PARTICIPATORY APPROACH FOR FLOOD VULNERABILITY ASSESSMENT IN SELECTED COMMUNITIES DOWNSTREAM OF JEBBA DAM NIGER STATE, NIGERIA

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MTech/SPS/2017/7219

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MINNA

DECEMBER, 2022

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A THESIS SUBMITTED TO THE POSTGRADUATE SCHOOL FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA, NIGERIA IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE OF MASTER OF TECHNOLOGY IN GEOGRAPHY

DECEMBER, 2022

ABSTRACT

People possess a creative set of strategies based on their local knowledge that allow them to stay in flood-prone areas. Stakeholders involved with local level flood risk management (FRM) often overlook and underutilize this local knowledge. There is thus an increasing need for its identification, documentation and assessment. Based on qualitative research, this research paper critically explores the notion of local knowledge in Jebba Dam.The aim of this study is to map the vulnerability of certain communities downstream of Jebba dam for flood hazard by using participatory geographical information system approach (PGIS). The primary data for the study were collected using Global Positioning System (GPS), focus group discussion (FGD) and high-resolution satellite image downloaded from Google Earth. Participatory sketch mapping method combined with Field surveying and GPS points taken with geo-referenced satellite image through step-by-step approach to record information on spatial extent of flood in the community to obtain valid exposure to flood map was adopted, GIS and remote sensing techniques is used to classified the terrain of the study area to produce flood vulnerability map based on elevation and to map the community infrastructure to generate flood vulnerability map based on distance. The produced sketch map from participatory community mapping showed local knowledge on flooded and non-flooded areas, flood channel, direction and flood entrance points that support the exposure to flood where identified. Exposure to flood Map results showed that in kosogi community the flooded area is 16.2hectre and not flooded is 17.84hectre, 48% of the area is flooded. In Lwafu community the flooded area is 25.5hectre, not flooded building area is 9.72hectre, 66.25% of the area is flooded. In Sunti community the flooded area is 9.72hectre and not flooded area is 4.05hectre, 62.505% area is flooded. Results show that participatory approach (PGIS and PMAPPING) can be useful to record local spatial knowledge on flood vulnerability that supports the development of vulnerability reduction measures. By helping community members understand and manage vulnerability, this approach has the potential to become an important mechanism to support vulnerability reduction in Jebba dam downstream.

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CHAPTER ONE

1.0 INTRODUCTION

1.1 Background to the Study

A flood is an accumulation of water in an area where water normally does not exist, submerging a region that is normally dry (Muhammad & Iyortim, 2013). The European Union Floods Directive classifies a flood as a situation in which an area of land covered by water is uncovered while not under water. Overflowing water from water bodies such as rivers and lakes results in part of the water leaving its customary bounds.

People are increasingly concerned about the possibility of flooding as a result of climate change (including more increasingly severe rainfall events), rising sea levels, growing populations, and urbanization, along with the general awareness of the threat, the narrow efforts to prevent floods, and the wide-ranging exposure and vulnerabilities of people (Peduzzi *et al.*, 2009). Flooding has wreaked havoc on communities for the past two decades, costing huge amounts of money that runs in Billions of US dollars (Guha-Sapir *et al.*, 2013). During the 1985-2014 period, almost 3700 flood catastrophes have been documented in the EM-DAT database (EM-DAT, 2014).

The prosperity of West African communities has seen the impacts of water-related risks damage their livelihood since the 1970s (Oyerinde *et al.*, 2014). Despite there have been an overall reduction in yearly rainfall in West Africa since the 1960s, the amount of rainfall has increased during the past decade (Aich *et al.*, 2014). An increase has been found on the African Coast of Guinea (AMCEN, 2011) and in the Sahel zone of West Africa (Tschakert *et al.*, 2010). When a flood occurs, it may cause massive harm to socioeconomic systems, including mortality, the destruction of farms and other infrastructure, as well as interruption of socioeconomic activity, such as businesses closing or sales revenue decreasing. There is an increase in the frequency of intense rainfall anticipated for West Africa, according to current estimates (IPCC, 2013). Heavy precipitation is predicted to increase in frequency and severity in the future, which may lead to greater danger of flooding.

Flooding and its solutions are big concerns in Nigeria, especially when it comes to the impact of flooding (Obeta, 2014). Flood mitigation measures in Nigeria should be given an even higher priority because of the country's history of severe floods that harmed millions of human populations and generated billions of dollars in fiscal losses (OCHA, 2012). Nigeria's recent floods have been characterized as fluvial, coastal, and pluvial in nature and are major worries for cities and rural areas within Nigeria (Bashir *et al.*, 2012; Houston *et al.*, 2011).

The Niger River basin, is also suffering floods. Because of the 1997 to 2010 recovery of rainfall, floods caused by heavy rainfall were more prevalent in the region from 1995 to 2010, according to (Goulden & Few 2011). As a result of a disaster with significant consequences on human security, flooding occurs often in the Niger River Basin (Okpara *et al.,* 2013), particularly causing harm to agricultural output, communication infrastructure, and people's livelihood and health.

Similar issues were found in the Benin Niger River Valley. This area had severe social and economic impacts as a result of flood disasters. In 2010, about 14,000 individuals (WB/UNDP, 2011) were impacted. Over the course of the year, 8 deaths were recorded, and at least 2,888 houses were impacted by 43,857 victims and 23,640 hectares of farmland were lost (www.foodsecuritycluster.net). Over 21,500ha of crops were lost in 2013, and 9,200 families were negatively affected (BAD, 2014). Since floodwaters routinely inundate the area's residents, the population in 2013 is projected to be 234,681 (INSAE, 2013).

The attempts of stakeholders to combat the danger have thus far failed to produce acceptable outcomes, however, they have been criticized for being haphazard, unorganised, opaque, and lacking in generality (Obeta, 2014). It can be argued, however, these stakeholders' efforts are only restricted because of a lack of accurate data, despite unsurpassed cultures in flood risk lessening and schoolings acquired from other nations' flood expertise. This is due to the fact that these stakeholders do not have enough of the right kind of data, which is essential to deal with flooding systematically, due to the fact that the general population does not fully comprehend flooding, there are not enough financial resources, and also because the availability of more sophisticated technology and political will power has not significantly improved.

When the number of flood victims grows, and as there are fewer places where the land can be developed because of floods, it's very probable that what we think we know about floods in the country is wrong. One of the most populous nations in the world is Nigeria, which has an estimated population of about 170 million people (World Bank, 2013). There is strong interest in creating capacity to deal with future flooding, due to the idea that the expansion of the human population would result in future flood danger.

Grasp vulnerability necessitates a greater knowledge of the effects of hazards on communities and systems that are vulnerable to their repercussions in order to control flood risk (Reilly, 2009). When spoken aloud, this means that the vulnerability of the exposed parts will be the deciding factor when it comes to whether or not a tragedy ensues (Birkmann *et al.,* 2014). Although we have learned a lot about flood hazard over the years, we have a lot to learn about the vulnerabilities that come with that knowledge. This knowledge gap is viewed as the “missing link” in risk assessment and better assessment of risk is seen as an important step in gaining a better understanding of risk (Jongman *et al.,* 2015). Vulnerability is the state in which vulnerable elements are more susceptible to the influence of risks (UNISDR, 2009). Among several techniques to evaluate vulnerability, including damage curves (PapathomaKöhle, 2016), fragility curves (Tsubaki *et al.*, 2016), and vulnerability indicators, damage curves (PapathomaKöhle, 2016) are the most popular (Roy & Blaschke, 2015). This focuses on the physical susceptibility of structures to specific hazards, disregarding the social vulnerability and capacity to cope of the people who reside in these structures (Koks *et al.,* 2015). It is also critical to examine a society's ability to foresee, respond to, and recover from calamities.

Due to this, some writers see the need for a comprehensive knowledge of vulnerability by using multiple indicators that link diverse dimensions of vulnerability together into a comprehensive framework (Godfrey *et al.*, 2015). Indicator-based methods are simple and stress-free to understand and apply (Ciurean *et al.,* 2013). The fact that flood susceptibility indicators do not need information regarding damage and instability curves is one of its advantages; moreover, flood susceptibility indicators have been used to measure societal vulnerability (Frigerio and de Amicis, 2016), vulnerability in terms of socioeconomic status (Kienberger *et al.*, 2009), as well as physical susceptibility (Kappes *et al.*, 2012), as well as various levels of susceptibility (Vojinovic *et al.*, 2016).

Many different motivations and practices exist, but developers must still confront numerous difficult decisions while developing vulnerability indices. This introduces subjectivity into the modelling process. The main problems are to find relevant input criteria, standardize data, and rank criterion relevance (Rufat *et al.,* 2015). Most often, judgments on selection criteria, weighting, and aggregate are made without any rationale whatsoever. Several of the decisions are limited to project participants and no rationale is offered (Rufat *et al.,* 2015). The vast majority of vulnerability indices are weighted equally (Tate, 2012). Due to this, even if the linkages between vulnerability metrics are complicated and diverse (Fuchs, 2009), it is considered that the links between criteria are independent (Chang & Huang, 2015).

Vulnerability indices would thus benefit from explicitly demonstrating how various model criteria relate to one other, how they are weighted, and why a particular model choice was made. Even in addition to these problems, involvement in index creation is rarely done in a cohesive manner across various stakeholders. De Brito and Evers (2016) found that none of the risk indicators examined had a widespread effect that encouraged involvement in the process of vulnerability modeling. Typically, only important stakeholders who were identified as key experts were asked for their opinion in the weight assessment stage. Procedures to be followed, such which criteria to use and how to standardize the data, were normally reserved for those doing the research.

But involvement and cooperation are important to facilitating communication between scientists and the general public and ultimately between research and public policy (Barthel *et al.,* 2015). If practitioners help design and implement an index they use, they are more likely to make judgments based on that index (Oulahen *et al*., 2015). Also, perceptions can be attained when information beyond the scope of a business is taken into consideration. As a result, it is possible to obtain a more extensive and all-encompassing understanding of the situation, which gives rise to more operational susceptibility models (Müller *et al.*, 2012).

By engaging with the community, participatory mapping (PGIS) creates, depicts, and this verifies a type of local spatial knowledge that is rarely found on official maps. This fact is explicit to a particular location, and this makes it appear as though it has to do with community significances, tenets, and views. The whole process is driven by the interests and objectives of the local community; it is inclusive and representational of community values and those of individuals. People feel that they have an ownership stake in the results, and their activities are perceived as legitimate. Capacity building is made possible through community participation and the empowerment of communities and groups; both self-assurances, as well as technical and political abilities are thus improved. Another use of PGIS might be providing the additional value of digital data to local capacities in a GIS context (Brown & Kyttä, 2014).

The local population is being taught participatory approaches in order to improve their capacity to share and analyze their knowledge of living circumstances and habits, making it easier for them to plan (Chambers). A major element of this process is empowering the individuals who will be acting. The study wasn't created for individuals from outside the community to learn about local circumstances, but instead to let the people from inside the community do their own research and craft their own agendas (Chambers).

1.2 Statement of the Research Problem

Flooding is a major environmental issue in Nigeria, and its frequency and severity have been on the rise recently (Agbonkhese *et al.*, 2014). The 2012 Nigeria floods began in early July 2012, and by November 5, 2012, the death toll had risen to 363 and the number of displaced persons had increased to nearly 2.1 million. For a three-month period in the spring, summer, and fall (NEMA, 2012), flooding is widespread, destructive, and often a natural danger. River Niger flooding has temporarily disrupted socio-economic activity in the area. The flooding of extraordinary proportions drowning the surrounding flat lands or floodplains that are found along the river basin is typically situated near the river. According to studies, the problem of river flooding on the Niger River is growing, and year after year, an alarming number of people are affected. As water is discharged from Jebba Dam, several downstream towns are at risk. In the rural settlements of Sunti, Kusogi, and Lwafu, close to 80% of the population is engaged in subsistence farming, which relies on agriculture for their existence. Their rice crops were washed away by the storm, as were a significant number of cattle owned by the ordinary family (NEMA, 2018). Some of the houses built along the flood plain were also destroyed leaving some of the villagers homeless.

To better detect and minimize community dangers, it is critical to incorporate local knowledge (Mercer, 2010). The people who will be directly impacted by the crisis are on the front lines of reaction when it occurs (Butler *et al.,* 2015). The adoption of management methods is better when people from the community are involved in the research process and local and scientific knowledge is used (Fazey *et al.,* 2010).

In order to avoid the issues that many nations across the world are currently experiencing due to floods, the state must undertake this kind of study.

1.3 Scope and Limitation of the Study

This research studies cover three communities of Sunti, Kusogi and Lwafu downstream of Jebba Dam.

The vulnerable element is focused on the physical aspects of the community and does not cover economic and social vulnerability. The data used to identify places vulnerable to flooding is drawn from personal knowledge in the community, but the structural and hydrological aspects are not considered.

1.4 Justification for the Study

The flooding in Nigeria has gotten a lot of attention, as well as ways to cope with the issues that come with it (for examples: Ali & Hamidu; 2014, Bashir *et al.,* 2012; Agbonkhese *et al.,* 2014; Adedeji *et al.,* 2012). According to the factors which produce the hazard, global warming, ineffective urban planning, and mismanagement of the environment, together with human activity, have been mentioned (Aderogba *et al.*, 2012; Adeloye & Rustum, 2011).

While there is a strong belief that addressing the hazard is difficult because of the absence of definite measures and the inability to substantially handle the threat, the public has nonetheless attempted to tackle the problem by implementing environmental and infrastructural design, policy dictates, social rejoinders, physical interpolation, and increased public awareness efforts (Agbola *et al.*, 2012; Ali and Hamidu 2014; Bashir *et al.*, 2012). Emergency early warning systems (Adeoye *et al*., 2009), such as those conducted by nongovernmental organizations (NGOs) (Agbonkhese *et al.*, 2014), are among the other methods explored (Adedeji *et al.*, 2012).

Water resource hazard mapping, in addition to understanding the threat of floods and property vulnerabilities, are critical in helping communities become more resilient to flooding in Nigeria (Ajibade *et al.*, 2013; Adelekan, 2010), therefore, the need to embrace and strengthened environmental education in Nigeria (Terungwa and Torkwase, 2013). It is stressed that strengthening all agencies' existing strength and capacities, including local communities in Nigeria, must be done in order to handle flooding danger scenarios (Obeta, 2014). Even though there has been a lot of attention to this research, the "cure for recurring floods in Nigeria" is still unresolved.

One of the biggest barriers to flood control in the country is the lack of flood information and other auxiliary records. That information was raised, but it was not taken into consideration. The fact that all the research done so far have mostly focused on flood knowledge, and in particular on general understanding of the causes, consequences, and treatments, suggests that these studies have had an overly wide perspective. In industrialized nations, new scientific techniques like flood modelling are needed in order to control flood risk. A well-rounded critique is missing and voids between growing flood manifestations and the communities' vulnerability have not been highlighted.

To better detect and minimize community dangers, it is critical to incorporate local knowledge (Mercer, 2010). Combining professional judgment with community engagement yields the most effective hazard mapping and exposure assessment. It has not been done in the study region if mapping of danger and identifying vulnerabilities at the community level can be achieved by asking the community or if they can be reached by tapping into community knowledge.

To see these, it becomes necessary for us to implement a participatory geographic information system (PGIS) for flood mapping in order to produce a map of flood-prone regions, detect areas of risk, and assess the vulnerability of each individual piece in terms of community perception.

1.5 Aim and Objectives of the Study

The aim of this research is to map the vulnerability of some communities downstream of Jebba Dam, whose susceptibility to climate-aggravated catastrophes (flood hazard) has increased due to climate change.

The objectives of this research are to:

i. Map the flood event based on community participatory mapping.
ii. Validate the sketch map of study area using field surveying and satellite image.
iii. Produce and analyze the classes of terrain of the study area.
iv. Map community infrastructures and identify those at different vulnerable level.

1.6 Research Questions

i. What is the community knowledge of spatial extent of flood?

ii. How can the community sketch map of the flood extent be validated?

iii. What are the classes of terrain in study area?

iv. What are community's infrastructures and which are most vulnerable to flood?

1.7 Study Area

This section detailed the description of the geographic features of the Study region, taking location, climate, vegetation, relief, soil types, and population into consideration.

1.7.1 Geographical location and population

These study areas are chosen villages located in Mokwa LGAs in Niger State, with a total area of about 4,338 square kilometers that lies within 4040' to 6010' East of Greenwich Meridian and 8045' to 9045' North of the Equator (Figure 1.1). These communities are Sunti latitude 1000326.290mN and 1007762.050mN longitude, Kusogi in latitude 1007762.050mN and longitude 742733.470mE, Lwafu in latitude 1009283.110mN and longitude 739282.440mE local government region in Niger State.

Niger state's population is estimated to be 3,950,249, with Mokwa estimated to be 242,858 people (National population census 2006).

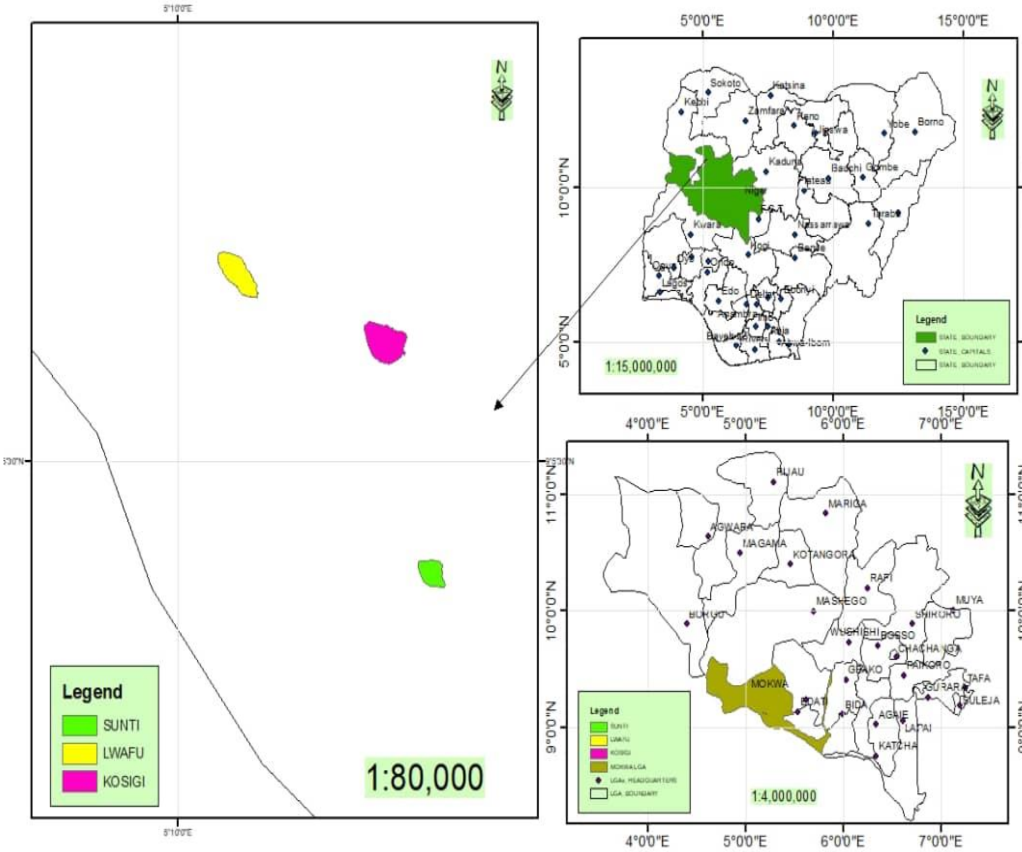

Figure 1.1: The Study Area

1.7.2 Climate

Tropical savanna climate, also known as tropical wet and dry climate, is a kind of climate that occurs in the tropics, which shows two separate prevailing air masses in response to seasonal variations, may be found in the research area's location, due to its placement on the Tropic of Cancer. the desert-sourced dry continental air masses move across the Atlantic Ocean into the maritime-sourced moist tropical air masses The weather is highly dependent on the mass of air that covers the area, and the depth of that mass. At the border between the two air masses, where the Inter-Tropical Convergence Zone (ITCZ) bends north and south, there is a discontinuity zone regarded to as the Inter-Tropical Convergence Zone (ITCZ) discontinuity zone that swings north and south with the nation.

