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Research Paper

Flood risk analysis and hazard assessment in Gusoro community downstream of Shiroro dam using geospatial approach

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ABSTRACT

In October 2012, several lives and properties were lost and many people rendered homeless as a result of a heavy rainfall in Gusoro Community. The study undertakes flood risk analysis and hazard assessment in Gusoro downstream of Shiroro dam using remote sensing technique. Rural communities residing close to the flood plain of Shiroro Dam are predominately farmers and fishermen, who depend in land and water resources for their social and economic livelihood. Flood events in Gusoro community do not only threaten the basic rural infrastructure but also have destroyed farmland and economic crops. The data used were sourced from satellite imageries Landsat ETM imagery of 2006, topographic map Niger State Geographic Information System (NIGIS). Hydrological data for 10 years (2003-2012) sourced from Shiroro Hydro Electric Power Dam Niger State. The analyses results show that in year 2012, the total rainfall was 1659.7(mm) and the heavy downpour affected the surrounding environment of the river. The Landsat imagery was classified to show the land use in the study area and to show flood prone areas. It was also discovered that human activities by the river side are also contribute to flooding in the area. It was thereby recommended that buffer zone should be created by the riverside, to restrict people from erecting structures or practicing Fadama activities along the river banks and also the Niger State Urban Development Environmental Protection Agency must ensure full compliance with development guidelines for Niger State as regards the encroachment of flood plains especially at Gusoro.

Key words: Flood risk, hazard, downstream, environmental, urban development.

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INTRODUCTION

Flood is described as any abnormally high water level of flow overland (Agasa, 2002). Like other naturally disaster such as hurricanes, tornadoes, earthquakes, volcanic eruptions, earth tremor, thunder storms, landslides, typhoons, soil erosion etc, the consequences of flood are followed by a significant damage of property, environment and even loss of lives. Flood occurs in almost every year in different parts of Nigeria and the world at large.

This has prompted public debate on the apparent increased frequency of extreme and in particular on perceived increase in rainfall intensities.

However, floods are natural phenomena that often occur as natural disaster in environment where man has interfered with the natural course of rivers. These floods occur when a body of water rises to over flow land which is normally not submerged, usually after an intensive rain event, causing inundation and damage to lives and properties (National Center for Remote Sensing, Jos NCRS 2006).

Most human activities produce potential adverse environment effects, some of these activities include the construction and operation of Dams, high ways, power plants commercial and residential development projects, land full, sanitation and hazardous waste disposal

