ABSTRACT

Flood is characterized as a batch of water spreading over an extent that was mostly dry. Flooding results into a lot of damages and the extent of damage varies from place to place. Lokoja and environs witness flood almost every year with tremendous loss of lives, properties and degradation of the environment. The aim of this research is to evaluate flood in Lokoja and the environs using less complex geo-spatial flood inundation mapping tool. The assessment was carried out using HAND' (Height Above Nearest Drainage) tool to identify the probable extent of flood and vulnerable communities at different levels of flood. Datasets used in the study were SRTM based DEM, settlement map and topographic map. Stream was digitized using topographic sheet in polyline format and later converted into raster format in GIS environment using ArcGIS toolbox. HAND is a hydrological terrain analysis approach which uses DEM and steam network as the only input for producing flood inundation maps. HAND value is defined as difference between elevation of a given cell and elevation of nearest cell along stream where it drains. Thus, all cells on the landscape that have a HAND value smaller than the specified stage (water level) were treated as inundated. Different flood inundation scenarios were generated based on varying threshold and corresponding vulnerable communities were identified. It was concluded that the HAND has a reasonably good prediction skills, and is a low-complexity flood models that can be considered as a suitable alternative for fast predictions in large-scale hyper-resolution operational frameworks, without completely overriding hydrodynamic models' efficacy.

Keywords: DEM, Flood, HAND, Mapping.

1 INTRODUCTION

The globe has suffered disasters in many different regions depending on location and variation in the climatic zones or conditions. These include: major natural disasters such as, flood, cyclone, drought, earthquake, sunstroke and minor natural disasters: cold wave, snow fall, thunder storm to mention just a few. Man-made disasters are not left out. UNDP (2004) estimated that about 190 million people in about 90 countries or more are vulnerable to flood risk and estimated 170,000 deaths from this globally from 1980 to year 2000. This statistics illustrate that flooding is a major disaster in many regions of the world. IFRC (2001) compared flood disasters with other natural disasters around the globe for a period of ten years, 1993 to 2002 and concluded that flood disasters had impacted more people than the others.

Flood is characterized as a batch of water spreading over an extent that was mostly dry (Olajuyigbe*et al.*, 2012). Flooding results into a lot of damages and the extent of damage varies from place to place. Vulnerability is the degree of fragility of a natural or socio economic, community system towards natural hazards. It is a set of conditions and processes resulting from physical, social, economic and environmental factors, which increase the susceptibility of the impact and the consequences of natural hazards. It is determined by the potential of a natural hazard, the resulting risk and the potential to react to and/or to withstand it, i.e. its adaptability, adaptive capacity and/or coping capacity. The concept of vulnerability originated in research communities examining risks and hazards, climate impacts and resilience (Donelly, 2008). Poorer communities adaptation capabilities are less in terms of disasters resilience compared with developed societies.

African continent with regions comprising mostly low in-come people is worst hit by this disaster. Nigeria as an entity also has its fair piece of natural and man-made disasters depending on the geopolitical zone one is looking at, prominent amongst is flood. This phenomenon is a function of a set of active processes as heavy rainfall, over flow of river banks, steepness of slope or flood plains, soil types as well as anthropogenic activities. Low in-come people lived in densely populated areas with their assets, in most cases farms around them. When flood struck, many lives are lost along with their assets. Lokoja, the confluence area is one of such settlements. The vulnerability of these communities to flood disaster could be attributed to factors such as the location of large parts of the area in a lower terrain (Niger valleys and Plains) along the largest rivers in Nigeria, that is, River Niger, making the land and communities that are located in this terrain area prone to annual flooding. Muhammad et al., (2013). This process degrades the environment by disrupting and dislocating the social and economic structure of the society. Many lives, property, physical and biological strata of the environment are lost. Urgent need is therefore required to manage this phenomenon to reduce its impact on the society and the environment.

Advancements in remote sensing technology and Geographic Information Systems (GIS) help in real time monitoring, early warning and quick damage assessment of flood disasters. Its repetitive coverage, spectral and spatial resolution, near real time and real time data provision characteristics makes is viable for its integration with GIS capabilities of data capture, storage, manipulation and analysis for identification of the people and features that are vulnerable along this axis.

