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GIS Approach to Flood Risk Mapping

Chris Adebola Odeyemi[*1], Anthony Peter[2]

[*1]The Federal Polytechnic, Department of Surveying & Geo-Informatics, P.M.B 5351, Ado-Ekiti, NIGERIA
[2]The Federal Polytechnic, Department of Architecture Technnology, P.M.B 5351, Ado-Ekiti, NIGERIA
Email id - [1]chrisodeyemi@gmail.com, [2]anthonypeter56@yahoo.com

Abstract:

Flood is becoming the most environmental challenge menacing Ado-Ekiti in recent times. The aim of this study is to evaluate and map flood risk in the study area, using GIS techniques, to achieve this aim, the study has the following objectives, assess the extent and magnitude of flooding in the study area, also it assesses elements at risk in the study area, hence integrate the outcome of these analysis in a GIS environment. Primary data was sourced with the use of structured questionnaires, while the secondary data sources are from Google earth map and literatures. Simple statistics was use to analyse the data to help develop indicators of vulnerability. A hazard and vulnerability maps were produced based on the perception the population living in the area, the map was then combined with the hazard map, and thus to produce an integrated risk map for the study area. Results reveal that from Vulnerability, Hazard and Risk maps showed that buildings closer to rivers and stream all have higher index. The impact of flood on households sampled revealed that some of the household believed that flood occurrence in the study area have some of impacts on their properties and expenditure. The methodology has proven to be a suitable tool to provide a first overview of spatial distribution of risk which is considered by the households

Keywords: Urbanization, Flash floods, Households, Hazard, Risk, Vulnerability

Introduction

In the last few decades there has been an increase in the occurrence of natural and man-made disasters all around the world. Accordingly, its consequences on human and economic activities are becoming great concern to governments at all levels, both in the developed and developing counties of the world. The Emergency Disasters Data Base (EM-DAT) an international disaster database statistics show that in the last century, the mortality risk associated with major weather-related hazards has declined globally, but there has been a rapid increase in the exposure of economic assets to natural hazards (Jha et al., 2012). According to Safaripour et al. (2012) in Hosseini and Mehdiyar (2006), in the last 20 years natural disaster had resulted in the death of about 3 million people and had adversely affected nearly 800million people world. Flooding one of the most common disaster phenomena is causing considerable personal injury and property damage. In addition problems related to flooding and vulnerability of the population have greatly increased in recent decades due to several factors, including changes in urban land-use urbanization of flood-prone sites, proliferation on squatter settlements and sub-standard material use in constructions, and increased household density (Pelling, 2003). Nigeria is vulnerable to a variety of natural and man-made disasters that hinder the country's socioeconomic growth; some of them are desertification, erosion, droughts, flooding among others. The most severe of these natural disaster experienced in the country is flooding, although flooding occurs mostly in the Southern part of the country, but recently there have been reported cases of floods in nearly every states in the northern part of the country. For instance, Flash floods were reported in 2008, also in 2012, Rivers, Niger and Benue overflow their banks. This resulted into devastating loss in major town and villages, such as Lokoja, Markudi, Baro, Eggan, Bugana, Kastina-Ala just to mention a few. According to National Emergency Management Agency (NEMA), between July and October 2012, the both rivers flooded and submerged thousands of hectares of farmland, settlements and infrastructure. In addition, by mid-October 2012, about 1.3 million people were displaced from their homes, 363 people died, while 5,851 persons sustained various degrees of injuries during the floods. Flood is a threat to the environment and the habitat. The carnage associated with flood can be prevented or minimized through proper planning policy by the government. Understanding flood risk is an essential step in managing the associated impacts of flooding and in making informed decision in addressing such impacts. Ifatimehin and Ufuah (2006) were of the opinion, that the most significant impact of flooding arises from urbanization, because it involves deforestation, land-use changes, temperature modification of soil physical properties and structures and the exposure of bare soil surfaces especially of construction sites all of which bring about changes in the morphological and hydrological state of water. Flood waters can destroy homes and businesses; disrupt road, rail and communication lines, and rain crops and agricultural land. Floods can also disrupt drainage and sewage systems, presenting a serious health hazard resulting from pollution and water borne-disease (Etuonovbe, 2011). Flooding of river is a natural phenomenon. The damage caused by flooding however has increased due to decreasing space for rivers and growing population pressure on valley grounds and wetlands It is now generally accepted that increasing urban coverage and other development have led to a worldwide increase in both the risk and economic burden of floods(Jha et al., 2012).

