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Flood Vulnerability Mapping in the Lower Mono River Basin in Togo, West Africa

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Abstract— The Lower Mono River Basin has been identified as an annual flood hotspot in Togo, where human and ecological systems are negatively impacted. As a result, this paper focused on the assessment and mapping of the vulnerability of communities to flooding. Indicator-based assessment, using the MOVE Framework and GIS technique are used in mapping the vulnerability. The use of indicators in vulnerability studies proved as an effective tool for investigating into the social, economic, and biophysical characteristics of social ecological systems. The vulnerability mapping revealed the various levels at which the communities are exposed, susceptible and lack resilience to flooding. It has been found that all the communities in the Lower Mono River Basin are vulnerable to flooding. Vulnerability is directly related to the degree of exposure, susceptibility and inversely related to the capacity to cope and recover from flood disaster. Identifying, helping, and empowering vulnerable communities are sustainable means of reducing disaster risk.

Index Terms— Flood Vulnerability, Indicators, Mapping,GIS,Mono River Basin

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1. INTRODUCTION

Worldwide, in recent times, it is no more surprising to hear of flooding. Extreme events such as floods, droughts, and windstorms are acute examples where climate and socio-economic systems interact resulting in loss of lives, economic damages, disruption of infrastructure, and ecosystems [1]. Most particularly, flooding has become one of the most devastating disasters, through which health, food, environment and community security are exposed to danger. Vulnerability is conceptualized as the conditions determined by physical, social, economic and environmental factors or processes, which increase the susceptibility of a community to the impact of hazards [2]. From a hazards perspective, vulnerability assessments provide insights into responses necessary to prevent loss of life, damages, or in worst cases disasters [3]. From a climate change perspective, capturing the different elements of vulnerability is a prerequisite for developing adaptation policies that promote sustainable development [4]. The worldwide increase in the occurrences of hydro-meteorological hazards is likely the result of climate change [5].

West Africa is not an exception in flood disaster reports in Africa. In 2007, Togo, as a result of flooding, over 127,880people were affected, 13,764 people were displaced, and dozens were killed in in Togo. Again, in 2008, heavy rains caused severe floods in the downstream of the Mono RiverBasin, displacing about 20% of the people [6]. The 2010 flooding in the West Africa Sub-region, had great negative impacts on human security as most communities were affected [7].

Vulnerability, a key concept in human-environment research, is multi-dimensional and its conceptualization has developed over time [8]. More recently, vulnerability assessments have explored the social, economic, and political conditions that are likely to affect the capacity of individuals or communities to cope with or adapt to hazard [1]. The vulnerability profile of a community is not only dependent on external environmental conditions: the hazard and biophysical characteristics of the system influencing susceptibility but is also socially dependent through the attributes of individuals and social groups within the system and external human factors such as policies and institutions, which affect the capacity to respond or adapt [9]. Reducing risk and Vulnerability of communities to hazards is a major challenge at present regarding global climate change economic constraints [10].

There are many powerful tools for vulnerability studies and mapping. Among these is Geographic Information System (GIS). GIS facilitates the input, storage, management, analysis, integration, and retrieval of spatial data, which aids real-time forecasting, decision making and strategic planning for effective hazard preparedness and risk management [11], [5]. In climate impact and vulnerability assessments, GIS allows for the monitoring of vulnerable objects over time and space, identifying "hot spots" that require adaptation policies and developing an understanding of the processes underlying vulnerability [12].

In Togo, West Africa, vulnerability assessments have been conducted on different hazards and for different purposes but a comprehensive study on the vulnerability of communities to flooding, using indicators and GIS, as means of assessing

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andmapping vulnerability at community level (in the Lacs District) is not known at the time of writing this paper. In light of this, the objective of this paper focused on the

2. STUDY AREA

The study is conducted in the Lower Mono River Basin (Lacs District) in the Maritime Region, Togo, where six (6) communities including Aklakou-Zongo, Aveve, Adame, Agbanakin, Azime Dossou and Togbavi were selected. Mono River Basin, the largest river system in Togo, occupies an area of 20,600 km2 and is 560 km long [13]. The targeted district is

assessment and mapping the vulnerability of communities to flooding to help close the research gap in the Lower Mono River Basin in Togo.