During the rainy season, which begins around the end of March and lasts until October, the harmattan, a north easterly airstream, adds to the dry season's dust that is often carried from the Sahara. During this period, a fine layer of dust and haze from the Sahara is carried in by seasonal winds. As a result, the visibility is decreased. In most cases, it is felt only between the fall and spring months. This time of year, is usually more comfortable because of the lower humidity. year-round temperatures range from 18°C (64°F) to almost 20°C (68°F), and an annual rainfall of around 1500 millimeters is distributed throughout the year, with peak precipitation occurring in September (http://www.nigerstate.gov.ng/about.ph)

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Conceptual Framework

This chapter duels on the general and scientific concepts together with literatures guiding and relating to the study on the participatory Approach for vulnerability mapping of flood.

2.1.1 Conceptual review and citations relevant to the study

This section discusses the concept relevant to the study under the following themes: Flood Vulnerability, Flood as hazard, Floodplains in Nigeria, Flood control and mitigation measures, participatory community mapping, and Empirical studies on using Participatory Approach for mapping vulnerability of floods.

2.1.2 Flood vulnerability

Vulnerability is described by the interplay between an individual's level of exposure, his or her sensitivity to risk, and the community's capacity to withstand risk (Balica and Wright, 2010). Vulnerability assessment techniques have many definitions, theoretical frameworks, variables, and procedures, each with its own unique properties. Various vulnerability assessment methodologies have been divided into four groups: according to prior literature, they may be divided into four groups (Dapeng, 2012).

There are two common ways to perform a vulnerability assessment. One is the "vulnerability indicators" technique, which makes use of existing data to build a coherent picture of the risk. To be more precise, it is commonly employed in flood risk assessments, and this has led decision-makers to prefer it since it produces a clean and understandable visualization of the threat. This particular category of techniques relies on complex indicators which may be standardized, weighted, and aggregated. It is one additional battle to deal with the lack of assurance. Since each layer in the additivity contains a different variable, struggles over variable issues will have to be dealt with. There is a proposal to weight variables to decrease their influence on the expression's final value (Lein, 2010). The computation of social indicators is complicated by the difficulty in quantification (Khan, 2012). When discussing the indicators selection technique based on (Fussel, 2010), there are two approaches to select from: theory-based (deductive) and data-based (inductive). Even if they have distinct methodologies, these attitudes combined create a better view of the vulnerability on the local level. Inductive method picks indicators relative to statistical association with observed vulnerability outcomes (such as death from floods). Without a specific definition for what vulnerability system means, it is just helpful for particular flood coverage systems. While all data-based indexes are hampered by the limitations of short-term instability, developing and testing an index for temporary unpredictability is the main restriction of all data-based indexes (Fussel, 2009).

Susceptibility curve technique: Empirical damage or fragility curves are used to study the link between flood danger and items at risk. While most theories can only be tried on specific case studies, this method is based on data from well-documented past experiments and only involves homes in a certain geographic region. This set of technique uses a list of available subjects to select a sample of things from each specified class. Data is mean and step-damage profiles are then produced for all trials of each component class. Similarly, the stage-damage curves shown depict prospective damage, even though the damage that occurs immediately after a flood may be estimated using the same methods (real damage analyses). The approach is used on the basis of the real survey of damage and so requires a lot of time and resources. Also, this method's effectiveness in other places is questionable since it is not applicable.

Method of calculating disaster losses: This approach is based on records gathering from genuine flood hazards and their application as a direct to forthcoming occurrences. It is a straightforward approach, but the results may be erroneous due to unevenly collected data. As a consequence, the results of these approaches should be regarded with care.

Methods of modeling: The hydrograph's depth, height, and speed may be assessed with frequency, magnitude and form by means of computer models. One one-dimensional (1D) or 2D model based on results of complete or approximation surface water equations is predominant in the computation of flood inundation. These approaches are dependent on the correctness of precise data on topographical, hydrographic and economic evidence in the research area. In this technique, economic loss information is publicly understandable. However, in the absence of sufficient data, the models are subject to considerable anomalies that might lead to questioning and mixing decision-makers (Balica, 2013).

Variables utilized as data are geo-referenced and transformed into raster formats in the geographic information system-based vulnerability (GIS). This modelling technique may assess local vulnerability more sensitive than other, but does not take into account local elements to explain a clear connection between the forecast map and the actual flood damage level (Lein, 2010).

Various flood risk and vulnerability assessment approaches are the indicator-based method, profile method, adversity loss data and model method

2.1.3 Flood as a hazard

Even for natural hazards, such as floods, no unique definitions and assessment procedures have been widely accepted (Pistrika & Tsakiris, 2007). Hazard is the probability of occurrence within a specified period of time and within a given area of a potentially damaging phenomenon (Maiti, 2007). This definition adds both spatial and temporal components to the definition of hazards while another definition from UNISDR (2009) refers hazard to "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." Hazard is, in the case of river-floods, a natural event that is perceived as a threat and not as a resource by humans (Fekete, 2010).

Hazard becomes a disaster when it hits a vulnerable community. It causes disaster when large numbers of people are killed, injured or affected in some ways (Maiti, 2007). In the same line of thought FAO (2008) points out that disasters of all kinds happen when hazards seriously affect communities and destroy temporarily or for many years the livelihood security of their members. Another definition from ISDR refers disaster to “a serious disruption of the functioning of a community or a society causing widespread human, material, economic or environmental losses which exceed the ability of the affected community or society to cope using its own resources". A disaster results then from the combination of exposure to a hazard, socio-ecological vulnerability that are present, and the limited capacities of households or communities to reduce or cope with the potential negative impacts of the hazard.

Flood risk is related to social systems' exposure to flood catastrophes and susceptibilities (the likelihood of being negatively affected by floods due to a lack of coping ability) (Balbi *et al.,* 2012). It is also the outcome of the possibility of a flood danger occurring and the implications indicated as probable flood losses (Jeffers, 2013). The percentage chance of a flood return period may be defined as the likelihood of flooding occurring. The chance of flood incidence is typically defined by the 100-year flood within study circles (EA, 2010). These are major problems that are driving efforts to reduce the danger of water overflowing in many areas and states across the world (Houston *et al*., 2011; Agbola *et al.,* 2012; EA 2010; Merz *et al.,* 2010).

2.1.4 Floodplains in Nigeria

Flood plains are dry regions next to rivers and streams that are inundated during floods. Floods can cause damage to buildings and extra features situated in flood plains. They can alter the behaviour of water movement and create overflowing and flood destruction on surrounding valuables by blocking the flow of water and increasing the dimensions or speed of flood waters **(**Agbola *et al.*, 2012).

The three main kinds of flooding in Nigeria are river overflowing, and coastal flooding, urban water overflowing. Many individuals have been homeless as a result of heavy rains, anthropogenic activities (human activities that have an influence on the environment), and poor excess water flow groundwork in most Nigerian cities. Crises resulting from an increase in industrialization and urbanization, as well as an increase in population, the exploitation of natural resources, and the presence of infrastructure are all precursors to flooding. Floods are not all created equal. While some floods are made up of a long, gradual buildup of water, flash floods come suddenly and might happen without any obvious evidence of rain.

In recent years, the worst years for flooding in Nigeria appear to have been 2011 and 2012, with numerous reports claiming that the Lagdo Dam in Cameroon spilled water, wreaking havoc on the country's affected regions. Despite the Nigerian Meteorological Agency's (NIMET) warning that there will be above-average rainfall in crucial regions of the country, potentially resulting in floods in 12 states, no one heeded the warning. The following Nigerian localities, however, are more exposed to the threat than others:

i. Low-lying locations in the south of the country that receive a lot of rain each year

ii. The floodplains of the Niger, Benue, Taraba, Sokoto, Hadeja, and Cross River rivers.

iii. The Niger delta zones

2.1.5 Flood experience in Nigeria and other developing nations

The impoverished in society have been recognized as the most vulnerable to floods, as they have no option but to live in flood-prone regions (Lutz *et al.*, 2008). According to Stephen (2011), the number of people killed by floods in affluent nations is fewer than in poor countries. Because of the lack of adequate zoning rules, flood management, emergency infrastructure response, and early warning systems in developing countries, Stephen (2011) and Lutz *et al*. (2008) appear to be correct.

Bangladesh, for example, is a developing country that is one of the most vulnerable to flood disasters worldwide. Flood waters have inundated over 30% of the nation, and floods claimed the lives of over 200,000 people in Bangladesh in 1991 (Stephen, 2011). Wright (2011) describes the disastrous flood in Lahore, Pakistan, in July 2011, which stopped transit and forced businesses to close for days.

The first devastating flood events in Nigeria occurred in Ibadan city in 1963, when the Ogunpa River overflowed, resulting in the loss of lives and property; these dangerous events recurred in 1978, 1980, and 2011, the Ogunpa River became nationally and globally famous after inflicting estimated damages and fatalities of over 30 billion naira and 100 persons, respectively (Adegbola & Jolayemi, 2012; Agbola *et al.,* 2012). Between 2011 and 2012, Lagos state saw at least eight severe floods, resulting in the deaths of over 30 persons and significant property damage (Komolafe *et al.,* 2014). Apart from the Ogunpa Stream in Ibadan, which killed numerous people and halted socioeconomic activity in 1980, Nigeria has a long history of natural disasters (Emeribeole, 2015).

Despite the National Meteorological Agency of Nigeria (NIMET) issuing three flood warning prior to March 2012, it is still difficult to overlook the July-September 2012 flooding in Nigeria, which killed 363 people and affected over 2 million (NEMA, 2012). Furthermore, a study conducted by the National Emergency Management Agency (NEMA) revealed that there were over 256 floods in 774 local governments, and that flood death rates were especially high in Kogi, Niger, and Adamawa states. Kogi state was greatly affected by the 2012 floods since it is located at the confluence of the Niger and Benue rivers.

The 2012 floods in Nigeria can be connected to the flow of water from the Lagdo Dam in Cameroon, as well as heavy rainfall and climate change events (Agbonkhese *et al.*, 2014). Many affluent countries, on the other hand, are not immune to the devastating effects of floods. Floods induced by severe rains killed scores of people across China in May 2008, while landslides prompted by the storms killed thousands more (Emeribeole, 2015). Floods are a global problem, but they are especially dangerous in underdeveloped countries, like Nigeria.

Floods have continued to be an annual source of misery for the majority of Nigerians, and despite the frequent loss of lives and property, nothing has been done to prevent the destruction caused by floods in Nigeria. Similarly, Komolafe *et al.* (2015) contend that, although though Nigerians frequently face the hazards of flooding and the risk associated with them, almost little effort has been put into managing these risks effectively and effectively preparing for any future disasters.

2.1.6 Flood control and mitigation measures in Nigeria

According to Bariweni *et al.* (2012), Flood control includes any techniques intended to reduce or avoid harmful effects of flood water. Flood control includes the effects of the floods are severe. The fundamental impacts of flooding, as Kolawole *et al*. (2011) explained, included human lives loss, the submergence of homes and streets, wastewater flows, municipal pollution, property damage, health hazards, clean-up costs, service disturbance, esthetic discoloration, economic loss and infrastructural damage. Every society must thus take all necessary steps to avert flooding. Flood control methods used for past years include the planting of planting vegetation to retain water, establishment of flood forecasting systems, drainage and dam building, ensuring public consciousness and preparation, proactive city planning and discouraging development of flood-prone areas and the development of other institutional capacity for environmental protection. Agbonkhese *et al.* (2014) propose a proactive approach for flood protection in Nigeria, "Early Warning." Early warning is a proactive mechanism by which certain recognized entities or agencies investigate climate and human interactions with the environment to predict floods, thereby warning individuals and the government to effectively prepare and curb floods, preventing loss of life and property (Agbonkhese *et al.*, 2014).

Aderoju *et al.* (2012) also feel that current day approaches should be used in establishing measures that would aid government and relief agencies in identifying flood-prone regions and planning for future flooding occurrences. Remote sensing and geographic information system (GIS) expertise may be used to explore and map regions that are less or more sensitive to floods, as well as forecasting approaches to anticipate precipitation intensity and duration in the near future (Aderoju *et al.*, 2012).

Agbonkhese *et al.* (2014) provide a clear picture of how structural and non-structural flood mitigation methods might be implemented. Appropriate flood controls in flood-prone areas will help control the dams, levees, flood walls, and drainages in these areas as an alternative to the water-excess absorption from Cameroon by means of excess irrigation structures and excess water run-offs; a control dam will reduce maximal water flows (Agbonkhese *et al.,* 2014). The new flood management paradigm, instead, is gaining momentum by effectively implementing both risk mitigation (structural measures, defense measures for the defense of floods, such as dams and dams and polders) and adaptation (nonstructural measures, soft measures such as community preparedness, flood insurance, information and social networks) (Kubal *et al.,* 2009).

2.1.7 Participatory community mapping

Conversely, participative mapping is a "bottom-up" technique that helps the public to develop maps for all individuals with authority and resources to directly or indirectly benefit the masses. Mapping is crucial for planners, politicians and residents to gather information, to define borders, to manage municipal services and to empower the workforce. Data might be personal or intangible, such as roads, houses, businesses or bus stops, sentiments of safety, belonging and accessibility. The second kind of data is part of local knowledge that may be obtained via direct contact with a contextual and personal environment. Cartography of the global positioning system (GPS) and databases may be performed using a variety of techniques and technology, including surveys.

Participatory mapping, which began in the 1970s as a way to voice local people's expertise and concerns in development initiatives, now aims to use the knowledge and manpower of a broader community to generate maps. These maps can be simple geographic or topological maps, but there is also the possibility of accumulating personal environmental data to create a map with finer precision than is feasible with the limited knowledge and personnel available at the "top." According to Rachel Pain, participatory research is commonly used to address sidelining and social barring of groups, including the fresh, the elderly, ethnic and cultural minorities, and people from lower socioeconomic levels. Many of the earlier research and case studies revealed today focus on participatory mapping projects in underdeveloped nations, where the government (or lack thereof) and big corporations typically disempower individuals.

Participatory mapping recognizes that someone who is closely familiar with an area will have a different perspective than a hired municipal surveyor in charge of hundreds of square kilometers of land, and that each little region has dozens of people with that unique experience. Participatory mapping seeks to gather and agglomerate all of these people's local knowledge in order to create a high-resolution composite map that contains more information than traditional mapping methods.

2.1.7.1 Participatory (community-based) research

Participatory research is a developing area of several study fields, particularly in the social and environmental sciences, when standard research methods make obtaining a comprehensive picture difficult to impossible. The community's involvement therefore aids in the production and mobilisation of knowledge while also preserving significance and credibility among the field's stakeholders.

2.1.7.2 Levels of participation

Though participatory research is a popular topic, not all participatory studies need the same level of engagement and commitment. At the bottom is 'crowdsourcing,' in which people volunteer their data or computer power as research participants but have no stake in the conclusion and no influence in how the study is conducted. Many people believe this to be participatory research.

Other studies, on the other hand, teach "participants" to spot patterns, aiding in the analysis of massive data sets (what Haklay referred to as "distributed intelligence"), or will assist in the definition of the study's goals and design (what Haklay referred to as "community science"). At this level of community science, participants are no longer merely involved; they are empowered in such a manner that their knowledge and ideas are seen as vital to the project. "Collaborative research," in which academics see themselves as equal partners with the community and just serve as facilitators, is at the top of the list. The contact between "planner" and "participant" operates on a spectrum, from strangers to employer/worker to co-partners to facilitator/analyst.

2.1.7.3 Local knowledge

Individuals and groups possess informal knowledge that has developed through time. It is informed by human experience and customized to the community's culture and environment, as well as communal conventions, establishments, and rites. Homegrown awareness is transient and is different depending on demographics and even within a community.

Citizens have personal knowledge about their local spaces, which are an important part of this informal knowledge. This might include a variety of scenarios, such as where people congregate for social events, where they feel secure and comfortable, and where paths are too complex to navigate. Collecting geographical homegrown information from individual subject residents in environmental thinking, motivates their involvement in planning, and adds a layer of space information to the knowledge planners use to make decisions.

2.1.7.4 Mapping

Geographic information volunteered by persons who are not trained is referred to as VGI (Volunteer Geographic Information). Users' smartphones or portable receivers, which are frequently combined and aggregated to create maps, are one example of a GPS user's data. Community mapping is a form of participatory mapping that incorporates both quantitative and qualitative data in a given geographic area. A mapping of an urban area organizes data into four distinct layers. It is situated at the bottom of the municipality data, which contains information on buildings, streets, and bus stops. This is the foundational layer of the GIS (Global Information Systems) framework; it incorporates data that is clearly objective and available to the public. This is already accounted for and might be used to one's advantage. That detail is finer than the city is capable of mapping, therefore it exists on another layer above. For example, a layer that is able to keep track of what is happening yet is not in everyone's view.