Flooding is regarded as a major agent of environmental degradation and threat to most urban areas. Its consequential effects on buildings, utility works, housing, household assets, income losses in industries and trade, loss of employment to daily earners or temporary workers, and interruption to transport systems cannot be overemphasized (Jha et al., 2012; Ogundele & Jegede, 2011). Flooding constitutes a substantial risk to social and economic activities, human health and the environment and if not checked, its risks could be increased overtime. This increase is owned to the facts that as the rainfall intensifies, there is likelihood increase in the magnitude and frequency of flooding and this has increased vulnerability in flood risk zones due to economic growth and developmental projects due to population growth. Also the significant consequence of river flooding on human health (physically and psychologically) could have serious health implications in terms of water-borne diseases, or a situation where contaminate water for agricultural activities (EU, 2006; IPCC, 2001). Specifically floods frequently occur in Ado-Ekiti and its environs, which is as a result of heavy rains between the months of April and November, and sometimes these heavy rains come with heavy storms and whirlwinds. Consequently, leading to loss of lives, damage to property, environmental hazards, and traffic congestions among others. Urban floods typically stem from a complex combination of causes. The urban environment is subject to the same natural forces as the natural environment and the presence of urban settlements exacerbates the problem. However, a relationship does exist between urbanization and the risk of flooding. This therefore, form the thrust of the study in which, Ado-Ekiti, the capital city of Ekiti State, a metropolitan with rapid urbanization is being evaluated to understand flood risks in the capital. The aim of this study is to evaluate and map flood risk in using GIS techniques. Assess the extent and magnitude of flooding in the study area, elements at risk in the study area, and to integrate these elements in a GIS environment. The is increasing awareness in the importance of Disaster risk management is leading scholars and researchers to a growing demand for better approaches to risk identification and assessment. This study seeks therefore to understand the way which people living in flood-prone areas in an urban environment perceive and understand flooding which is a threat to their lives and properties. Understanding what knowledge, the people have about flood events, how it affects their socioeconomic situation and changes to their physical environment, which leads to variation of flood risk over time can be combined using GIS and spatial tools to help to envisage risk scenarios.

Conceptual Framework and Literature Review

The general framework for this study is based on Integrated Flood Management (IFM). IFM calls for a paradigm shift from the traditional, fragmented and localized approach, and encourages the use of the resources of a river basin as a whole, employing strategies to maintain or augment the productivity of floodplains, while at the same time providing protective measures against losses due to flooding. IFM addresses issues of flood management from the perspective of human security and sustainable development, there are no universal criteria to determine environmentally friendly flood management practices (WMO, 2011). Both population growth and economic growth exert considerable pressure on the natural resources of a system. Increased population pressure and enhanced economic activities in floodplains, such as the construction of buildings and infrastructure, further increase the risk of flooding (APFM, 2004). Therefore, this study is based on this extended definition of risk, which is "Risk is the probability of a loss, and this depends on three elements: hazard, vulnerability, and exposure. If any of these three elements in risk increases or decreases, then the risk increases or decreases respectively." (Satterthwaite et al., 2007; Thywissen, 2006). There is no one definition of flood risk, but according to the UN-ISDR Report there are two essential elements in the formulation of Flood risk (Eq. 1): a potential event - hazard, and the degree of susceptibility of the elements exposed to that source - vulnerability.

RISK = HAZARD x VULNERABILITY………………1

RISK = HAZARD (FLOOD) * VULNERABILITY (OF THE SOCIETY/AREA)

This definition is often preferred by social scientists, as it allows a focus on the individuals and societies affected, and among planners, who usually regard the hazard as a given and the spatial planning as the means to adapt to that given flood event. Flood depth and extent are considered to be essential hazard characteristics, alongside with probability of flood event (De Bruijn, 2005). In UN International Strategy for Disaster Reduction (UN-ISDR) terminology on Disaster Risk Reduction «risk is defined as the combination of the probability of an event and its negative consequences". A hazard is "a dangerous phenomenon, substance, human activity or condition that may cause loss of life, injury or other health impacts, property damage, loss of livelihoods and services, social and economic disruption, or environmental damage" (UN-ISDR, 2011). An urban flood risk management plan has to start with the assessment of present and future flood risks.

Flood Risk Mapping

According to EXCIMAP Handbook on Good Practices on Flood Mapping, outlines some aspect of flood mapping, to comprise flood hazard maps and flood risk maps, While flood hazard maps covers the geographical areas which could be flooded according to different scenarios; shows areas which could be flooded according to three probabilities (low, medium, high) complemented with: type of flood, the flood extent; water depths or water level while the flood risk maps shows the potential adverse consequences associated with floods under those scenarios. Areas at risk of flooding can be dynamic in nature. With a changing level of development, the nature and degree of risk also changes. Flood risk increases mainly because of an increased level of exposure of the elements under threat. Flood risk maps represent a spatial integration of the hazard, exposure and the level of vulnerability. They effectively combine vulnerability maps with flood hazard maps to give an overall view of risk (Jha et al., 2012).Continuous updating and monitoring of risk maps is, therefore, most important for proper flood risk management: decision-makers need up-to-date information in order to allocate resources appropriately.