Zheng, (2016) acknowledged flood mapping as a vital practice that generates images with many useful information which include levels of flood risk of a given area. Such inundation maps can provide communities with important, action oriented knowledge, which serves to educate, inform and better prepare such communities for the possible risks associated with natural disasters such as flood. According to him efforts to inform and educate the general communities on varying levels of flood risks using inundation maps should be made a top priority. On the other hand, the quality of such type of information used to generate such inundation map must be well improved as a result of this the need for a model such as HAND (Height Above Nearest Drainage) becomes paramount so as to generate the inundation map.

HAND is a hydrological terrain analysis approach, which has been tested for reasonable functionality in producing flood inundation maps (Rodda, 2005; Renno et al., 2008). The HAND method as describe by Nobre et al., (2015), uses the Local Drainage Directions (LDD) and its drainage network extracted from a Digital Elevation Model DEM) of the study area. The LDD with the drainage network were then used to generate the closest drainage map in a way that each drainage cell is spatially associated with all DEM cells that drains into it. The HAND tool can be used as a predictor of flood potential and extent and as an original static assessment of floodwater across the landscape. The HAND contour method could be used to map flood hazards in areas with poor information and could promote the development of new method for predicting hydrological hazards (Anthonio et al, 2015). Irrespective of the configurations, the low-complexity models like HAND can be able to produce inundation extents similar to HECRAS 2D (Shahab et al., 2017).

Accordingly Nobre et al., (2010), posited that the application of HAND model provides the possibility of capturing and examining heterogeneities in local environment in a qualitative and widely comparable manner provided that the drainage network density is accurately represented in the HAND model. Representation of local soil draining potential could be replicable for any type of terrain in which there is digital elevation data, irrespective of geology, geomorphology, or soil complexities.

Shahab et al., (2017) noted that based on the reasonably good prediction skills, low-complexity flood models like HAND can be considered as a suitable alternative for fast predictions in large-scale hyper-resolution operational frameworks, without completely overriding hydrodynamic models' efficacy. But also stated that for inundation depth, the low-complexity models may show an overestimating tendency, especially in the deeper segments of the channel.

1.1 PROBLEM STATEMENT

Lokoja confluence area and the environs witness flood almost every year, sometimes in between are flash floods. There is always tremendous loss of lives, properties and degradation of the environment. According to Anunobi (2013), historically, Nigerian floodplains have always attracted settlements especially in the northern part of Nigeria where the population is mostly agrarian. Those involved in the fishing sector of the agrarian industry normally settle along river banks and tributaries which are naturally flood prone. These farmers because of fishing and the rich deposit of alluvial sediment that makes the soil very fertile refused to be relocated even with the Federal Government pressure on them to do so. Government therefore keeps spending huge amounts of money in-vain. With climate change and global warming worst scenarios are being expected. Thus there is need of detailed space based research to ascertain flood parameters that addresses the vulnerability of the area.

1.2 THE STUDY AREA AND DATA USED

Kogi state is situated in the North central Nigeria, located between latitude 6° 31´49.26''N and 8° 43´53.682''N and between, longitude 5°20´16.407''E and 7°53´7.2333''E. State has a total land area of 29,833 km^2 and has a population of 3,595,789 in the year 2005 (2006 census). River Niger and Benue meet at Lokoja the capital of the state (figure 1).
The data used are Shuttle Radar Topographic Mission (SRTM) based Digital Elevation model (DEM), administrative map, topographic map sourced from NASRDA and HAND tool sourced from the Department of water resource Indian Institute of Remote Sensing.

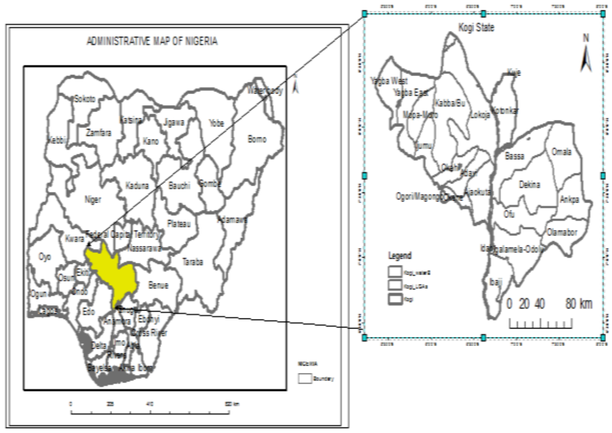

Figure 1: The Study Area

1.3 AIM AND THE OBJECTIVES

The aim of this research is to evaluate flood inundation in Lokoja and the environs using geo-spatial technique, this was achieved using the following sets of objectives:

1. To identify the probable extent of flood in the study area using 'HAND' (Height Above Nearest Drainage)
2. To identify vulnerable communities based on varying HAND thresholding

2 METHODOLOGY

This research employed different hydrological approaches and procedures to come up with adopted methodology which is aimed at achieving the objectives set up for the study. Overall methodology is explained in figure 2.