In this case, public benches, garbage, poorly zoned areas, trees, and community centers might all be seen as part of the Creative Defects. The third layer is the intangible feeling individuals have about the world around them. When a municipality sees a sidewalk (the first layer), a resident could see a decaying, sleep-inducing stairway (the second layer) (third layer). At the fourth layer, people come up with ways to improve a community, and share their ideas with one another. the land is overgrown with weeds where drug dealing and gang activities are rife, where the community would want to see a park for young children (fourth layer). The fifth layer might be personal experiences and relationships individuals have with the locals. These latter three layers account for the majority of geographic local knowledge, opening the way for citizen participation in planning and policy-making. These latter three levels are also the most difficult to gather, analyze, combine, and show graphically.

2.1.7.5 Relationship between vulnerability and participatory approach

Vulnerability awareness aids in recognizing the situations that put individuals and environments at danger. It also seeks to comprehend the circumstances that make it difficult to respond to environmental hazards. The explanation of successful risk, hazard, and catastrophe impact reduction strategies and policies that directly affect persons and communities requires a vulnerability assessment. Because most data have a geographical reference, GIS is the best tool for visualizing, analyzing, and modeling the "real world," transforming data into useful knowledge. The Participatory Approach is a very effective technique for gathering indigenous knowledge, as well as views of environmental issues and risks, and disseminating it to environmental scientists and local governments.

The link to "participation" is the goal of empowering and securing information flow. In actuality, and particularly from a GIS standpoint, one must specify the rights to participate, object, or collaborate. In addition to "vulnerability," there are continuing conceptual and methodological disputes in the field of P-GIS, as well as evaluations of these methods' usefulness. Standardized techniques are not stated, and terms and ideas are not always utilized in the same way. The emergence of participatory mapping in the community development discourse is new, according to (Pánek, 2016). With its origins in Participatory Rural Evaluation, it emphasizes community participation as well as the subjectivity of non-cartographers.

The important challenge is how to select the most appropriate approach for participatory mapping while taking into consideration the community's unique requirements and assets. Pánek (2016) identified 10 methodologies of participatory mapping after reviewing methodologies presented in works of Corbett *et al*. (2006), Warren (2010) and Corbett *et al*. (2010) as follows:

i. Ephemeral mapping – A simple mapping approach in which community participants construct maps on the ground from recollection using whatever tools they have on hand, such as plants, pebbles, and household items. The finished result is only useful for a brief period of time.

ii. Sketch mapping – Maps are huge sheets of paper with free-hand drawings produced from recollection. They show the region from a bird's eye viewpoint and contain depictions of important community-identified components. There are no exact measurements, a uniform scale, or geo-referencing in the results. The relative size and location of characteristics as they are interpreted and viewed by the mapmakers is an important factor.

iii. Transect mapping, also known as transect mapping, is the process of creating a geographical cross-section of a region using transect maps or diagrams. Once the transect maps are completed, the geographic characteristics identified (such as infrastructure, local markets, and schools) are shown as well as different land-use types and vegetation zones. Transect maps highlight potential challenges and opportunities as well.

iv. Scale mapping – Scale maps show data that is precisely geo-referenced. Knowledge holders can acquire indigenous information by having conversations around a scale map, which is then drawn directly on the map (Pánek & Vlok 2013). The placement of features is determined by their position in respect to natural markers.

v. Photo mapping – This approach, like scale mapping, employs a prevailing map as a geo-referenced backdrop. It is an aerial image of the research region in this case (Vlok & Pánek, 2012). While aerial maps have lately been simpler to get and are frequently free, there are still areas where they may not be accessible or were obtaining authorization to use them may be challenging. While those who are interested in geography might benefit from aerial maps since they provide them with new perspectives, some inhabitants may find the material to be too abstract.

Additionally, aerial maps cannot always provide helpful information for the public.

vi. Participatory 3D modeling (P3DM) – Topographic data (i.e., contour lines) is extracted from scale maps and used to a physical model in order to provide a specialized mapping technique for recognizing specific geographical information. Spatial awareness, intergenerational knowledge transmission, and community engagement are promoted via Participatory 3D Modeling, an approach that goes beyond map-making. To make sure the models stay in the communities where they are created, the end sizes and weights are massive.

vii. GPS mapping – In the field, a GPS receiver is used to record a precise location on the globe using a well-known coordinate system such as latitude and longitude. Information is recorded in digital form and may subsequently be seen on a map (such as a topographic base map). GPS gadgets are great for identifying exact positions inside a community, which are usually easier for government agencies to recognize.

viii. Grassroots aerial mapping – This method captures aerial pictures for mapping using balloon and kite aerial photography. It is cheap and easy to absorb. It demonstrates how to utilize a new open-source online application for orthorectification and map compositing (Warren, 2010).

ix. Multimedia mapping – This method is far more comparable to customary oral information delivery, comprising geographic data. The maps are usually in digital format, and often include audio and video information from the communities.

Participatory GIS – GIS technology has long been seen to be difficult or expensive, and hence only utilized by professionals. The objective of the PGIS movement, which started in the 1990s, was to incorporate indigenous understanding and qualitative data into GIS for community use. This category includes participatory GIS, public participation GIS, bottom-up GIS, community GIS, and qualitative GIS.

2.2 Literature Review Using PGIS for Mapping Vulnerability of Floods

2.2.1 Research conducted in South and North America

Canevari-luzardo *et al*. (2015) reported the results of a new Participatory Geographic Information Systems (PGISs) method targeted at assisting susceptibility and Disaster Risk Management (DRM) operations in small villages in Grenada. By combining geo-referenced home data with community vulnerability mapping, a step-by-step technique is used to obtain information on the vulnerability of individual households and local community issues. They employed a participatory mapping technique that combined with an external facilitator to showcase the potential benefits of PGIS, while also managing the technical parts of the mapping process. Quantum GIS was used to link geo-referenced susceptibility household data to community hazard sketch mapping (QGIS).

When creating partial PGIS, the overall stages follow these general steps: A satellite picture of the area (using Google Maps, orthophotos, and field verification) was used to identify and number each house in the community. In order to determine how the gathered house data would be used at the community level, two community meetings were held. All participants at the end of each session were given a short feedback form to assess their experiences and thoughts about the exercises' difficulty and usefulness. As part of the community session, transparencies displaying a map were mounted on the wall, and the map was printed on a separate piece of paper.

Additionally, participants were provided with a second map with the name of each home owner, as a reference for them to become more comfortable with the scaled map. A community-made drawing sketch VCA (vulnerability capacity assessment) map was previously made. During the session, these key community infrastructure characteristics were shown on a map that was then posted to a wall. The participants were each given markers and instructed to complete three separate exercises. During the remapping activity, participants were asked to add any new geographical elements they felt were necessary but that were missing from the initial VCA (vulnerability capacity assessment) map. At the same time, participants were shown a second page where they were asked to identify locations that have been susceptible to flooding or landslides because of past or current data. To assist with preparation, participants were given a list of planned adaptation and mitigation measures, and they were asked to locate the proposed activity sites (for example, where should trees be planted for land stability and blocking strong winds). In the study, the researchers found that people who take PGIS saw information on hazards and vulnerabilities as well as methods for reducing risks and vulnerabilities in their community.

De Brito *et al.* (2017) conducted a research in the municipalities of Ladeajo and Estrella in southern Brazil on Participatory flood vulnerability assessment: a multi-criteria approach. In this study, an expert is defined as someone who has a thorough understanding of flood vulnerability assessments gained via experience or education (Krueger *et al.,* 2012). 117 Brazilian specialists with substantial practical expertise in the field of susceptibility assessments were chosen using the chain-referral sampling approach (Wright & Stein, 2005). At the study's latter phases, those performers who were named by the most people were called in for training and focus groups, which they found extremely valuable. In order to demonstrate the connections between the subject specialists, the researcher implements a social network analysis. In a two-round Delphi survey, scientific and transparent input criteria were determined using a Delphi survey. To help get opinions from experts, you may use the Delphi technique.

This consists of a series of questions interspersed with controlled feedback, with the aim of determining whether or not the anonymous participants are in agreement (Linstone & Turoff, 2002). Eleven input criteria were used to create the vulnerability index, which was based on the Delphi survey. The majority of participants agreed on the significance of all of the criteria with the exception of monthly income. The response rates for the first and second surveys were 86.32 percent (n=101) and 79.20 percent (n=80), respectively. The individuals' backgrounds, work affiliations, and educational levels are all described. The data used to demonstrate the chosen criteria came mostly from the 2010 Brazilian Census. (According to the IBGE, 2010). DATASUS was utilized to track out the locations of handicapped individuals and health-care facilities (MS, 2016). Interviews with local civil defense authorities were also undertaken to gather information on the locations of shelters and disaster-prevention organizations, as well as the frequency of evacuation drills and training. All data sets were converted into raster files with a resolution of 20m using the cell centre method (ESRI, 2017).

Experts who used the Delphi approach to define their own opinions and reflect on their underlying assumptions were able to share that knowledge with one another, and so influence the creation of new perspectives. Everyone was anonymous, so all participants had an equal chance to participate without anybody else exerting influence on the process. With the exception of one person, 95% of respondents were very satisfied or happy with the given criteria. Nonetheless, as the Oulahen *et al.* (2015) study shows, any index is certain to leave out elements important to certain stakeholders in the design and development stages. When the two focus groups were conducted, participants were given the opportunity to investigate and debate the vulnerabilities sub-indices' many structural alternatives.

They were also asked to think about each criterion's specific role in increasing vulnerability. It was possible to transform tacit and implicit knowledge into usable vulnerability information using the various elicitation methods employed. Even while participants did vary on certain points, they were generally open to the opinions of others and able to arrive at solutions to the overall conceptual model and value functions that were acceptable to all participants. To be able to ensure everyone could contribute equally, focus groups had a small number of participants, and therefore were limited to a small number of people. In spite of this, because 95% of the experts surveyed said they were content or happy with the conceptual models, the results are accurate. The four workshops used to assign the criterion weights went well, as demonstrated by the participants' enthusiasm and response. The analytical hierarchy process (AHP) and Analytic Network Process (ANP) tools enabled for the documenting of differing perspectives on the relevance of the criteria without silencing dissident voices, allowing for the explicit expression of conflicting framing assumptions. This was crucial to this research since vulnerability is still an ill-structured problem (Müller, 2012), with many solution routes and a lack of clarity regarding the input criteria and their relevance. As a result, we feel that methodically presenting opposing viewpoints as well as the underlying causes for diverse explanations is a clearer methodology than attempting to find a distinct answer.

This study shows how multi-criteria decision-making (MCDM) methods may be used to integrate interdisciplinary information in order to create a usable model that fulfills end-user expectations while also improving vulnerability map acceptance. The approach presented below is notable in the context of susceptibility assessment since partakers were keenly involved in all phases of the vulnerability modeling stages. This led to (1) an increased common understanding of the problem by avoiding the limitations of a single expert's point of view, (2) an increase in the capacity to transform tacit and implicit knowledge into information that is useful for modelling vulnerabilities and, as compared with studies that have not been carried out without any participation or collaboration, (3).This is the first time, to our knowledge, that the interdependence of criteria has been taken into account while assessing flood risk. The AHP and ANP techniques have both been proved to be effective in predicting flood susceptibility. However, ANP should be utilized whenever feasible since it enables for the clear capture of complicated connections among vulnerability criteria.

In terms of application, the maps generated may assist local authorities in better understanding the geographical distribution of flood susceptibility in the region. The findings may also be used to pinpoint locations for site-specific risk assessments, allowing for better allocation of human, technological, and financial resources and, as a consequence, better risk mitigation.

2.2.2 Research conducted in Asia

Senanayake (2006) investigated the application of participatory GIS for flood mapping in the Sri Lankan city of Batticaloa. The study developed a base map by summing the administration boundaries, highways, and geographical characteristics to an Arc GIS layer using a Google earth picture and land use map of the study region. Preliminary field observations were conducted to identify flooded regions, and thorough participatory GPS-based flood mapping was completed to determine sample points, from which 500 dwellings were chosen for the survey via questionnaire. The water overflow was ticked on the map to identify flood-prone areas, detect flood water entrance and outflow directions, and designate a safe location or evacuation shelter, as well as an evacuation path from the safe spot to a temporary evacuation shelter. The survey was carried out by the research team using the techniques outlined above. GPS points were collected when the survey was done in the houses that conducted the survey questionnaire. The field mapping revealed flood-prone regions and flood levels. The community was included in the research team. A geographic database was developed for the study region of the Municipal Council of Batticaloa by integrating GPS data with a questionnaire survey.

The steps used in compilation and preparations of the database are:

i. Transferring the GPS data to Google earth to identify the exact flooding locations and converting the GPX files to KML files.

ii. Converting the KML files to SHP files.

iii. Using the converted SHP files in Arc GIS.

iv. Entering the data gathered by questionnaire survey to the Ms Excel database.

v. Joining excel sheet and the GPS data in Arc GIS as SHP files to make the database

The outputs of the PGIS process and the developed spatial information database are;

The flood elevation model was used to create a flood contour/level map. Using the GIS interpolation tool, a 3D elevation model was created. Flood variation was identified using this approach. Using this model and the contour option of GIS spatial analysis tools, a flood contour map was created. The flood contour map is made up of contours with flood heights, whereas the flood exposure map is made up of field maps that have been digitized. A disaster response map was developed by incorporating safe places and routes to these areas; a digital elevation profile map series was created; and a database on socioeconomic data for the research region was created.

According to the research, flooding is one of the most serious climate-related threats in Batticaloa Municipal Council. At the city level, the community's and relevant authorities' knowledge and information base on floods and climate change was inadequate.

Furthermore, information moved inefficiently from top to bottom and bottom to top, and disaster data and information were frequently overlapping or overlooked. Because there was a knowledge and information vacuum in this situation, a participatory geographical information system technique was utilized to raise flood awareness and prepare society and government to respond appropriately to the flood. Based on the results from these discoveries, a Spatial Info Database was further established to respond to climate-acquired catastrophes in the form of a digital map profile series, a socio-economic data base, a flood exposure map, an overall flood map, and safe location and evacuation maps. The study stated, as a consequence, that participatory GIS is an efficient and effective instrument for the creation of an intelligent spatial information database to respond promptly to local catastrophes that worsen climate, therefore helping cities to become more robust to catastrophic conditions.

Jean *et al.* (2019), researched on the use of Participatory GIS Approach for Flood Mapping, A case study of Meloor Penchant, India. Participatory GIS. Since no satellite images were available for peak hours of a flood, the best option is to ask the affected people, do a post-flood survey. It was very important to survey the affected area immediately after the flood event because people tend to forget the flood level and also the flood marks which is useful for verification will also become disappear during the post flood rehabilitation. The questionnaire was prepared and uploaded to an open-source mobile application "Open Data Kit (ODK) Collect". Open Data Kit is a package of open-source tools used to collect and manage data. The ODK tools used was

1. ODK Build 2. ODK Aggregate 3. ODK Collect

ODK Build. ODK Build is a website form designer, which is having a very easy drag and drop user interface. Simple forms can be designed using this web application. To build forms you have to sign in to website "http://build.opendatakit.org". Then Survey forms are prepared using the drag and drop facility available and questions are typed. Questions for data collection are: Location Details: GPS Latitude, Longitude, and Altitude & Accuracy. Basic Details: Name, Ward number, Building number, Contact.

Flood Details: Flood level, Time, Sudden or Gradual, Rate (Height/ hour), Flood duration, Rescued or Evacuated, Rescue method, Time of rescue, Water level during rescue time, the Evacuation route, Route name, Relief Camp name. This Questionnaire is uploaded to ODK Aggregate server.

ODK Aggregate. ODK Aggregate is an application used to store survey data collected using ODK collects. Aggregate need to be hosted in local or cloud servers, google cloud server was used for this purpose. Forms are uploaded to ODK Aggregate server and using android app ODK collect we can conduct the survey.

ODK Collect. ODK Collect is an open-source Android app. This app is capable to replace paper forms and questionnaire used in mobile survey data collection. It can handle a broad range of formats and forms and is designed to function without the need of a network. ODK Collect is an android app available in google play store which can replace paper forms for the mass survey

The flood boundaries were mapped using Flood depth points collected and SRTM DEM. SRTM DEM was downloaded from “https://search.earthdata.nasa.gov”. Registration is required in this website; this website is an initiative by NASA for sharing and archiving earth data from multiple missions worldwide.

2.2.2.1 Flood surface raster

The surveyed data was downloaded from the ODK Aggregate server as Tabular format (.csv). This Table contains the Latitude (Y) and Longitude (X) collected using mobile GPS. This table is added to the “Arc Catalog” GIS software. Using create feature class from “X-Y table” tool, the point feature class with entire survey details were created. In “X-Y table” tool dialogue box the X Field is selected as Longitude column and Y field is selected as Latitude value. The coordinate system is set as Geographic coordinate system “WGS1984” because the GPS collects coordinates in “WGS1984”. This Point has the survey results in its attribute table, which is useful in using for further analysis. Project Geo-database was created and DEM and Survey point feature class was imported to it. For analysis and manipulation, the data must be in a projected coordinate system. According to the standards, the UTM Projection was chosen and for the study area the UTM zone is “UTM 43 North zone”. SRTM DEM was projected using the “Project Raster” tool in ArcGIS and Survey Point feature class projected using “Project (Data management)” tool. Small imperfections and sinks are removed using the “Fill” tool in the “Hydrology” toolset. This will remove the error pixels in DEM. The Flood depth collected is from ground level and for finding out the inundated area, Flood level above sea level is needed. In that case, SRTM DEM was used; the elevation values in SRTM DEM are above sea level. The Ground elevation is added with surveyed flood depth to get the flood height above sea level. The Elevation values from DEM is extracted and added to survey Point feature class using the “Extract by points” tool in ArcGIS. This tool captures the elevation values from pixels, where the points are located. A new field was added to the attribute table, prior to the running of the tool. So, the DEM elevation and Flood depth values were added using the “Field calculator” in attribute, to get the Flood level above sea level. These Flood level points are interpolated to get the flood surface raster. Interpolation method used was “Kriging”.

Flood boundary was delineated using Raster calculation. SRTM DEM and Flood surface raster (created in the last step) were used in the “Raster calculator” tool. In “Raster Calculator”, the following equation was done.

“Flood inundated area = Flood surface raster – DEM”

In resultant raster, all Positive values are flood inundated area and negative values should be removed for extracting flood inundated area raster. This is the result when subtracting the flood level with DEM, flood inundated area was found. Blue colored area with positively valued pixels represents the flood inundated area and red colored area represents the pixel with negative values. So, to remove the error in raster calculation, Cost distance method was used. This tool calculates least accumulated cost distance for a single pixel from the source over a cost surface. Here the source is a river, so river polygon was converted to raster using “polygon to raster” tool to get the source raster. The Cost raster to be input into the tool is the Flood inundated area raster with positive values as flooded area and negative values as the non-flooded area.