Geo Information in Disaster Situations

The use of Geographic Information System (GIS) in a wide range of applications has been practical and successful for the last years. The enormous possibilities of these systems are thoroughly appreciated and have been established as decision supporting tools in many areas of human activities. Up-to-date risk maps can be the most valuable tools for avoiding severe social and economic losses from floods; it can also improve public safety. GIS is therefore ideally suited for various flood risk management activities such as, base mapping, topographic mapping, and post-disaster verification of mapped floodplain extents and depths. Attribute data were entered into a separate database and later linked to the appropriate map location. GIS is useful in capturing and communicating a vast amount of information about the study area and the river. While the use of GIS and the process to gather and record data were not without problems, the overall value of GIS was found to overweigh those challenges (Shamsi, 2001).

The flood risk assessment consists in evaluating: a) the causes of the flood hazard, b) the frequency of flood events, c) the identification and location of flood prone areas, d) the depth of floods, e) the duration of the flood, the elements at risk (people and valuable materials) and its vulnerabilities. In consequence, flood risk assessment should investigate the flood process and this could be done through the following two analysis of Hazard and Vulnerability, consist in analyzing physical, health and social vulnerability to flooding (Díaz-Delgado & Gaytán Iniestra, 2014). In this study the knowledge gap to be addressed has been acknowledged by the following studies. As discussed in the previous section of this work, flood risk is viewed from two elements hazards and vulnerability. Flood risk mapping is a very significant factor of flood risk management, as flood mapping is limited to flood-prone hazard mapping (Dang et al., 2010; De Moel et al., 2009). In, Guarín et al. (2004) performed a basic flood risk assessment, using an alternative method for producing several sets of data, this was implemented by combining aerial photo interpretation, the use of data questionnaires in a community-based field data collection campaign, and subsequent analysis using Geographical Information Systems (GIS). While Evans et al. (2005), studies how GIS applications in flood risk mapping range can help in storing and managing hydrological data to generating flood inundation and hazard maps to assist flood risk management. They believe that over the last decade in particular, a great deal of knowledge and experience has been gained in using GIS in flood risk mapping. The work also illustrates through a case study of the Medway Estuary Strategic Flood Risk Assessment how a wide range of GIS data sets were integrated. It shows how near shore bathymetry, low level LIDAR, forward and downward looking video, LIDAR, flood defenses asset data and a range of bespoke and other datasets were combined to assess flood risk for a tidal estuary. In their study,Díaz-Delgado and Gaytán Iniestra (2014) sees the relationship between a flood risk assessment and the humanitarian logistics process design related to emergency events caused by flooding. They estimated the magnitude and timing of the flooding as a forecasting model that requires a hydrologic component to convert rainfall into runoff as well as a hydraulic component to route the flow through the stream network predicting time and severity of the flood wave. Once these components are known, and with the intention of mitigating the impact of the flood wave on the population, they provided the relevant aspects to define humanitarian aid and evacuation plans including processes and metrics of it. Finally, an example that integrates both methodologies was included in their study. A methodical investigation based on the historic flood records and an analysis of the geo-environmental factors was being performed, using a GIS methodology for database processing in order to identify the distribution of areas with different risk degrees was carried out by (Forte et al., 2005). Safaripour et al. (2012), build a database of six (6) sub watershed in the Gorganroud watershed were prepared of five (5) layers affecting flooding in the region, by overlaying and weighing three (3) layers in a GIS software, a layer of flood intensity was obtained. Hasson et al. (2008), provided multi-criteria evaluation methodology for analysis of flood risk. The city of Toronto has experienced many major floods over the past century, while floodplain maps are generally available, the estimation of flood risk maps based on population, economic development, and critical infrastructure will enhance city's flood mitigation and preparedness planning.

