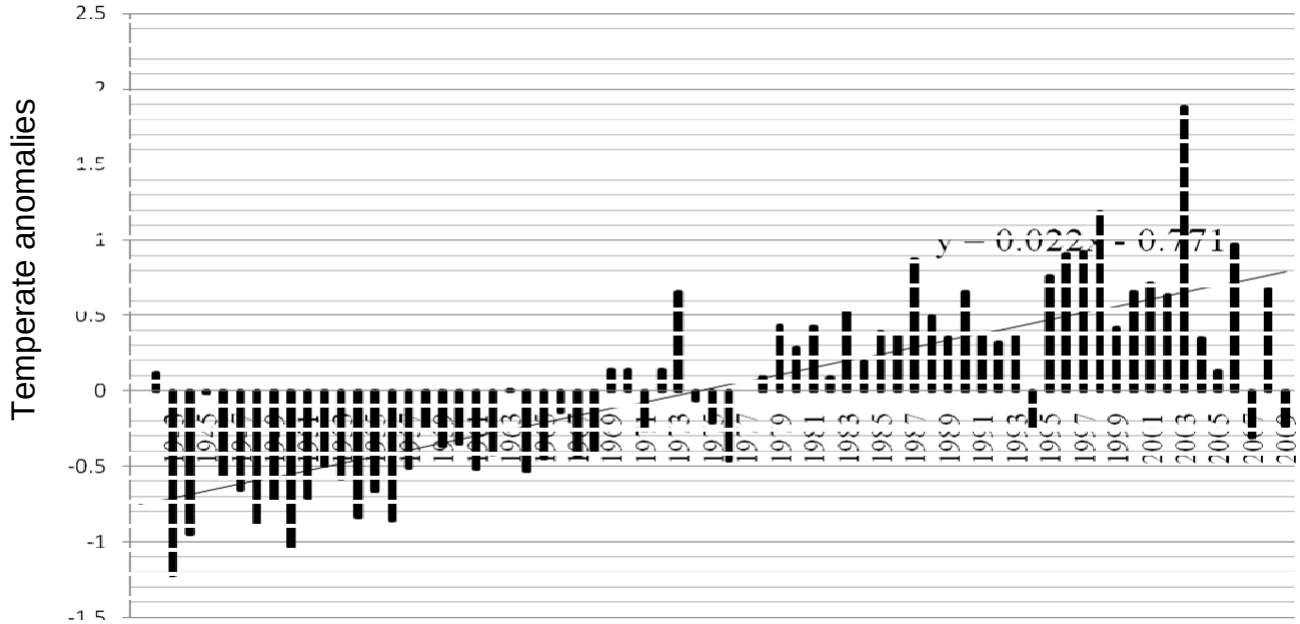

Figure 4. Standard anomalities of mean air temperature using 1941-2009 normal.

probability of longer and/or more intense rainfall due to the potential of the warm air to hold additional vapour which condenses and precipitates (O'Hare, 1999). The increasing cases of flooding in different parts of the country have therefore been blamed on increasing rainstorm incidence (Olaniran, 2002; Odjugo, 2004).

Perceived impacts of flooding

Figure 6 reveals that flooding has impacted adversely on people in Benin City mainly leading to disruption of socio-economic activities, loss of properties (Figures 10 and 11), inaccessibility and reduction of the aesthetic quality