This research paved the way to found the flood inundated area and the preparation of the map. This map will facilitate future uses in disaster preparedness and land use planning, for effectively using the flood plain. The participatory survey conducted was very effective in collecting required data and it strengthens the community involvement in decision making, which will empower them.

Bijay (2014) used Participatory Geographical Information System (PGIS) Mapping for Flood Hazard Mapping in Gorakhpur, India. The current research and survey were carried out in Gorakhpur's Mahewa Ward, which is located in the city's south western portion. The ward is physically positioned on the outskirts of the city, where land use change is extremely rapid. Aside from that, the ward is a true reflection of Gorakhpur's circumstances. The capacity of the ward's natural, social, institutional, and infrastructural systems to meet people's needs is now weak and of poor quality (Wajih *et al.*, 2010). Water logging and river flooding have affected the whole ward. Flooding in the western part of the ward damages buildings, but waterlogging in the eastern half is caused by ineffective solid waste management, low-lying topography, and inadequate delivery systems.

While surface run-off of water in the ward has increased as a result of increased concretization through building construction, the natural water holding capacity of the existing drainage system has decreased due to poor solid waste management and irregular cleaning activity by the municipal corporation. The PRA/PLA tools are very effective in gathering both qualitative and quantitative data to determine the nature of community needs and the degree of their complexity. Participatory GIS is the inevitable outcome of the symbiotic relationship between methodologies like PLA and visualization of the results. The collaborative endeavor involves articulating qualitative and quantitative data using scientific approaches to spatially depict people's knowledge and opinions. Experts from throughout the world agree that initiatives with heavy government involvement don't provide particular benefits to communities prone to disasters, and may potentially make them more vulnerable. A wide consensus on the necessity of a participatory approach to risk assessment and mitigation has been achieved as a consequence.

In order to avoid misperceptions of the greater vulnerability of a population, participants from vulnerable groups should have a seat at the risk management table during design and implementation. This partnership with national, provincial, and local organizations will yield long-term risk management and impact mitigation solutions (UNISDR, 2011). Residents of the ward have never been exposed to the scientific notion of climate change, and have no idea of its potential impact, but they know a lot about the neighborhood hazards and their origins. 300 households were randomly selected and asked a series of brief semi-structured questions to discover the depth and length of water logging, as well as the reasons of water logging/flood, and the associated flood-related asset losses.

A full database was built with 120 points taken to cover the whole ward. Participants included local facilitators in the survey. Printed Google satellite pictures, GPS, and semi-structured questions were part of the mapping crew's equipment. to locate the boundaries of the ward, the team conducted interviews with local residents and did a land use and settlement analysis Team members spoke about the survey's goals, statistics, and logic while they went over all of the survey questions. The villagers became interested in the Google satellite image. As they were accustomed with the visualization, they reacted to their neighborhood vividly. An evaluation of flood danger requires detailed data on the frequency and intensity of flooding, rainfall, and property damage. Due to a paucity of historical flood records and rainfall data at the local level, the current study relies on recollections of prior floods and water logging events.

The whole ward's waypoints (numbering 120) were collected using GPS, and participants were requested to fill out a half-structured survey form at each location. The depth and length of the water inundation, as well as the absolute height at the time, were all included in this information. Data on the number of dwellings in the region, socioeconomic categories in the area, flooding/water logging causes, and types of losses were added to this. The GPS path-points were mapped on Google Earth and saved in KML/KMZ1 format once the survey was done. These were then put into the different GIS as a layer of data. The community border was created on a Google picture, saved as a shape file, then imported into the GIS platform by the community during the survey. Attribute data from community consultations at each waypoint was compiled in a Microsoft Excel spreadsheet using semi-structured questionnaires. This procedure converts data into an electronic format. These Excel data sets were subsequently connected with waypoints, resulting in a full database for hazard and vulnerability evaluation.

This susceptibility mapping and risk evaluation approach has demonstrated how scientific technology (GPS and GIS) may be coupled with local people knowledge to produce meaningful findings for disaster risk reduction planning. The survey and mapping exercise took a long period: from the field survey to the final distribution of maps to the steering groups created under the ACCCRN program in Gorakhpur, the study lasted three months and covered just 2.5 square kilometers. Meanwhile, the study has exposed a number of infinite advantages to the municipal planning department in terms of understanding the scale of flood risk, the breadth of vulnerable populations' exposure, and the threshold value between hazard and tragedy. Local residents have been able to engage in decision-making processes as a result of this method. This is useful not only for better understanding the nature and complexities of flood-related problems as they are experienced by local residents, but also for adding value to the communication between native citizens and their government, which is currently lacking in many emerging countries and emerging urban centers' democratic development processes.

2.2.3 Research conducted in Africa

In Munamicua District of Bu zi, Mozambique, Taylor and Kienberger (2014) conducted a study on participatory mapping of flood hazard risk. The flood hazard mapping approach used consisted of two key steps: To begin, extremely high-quality satellite data was obtained and provided to inhabitants as a "blank" map to allow for debate and mapping of specific characteristics. These data were then incorporated into a GIS and improved with further geographical analysis in a second phase. As a group, committee members selected and highlighted distinctive characteristics on the paper map using various colored pens, after which the committee divided into two subcommittees. This included (a) the names of neighboring communities, (b) the community boundary (which is usually required because this is a frequently discussed but never documented issue), (c) flood hazard zones (high-risk/low-risk/safe areas and past flood affected areas), (d) lower and higher elevated areas and areas close to the river, (e) agricultural zones, and (f) special infrastructure of the community. Transparencies may be inconvenient; thus, it was suggested that individuals sketch directly on the paper.

In a subsequent phase, GPS measurements and/or georeferenced photos were used to collect the locations of individual community sites. A second copy of the finished map was created when agreement was reached on the mapped features, with one of these copies presented to the community as a first prize while the other of these copies was utilized to digitize the data for further research. A prominent focus was put on the use of spatial analytic tools and methodologies with the use of digital representations of characteristics found and mapped during the community mapping exercise.

Sy *et al.* (2016) used a participative method to conduct a research in Yeumbeul Nord (YN), Dakar, Senegal, to estimate flood risk. They relied on precise information on flood extent, exposure, and susceptibility. The study's goal is to collect this data using a combination of remote sensing information and native awareness. Interviews with locals were used to gather data for the fieldwork. According to their techniques, data on floods in YN was obtained utilising remote sensing and ground-based data. Using satellite data, a preliminary land use map was generated, which contained the geographical distribution of structures as well as the spatial distribution of the flood extent in 2009. As a result, local geographic expertise was used to supply the remaining content. This was achieved by means of a wide-ranging study of home and family demographics, and a mapping process that allows families to assist in the analysis. Information on socioeconomic variables, exposure to physical hazards, length of flooding, and the levels of risk mitigation implemented at the household level was extracted from the interviews. To locate the specific locations of objects in risk and water bodies, P-mapping was employed in this investigation. After analyzing remote sensing data, conducting interviews, and performing P-mapping, P-GIS was utilized to double-check the results. We first built our land use map using satellite pictures taken from Google Earth from January to July of 2015. Google Earth shot and scanned many land uses, including infrastructure, agricultural regions, water bodies, and others. They next converted the KML data into shape files using the UTM reference system, and then they used Global mapper 15 to swiftly transform the shape files into KML data (Zone 28N).

Chingombe *et al.* (2015) utilised a participatory method to acquire GIS data for flood risk management in Zimbabwe's Muzarabani area. The study triangulated with PGIS mapping and used four techniques. Here are many topics we want to cover, including focus group discussions (FGDs), disaster timelines, fieldwork, interviews, and archival analysis. One of the approaches utilized was using a disaster checklist in focused groups. involved collecting field notes and using two handheld Garmin GPS devices to capture coordinates with an inaccuracy of less than 7 meters (GPS 76 and Etrex 12 channel). This data was collected using the aforementioned field observations that employed field notes and two handheld Garmin GPS devices (GPS 76 and Etrex 12). Each unit was accurate to within less than 7 meters. Two hand-held Garmin global positioning systems (GPS 76 and Etrex 12 channel) were used to gather coordinates, with which a positional inaccuracy of less than 7m was found. Archival data was given through NGOs, the internet, and discussions with local leaders.

Using community input and prior experiences, three groups prepared a risk schedule and checklist for major catastrophes in the region, such as floods, cholera, and dysentery. After that, interactions were conducted to determine which regions had been flooded and which had not. Twelve groups of five people (adults, elementary and secondary school students) were given the job of mapping the flood extent on December 13, 2007, using a

1:50,000 topographic map as a base map. People were classified according to their age groups and whether or not they were in school. Primary school students in Zimbabwe are 7–13 years old, secondary school children are 14–19 years old, and adults are those above the age of 19. The flood extent maps that resulted were compared to those produced from field research and interviews.

A visual examination of PGIS maps was carried out to check for any significant discrepancies or inconsistencies. The triangulation of the 12 PGIS maps in the local community generated the flood extent assessment map. The results of the study demonstrated that in addition to conventional GIS and flood modeling with PGIS and fieldwork data, flood profiling in Chadereka ward may be enhanced via the use of both traditional GIS and flood modeling with PGIS and fieldwork data. Furthermore, the team of researchers discovered three theories as a result of their study: first, PGIS may be an effective method for gathering flood data when used in conjunction with other social and field-based approaches. A second point in the Chadereka ward is that using PGIS to map the geographic range of flood zones has shown to be an efficient approach because of the paucity of historical hydro meteorological and climatic data. Third, as this study shows, the accuracy of community people' flood perceptions is sometimes inaccurate, and depends on a variety of factors, such as age and educational level. The perceptions of the elderly are wrong at Chadereka ward. Also, because adults have the last say over where to reside and what sort of livelihoods to pursue, we must assume that this system leaves the community vulnerable all of the time.

In Thohoyandou, South Africa, Sinthumule and Mudau (2019) conducted research on a Participatory Approach to Flood Disaster Management. Participatory diagramming is used with other techniques such as interviews and observation as part of the approach. Researchers conducting field work in the aforementioned locations (Ndondola village, Duthuni village, Maniini village, Makwarela Extension 3, and Thohoyandou Block F and G; Thohoyandou town; and Vhembe officials) partnered with the following locals (52 people from the community and eight traditional leaders), as well as business people (seven people), Thulamela and Vhembe officials (four), and government officials dealing with disaster management (two).

The cornerstone of the study was participatory diagramming in small groups of four to six individuals, which was done using a range of approaches, including semi-structured interviews and observation. The participants were 25- to 50-year-olds of various ages. After reading about the floods in 2000 and 2010, each group was given a big sheet of white paper, a glue stick, scissors, colored highlighters, and colored markers so that they could use these implements to construct artwork and write about their flood experiences. To enhance the effectiveness of participatory evaluation, project participants were provided with a collection of instruments tailored to the project.

This was conducted to encourage organizations to express, discuss, expand on, and prioritize their flood-related issues, as well as suggest and evaluate potential solutions. Participants were also questioned and observed in order to get more information about some of the points raised and discussed throughout the discussions. Those stakeholders who were unable to attend the community participation sessions were also interviewed. Members to be interviewed were chosen through purposeful sampling. The researcher qualitatively analyzed the material written on huge sheets of paper and notes made throughout the conversation. The major points that emerged from the group work materials were taken into consideration.

Similarly, the primary narrative derived from semi-structured interviews was utilized to examine community perceptions and responses to flood threats. Field observations in the impacted areas confirmed the major issues that came from group discussions and interviews. Newspaper articles published during floods in the research region were also used as additional sources of data. Agriculture on steep slopes or in hilly environments, as well as relief effects, can create floods. For example, Ndondola village, Duthuni village, Makwarela Extension 3, Thohoyandou Block F and G, and Thohoyandou town are all situated at the foot of the mountains, with Maniini village situated on a moderate slope on the southern side of Thohoyandou town. According to the study, water from mountains arrived at a faster rate, causing serious harm to human communities at the mountain's base. Furthermore, some residents in Thohoyandou Blocks F and G, Thohoyandou town, and Makwarela Extension 3 thought that urbanisation increased floods by reducing ground surface permeability and increasing runoff rates, similar to Parker's results published by Few in 1999 and 2003. The use of concrete and asphalt in road and pavement building in Thohoyandou town is believed to have left the area impermeable, allowing a huge volume of water to stagnate and cause infrastructure damage.

The participants in the survey agreed that flooding is caused by heavy rainfall and that flooding is a natural phenomenon that cannot be controlled. Participants also agreed that flooding is a serious hazard to everyone. Despite the fact that floods are dangerous to humans, it was acknowledged that human undertakings increase the likelihood of water overflow. Clearing vegetation has been highlighted by local people as one of the causes that has worsened the danger of floods in their region. Local communities clean area for cultivation and fuel wood by felling trees. As a result, the land is left exposed, resulting in severe soil erosion. Water rushes at a fast rate when there are no trees, causing property damage. Planting trees within the home has been proposed as a method that everyone should employ to lessen the pace of water flow during flooding. Flooding is expected to be lessened in the future as a result of this.

Newspaper articles produced during floods in the research region were also used as sources of data. Agriculture in high and steep slopes can all contribute to flooding and the impact of relief. Ndondola village, the hamlet of Duthuni, Makwarela Extension 3, Thohoyandou Block F, G and the community of Thohoyandou are all located on a modest slope at the southern end of Thohoyandou. The research showed that mountain water flowed faster, causing considerable damage to the people at the mountain base.

Moreover, some people in Thohoyandou F and G blocks in Thohoyandou and Makwarela Extension 3 believed that urbanization was worsening flooding by lowering ground permeability and increasing the rate of runoff, in line with the conclusions of Parker 1999 results. The use of asphalt and concrete in the street and pavement of the city of Thohoyandou was claimed to have made the region impervious and allowed enormous volumes of water to stagnate and cause very disastrous effects.

Furthermore, the survey discovered that local business owners had insurance to safeguard their shops and enterprises from any calamity that may occur in the region. Although company owners' stores could withstand floods, they were primarily concerned about the drainage infrastructure in Thohoyandou. Drainage systems would get blocked and the discharge of water would be sluggish during heavy rainfall or flooding, causing the region to remain flooded during the rain or floods. Poor drainage system design and maintenance are blamed for this problem in Thohoyandou. Businesspeople believe that the local municipality should examine the drainage system on a regular basis to verify that there are no water blockages, which would prevent future flood-related damages.

Municipal officials believed that, despite the importance of wetlands as an ecosystem, they were compelled to assign plots for either residential or commercial uses when the town needed to grow. Prior to the allocation, they said that an environmental bearing study and a geotechnical examination were done to guarantee the area's correctness. If the area was considered suitable, it was rezoned as a residential or commercial zone, with plots assigned to those in need.

CHAPTER THREE

3.0 MATERIALS AND METHODS

This chapter covered the resources and procedures needed to complete the study and arrive at the final outcome. For this study, primary and secondary data sources, as well as government archives, was used.

3.1 Type of Data Collected

The type of data that were collected for the research work are both primary and secondary data. The different data types depend on the various research objectives to be achieved. The data include;

i. Google Earth image and land use map of study area was used to develop a base map by adding features such roads, houses, schools to an ArcGIS layer.
ii. Data from the interview of the population of interest in the study area
iii. GPS points

3.2 Sources of Data

The primary and secondary data that were employed for this study are gathered from different sources based on their relevance to the study.

The summary of the data source is shown in the Table 3.1 the table of the data source give the synopsis of the data type, scale and the source of the data.

Table 3.1: Data Source

S/N	Data Type	Scale	Source
1.	Google Earth image	Google	
2.	DEM	30M	USGS web site
3.	Positional data		GPS

3.3 Field Equipment

This study used a variety of technology and hardware depending on the study's goals. Table 3.2 lists the various field equipment that was employed.

Table 3.2: Field Equipment

S/N	Equipment	Purpose
1.	GPS	Navigation and boundary delineation.
2.	Measuring tape (60 meter)	Height measurement
3.	Cardboard paper	Drawing Sketch map
5.	Digital camera	Photographs
6.	Fieldwork datasheet	Field data record
7.	Different Colour Markers	Feature identification

3.4 Software and Instruments

3.4.1 Software

The synopsis of categories of software utilised for this study and their purpose is given in table

Table 3.3: Software

S/N	Software	Purpose
1.	ArcGIS version 10.3	GIS analysis
2.	Microsoft word	Thesis writing
3.	Microsoft Excel	Statistical analysis
4.	Microsoft PowerPoint	Presentation of the research

3.4.2 Instruments for primary data collection

A focus group discussion was used to gather the essential information or data for this investigation (FGD). In order to achieve the goal of participatory flood extent mapping, a consultative forum with key stakeholders (researchers and community leaders) was convened in a focus group discussion that focused on the participant selection in the sketch map development. A laptop, 500GB external memory, and a printer were utilised as the analyses' minimum and recommended gear.

3.5 Ground-Truth (GT) Data

Ground truth data on geographical characteristics such as spatial position, land use, village topography, and road network were obtained from the research region. In addition to the ground trothing method, transect walks of the flood plain were conducted. Participants were invited to talk about various elements of the physical surroundings throughout the stroll. The information provided was utilized to complete the project's mapping, interpretation, and discussion sections.

3.6 Method of Data Analysis

3.6.1 Participatory mapping of flood extent

Using a participative mapping technique, a flood extent map for the year 2012 was created to illustrate the flood route, direction, evacuation centre, and flood-affected area. In this section of the study, the community members were invited to sketch the flood extent based on their prior knowledge, using the participatory mapping technique of sketch mapping to capture the geographical extent of the flood and its features. Because the village has been their ancestral home for many decades, they were able to provide first-hand knowledge. The data was gathered using a combination of semi-structured focus groups and participatory mapping.

Each community group will have 4-6 members, primarily divided along gender lines. The village chief or communal leader chose the participants. During the semi-structured session, the participants were encouraged to sketch on cardboard paper. With the aid of the participants, key elements such as main and minor highways and the Niger River were drawn on the mapping paper. Participants debated for quite some time before settling on a single symbol to symbolize each of the physical elements they wanted to depict on the map. This is usually due to the colors or symbols that the community connects with each aspect.

3.6.2 Validation of sketch map of flooded area using field surveying and satellite image

The methodology employed were based on modification of method used by Sennayake (2006) in which Google Earth image and land use map of study area was used to develop a base map by adding features such roads, houses, schools to an ArcGIS layer.

Field observation were carried out to identify flooded areas, GPS point of the flooded area was collected, identified by the community. The GPS data was transfer to Google Earth to identify the exact flooding locations; a spatial information database was developed for the study area.