In this studyArmenakisa and Nirupama (2014) presented an approach for determining spatial flood risk index map based on population vulnerabilities and terrain morphological characteristics using a geographic information system. There are limited references related to the development of hazard indices. Thompson (2004) for instance, created hazard indices for flood hazards based on the flood depth and the flood duration. Suriya et al. (2012) transformed inundation maps for different discharges into hazard indices. Hence, both indices are based on hazard magnitude alone and do not consider return periods. In contrast, the hazard concept approved by the Swiss Government, and alsoSuroso et al. (2013) taken as a reference for the Andes region expresses hazard by magnitude and return period. Inundation and deposition depth is taken as an indicator of hazard magnitude for floods and debris flows. Altin (2014), presented the flood potential of the sub-basins, which are located in upper course of the Yeilimak River, Tokat Province. The potential was determined by analyzing shape indices which have been used for several decades to describe the characteristics and hydrological properties of drainages basins. These indices are Form Factor, Basin Elongation, compactness, circularity Ratio, Lemniscate ratio and shape index. The result help in better understanding relationship between flood events and basing shape for basin area planning and management. The Philippines is one of the most natural hazard prone countries in the world, especially for water-related disasters (floods and landslides) triggered by typhoon. Prawiranegara (2014) employed spatially explicit methods of assessment by using spatial multi-criteria analysis (SMCA). Necessary steps were taken including geo-database preparation, variables definition, standardization of parameters, weight assignment of indicators, and sensitivity analysis. At later stage, analysis was applied in Arc GIS 9.3 software environment to conduct risk mapping. Identified Very High Flood Risk Areas were also validated by Satellite Images. From the findings of Ogundele and Jegede (2011), they discovered that urban flood problem majorly emanates from the construction of poor drainage system and co-ordination. This development has contributed immensely to flood problem in Ado-Ekiti. There exist a number of approaches to reduce the limitation in data availability, including participatory GIS studies that take advantage of involvement of stakeholders to generate spatially relevant, additional data, which this study adopted.

3. Materials and Methods

Many areas had been flooded within Ado-Ekiti in recent times, Olorunda area was chosen because of the major flooding that happened in June 2013 that had a devastating effect on the study area. A random sampling technique was adopted to select the sample elements for the study. The fieldwork activities consist of collecting data with the use of questionnaire, also, discussion were carried out with some people living in the area, this to further provide insights about the flooding problem in the study area. The questionnaires were distributed among the respondents using simple random sampling to ensure equality of sampling and to avoid concentration on some particular area within the study area. Questionnaires were administered on samples at the level of the individual respondent, which is at home at the time of visit. The questionnaire is organized into three (3) parts these are, personal information of respondent, exposure/perception, and elements at risk. They are aimed at the biographical and emotional bonds of the respondents to the research location, as well as their collective and an individual perspective of flood events, as these issues are important to this research. A questionnaire was administered to each respondent who understood the questions posed and literate enough to fill after due explanation was given to such person or persons. The illiterate and semi-illiterate persons were interviewed directly through a face-to-face method and were assisted to make choices in the questionnaire. In summary 197 questionnaires were administered in the study area. Information that had been elicited on the experience of the people who had being affected by flood events will be structured in such way that such information will provide an overview of the flood problem at hand in the study area. The result of the data collected by means of GIS-based survey of peoples' perception and experience about flood depth, duration and distribution or extent that had happened in the past will be spatially analysed and mapped, the resultant risk map will be classed or quantified base on peoples' perception. The traditional socio-economics and socio-demographic indicators were identified and analysed using simple statistical analysis in SPSS, this was employed in the order to develop indicators of vulnerability in order to analyse risk in the study area, depth and duration of flood helped to develop the hazard map. The outcome shows how the component of risk, that is hazard and vulnerability interacts with each other in the study area.

4. Results and Discussion

Spatial extent of flood in the Study Area (Hazard Assessment)

Perception of Flood in the study Area

The study shows that 97% of the households are not aware of flooding in the study area before moving into the area. This is to ascertain if household are aware of the level of danger they can find themselves.

Frequency of Flood in the study Area

The frequency of flooding in the study area based on the perception of the household in the study area. This question was elicited to know how dangerous the study area is. The study shows that about 70% of the households that were interviewed had experienced flooding at more than once since moving to the area.

Duration of Flood and flood level in the study Area

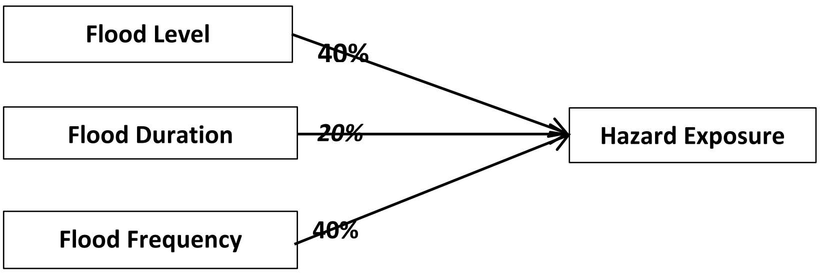
Flood duration was measured in number of hours it stays within and outside household houses. The study shows that 82% of residence says that food always stays more than 48 hours outside their houses. This was acquired from each household, while the flood depth was measured based on water level on walls of buildings. The study shows that the average height of flood level in the study area is about 0.6m.