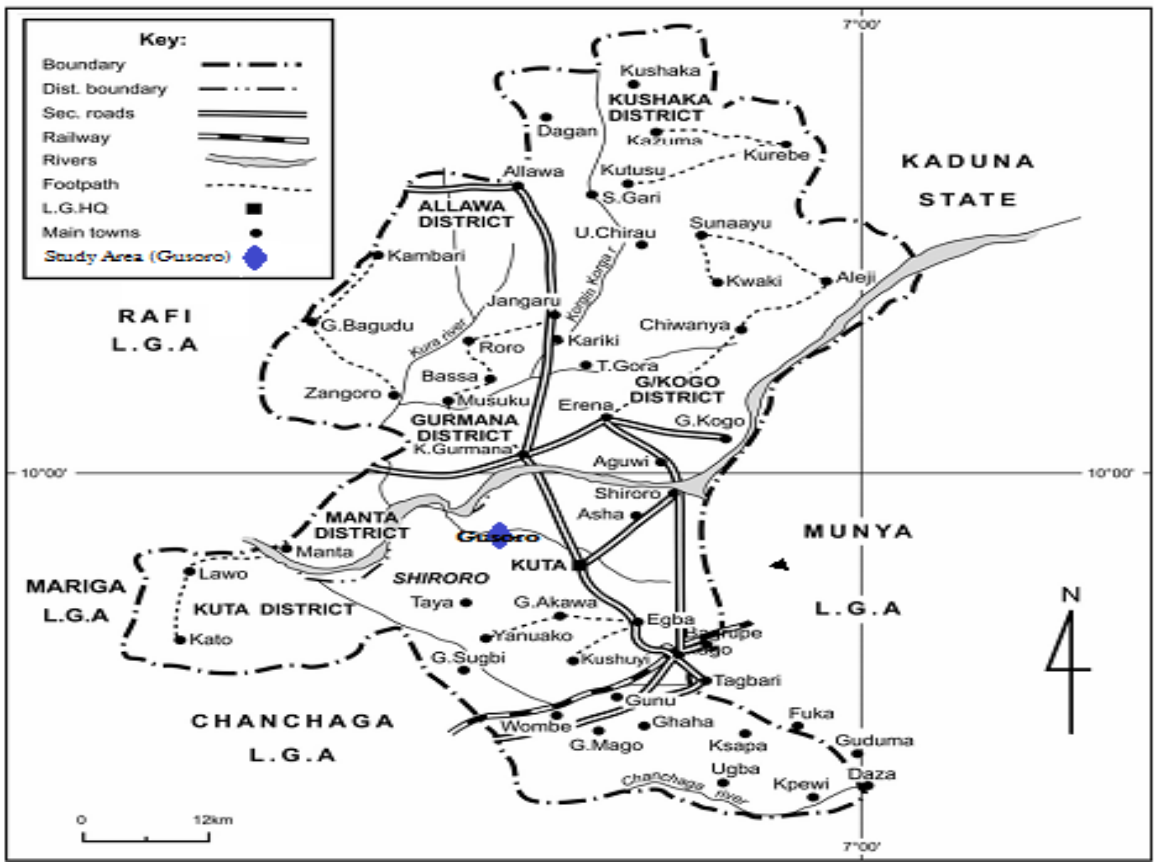

Figure 1. Map of Niger State. Source: Niger State Geographic Information System (NIGIS).

operations, large scale irrigation projects and Mineral mining.

In Nigeria, natural and anthropogenic induced flooding is a threat to physical infrastructure such as residential properties, Roads relines and bridges. In rural areas flooding had destroyed farm lands and economic crops worth millions of Naira. As reported by the National committee on the International decade for natural disaster reduction (IDNDR) 1994, at least 20% of the population of Nigeria is at risk from one form of flooding or another. And the report of 1994, opined that, successful flood fighting depends upon good organization, through advance planning well-trained personnel and effective coordination of operation at local, state and national level.

Over 20,000 residents of Kogi Community living along the bank of the Niger were on Sunday, 16th of September 2012 displaced by floods when the river overflowed its bank occasioned by the release of water from Kainji Dam, Jebba Hydropower plant and Shiroro Dam (Timeline of recent flood incidents in Nigeria).

Objectives of this research

(i) To creates land use-land cover map,

(ii) To map flood prone areas within the study area,

(iii) To proffer options for flood hazard mitigation and adaptation in the study area.

Study area

The study cover Gusoro village which is situated at the downstream of Shiroro hydroelectric Dam built on River Kaduna in Niger State Nigeria. It lies between latitude 9°55'60N and longitude 6°54'0E and Gusoro which lies between latitude 9°57'42"N and longitude 6°50'13" E of the Greenwich meridian with total population size of about 1,300 people (Figure 1).

Geology

Gusoro, like other communities on the same latitude, is covered by two major rock formations the sedimentary and basement complex rocks. The sedimentary rocks to the south are characterized of sandstones and alluvial deposits. To the north is the basement complex, characterized by granitic outcrops or inselbergs which can be found in the vast topography of rolling landscape.