The steps used in compilation and preparations of the database are:

i. Transferring the GPS data to Google earth to identify the exact flooding locations and converting the GPX files to KML files.

ii. Converting the KML files to SHP files.

iii. Using the converted SHP files in Arc GIS.

iv. Entering the data gathered by questionnaire survey to the Ms Excel database.

v. Joining excel sheet and the GPS data in Arc GIS as SHP files to make the database

The outputs of the Participatory process and the developed spatial information database are;

The flood elevation model was used to create a flood contour/level map. Using the GIS interpolation tool, a 3D elevation model was created. Flood variation was identified using this approach. Using this model and the contour option of GIS spatial analysis tools, a flood contour map was created. The flood contour map is made up of contours with flood heights, and the flood exposure map was created by digitizing field maps.

3.6.3 Generation and classification of digital elevation model (Dem) of study area

The approach used is based on the modification of the method used by (Mayomi *et al.*, 2013). The terrain of the villages was produced using DEM images of the settlements, as one of the objectives focuses heavily on terrain analysis. The DEM generation module of ArcGIS 10.3 was used to produce DEMs of communities using the Shuttle Radar Topographical Mission's Digital Elevation Dataset in this study (SRTM). The obtained dataset was vectorized using ArcGIS' raster polygon module, and the resulting polygon map was categorized into three primary groups for each community: I extremely sensitive to flooding (ii) moderately vulnerable to flooding (iii) low vulnerable to flooding. The building layer was introduced to categorize DEM in order to detect flood-prone structures.

3.6.4 Community infrastructure and spatial analysis

This was done using a GIS and remote sensing strategy; employing Google Earth image and field mapping, digital elevation modeling, and a smaller study area, the integrated approach of remote sensing and GIS approaches in flood management was demonstrated. High-resolution images were required to provide a good sense of the level of susceptibility. The Google Earth program was utilized to acquire the high-resolution images, and the ArcGIS 10.3 software suite was used to analyze it. In Google Earth, the study area was delineated in strips, and the longitude and latitude coordinates of the extreme corners were tabulated in a Microsoft excel spreadsheet and combined with an exported image of the study area, also from Google Earth, to create a geo-referenced and mosaic map in the WGS 1984 Geographic coordinate system.

With the aid of the GPS points previously acquired during field work, the research region was then extracted using the Spatial Analyst tool of the ArcGIS 10.3 software's extraction by masking tool. Then, for each feature of interest, an Arc Catalog extension of ArcGIS 10.3 was utilized to construct a bespoke geo-database. For feature extraction, the digitizing procedure was carried out in the Arc Map environment. The process of digitizing geographical elements from an analogue or raster map into vector format is known as digitization. The footprint of the building, water bodies, roadways, and other spatial elements will all be digitized in this project.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

The results of the finding of the study are presented, according to the set objectives, in figures, tables, maps and charts. All representations in maps are well explained by the discussion that follows them.

4.1 Participatory Mapping (Pmapping) of the Flood Extend

One of basic interest of this research work is to identify the areas that were inundated by flood based on community knowledge using sketch mapping method. This was to identify flood affected areas, flood entrance points and flood channel and to also map the important infrastructures such as buildings, roads and other resources such as rivers.

4.1.1 Local area sketch guide of Kusogi

Figure 4.1 shows community sketch map of Kusogi produce by the community members during participatory mapping in which red color was use to show buildings, green color for flood plains, blue color represents river Niger, red dotted line indicate flood boundary and blue dotted line shows flood direction.

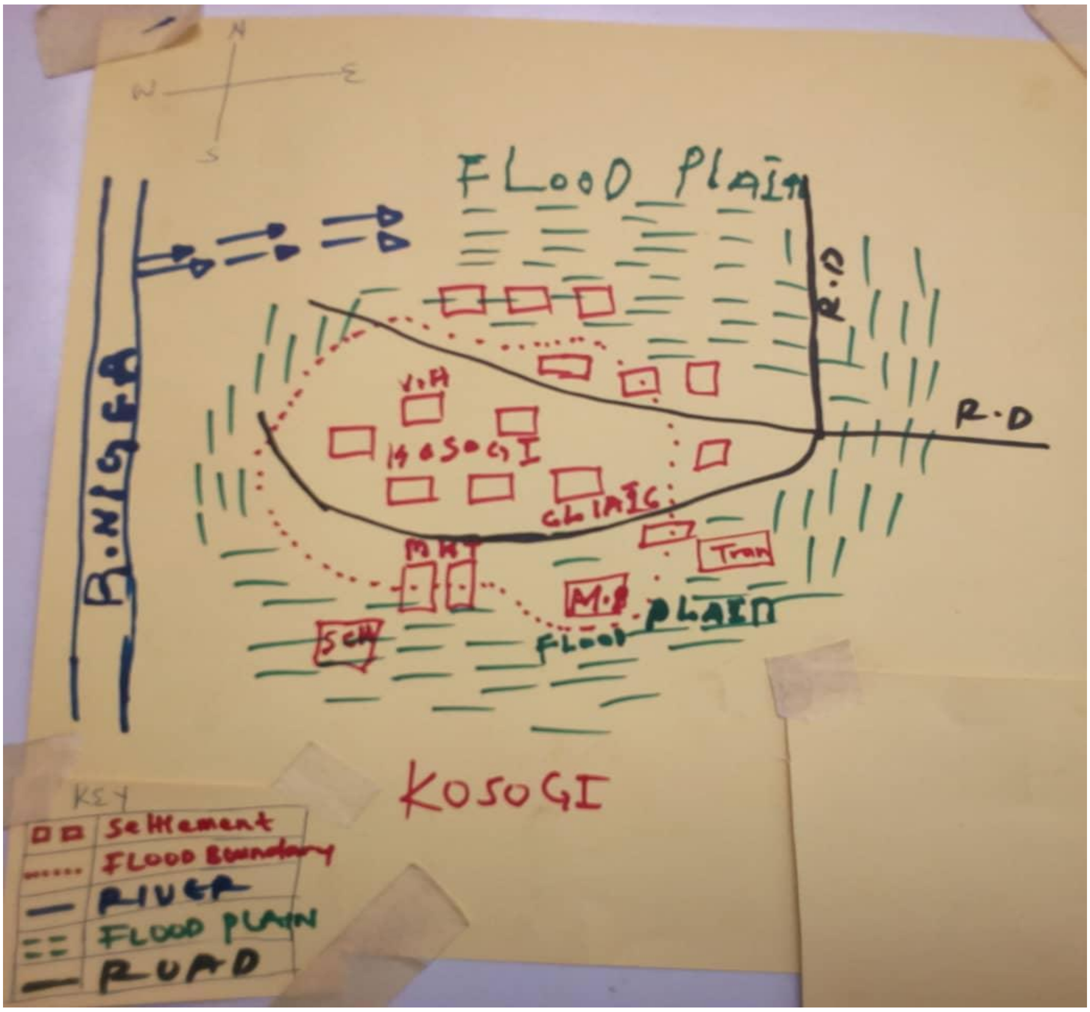

Figure 4.1: Local Area Sketch Guide of Kusogi

The River Niger on western part of the map is the source of flood water, the flood water entre the community via flood entrance points on east of River Niger through flood channel and separate to other parts of the community. The infrastructures mostly affected by the flood are buildings and main road located situated along the flood plains.

4.1.2 Local area sketch guide of Lwafu

Figure 4.2 is Lwafu community sketch map produce by the community members during participatory mapping, red represent building, green line represents River Niger, green dotted line represent flood plain, red dotted line indicates flood boundary, black is road.

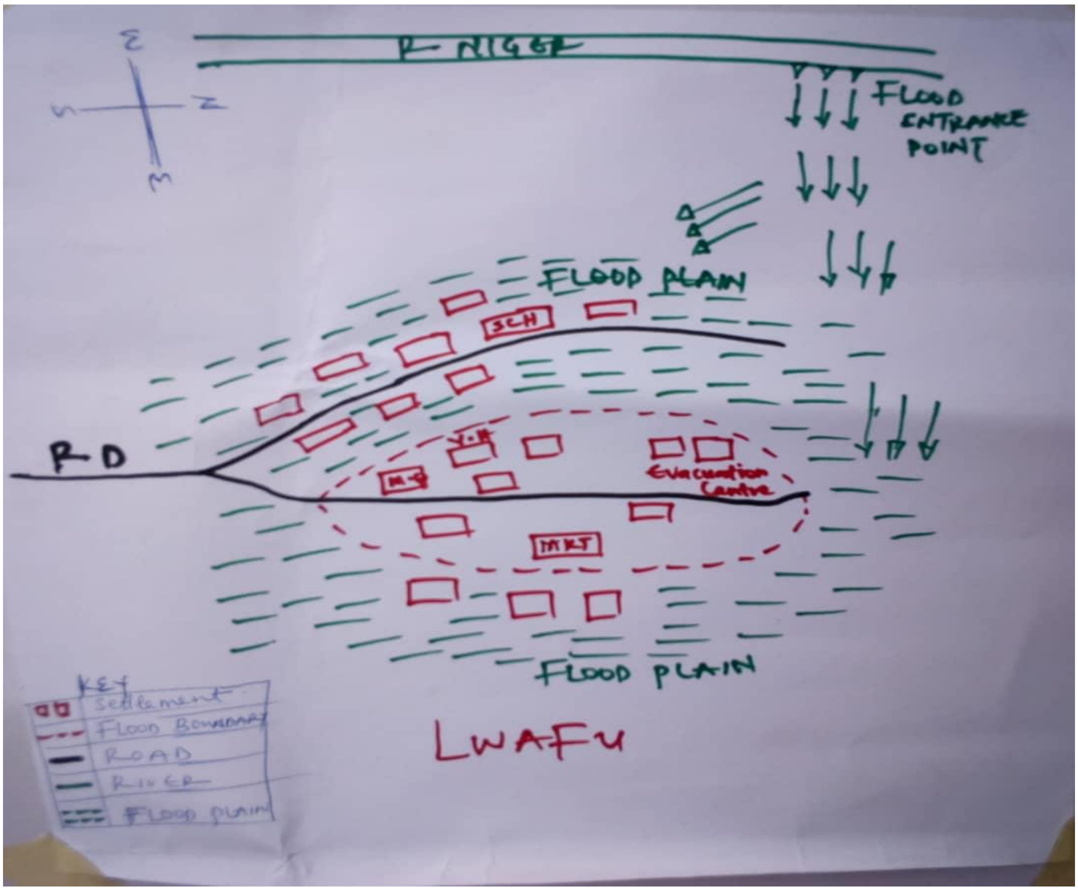

Figure 4.2: Local Area Sketch Guide of Lwafu

The River Niger on western part of the map is the source of flood water, the flood water flow to the community via flood entrance points on east and south part of River Niger through flood channel and separate to other parts of the community. The infrastructures mostly affected by the flood are Primary school on south-west of the map, houses, and main road cutting across the community. Some part of the village head house on the map are used as evacuation center due their higher elevation.

4.1.3 Local area sketch guide of Sunti

Sunti community sketch map produce by the community members during participatory mapping is depicted in Figure 4.3

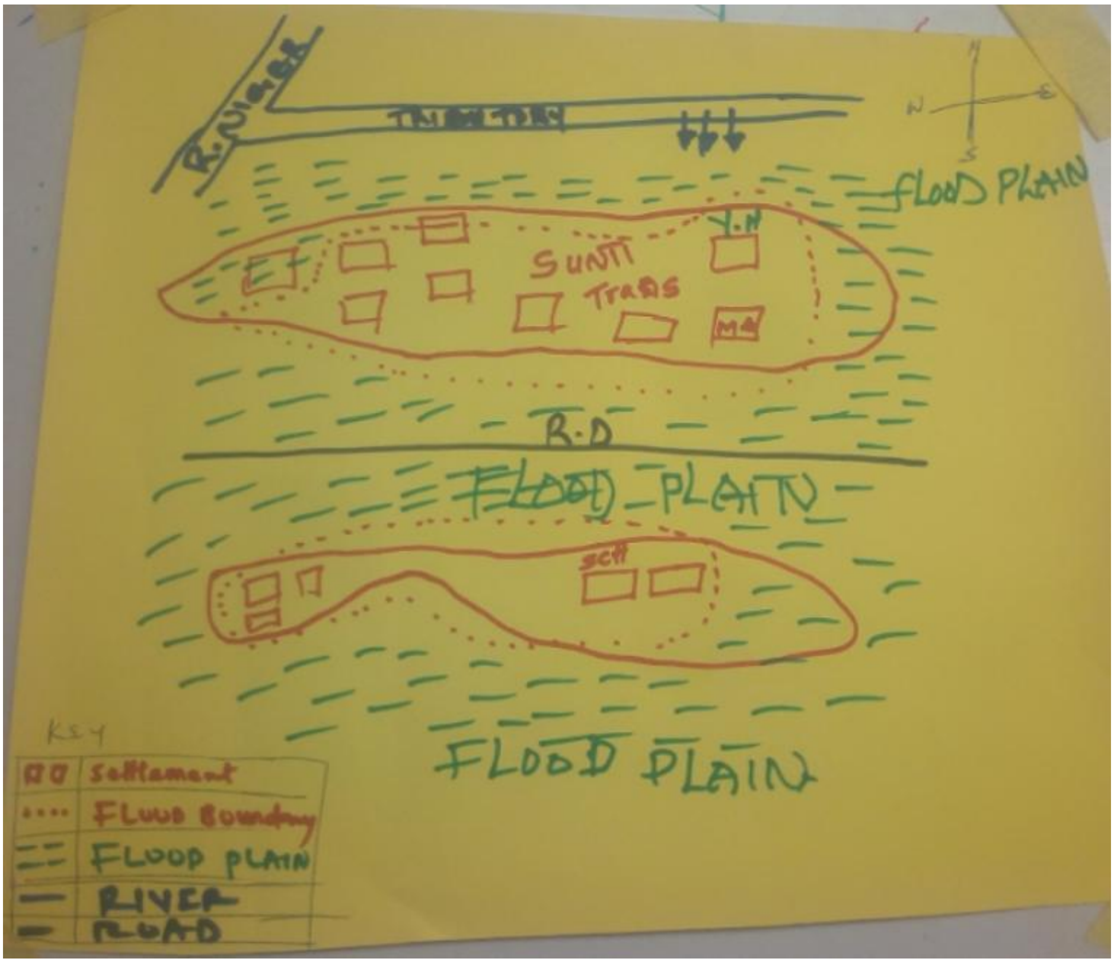

Figure 4.3: Local Area Sketch Guide of Sunti

Figure 4.3 is sketch map of Sunti which blue color has been used to indicate river Niger and red for buildings, green color has been used for flood channel and flood affected area boundary and black represent road.

In synopsis, the sketch maps express communities' local knowledge about flooding and how it affects their environment. It was established through the local knowledge depicted on the sketch map that Kusogi, Lwafu and Sunti can only experience flooding from river Niger. It was observed that Kusogi and Lwafu are the communities whose settlements are mostly affected by flooding, the settlement of Sunti is not affected due to the fact there are natural outlets that served as flood reservoirs but other land use types such as farm lands are affected which is not within the limit and jurisdiction of this study.

This is in line with research carried out by Canevari-Luzardo *et al* (2015) Granada. The study combines sketch mapping of the community hazards with vulnerability household data using Quantum GIS (QGIS). This method used is cost effective and also time consuming because the community participants were trained on GIS skills to be able to carry out mapping process on QGIS

4.2 Validation of Sketch Map

The overall aim is to produce exposure to flood map of community key infrastructures (buildings and roads). Field surveying and satellite image approach were employed to map buildings and roads and also identify flooded areas and non-flooded area.

4.2.1 Validation of sketch map of Kusogi

Figure 4.4 Shows exposure to flood map of Kusogi community relative to flooded and non-flooded areas.

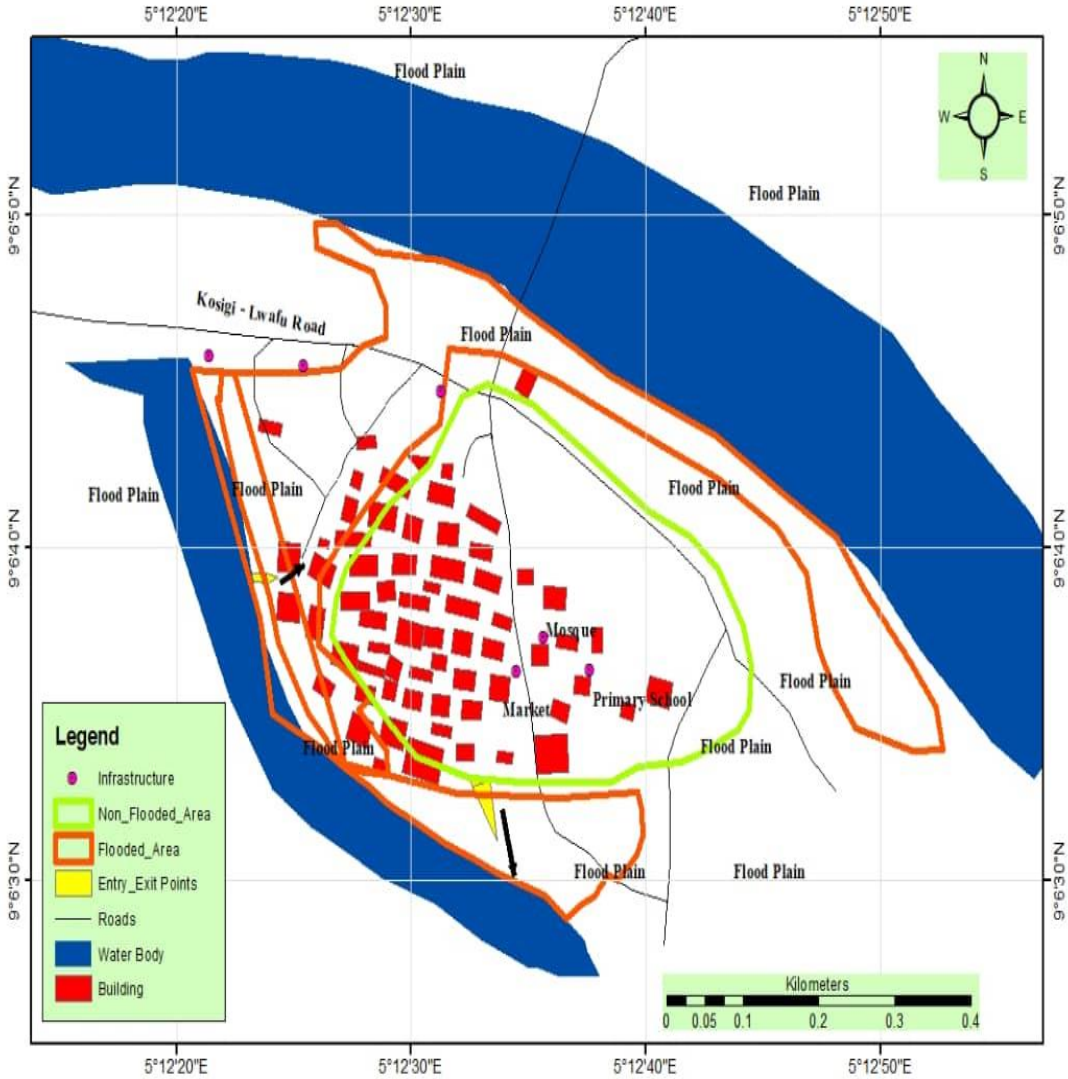

Figure 4.4: Validation Sketch Guide of Kusogi

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In Kusogi community, the identified flooded area is 16.2-hectare, non-flooded area is 17.84 hectare, as seen in Figure 4.4. This has shown that 48.5% of Kusogi is inundated by flood while 51.5 is not flooded.