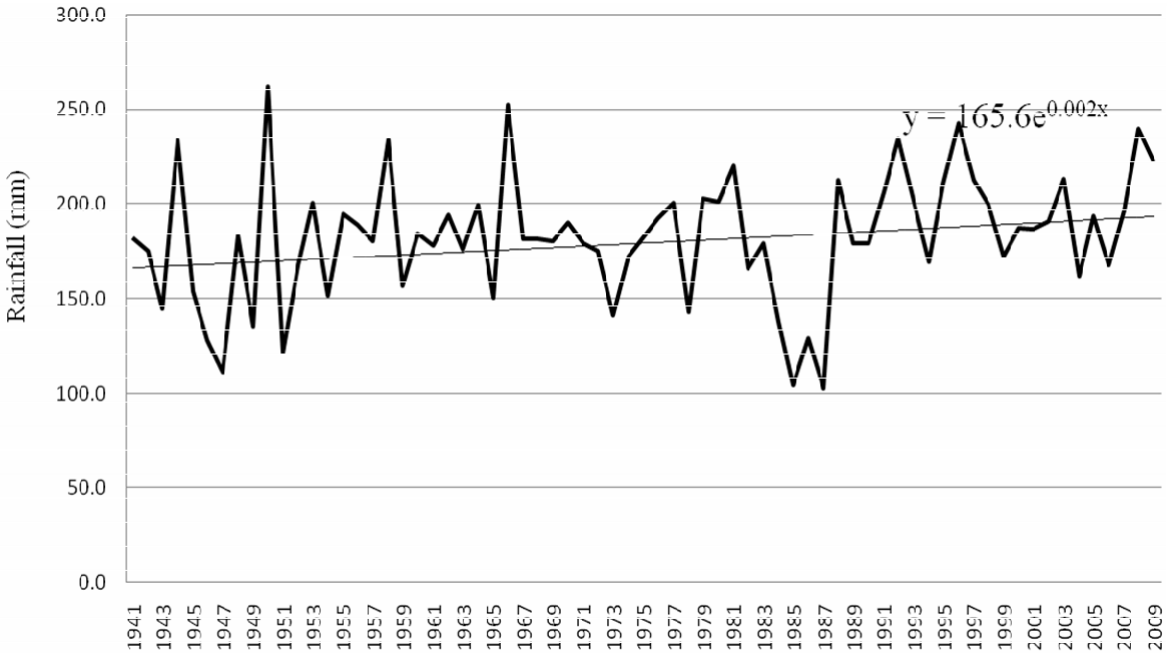

Figure 5. Annual rainfall in Benin City (1942-2009).

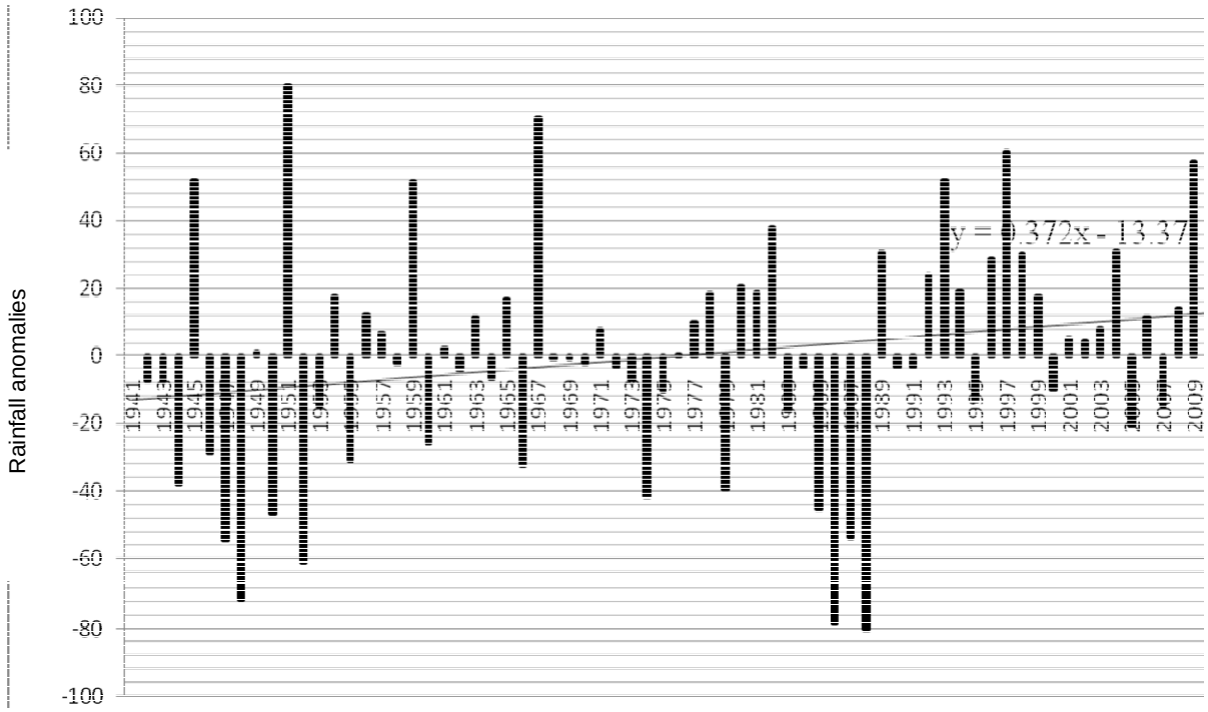

Figure 6. Rainfall anomalies using 1941-2009 normal.

of the environment. Other impacts of floods in the selected areas of this study are increase in transport fare, malaria, decrease in rent and stroke and loss of lives. Based on field observations, Teachers' House area along Siluko Road and Adolor Junction along Ugbowo-Lagos Express area) are permanently flooded while other flood areas are flash floods resulting from rainstorms. Buildings owners in the flood areas died of stroke due to the