located in the downstream of the river below the Nangbeto Dam [14]. The study area extends between 6° 16' N to 60 25' N and 1° 42' E to 1' 490 E: at the immediate south of BasMono. To the west is the Vo district and the eastern part is the Republic of Benin, while on the southern part lies the Bight of Benin and Atlantic Ocean. It covers a land area of about 406 km2 with an average elevation of about 10 meters above sea level, which decreases towards the Atlantic Ocean [15]. The study area is presented in figure 1 (below)

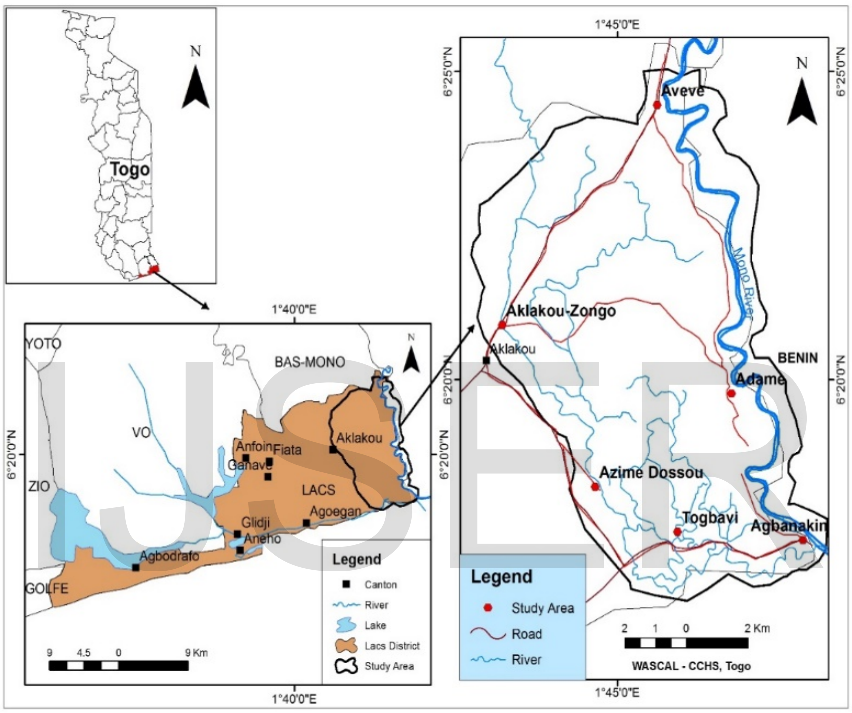

Figure 1. Map showing the study area in the Lacs District, Togo.

3. MATERIALS AND METHODS

3.1. Data sources and data collection methods

The study used both primary and secondary data sources. Socioeconomic data was obtained through field survey. Population and flood history data are secondary data sources that was obtained from the Togo National population census (2010), EM-DAT and Togo Red Cross. It mainly adopted interviews, focused group discussions (FGD), field measurements and observations. The target population is the six (6) selected communities in the Lacs District, key informants in disaster risk management, organizations and institutions in Togo.

Spatial data such as topographic map and shapefiles was obtained the Department of Geography, University of Lomé, Togo. Portably GPS receiver was used to obtain geographic coordinates of some key objects such as farmlands, building, roads, main river channels and among others. Field observation and measurements were also carried out as part of the transect walk.

3.2. Indicators for Vulnerability Assessment

Climate change impacts research and vulnerability assessments specifically as well as hazards research, have adopted the use of indicators to develop a better understanding and relationship between socio-economic and biophysical factors of vulnerability [16]. Indicators can be use as proxies for diverse situations and could be developed for virtually any scale [4], [17].

A vulnerability indicator could be described as a variable, which is an operational representation of a characteristic or quality of an object or subject that is able to provide information regarding the susceptibility, coping and adaptive capacity and resilience of a system [10]. The use of indicators in risk and vulnerability assessments is proved to be very efficient in research due to complexities posed by global environmental change however, this approach may not always be the best method to determine the level of a country or community's exposure, capacity or vulnerability regarding the fact that a country may have a high level of capacity but could experience devastating losses when hit by uncontrollable natural hazards (Earthquake, Volcanoes etc.). Also, a country, community or a person that has high capital investment is likely to stand a higher chance of capital loss [18]. At a local scale, vulnerability assessments are indirectly based on the perception of communities or individual victims, which also comes with its limitations. Victims or potential victims may have some level of capacity to cope and recover from disaster but ones an external aid is anticipated; a negative response might be given. However, these challenges could be controlled by researchers to some extent. These challenges could be reduced through validation of results.