4.2.2 Validation sketch guide of Lwafu

In Lwafu community the identified flooded area is 25.5 hectares, non-flooded building area is 9.72 hectares (Figure 4.5).

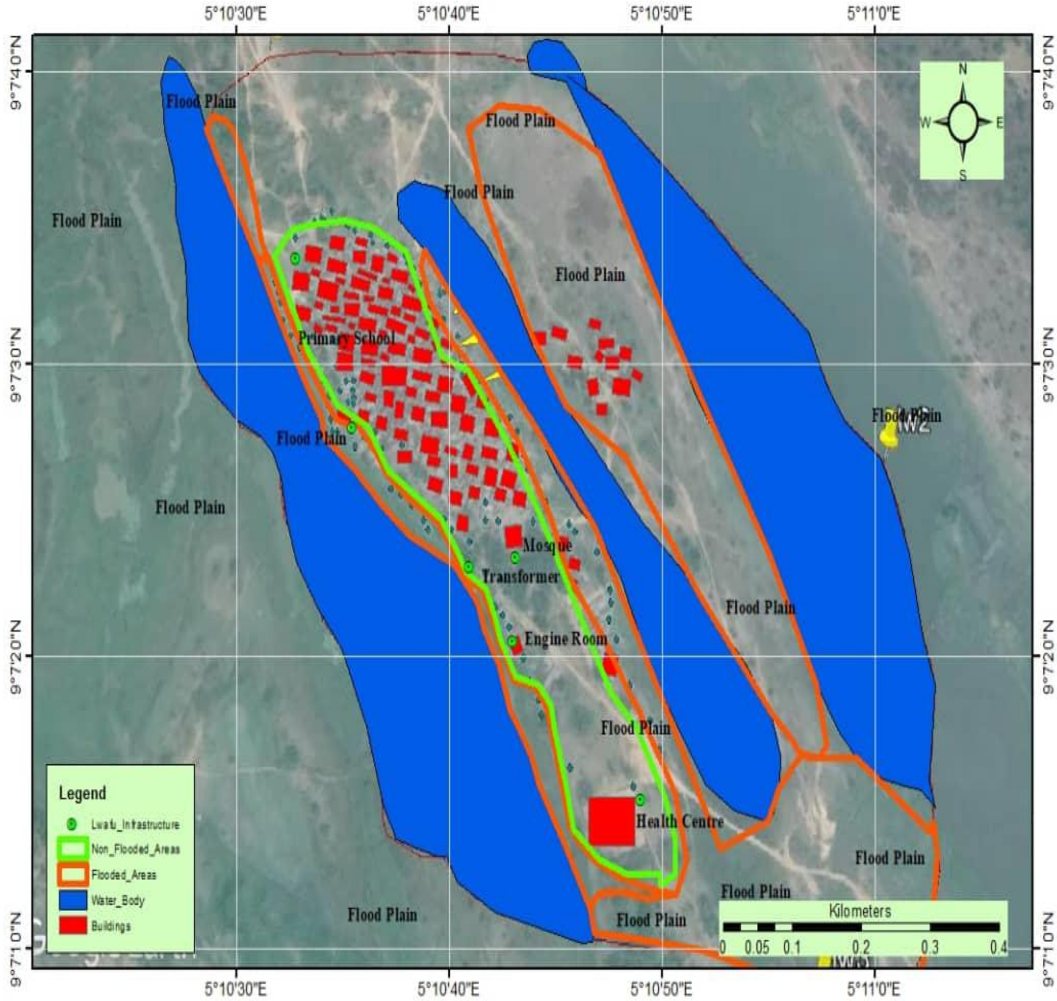

Figure 4.5: Validation Sketch Guide of Lwafu

Figure 4.5 demonstrated that 66.25% space of Lwafu is immersed by overflowing and 33.75% is not overwhelmed.

4.2.3 Validation sketch guide of Sunti

Figure 4.6 Shows building vulnerability plan of Sunti community relative to flooded and non-flooded areas.

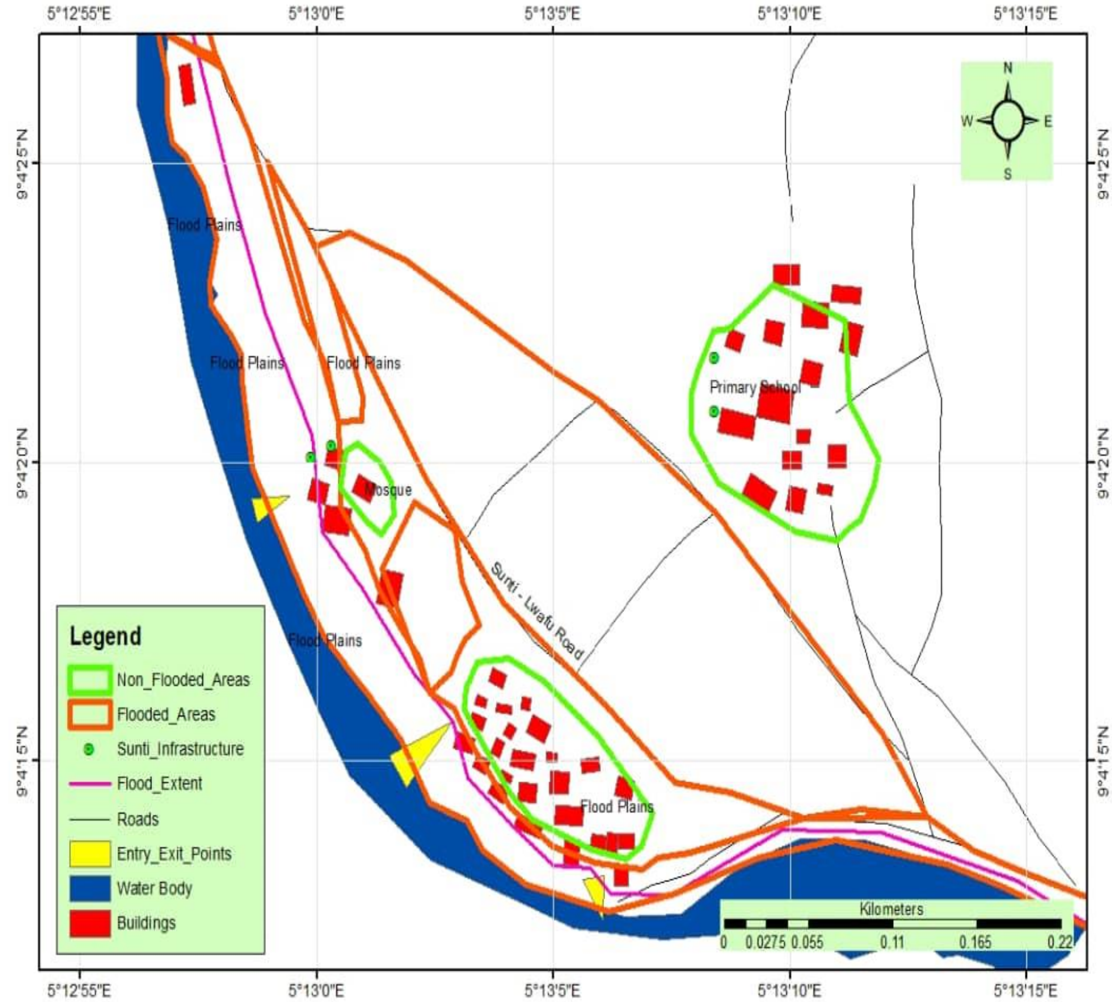

Figure 4.6: Validation Sketch Guide of Sunti

The distinguished overwhelmed space of Sunti is 9.72hectare, non-overflowed territory is 4.05 hectare. This has shown that 62.505% of Sunti is immersed by overflow while 4.05 isn't overwhelmed.

In synopsis, the study uncovered that Lwafu has about 25.5 hectares submerged in overflow, 16.2 hectares in Kusogi and in Sunti around two structures were influenced among settlement that covers about 9.72 hectares influenced by overflowing.

4.3 Community Terrain Analysis

4.3.1 Kusogi terrain analysis

4.3.1.1 Kusogi DEM

For Kusogi community, the areas used are the areas at risk from river Niger flood. DEM reclassified analysis was carried out to discover the regions that are highly at Risk, moderately at Risk and low risk of the area.

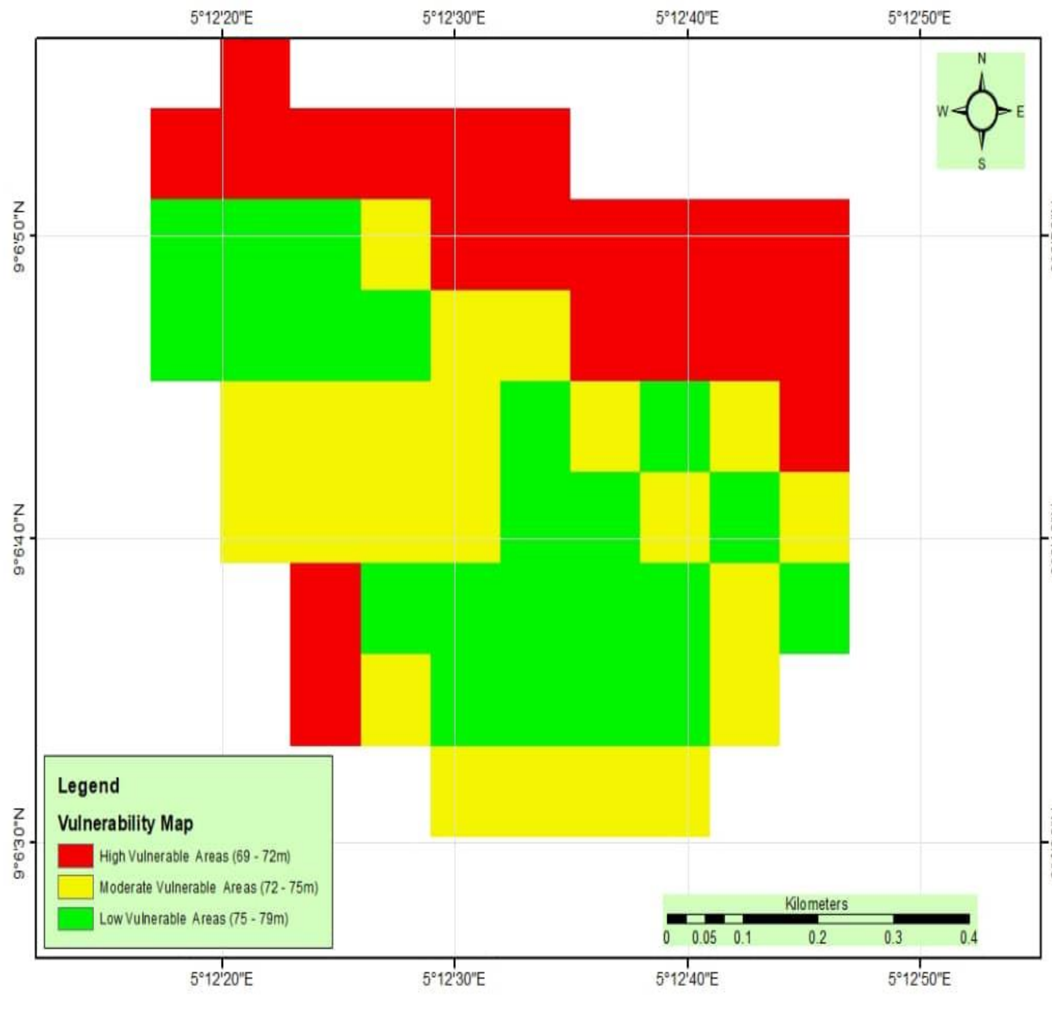

Figure 4.7: Kusogi Flood Exposure Map

From Figure 4.7, the blue colored portions with elevation range 69-72m show catchments that flood waters accumulate which will serve as reservoirs for flood waters. The regions within the yellow area (Figure 4.7) with elevation range between 72-75m are moderately vulnerable to flood than the areas in the green with elevation of 75-79m which are low vulnerable to flood

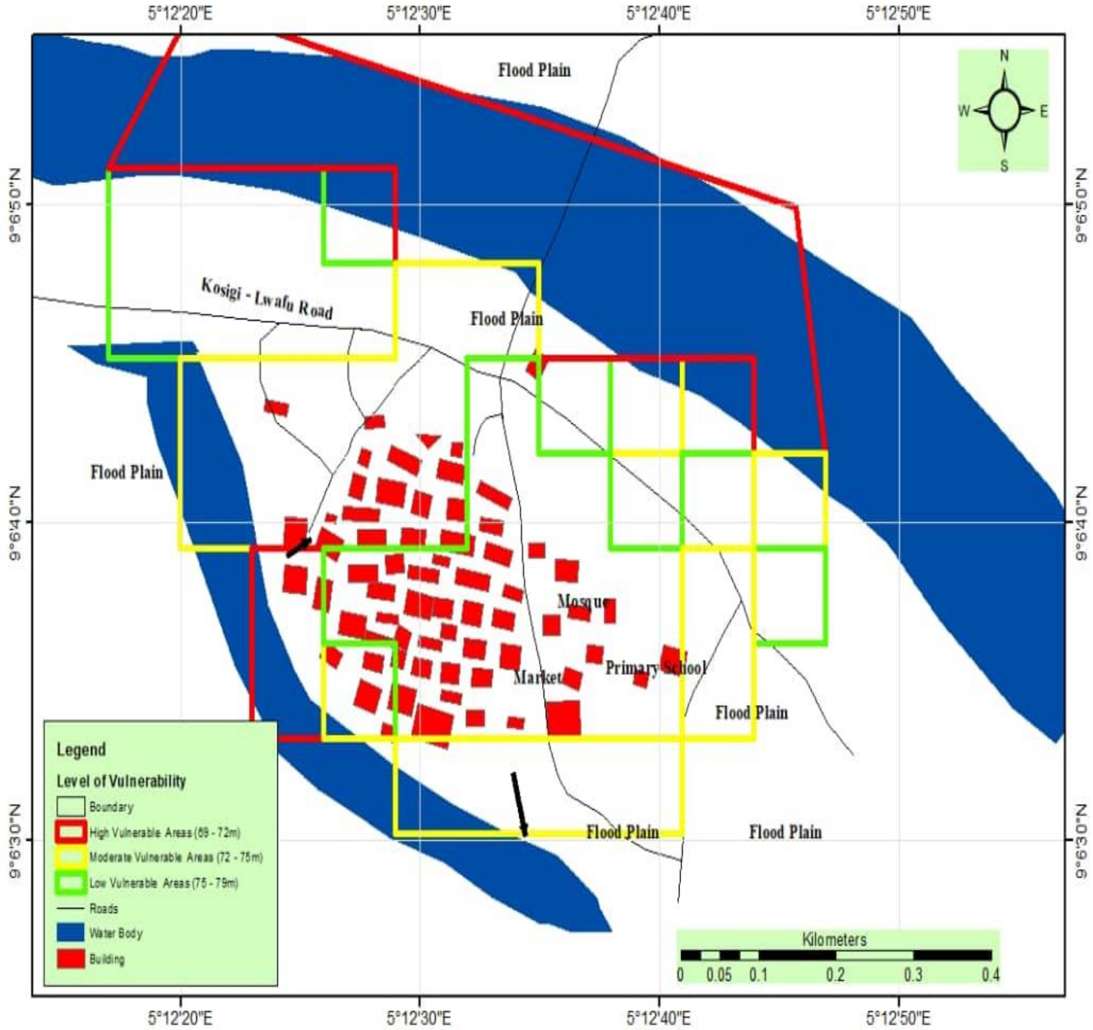

Figure 4.8: Kusogi DEM and Building Footprint

The analysis and field observation, it was discovered that the entire settlement of Kusogi was within the lower elevation region with elevation, which are highly vulnerable to flood (Figure 4.8).

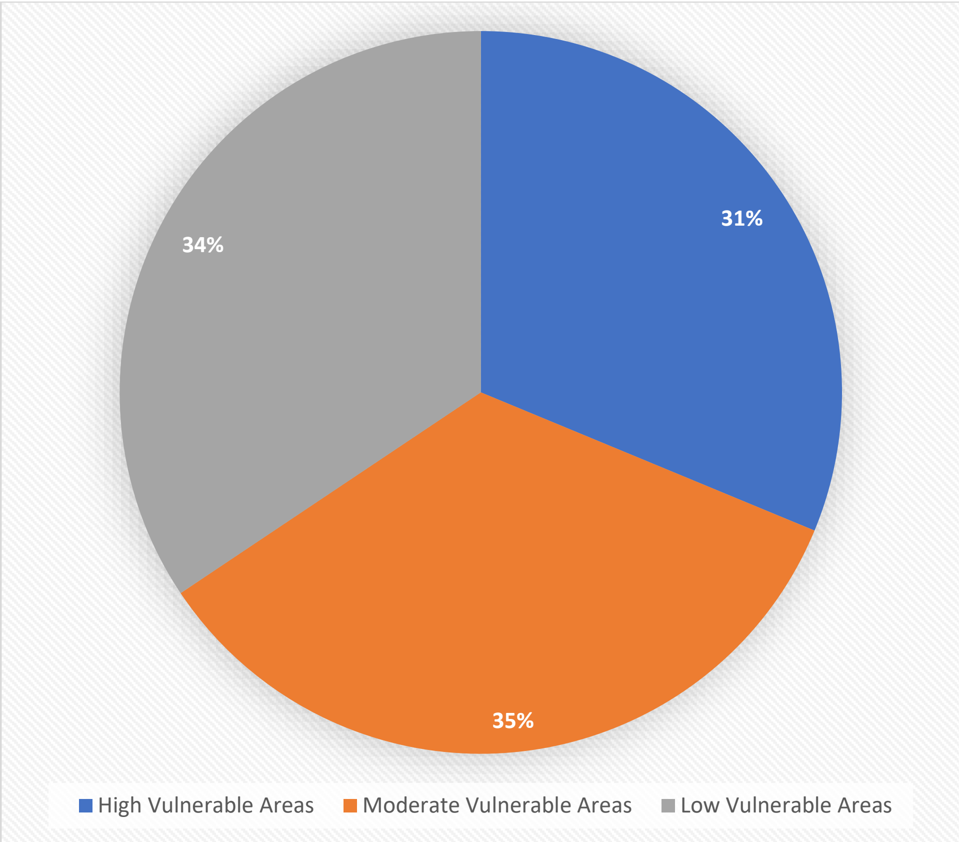

Figure 4.9: Percentages Distribution of Highly Vulnerable Area, Moderate Vulnerable Area and Low Vulnerable Area of Kusogi Community

The map reveals that 0.162 km2 (31%) of the areas are on highly vulnerable areas, 0.1782 km (34%) on low vulnerable area while 0.1784 km (35%) on moderate vulnerable area

4.3.2 Lwafu terrain analysis

4.3.2.1 Lwafu DEM

Using the elevation of the area, DEM reclassified analysis carried out in the region showed highly vulnerable, moderately vulnerable and low vulnerable of the area (Figure 4.10).