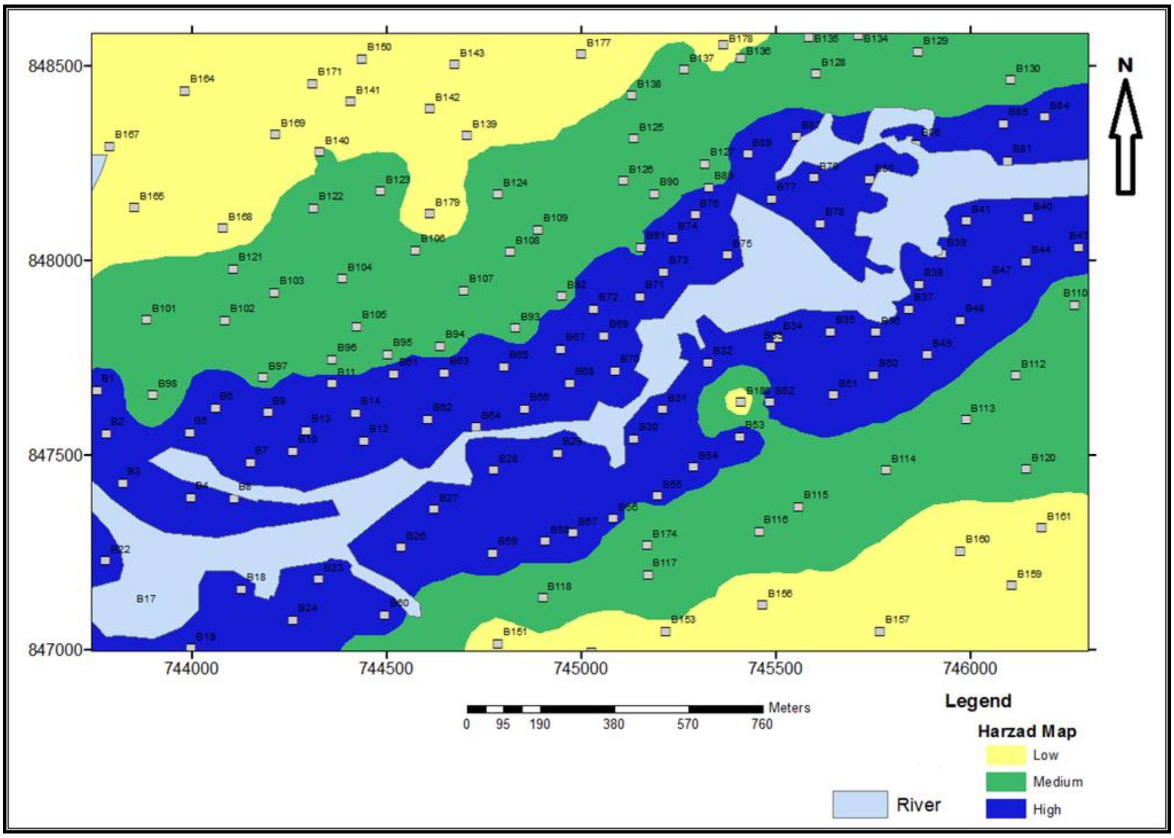
Causes of Flood in the study Area

9% and 12% of the respondents believe that flood in the study area is caused by excessive flooding and poor drainage management by residents respectively. Other causes of flooding in the study area from the respondents' perspectives are uncontrolled development or lack of adequate land use planning (22%) and lack of adequate drainage (57%). For the purpose of hazard assessment, flood hazard was modelled using flood depth (measured by tape), duration and frequency (perceived by the households) that allow for the production of flood hazard map of the study area, based on the flood events of June 2013. By assigning relative weights to each of these indicators in ArcGIS 10 environment, a hazard map was produced Figure 2 shows the level hazard index of households' the study area.

Indicators of Flood Hazard

Indicator	Threshold level	Data
Flood Level	> 30 cm	
Flood Duration	> 12 hours	Results from analysis of Questionnaires
Flood Frequency	5 (once)	





Source: Authors fieldwork, 2015

Fig. 4: Hazard Map of the Study area

Vulnerability Assessment

Quantitative approach was used vulnerability assessment for this study which aims at identifying households that are vulnerable to flash flood in the study area. This approach seeks, to better understand households' own perception of vulnerability. For the vulnerability analysis, an index-based approach was developed that considers several aspects of vulnerability as described in pertinent literature. The implementation of the concept into practice, however, is limited by data availability, a notorious problem for many. The indicators of a vulnerability analysis may vary considerably, since an important purpose of this study is to support risk reduction and management efforts, therefore, indicators were defined that assess from households' perception.