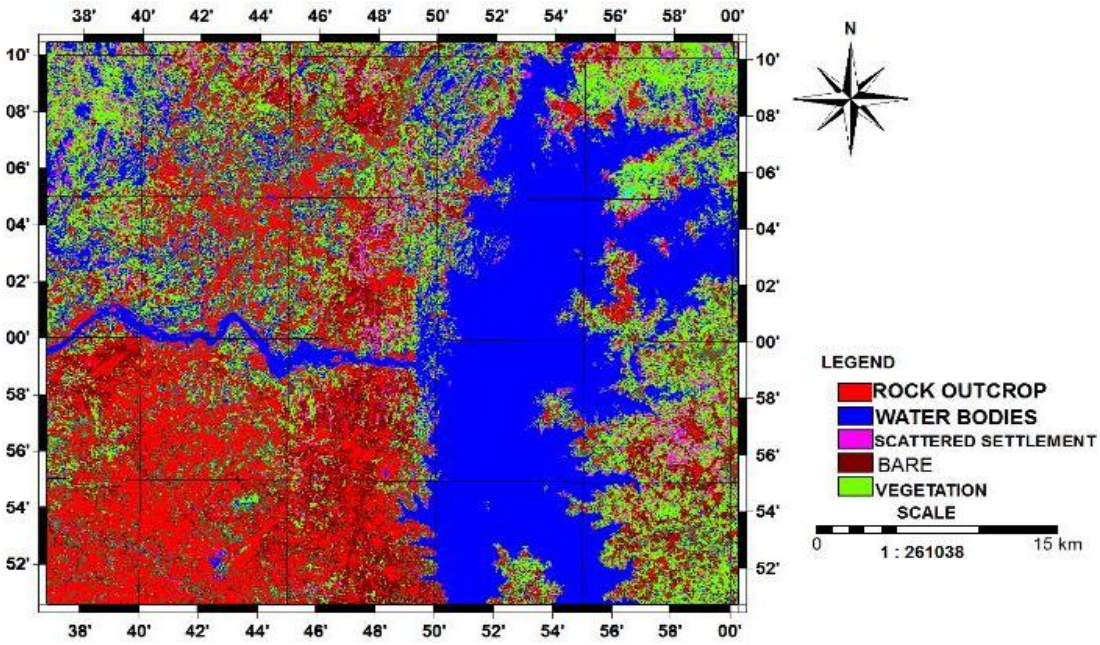

Figure 2. Land use imagery of the study area. Source: Global Land Cover Facility (GLCF).

Climate

The area experiences two distinct seasons the dry and wet seasons. The annual rainfall varies from about 1,600 mm in the south to 1,200 mm in the north. The duration of the rainy season ranges from 150-210 days or more from the north to the south.

Mean maximum temperature remains high throughout the year, hovering about 32Â°F, particularly in March and June. However, the lowest minimum temperatures occur usually between December and January when most parts of the state come under the influence of the tropical continental air mass which blows from the north. Dry season in Niger State commences in October.

METHODOLOGY

Landsat ETM imagery of 2006 covering the study area of Shiroro dam and Gusoro community was obtained from global land facilities from the internet and Topographic map covering the study area was obtained from Niger state Geographic information system(NIGIS), Minna and re-digitized. The image was analyze with aid of flood frequency, Geo-Referencing, Image Enhancement, Image Classification, Buffering, Boolean Analysis and Proximity Analysis.

ANALYSIS AND PRESENTATION OF RESULTS

The importance of this research work was to use remote sensing and GIS to map out areas prone to flooding in Gusoro downstream of Shiroro dam, and also to provide a flood risk map, and to identify areas of high and low vulnerability in the area from land use types and topography data (Figure 2).

Ground truth was carried out despite the fact that the image used was more than two years old, using physical features (floodable, vegetation and areas of high relief) as sample points. The interpreted image showed that area with high relief cover about 50 hectares (ha) water body occupied about 35 ha made up mainly of rivers which flows through the study area with stream flowing into it. Vegetation and farms as this cover just 15 ha (Figure 3).

Flood risk map of the study area

River flooding in this area is as a result of natural factors such as rainfall intensity duration, orientation of the river basin and presence of large bare exposed surface as well as human induced factors such as excess water spillage from the dam, the expansion of agricultural activities at the upper stream course of the river leading to serious environmental, social and economical problems (Figure 4).

Seasonal variability

The monthly rainfalls have been computed to obtain the seasonal variability of the flow pattern on the dam. Figure 5 indicates that the highest rainfall occurs in September and the minimum average discharge occurs in the month of