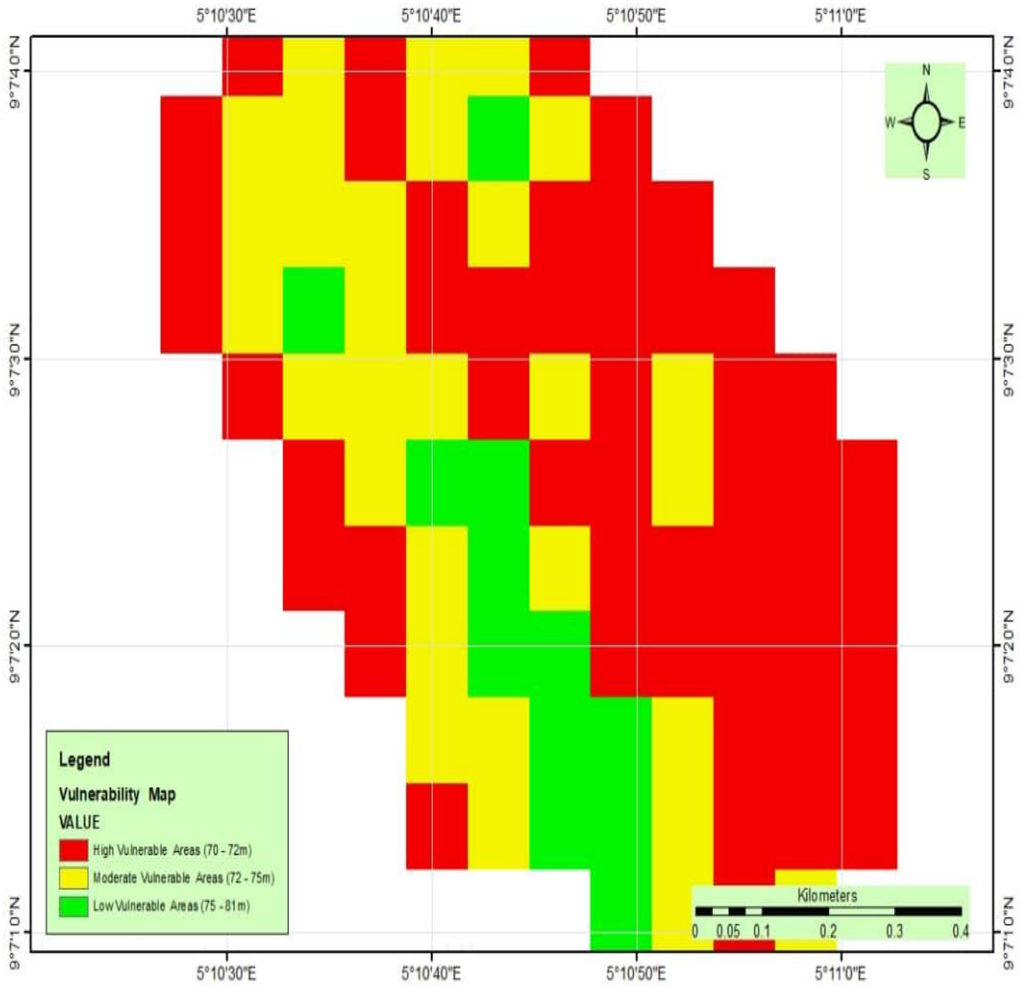

Figure 4.10: Lwafu DEM

From Figure 4.10 the red colored portions with elevation range 70-72m showed catchments that flood waters accumulate which will serve as reservoirs for flood waters. The regions within the yellow area (Figure 4.10) with elevation range between 72-75m are moderately vulnerable to flood than the areas in the green with elevation of 75-81m which are low vulnerable to flood.

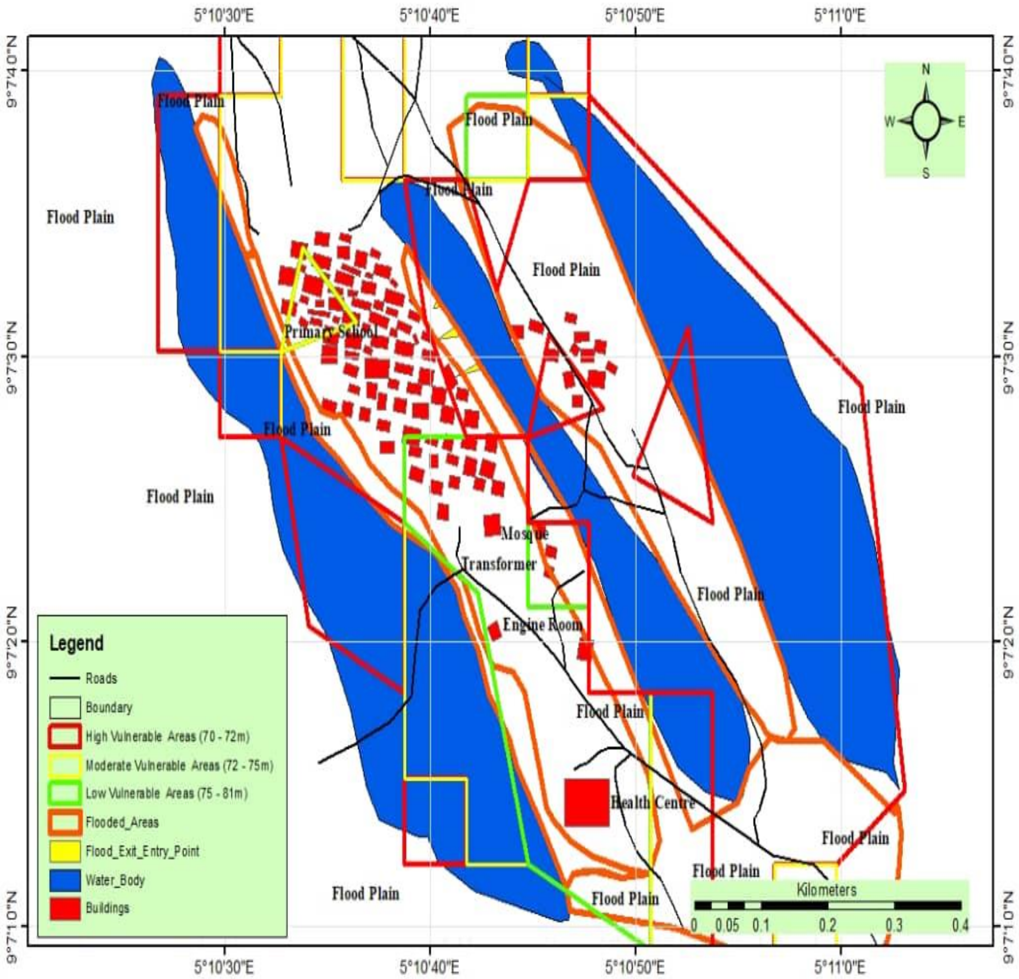

Figure 4.11: Lwafu DEM and Building Footprint

From the analysis and field observation it was discovered that the majority of settlement of Lwafu was within the moderate elevation region with elevation of 74-77m that are moderately vulnerable to flood (Figure 4.11) and it is only few that are in the high and low vulnerable region respectively.

4.13).

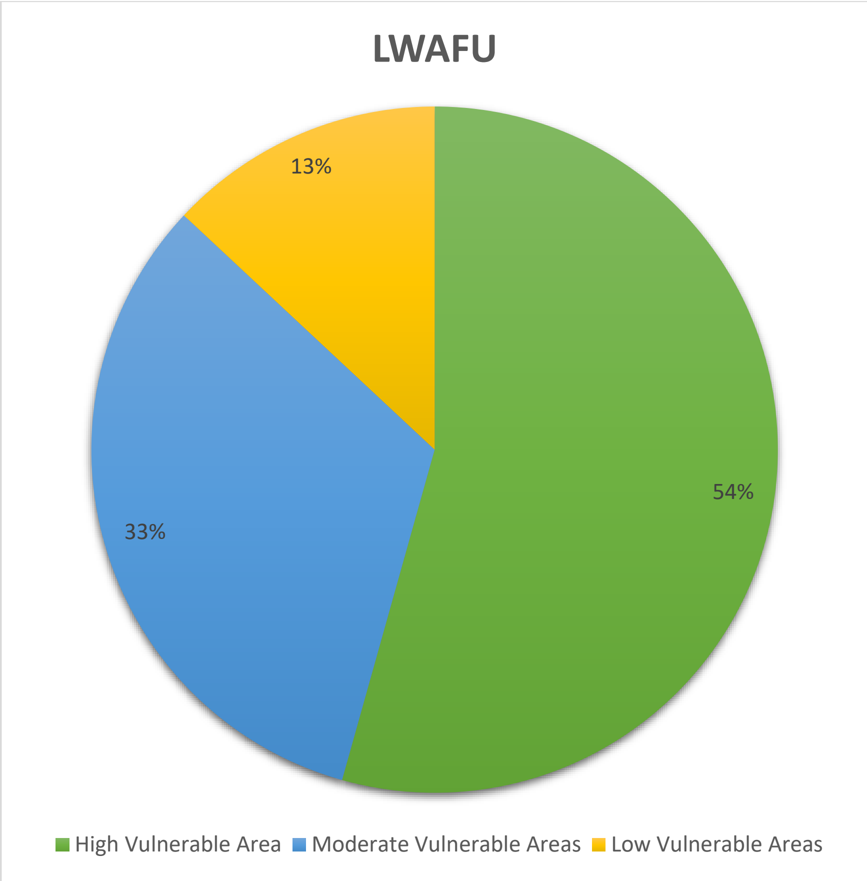

Figure 4.12: Percentages Distribution of Highly Vulnerable Area, Moderate Vulnerable Area and Low Vulnerable Area of Lwafu Community

The map reveals that 0.405km^2 (54.35%) of the areas are on highly vulnerable areas, 0.243 km^2 (32.61%) are on moderate vulnerable area while 0.0972 km^2 (13.04%) on low vulnerable area. The total area is 0.7452 km$^{2.}$

4.3.3 Sunti terrain analysis

4.3.3.1 Sunti DEM

Using the elevation of the area, DEM reclassified analysis carried out indicate the regions that are highly vulnerable, moderately vulnerable and low vulnerable of the area (Figure 4.13).

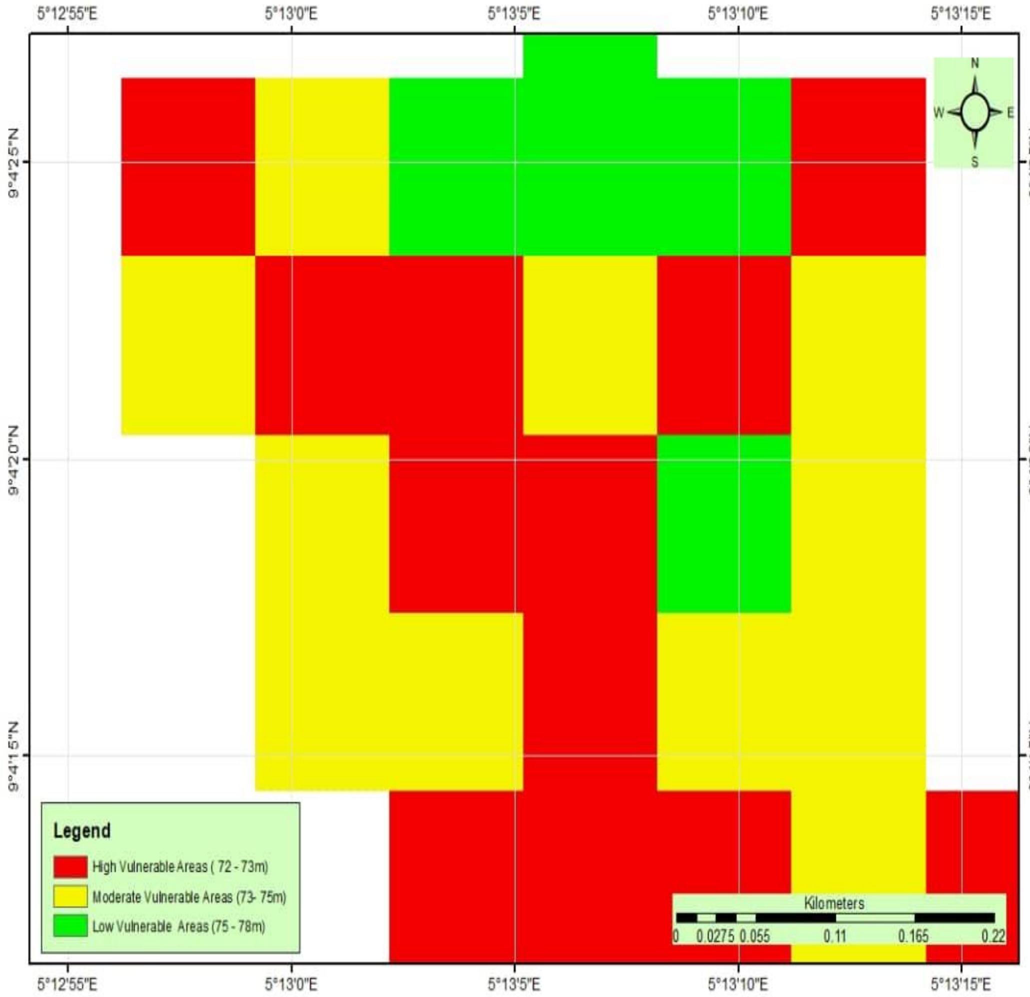

Figure 4.13: Sunti DEM

From Figure 4.13, the red colored portions show catchments that flood waters accumulate which will serve as reservoirs for flood waters. The regions within the yellow area are moderately vulnerable to flood than the areas in the green which are low vulnerable to flood.

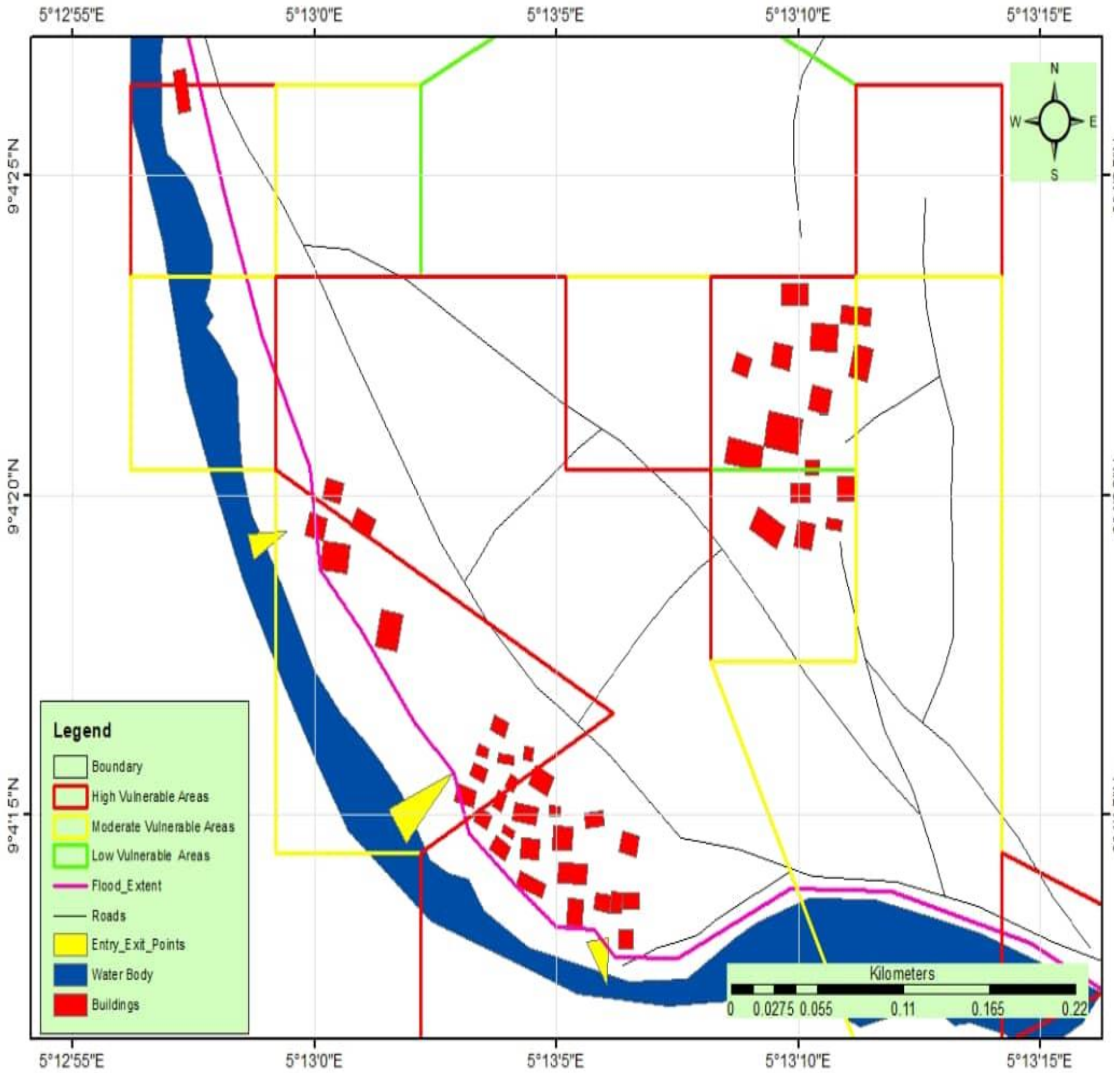

Figure 4.14: Sunti DEM and Building Footprint

The analysis and field observation revealed that the majority of settlements of Sunti are within the higher elevation that are low vulnerable to flood and it is only few are in the moderately and highly vulnerable region respectively.