Gender Structure

Gender is a factor to consider when assessing the impacts of flood event. It is assumed that women are more vulnerable than men not because of their biological differences, but their traditional role in the society of taking care of their family member tend to place some burden on them during disaster events. The gender structure of the whole questionnaire showed that there were more female respondent (63.7%) than male (36.3%) who took part in the survey. It is assumed that the traditional household structure and a respective internal structure of division of labour in traditional African society where the male goes to work during the day and the women stay back to take care of the home and children, may be responsible for the higher percentage of female respondent than male.

Age Structure

The respondents' age ranges from 18 to 59 years, with age group range of 20 to 49 years were mainly interviewed.

Household Type and Family Composition

When there are emergencies or when natural disasters happen, for example flooding, the assumption is the ability of household to react in an appropriate way, is very crucial, and this is dependent on the structure of the households. Households with dependent persons (with children and/or disabled or permanently ill persons) are often considered to be more vulnerable than households in which has less persons or in which every person can rely on herself/himself. In this survey household size was group in to One-person household representing 19%, Small family (with less than 5 persons) represent 36.6%, while large family (equal or more than 5 persons) is about 53.8% of the respondents.

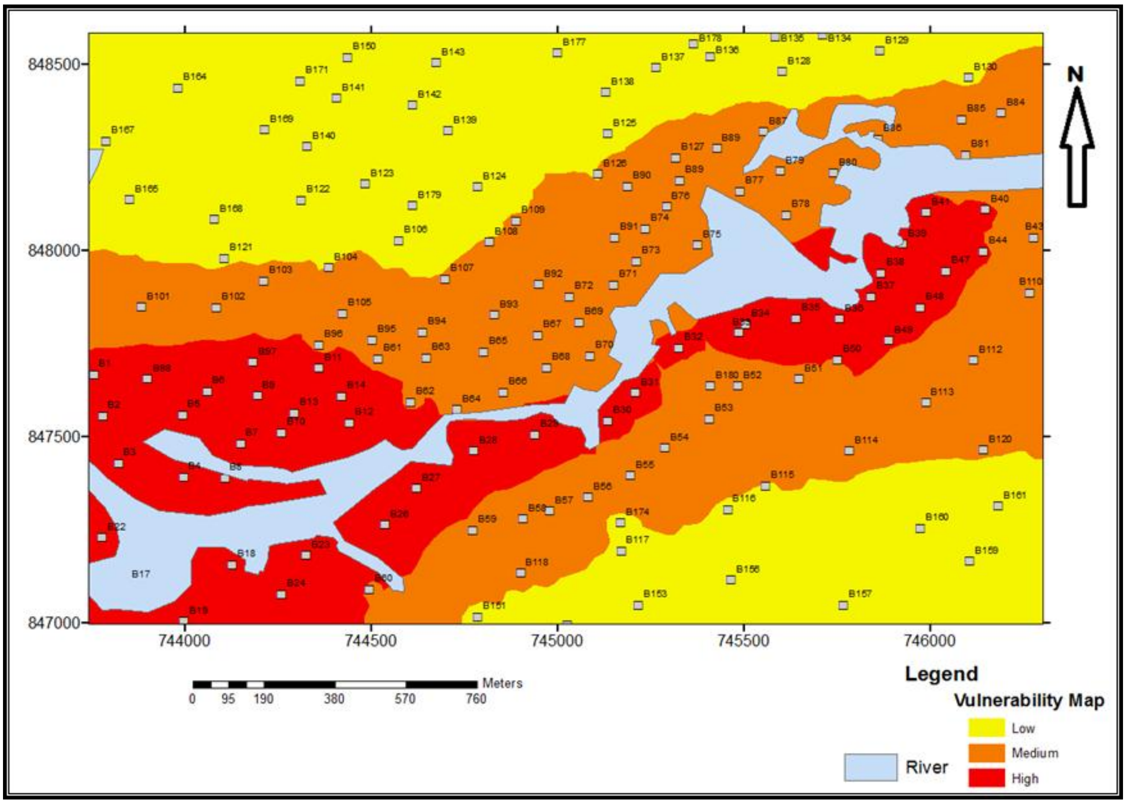
Educational structure and Employment Status of households