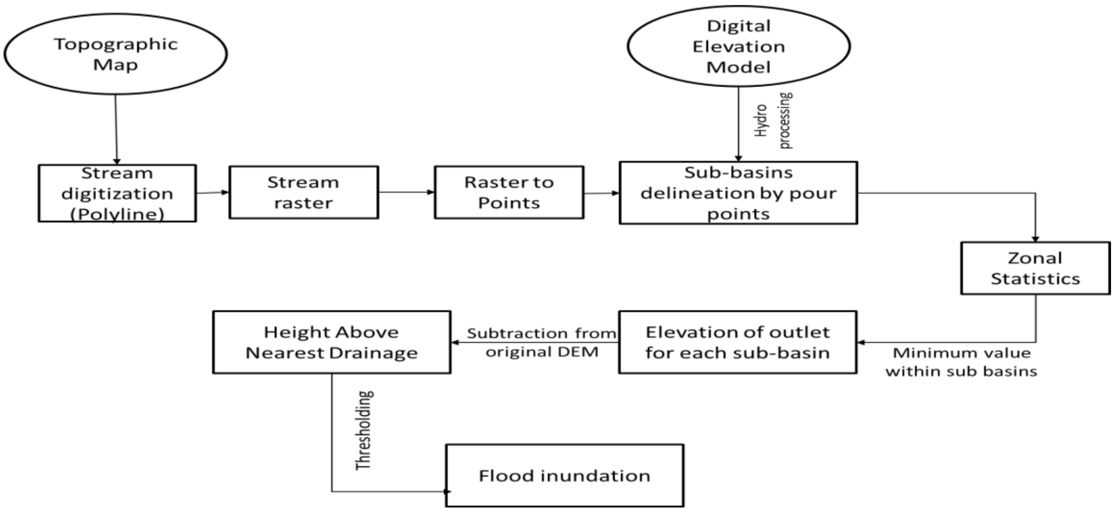

Figure 2: Overall methodology of the study

2.1 SATELLITE BASED SRTM DEM

Shuttle Radar Topographic Mission (SRTM) based Digital Elevation model (DEM) data with a resolution of 30 meters was used (figure 3) in the study.

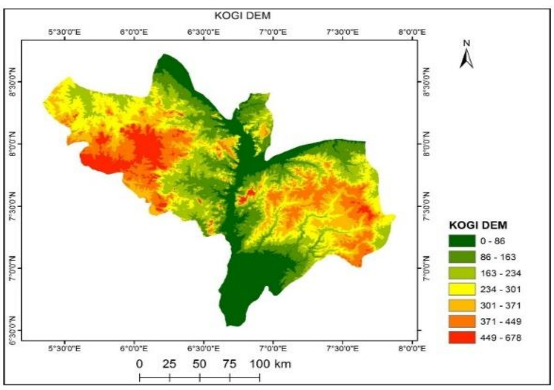

Figure 3: Digital Elevation Model

It is one of the parameters used for topographic feature based Height Above Nearest Drainage (HAND) method for flood inundation mapping.

2.2 STREAM FEATURE GENERATION

Stream generation was done by digitization using topographic map of the study area (figure 4). The data was converted from polyline to raster format using Arc Toolbox in ArcMap interface. Ancillary data was used, such as boundaries from Administrative map of Nigeria to facilitate clipping out the study area.