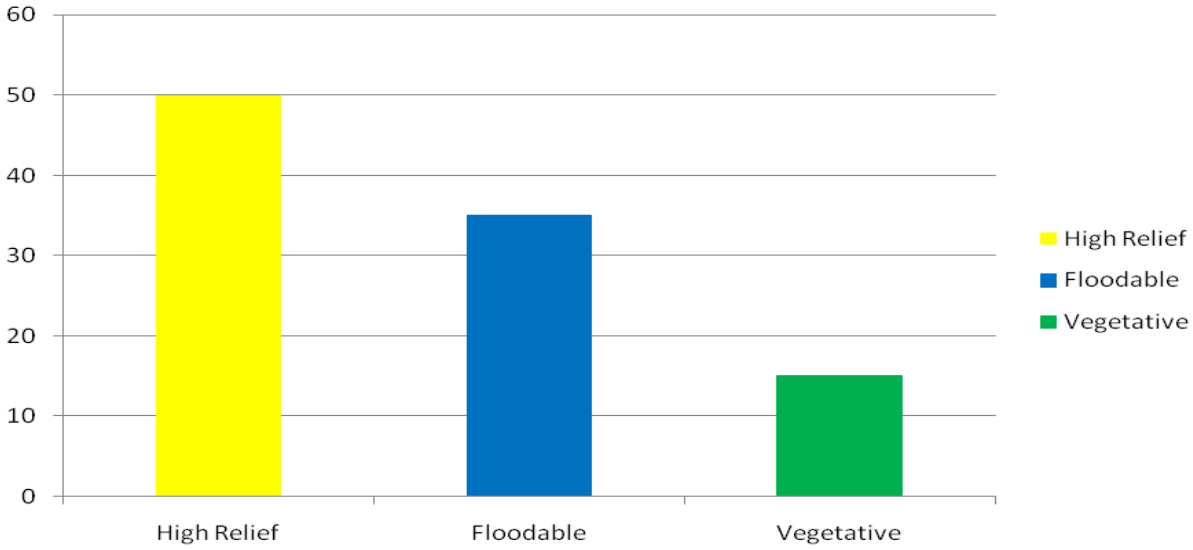

Figure 3. Category of land use in the study area. Source: Fieldwork Survey (2013).

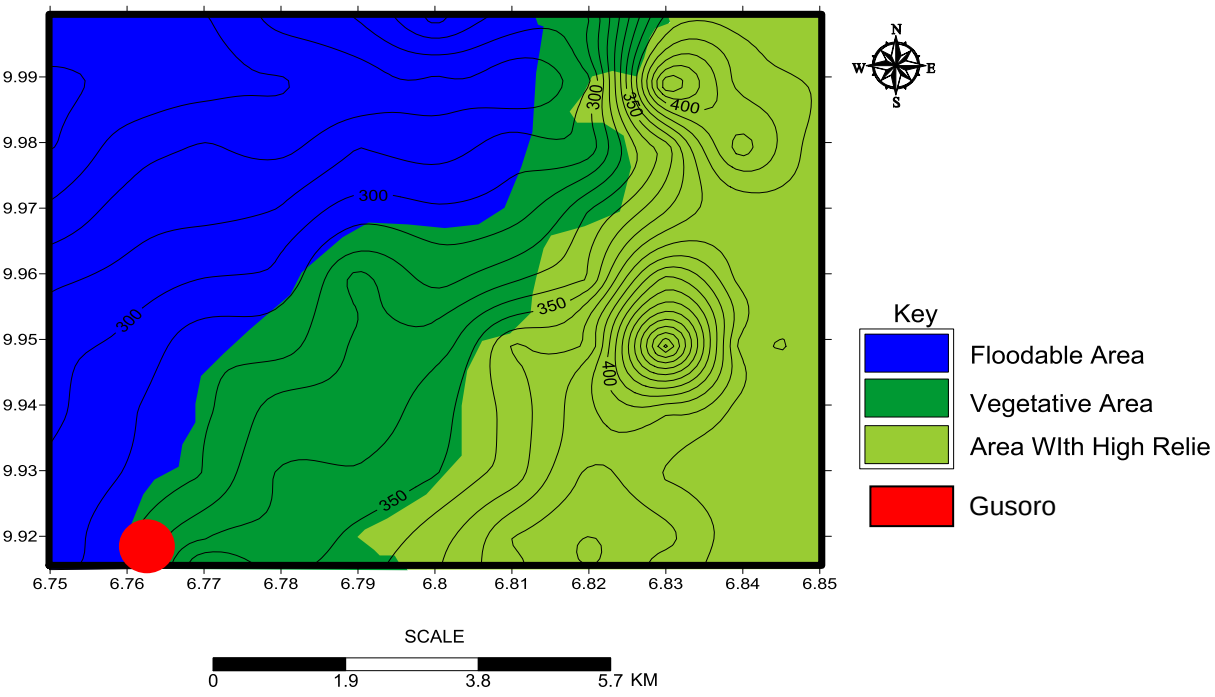

Figure 4. Flood risk map of the study area. Source: Vineyard Geological Company (2013).

April.