Economic, cultural and social capital is an systematic tool used to describe and interpret the social structures of modern societies (Jean-Baptiste et al., 2011). All forms of income and assets that are translated to monetary value are considered economic capital, while formal and informal qualification, skills are considered cultural capital. Social capital relates interpersonal relationships, which allow an individual or households to get access to resources. One of the widely used indicators of cultural capital is usually operationalized through formal educational qualification. This is assumed to be a decisive factor or predictor of the position one can attain in professional ladder, as stated earlier in this work that vulnerability is about social inequality. For the sake of this study formal educational qualification was operationalized through highest level of education and was classified into None, Primary School, Secondary School and Higher Education. Table 8 shows that about 47% of the respondents have a higher education. Study shows that 83% of the household interviewed have a source of income. The implication of this analysis is that the households that fall in these categories people will be less vulnerable. Household incomes used to measure economic capital in this study exhibit a tendency of low range in the study area. Vulnerability map being a major component of a risk assessment is the assessment of the study area's vulnerability to hazards. This consists of the both socio-demographic and socio-economic data analyzed above (Gender and Age Structure, Household Type and Family Composition, Educational structure of households and Employment Status). As depicted in Figure 4.2, these components of vulnerability were aggregated to create an integrated vulnerability map. Instead of weighting all components equally, a weighting of the socio-economic and socio-demographic components used to produce the vulnerability map. However, this weighting was made as a normative decision and could easily be determined differently. Finally, vulnerability map was classified into three ordinal classes.

Indicators of Vulnerability

Indicator	Threshold level	Data
Gender Structure	% of Women	Results from analysis of Questionnaires
Age Structure	Proportion > 75years Proportion < 5	
Proportion lone parents	Proportion lone parents	
Educational Structure of households	Proportion uneducated	
Employment Status of households	Proportion unemployed	

Source: Authors fieldwork, 2015

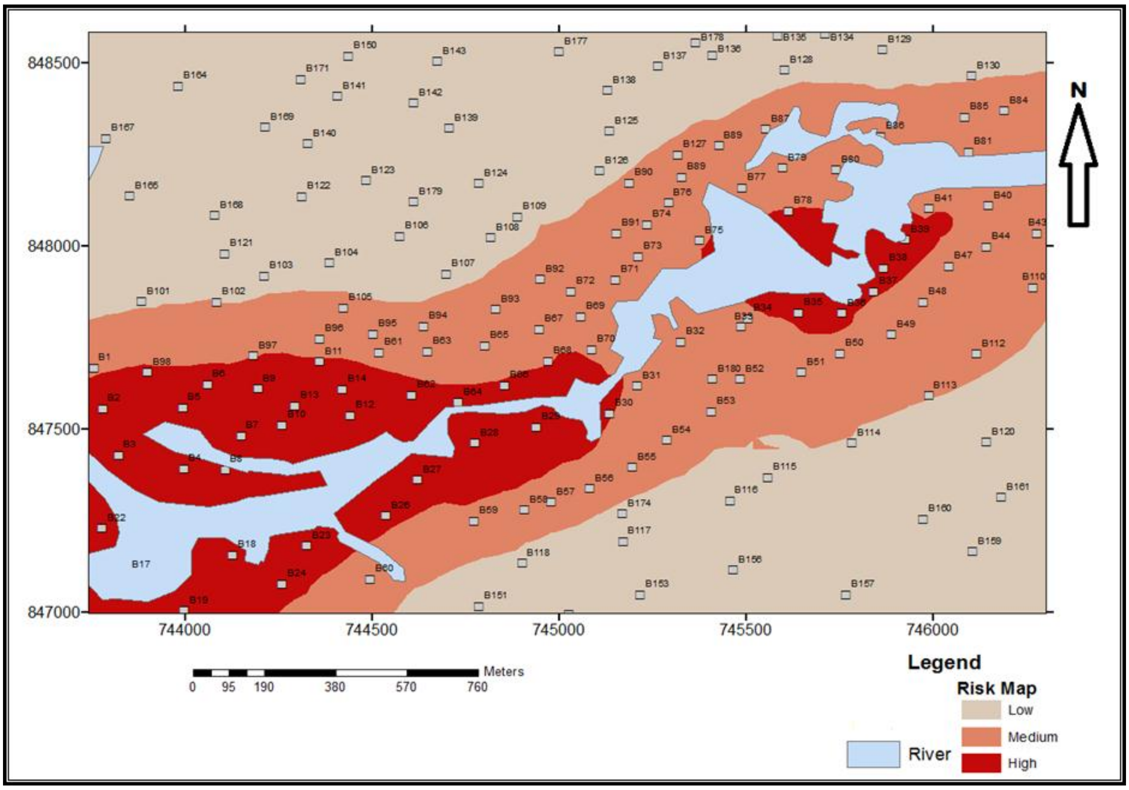


Source: Authors fieldwork, 2015

Fig. 5: Vulnerability map of the Study area

Risk Mapping

Vulnerability and hazard map are multiplied with each other using the following equation Risk=Hazard * Vulnerability, was implemented in ArcGIS 10.1 environment. The new integrated risk index makes it possible to distinguish between various risk degree in the study area, that also have a high degree of vulnerability the risk map is aggregated into High, Medium and Low. This methodology is derived from integrated risk assessment of spatially relevant hazards (Greiving et al., 2006)