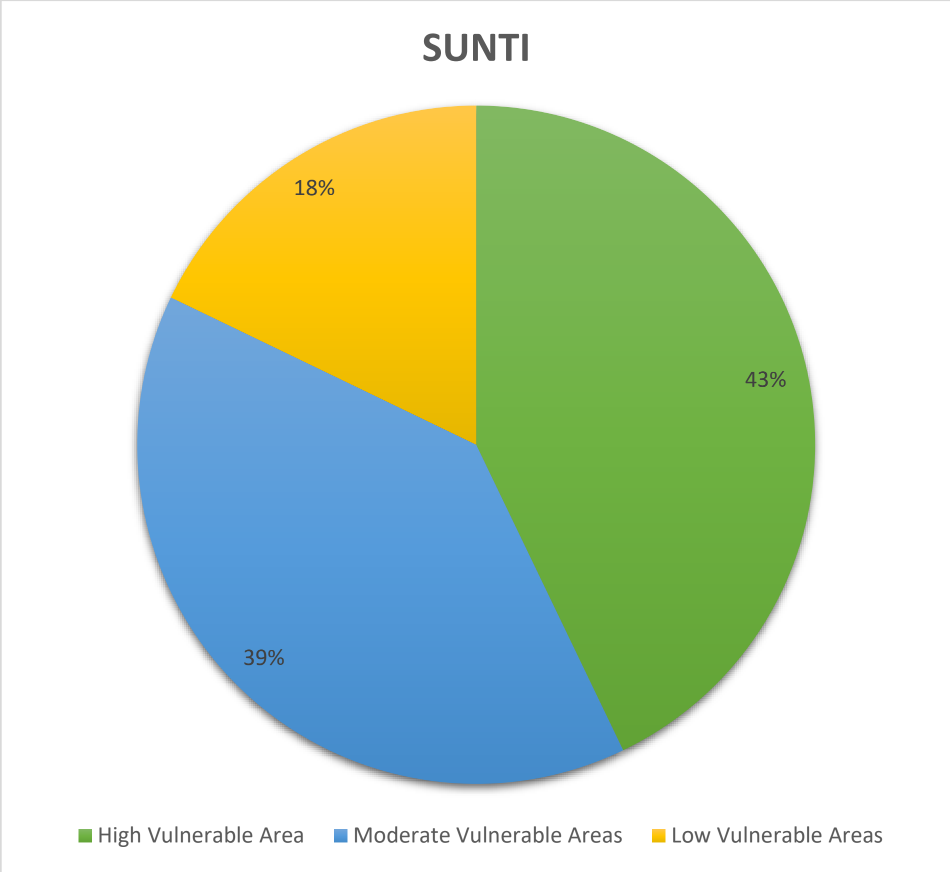

Figure 4.15: Percentages Distribution of Highly Vulnerable Area, Moderate Vulnerable Area and Low Vulnerable Area of Sunti Community

The map reveals that 0.0972 km^2 (42.86%) of the areas are on high vulnerable areas, 0.0891 km^2 (39.29%) are on moderate vulnerable area while 0.0405km^2 (17.85%) on low vulnerable area. The total area is 0.2268 km^2

This objective is in line with the study carryout out by Jean *et al. (*2019). In which Digital Elevation Model was generated from SRTM. SRTM DEM was projected using the "Project Raster" tool in ArcGIS and Survey Point feature class projected using "Project (Data management)" tool. The elevation values in SRTM DEM are above sea level. The Ground elevation is added with surveyed flood depth to get the flood height above sea level. The Elevation values from DEM is extracted and added to survey Point feature class using the "Extract by points" tool in ArcGIS. These Flood level points are interpolated to get the flood surface raster. Interpolation method used was “Kriging”. The participatory survey conducted was very effective in collecting required data and it strengthens the community involvement in decision making, which will empower them.

4.4 Community Infrastructure and Spatial Analysis

The features mapped are buildings, roads and river and others identified by community members during field work as important resources.

4.4.1 kusogi infrastructure map

Figure 4.16 is the Kusogi infrastructure map, blue for river Niger, light yellow for flood entrance point, pink color depicts flood extent, black represent roads, and red indicates buildings (Figure 4.16).

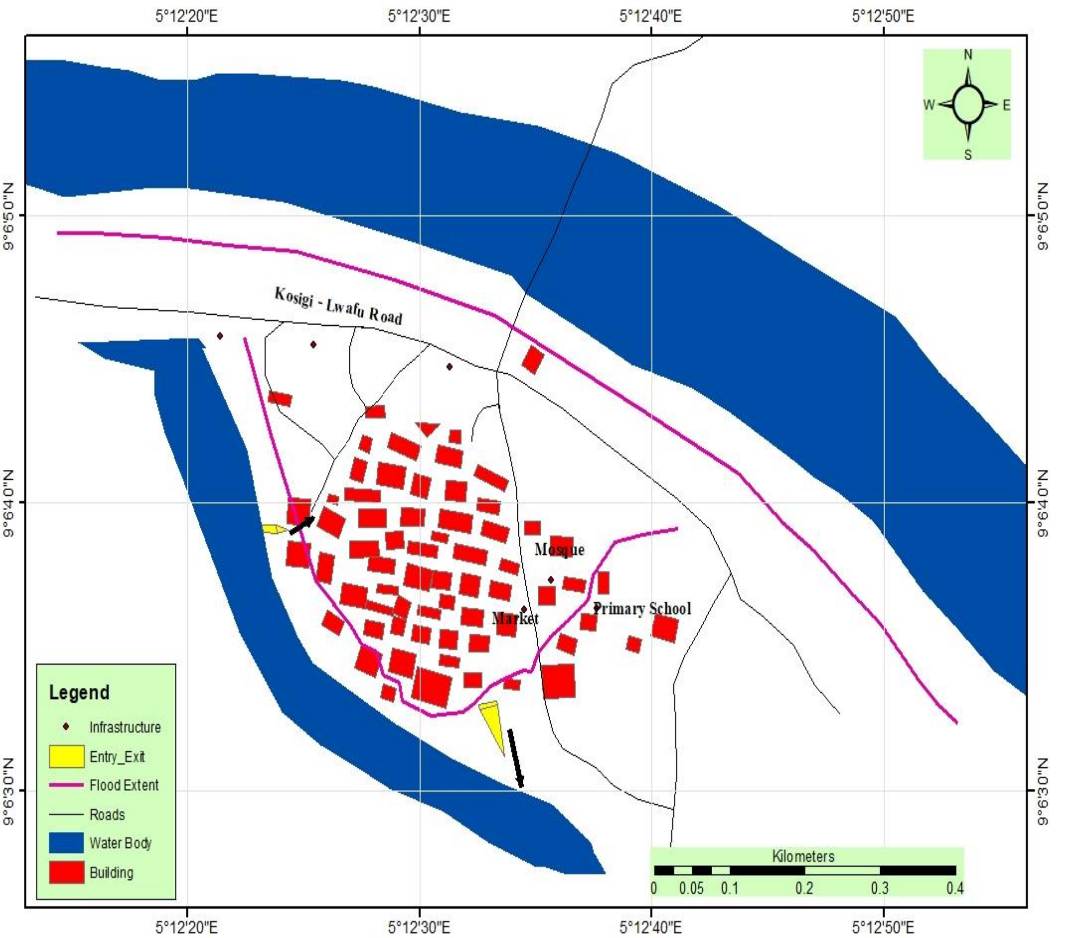

Figure 4.16: Kusogi Infrastructure Map

The study results revealed that there two flood entrance point at bank of river Niger were it boundaries with Kusogi, where the excess water released from Jebba Dam enter into the community via flood channel and spread to the other part of the community (Figure 4.16).

4.4.2 Lwafu infrastructure map

Lwafu infrastructure map depicted in Figure 4.17, pink color shows flood extent, blue for River Niger, light yellow for flood entrance points, red color shows flood channel, black represent roads and red indicates buildings (Figure 4.17).

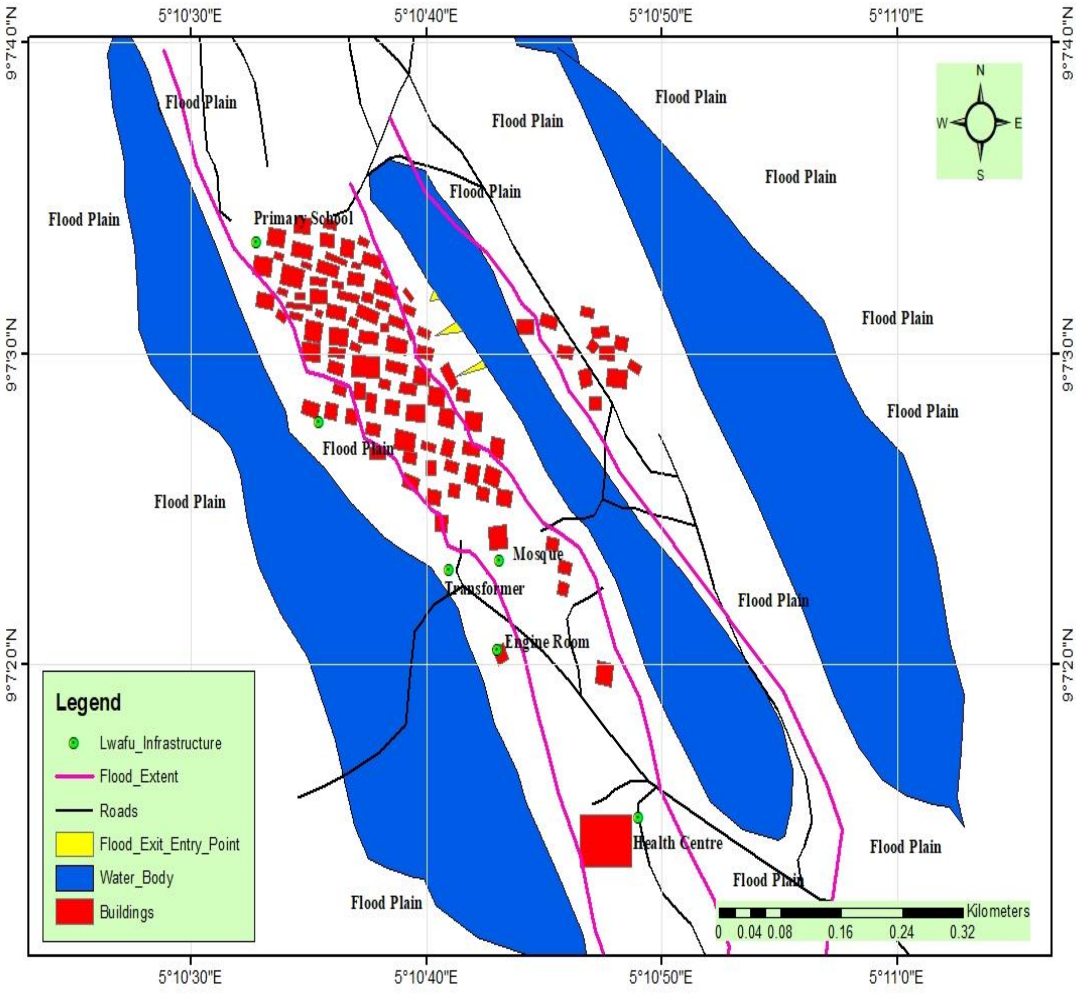

Figure 4.17: Lwafu Infrastructure Map

In Lwafu three flood entrances are identified where the community boundaries with river Niger which serves as points where excess water released from Jebba dam when the carrying capacity of the reservoir is exceeded entered into Lwafu community and spread to other part (Figure 4.17).

4.4.3 Sunti infrastructure map

Sunti infrastructure map is represented in Figure 4.18, deep yellow depicts entry and exit point of flood, blue for river Niger, black represent roads, pink color represent flood extent and red indicates buildings (Figure 4.18).

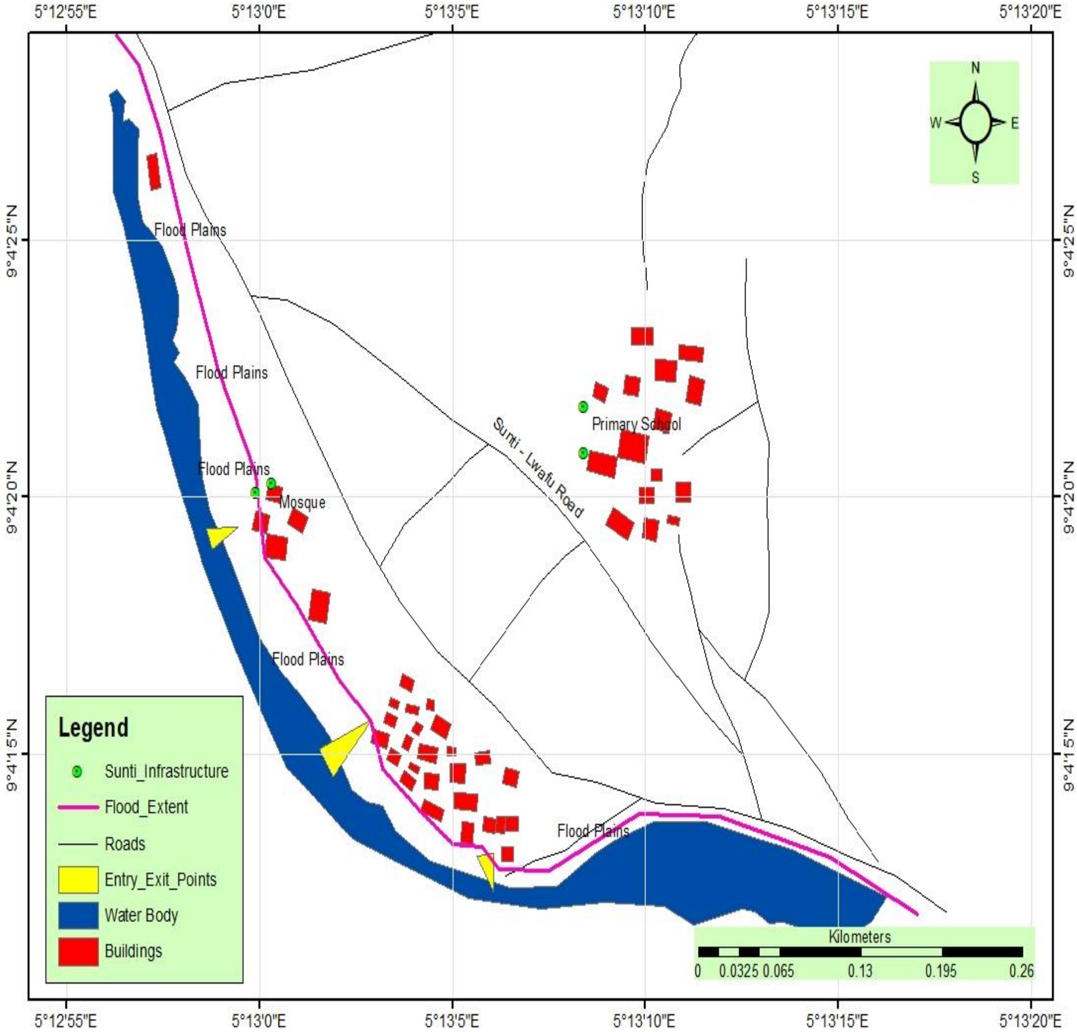

Figure 4.18: Sunti Infrastructure Map

However, in Sunti community the study results revealed that there are natural outlets around the settlement of Sunti that collect the excess waters coming from river Niger as a result of excess waters released from Jebba dam which prevent most of the settlement from flooding (Figure 4.18).

4.6 Summary of the Findings

With regard to exposure, it was found that the community's settlement around River Niger were exposed to the longest periods of flooding. It was established through the local knowledge depicted on the sketch map that Kusogi, Lwafu and Sunti can only experience flooding from River Niger. It was also observed that Kusogi and Lwafu are the communities whose settlements are mostly affected by flooding, the settlement of Sunti is not affected due to the fact there are natural outlets that served as flood reservoirs but other land use types such as farm lands.

The main problem associated with River Niger around these communities is its eroding nature. Valuable agricultural land and residential area is being lost with each flood season due to bank cutting and water impoundment. It was stated by community's head with certainty that River Niger is showing changes when water is being released from Jebba Dam at some places and meandering in various place. There is clear indication that the river morphology is changing. This change is also related to intensification of human activity in the study area, such activities are deforestation, unpredicted weather condition, extension of agricultural land into the flood plain.

The knowledge and information base of the community and the relevant authorities of the flood disaster at local level were low. Also, the information flow from top to bottom as well as bottom up didn't occur in a proper manner and the data and information on flood were often overlapped or ignored.

CHAPTER FIVE

5.0 CONLUSION AND RECOMMENDATIONS

5.1 Conclusion

This study set out to explore the applications of PGIS in community flood and vulnerability mapping. These results suggest that PGIS can be used as a mechanism to record local spatial knowledge on flood vulnerability mapping and to support these communities on prevention and vulnerability reduction measures. With a clear idea of who the map is for and how it is going to be used, facilitated PGIS exercises can bring to light important local knowledge on vulnerability factors, helping to steer decision-making processes. The identification of flood zones in a participatory manner was seen as one way to overcome the bottleneck of limited data (e.g., real time images of flood event) to conduct GIS-based hazard delineation. For community members it was easy to orientate themselves on the maps and to draw and highlight the essential features related to hazards in the community.

5.2 Recommendations

To meet this vision P-GIS can be a highly be useful instrument. However, to successfully integrate P-GIS applications and to address the various scales of flood vulnerability mapping, downstream communities, the study recommends the following:

1. Policies or social environments permitting participation must be in place
2. Maintaining an information flow Institutional requirements have to be set that the information flow is guaranteed. A network which is based on trust and good practice is necessary.
3. Strengthening of local GIS focal points for data processing as the modelling of different data involves GIS skills, local resource centers are necessary which can provide data and also information. Such centers could also serve as data

warehouse, however access of data and the need for Spatial Data Infrastructures is evident.

4. Involvement of Local people, who understand the complexity of their environment, are crucial for the success of participatory methods. Most important on the community level, trustworthy and motivated facilitators are needed to implement such concepts. Also, these concepts have to be adapted through lessons learnt and should always focus on a self-sustainability.
5. Finally, PGIS and the objectives of vulnerability assessments are often not linked up with practitioners, as the discussions are mainly discussed in a scientific circle. Practitioners, without any emphasis on research, should be more strongly involved in the scientific elaboration of vulnerability and P-GIS on the local level.

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