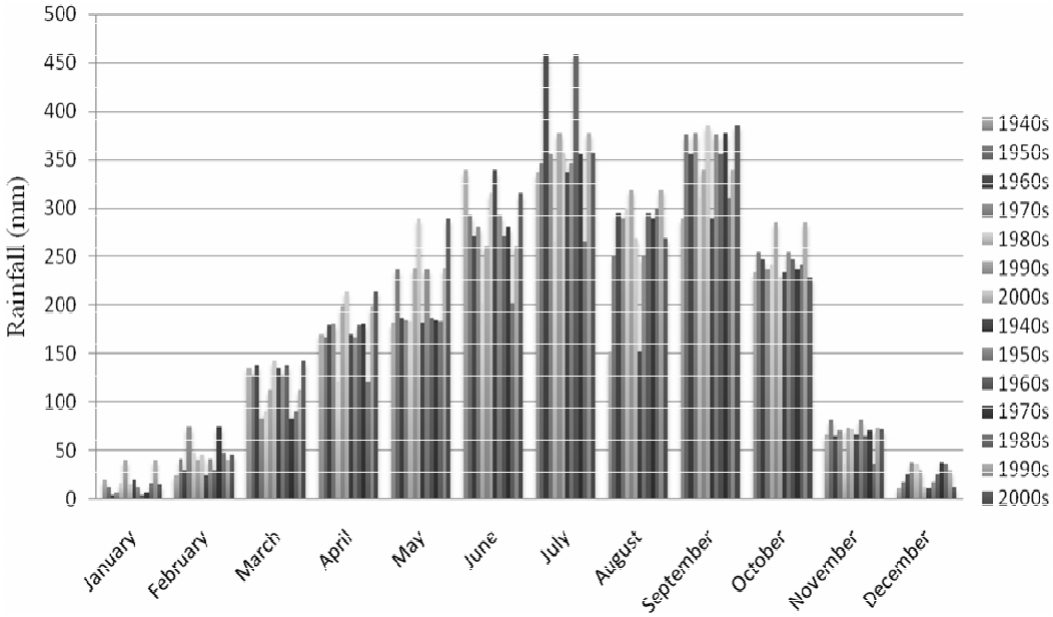

Figure 7. Monthly mean decadal rainfall. 9 years (2001-2009) monthly data were used in 2000s.

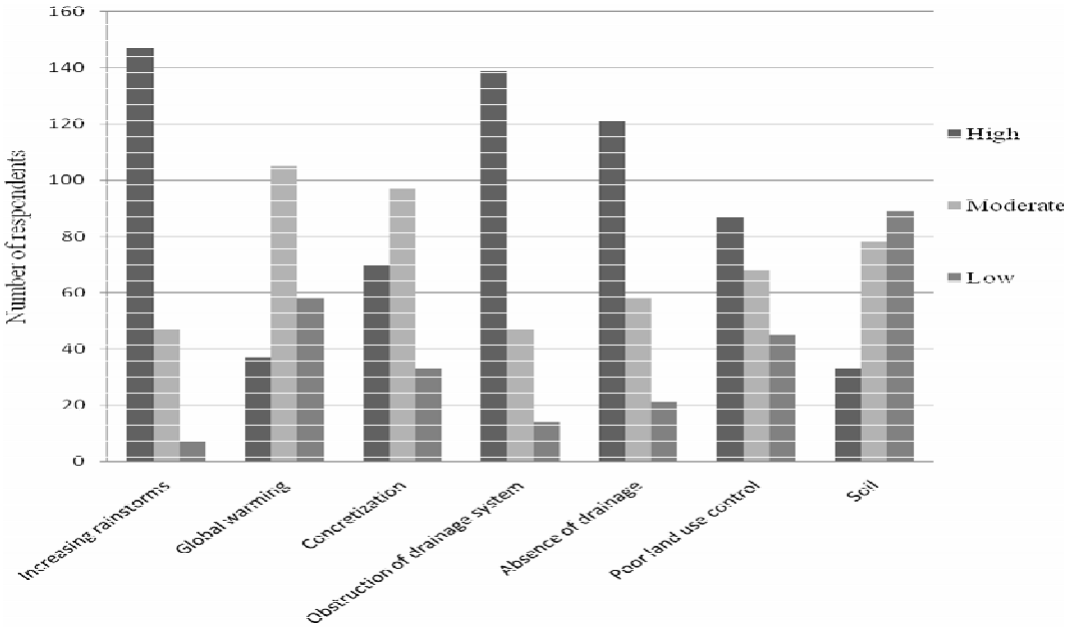

Figure 8. Causes of flooding in Benin City. Source: Fieldwork, 2010.

trauma occasioned by the loss of their properties.