Source: Authors fieldwork, 2015

Fig. 6: Risk map of the Study area

The conclusion of the analysis carried from the foregoing is that the hazard, vulnerability, and risk maps described in this study can be used in risk reduction efforts and providing relevant information to the local and regional authorities. The method of integrating information from hazard and vulnerability into a risk analysis, as presented here, allows for an identification and categorization of risks from floods at reasonable cost. The information and especially the maps can be highly appreciated by the responsible local authorities and served for risk reduction planning. Application of this method can be carried out for other areas where flood disaster is a problem and particularly useful in areas where no risk information at all exists. The hazard map as developed in this study represents a framework for a reasonable assessment of flood hazards. The risk analysis for the study area allows for identification of areas with different degrees of risk, an important input for further risk reduction measures.

Conclusion

This study has descriptive survey design with 197 subject of the study area. Questionnaires was used by the researcher to collect relevant data that were analysed using descriptive statistics to develop indicators for the various the Hazard, Vulnerability and risk Mapping, which were carried out in a GIS environment. As urbanization occurs people move to new areas for developmental purpose without taking into considerations and cognizance lowland areas that are liable to flood, the outcome of this study further substantiate this premise. From the result it shows that 97% (193) of the households are not aware of flooding in the study area before moving into the area, and probably this is because government has no land-use plan for the whole of Ado-Ekiti, which could had considered areas that are lowland and liable to flood non-developable. The study further shows that about 70% of the households that were interviewed had experienced flooding at least once, since moving into the area, and from research the area may likely flood again. The Vulnerability, Hazard and Risk maps showed that buildings closer to river Ofin all have higher index and, as buildings are getting further away from the river the index are getting lower. This study further substantiates the premise that flooding results from excessive rainfall, blockage of natural drainage channels, overflow of river banks and building river banks that are flood-prone areas. Other finding shows that, the city of Ado-Ekiti has been characterized with flooding over the past years, besides the recent flooding in the study areas shows that it had contributed to loss of properties and human lives. The study evaluated the major component of risk, which are hazard and vulnerability of household through the uses of questionnaire. The method of integrating information from hazard and vulnerability into a risk analysis, as presented here, allows for an identification and categorization of risks from floods at reasonable cost. The maps can serve as a tool by responsible local authorities in risk reduction planning. Application of this methodology can be further applied to other areas or regions where no risk information at all exists. This study further reveals the advantages of hazard map, vulnerability maps and risk map to land-use planning and management alternatives.

Recommendations

Urban flood risk depends on a combination of components comprising hazard and vulnerability. It underlines the combination of natural and human factors that create flood risks. Flood management measures have to be planned across administrative and sector boundaries. It is therefore recommended that in order to achieve sustainable development which require the contribution of all stakeholders, effective countermeasures should therefore be put in place to combat the issue of flood in the study area, by carrying out risk assessment as a procedure to test and select appropriate mitigation strategies, also vulnerability indicators are important tools to understand the driving forces and different impacts of potential disaster. The vulnerability map will also help in time any emergency to know where people are more vulnerable than others. The risk map can be used for environmental impact assessment to know why people build on the flood plains. Community participation in flood risk assessment as well as in planning and implementation of risk management measures is a key for the success of flood risk management plans. The meteorological agencies in the state should ensure that information on seasonal forecast and climate prediction data are made available, this is to ensure that strategies to reduce vulnerability are implemented. Hence government at all tiers should intervene by making available funds for such intervention. A drainage system for sewage and surface run-off in the entire metropolis is absolutely necessary, besides a paradigm shift of the behavioural pattern of the urban community, most especially with respect to urbanization is very crucial to the mitigation of flood disasters as well as ensuring an ecological sustainability in African countries in general, and in Ado Ekiti metropolis of Nigerian particular. In continuation to this study, floodplain mapping based on rainfall trends can be carried out supported by multi-criteria spatial analysis. The various spatial relationships among assets data, land use information and flood risk maps can also investigated, also there is also room for improvement, both on data and methodological levels. A higher spatial resolution of DEM and social data could improve the spatial accuracy of the results.

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