The table values have been used to develop the flood map shown in Figure 5. At first, there is a striking resemblance to the seasonal rainfall induced. The highest peak, which range from 371 to 310 mm, corresponds to the flood generated during the wet season experienced between May

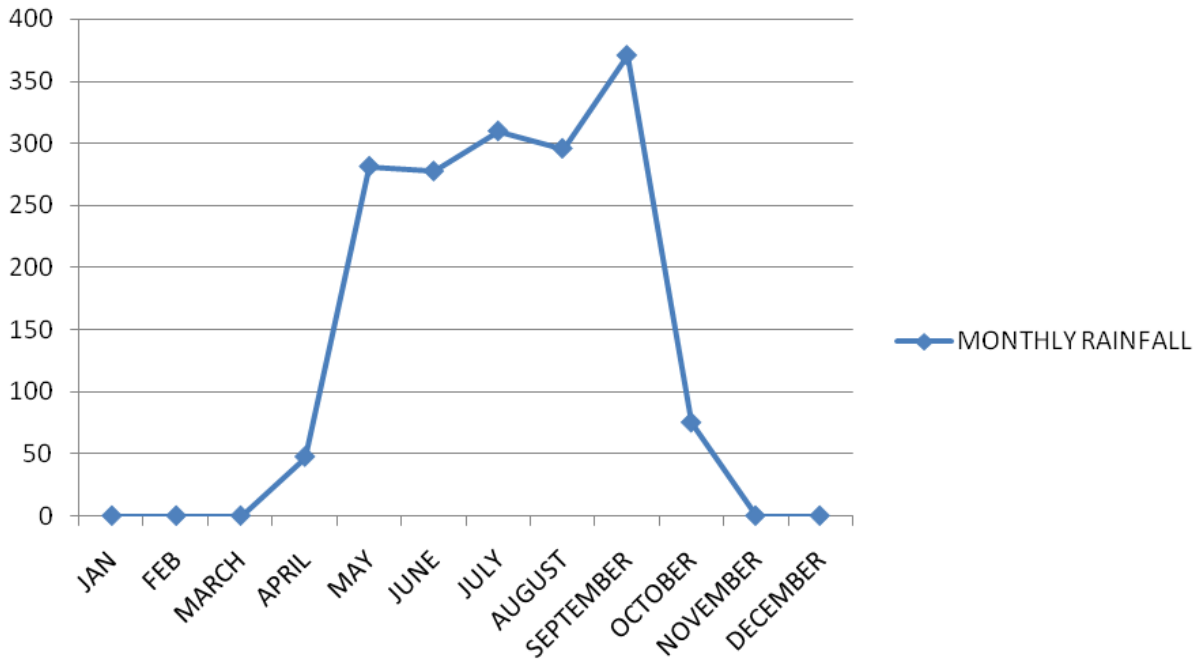

Figure 5. Monthly rainfall chart. Source: Shiroro Hydroelectric Power Station (2013).

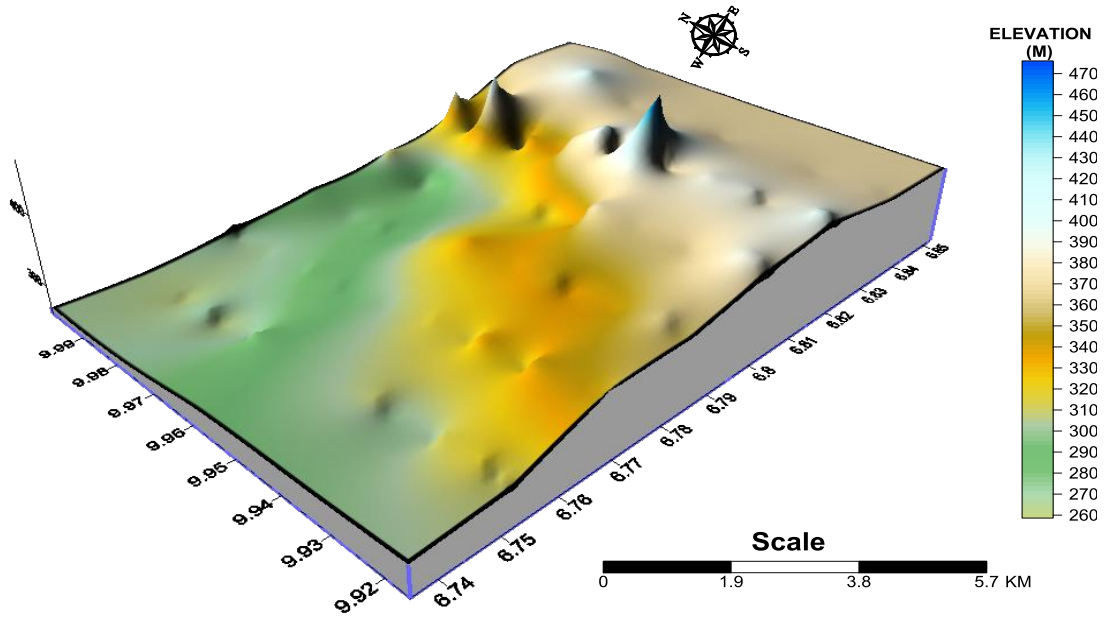

Figure 6. Relief map of the study area. Source: Vineyard Geological Company (2015).