Adaptation strategies

Due to the adverse effects of flooding, different adaptation strategies were observed to have been adopted by the people who live in the selected flood areas of Benin City. Where the floors of buildings are permanently covered with flood water, occupants are forced to relocate out of the flood area and where adjoining streets are flooded, wooden narrow bridges are constructed over the flood. Embankments are also constructed to prevent water from entering residential houses. These types of embankments are either concrete or sandy. An observed disadvantage of the use of

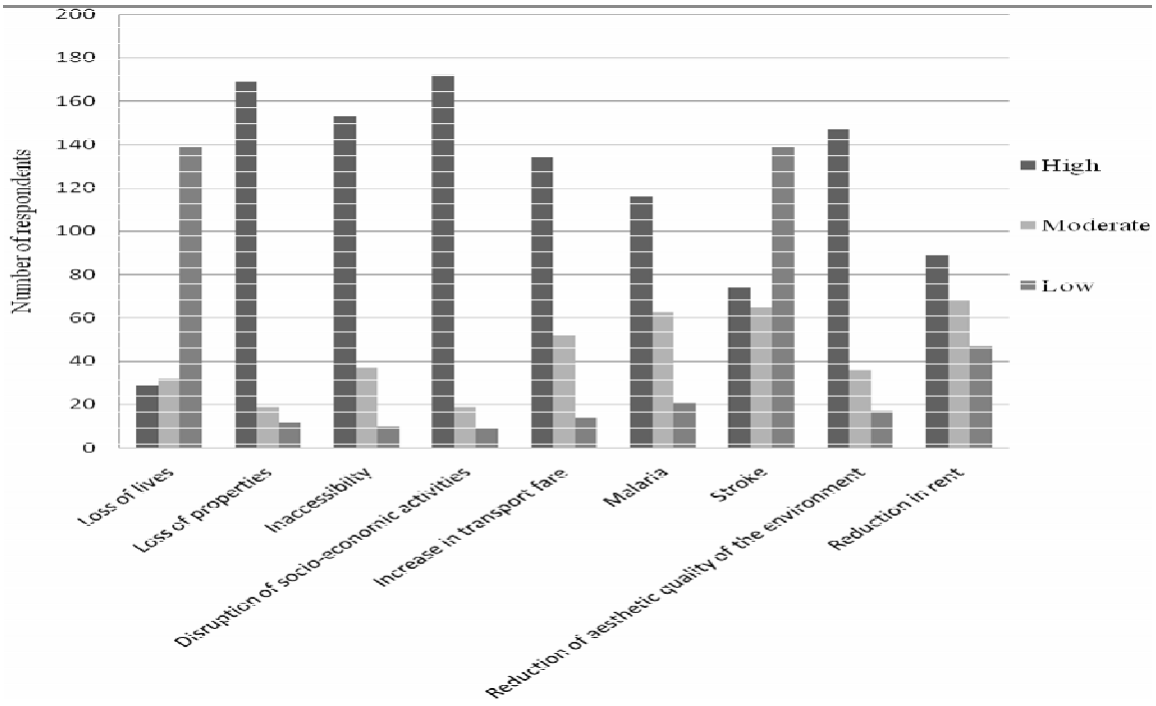

Figure 9. Impacts of flood in Benin City. Source: Fieldwork, 2010.

Figure 10. Abandoned residential house in flood area.

embankments in preventing flood water from getting into residential buildings is the trapping of flood water within the compounds, particularly when the floors are concretized thereby by inhibiting natural water infiltration.

It was also observed that shops in some of the flood areas (for example, around Teachers House axis in Upper Siluko Road) are operated on top of wooden platforms with wooden stair-cases through which the

Figure 11. Furniture destroyed by sudden flood.

Figure 12. Elevated wooden shop in flood area in Benin City.

owners of the shops and customers climb in (Figure 12).

Due to the erodibility of earthen material, residents also use old vehicle tires filled with sand to create raised platforms through which they get into their homes (Figure 13). Windows and in some cases doors were covered with nets in the flood areas to prevent mosquitoes from getting into houses. According to some of the respondents who operate shops in the flood areas, while floods have hindered normal patronage of some goods and services, increase in sales of rubber footwear have been experienced. This high patronage is because rubber footwear is more suitable for flood environments compared to leather footwear which easily wears out when exposed to water.

CONCLUSION AND RECOMMENDATION

Based on the findings in this paper, it is concluded that changing rainfall interfaced with anthropogenic factors such as non-expansion of drainage network, obstruction of drainage system, and poor land use control are responsible for the increasing incidence of flooding in Benin City. However, the combined effects of climate and anthropogenic factor on flooding may have been further aggravated due to low water infiltration because of soil type and concretization of the city's surfaces. This paper has also revealed that flooding has impacted negatively on people in the selected flood areas mainly resulting in disruption of socio-economic activities and loss of

Figure 13. Raised walkway with old vehicle tires as a strategy for reducing erodibility.

properties. It is therefore, recommended that government should carry out rapid drainage redesigning and expansion in Benin City to meet the prevailing challenges of climate change and its resultant increase in rainstorms. In addition, proper land use control should be enforced to prevent people from building on flood prone areas.

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