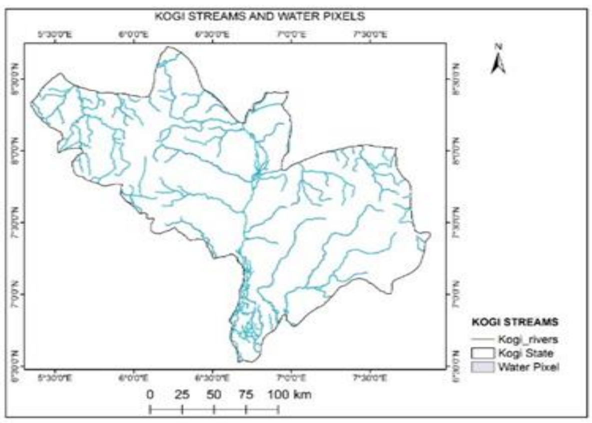

Figure 4: Stream Network

2.3 HAND TOOL FOR WATER FLOW AND FLOOD ANALYSIS.

HAND is a hydrological terrain analysis approach, which has been tested for reasonable functionality in producing flood inundation maps (Rodda, 2005; Renno et al., 2008). Stream network and DEM were the only two inputs required for HAND flood mapping tool. With this operation, the nearest drainage of the area was generated, in this way each drainage cell is spatially associated with all ground elevation cells that drains into it (figure 5).

The height of the corresponding drainage outlet elevation cell was subtracted from the height of each hill slope elevation cell and the nearest drainage information obtained; signifying subtraction of pairs producing the HAND model. What HAND model does is that each cell height represents the difference in level to its respective closest drainage cell. With this, the HAND value was obtained. All cells on the landscape that have a HAND value smaller than the specified stage (water level) are treated as inundated. HAND is entirely raster-based and defines the flooded areas by a corresponding river segment. To produce different levels of flood maps; 2 meters, 5 meters, 8 meters and 10 meters thresholding values were taken. The settlement map of the study area was then overlaid to identify communities that would be submerged at various levels or height of inundated water.

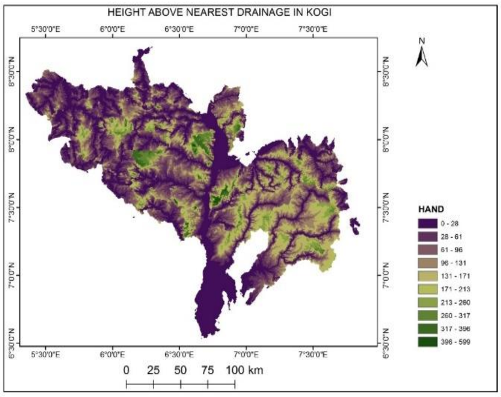

Figure 5: Height Above Nearest Drainage (HAND)

3 RESULTS AND DISCUSSION

The results for two meters threshold is presented in figure 6 at this level, two settlements: Lokoja the confluence town as well as the state capital with another large settlement called Idah are inundated.

At five meters (5m) threshold, in addition to lokoja and Idah two more communities would be inundated which are Ajaokuta and Itobe (figure 7). For a threshold of eight

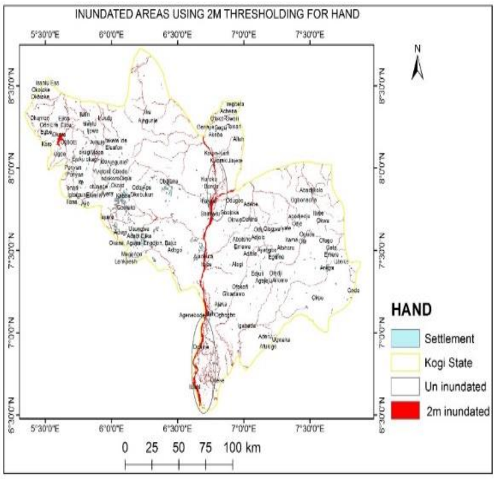

Figure 6: Inundated area at 2 meters

(8m) and ten meters (10) More communities would be inundated.