and October. The shorter peak corresponds to the flood period, which occurs between October and April the following year.

As a result of the distinctive demarcation between the wet and dry seasons in the region as indicated by the rainfall regime, Shiroro flow also varies accordingly. The resultant effect is that the dam is characterized with high annual rainfall of 1659.7 mm recorded in 2012. About 60% of the total annual discharge is received at Gusoro, Gurmana and other neighboring communities in Niger state during the flood season of July to September and the remainder is distributed over the rest of the year. Figure 6 shows the relief map of the study area, and Figure 7 shows the contour map of the area, indicating the nature of the

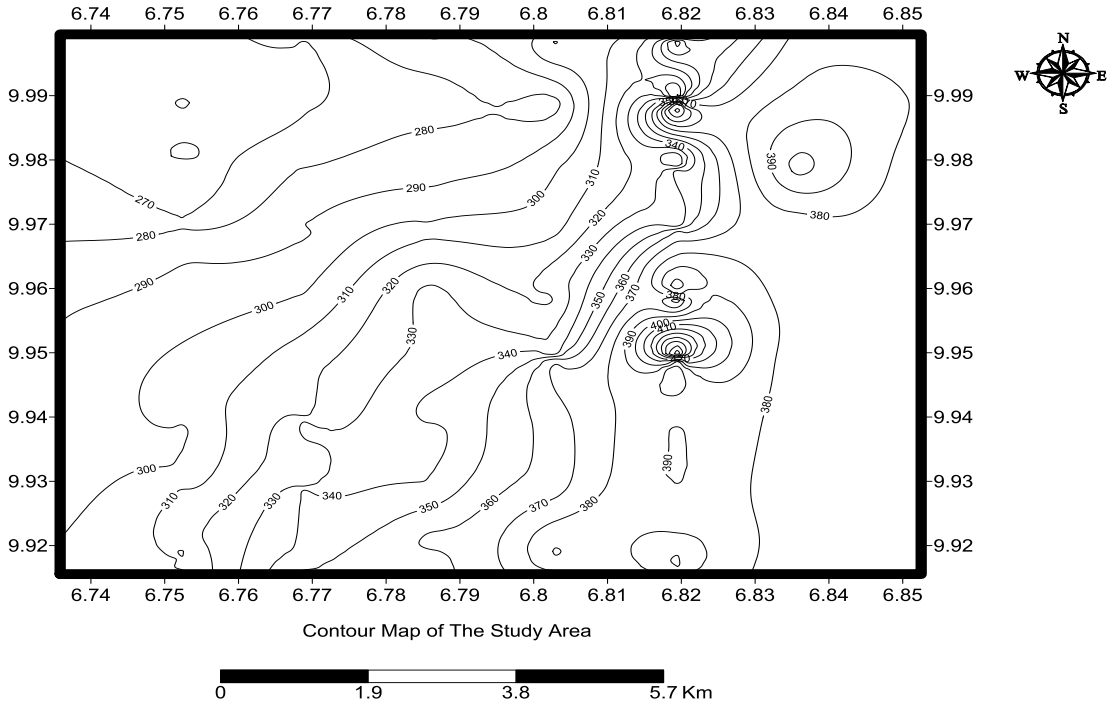

Figure 7. Contour map of the study area. Source: Vineyard Geological Company (2015).

terrain including the relief map.

DISCUSSION

From the result of this research work, the flooding at the downstream occurs as a result of high level of rainfall and human activities. During the research, it was observed that high amount of rainfall is the major contributor to flooding. Because this area is prone to flooding, flood is also caused by the river negligence and poor monitoring of the river downstream; the heavy rainfall was complemented by excess water release from the dam. Besides the human lives lost, properties worth millions of naira were lost including animals and farm produce during the year 2012.

Because of the difference in the wet and dry season in the region as a result of rainfall as shown Figure 5, Shiroro flow also varies accordingly. The effect is that the dam is characterized with high annual rainfall of about 1659.7 mm recorded in 2012 (Figure 8) About 60% of the total annual discharge is received at Gusoro, Gurmana and other neighboring communities in Niger state during the wet season of April to October as indicated by Figure 5 and the remainder is distributed over the rest of the year.

Flood frequency analysis

From the result of this research, Table 1 and Figure 9 show the estimation of the annual spillage which was as a result of excessive rainfall received from the month of April to October in the year 2012.

There, the flooding recorded during this period was a result of excessive rainfall. From this research it is obvious that the past records can be used in representation of the future, meaning that the flow records of the precipitation distribution and rainfall will be used in modeling to produce flow distribution.

The ability to look into future to see how many city blocks and roads might be flooded is becoming clearer with flood mapping. The National Oceanic and Atmospheric Administration (NOAA), National Weather Services (NWS) and National Ocean Service (NOS) Coastal services Center (CSC) are collaborating with the Federal Emergency Agency (FEMA) and other partners, to develop inundation maps for inland fresh water flooding. Libraries are been developed which include map layers depicting the spatial extent and the depth of water for various flood levels ranging from minor flooding all the way through the flood of record in the vicinity of NWS river forecast location. These new flood hazard graphics will help emergency managers and impacted citizens to be better prepared to make important decisions regarding evacuation, moving property and other mitigation efforts.

Combined with traditional NWS river forecast and flood bulletin information, these new flood maps show the area of likely inundation base on current conditions and future rainfall. Maps are produced using GIS and data based created in production of FEMA's Food Insurance Rate Maps.

These libraries are accessible via the Advanced

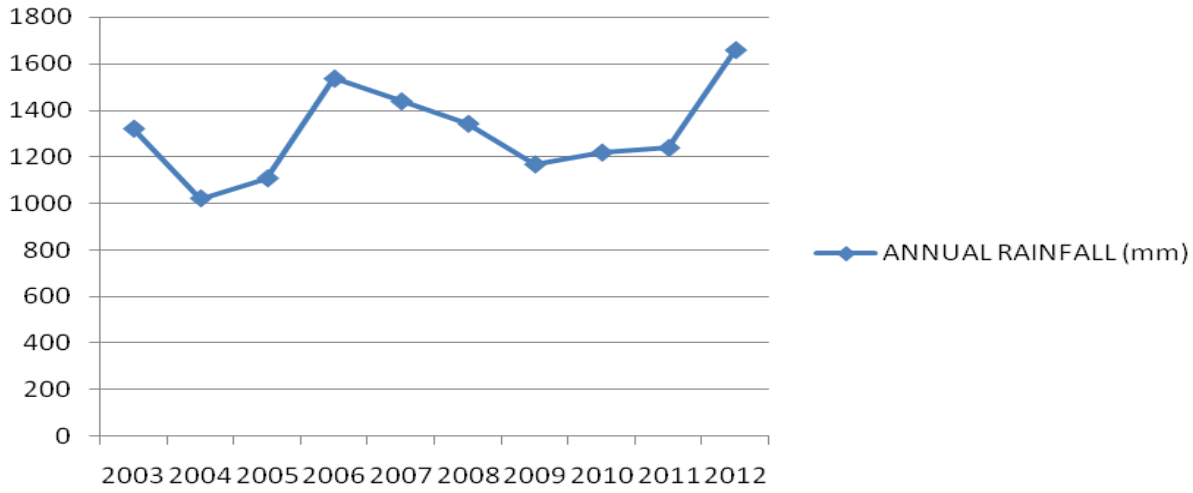

Figure 8. The annual rainfall pattern in the study area. Source: Shiroro Hydroelectric Power Station (2013).

Table 1. Annual spillage.

Year	Total
2003	1.5091
2004	0
2005	0
2006	0.6138
2007	0
2008	0
2009	0
2010	1.4055
2011	0
2012	1.7251

Source: Shiroro Hydroelectric Power Station (2013).