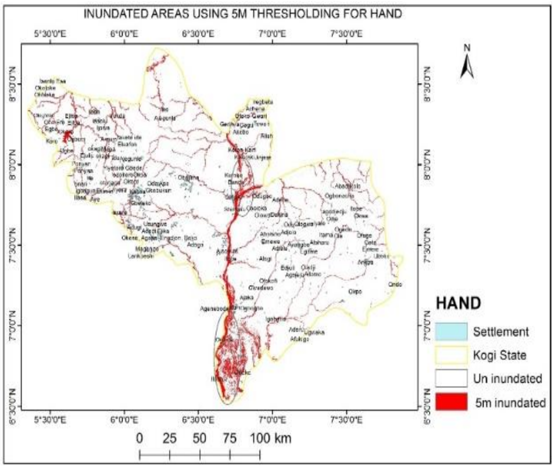

Figure 7: Inundated area at 5 meters

For thresholds of eight (8m) and ten meters (10) More communities would be inundated as presented in figure 9 and 10. The probability of flood hazard to occur at different level of height of water would determine how much area or communities would be inundated. Areas with a two meters threshold would have low risk and fewer communities at risk while areas covered by ten meter of water would have high risk and more communities and area would be inundated. The higher the level of water the more the damage and the lower the less. Shahab et al., (2017 in Comparing new generation low-complexity flood inundation mapping tools with a hydrodynamic model concluded that based on such reasonably good prediction skills, low-complexity flood models can be considered as a suitable alternative for fast predictions in large-scale hyper-resolution operational frameworks, without completely overriding hydrodynamic models' efficacy. This result unveils the high level risk typical of the community that justifies the need for immediate proactive (environment-friendly and structural) action for enhanced resilience across the confluence communities. There is a need to identify the risk in flood-prone areas to support decisions for risk management, from high-level planning proposals to detailed design (Balica et.al 2013).

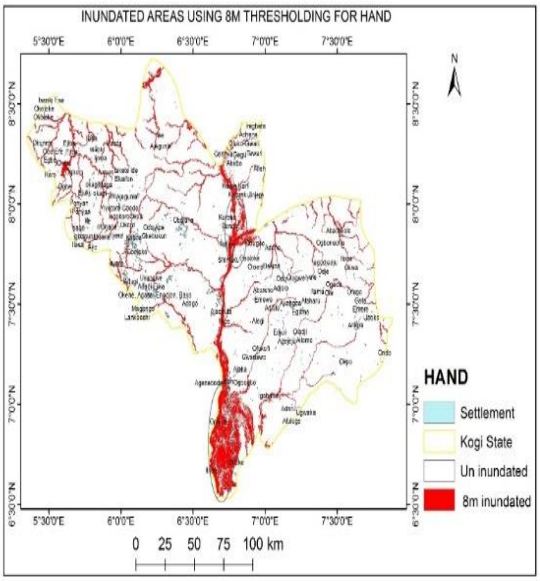

Figure 8: Inundated area at 8 meters

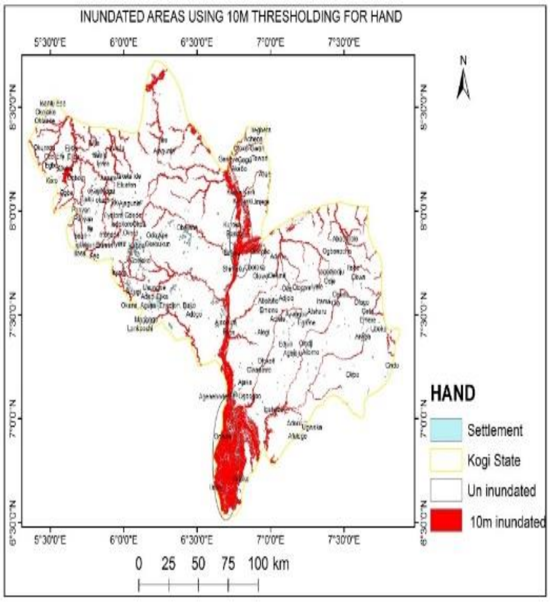

Figure 10: Inundated area at 10 meters

HAND tool alone cannot be used to determine flood risk but other socio-economic factors would need to be integrated such as settlement, population among others, because if an area is inundated and it does not affect lives and property it does not constitute a risk.

4 CONCLUSION

The study was able to identify the probable extent of flood in the study and identify vulnerable communities based on varying HAND thresholding. HAND has been used to identify flood inundated areas at different thresholding from 2 meters to 10 meters. It has a reasonably good prediction skills, and is a low-complexity flood models that can be considered as a suitable alternative for fast predictions in large-scale hyper-resolution operational frameworks, without completely overriding hydrodynamic models' efficacy. It is found that this method is less time consuming and adequate for mapping inundated areas at different levels of threshold.

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