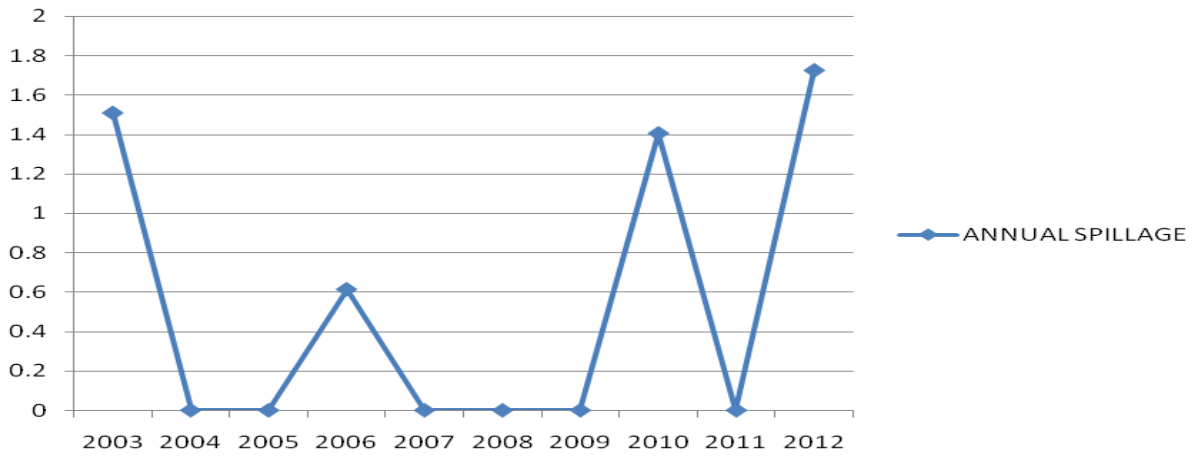

Figure 9. The annual spillage in the study area. Source: Shiroro Hydroelectric Power Station (2013).

Hydrological Prediction Service (AHPS) web portal, the NWS engine that host its vital river and flood forecast information. The national flood insurance program (NFIP) Community Rating System (CRS) is a voluntary incentive program that recognizes and encourages community flood plain management activities that exceed the minimum NFIP requirements. As a result, flood insurance premium rates are discounted to reflect the reduced flood risk resulting from the community actions meeting the three goals of CRS.

(i) Reduce flood losses
(ii) Facilitate accurate insurance rating
(iii) Promote the awareness of flood insurance.

Impact of Shiroro Dam on Gusoro Community

Resources and optimizes power supply of other generating options (thermal and variable renewable). It also have positive social cost such as creating opportunities for capacity building by local/indigenous governments, companies and individuals, often provides flood protection, may enhance navigation conditions, often enhances accessibility of the territory and its resources (access roads, ramps and bridges), provides opportunities for construction and operation with high percentage of local manpower, may improve living conditions, through sustained livelihoods, (freshwater, electricity and food supply). The positive environmental implications may also include: production of no atmospheric pollutants and only very few Green House Gases (GHGs) emission, enhances air quality, produces no waste, and avoids depleting non renewable fuel resources (coal, gas and oil). It can also create new freshwater ecosystem with increased productivity, enhances knowledge and improves management of valued species due to study results, finally it neither consumes nor pollutes the water it uses for electricity generation purposes.

The impacts of hydro-electric dams have been widely studied across the world. For examples, in Costa Rica hydro power dams has led to transformation of free flowing rivers of sarapique into altered system physically and biologically it has devastated 10% of streams length in the watershed upstream and 31 km of stream have been devastated, it has increased competition and conflicts over freshwater resources and it has also promoted river conservation.

CONCLUSION AND RECOMMENDATIONS

This research focused on flooding analysis and in particular on the mapping of floodable areas of Gusoro downstream of Shiroro dam. However, the result shows that there is a general increase in Dam, which is characterized with high annual rainfall of about 1659.7 mm recorded during this period. About 60% of the total annual discharge is received at Gusoro and other neighboring communities in Niger state during the wet season of April to October as recorded in Figure 4.

Remote sensing and Geographic Information System (GIS) technologies provide effective means of studying the flood problem as shown by the Landsat imagery in Figure 5. It is clear that proper monitoring, using remote sensing will enhance the positive environmental effects and reduce the effect of the negative ones.

Based on the findings of this study, the following are therefore recommended:

(i) Flood control structures or buffer zone should be created in areas of high vulnerability like Gusoro.
(ii) Given to the nature of the flood problem in Niger state; a quantitative methodology is required using very high resolution satellite imagery to estimate the lives at risk due to the flooding at each of the subject communities and comparison of lives at risk with available guideline or criteria of any.

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