3.3. The MOVE Framework and flood vulnerability Assessment

The study adopted the MOVE framework of [8] but modified and applied at a local scale. This framework is a thinking tool to guide systematic assessments of vulnerability and to provide a basis for comparative indicators and criteria development to assess key factors and various dimensions of vulnerability. [10] stated that the MOVE framework was developed within the context of the research project MOVE (Methods for the Improvement of Vulnerability Assessment in Europe).

The approach underlines that the key factors of such a common framework are related to the exposure of a society or system to a hazard or stressor, the susceptibility of the system or community exposed, and its adaptive capacity. Vulnerability in this regard is understood as a function of exposure, sensitivity and adaptive capacities [19], [20]. Exposure covers the extent to which a unit of assessment falls within the geographical range of a hazard event, susceptibility looks at the predisposition of elements at risk to suffer harm, while lack of resilience is defined by the "limitation in access to and mobilization of the resources of a community or a social-ecological system in responding to flooding", compromising the proactive flood-proofing actions prior to an event, responding during the flooding emergency, and recovering after flooding [8], [1].

3.3.1. Development of flood Vulnerability Indicators

There are many procedures for developing indicators, including inductive or deductive procedures [16], [18]. For thepurpose of this study, deductive procedure was used in developing the indicators. Socio-economic attributes of the population and physical attributes of the place are key factors in that they likely influence the capacity to cope or ability of communities to adapt to flood disaster. The indicators developed for Community-Based Risk Index by GTZ commonly used and widely applicable in a wide range of hazards including flooding. Following the conceptualization of disaster risk by [21], the indicators are adopted and modified to suit the current study. Some of these indicators are adopted due to their applicability at local scale and atthe community level.

Mapping vulnerability to flooding in the Lower Mono River Basin, a survey of the literature identified a range of factors that are relevant to developing socio-economic and biophysical vulnerability indicators. A total of 29 indicators were developed for the study (See Table. 1). Indicators ranged from age and gender, income level, location of building and farmlands, level of education, health status and household arrangements, early warning systems, community awareness and among others. A combination of socio-economic and physical factors and their functional relationship with the components of vulnerability such as being physically challenged and living close to flood zones increases vulnerability [17].

Table 1. Flood Vulnerability Indicators

Components	Indicators	Measurements (Variable)	Relationship	Indicator No.
Exposure	Population of people in Floodplain	% of people in floodplains	(+)	E1
	Flood duration	Average flood duration (days)	(+)	E2
	Floodwater depth	High depth of floodwater (m)	(+)	E3
	Proximity of community to water body	Communities located close to water bodies	(+)	E4
	Availability of electricity	Improper placement of elect cables	(+)	E5
Susceptibility				
Physical Susceptibility	Preparedness towards flooding	Poor preparation	(+)	S1
	Material in which the building is made.	Poor building material.	(+)	S2
	Material in which the roof is made of	Building with poor roof material.	(+)	S3
	Physically challenged persons	High # of physically challenged persons	(+)	S4
	Elderly (>65yrs) and children (<6yrs)	High # of elderly (>65yrs) & children (<6yrs)	(+)	S5
Social Susceptibility	Literacy level	Low Adult literacy rate (%)	(+)	S6
	Awareness of flood disaster	Low level of awareness (%)	(+)	S7
	Household size	Large household size (#)	(+)	S8
	Female headed households	High # of female headed households	(+)	S9
Economic Susceptibility	Income level	Low Income levels	(+)	S10
	People engaged in farming	High (%) of farmers	(+)	S11
	Unemployment	Unemployment rate (%)	(+)	S12
	Household expenditure per capita	Households with the high expenditures /capita	(+)	S13
Environmental Susceptibility	Forest area	Large area covered with forest	(-)	S14
	Protected area	Small protected forest area	(+)	S15
Capacity and	Measures			
Capacity to Anticipate	Early warning system	Access to early warning system	(-)	C1
	Meteorological data	Access to climate data	(-)	C2
	Listening to radio always	High # of people who listen to radio often	(-)	C3
Capacity to cope	Training to cope with flood	Access to flood training programs	(-)	C4
	Financial aid	Access to financial aid	(-)	C5
	Health care service	Accessibility of health service	(-)	C6
	Evacuation routes and facilities	Ability to evacuate	(-)	C7
Capacity to Recover	CommunityDisaster mgmt. committee	Availability of disaster mgmt. committee	(-)	C8
	Diversification of livelihood activities	High level of diversification	(-)	C9

3.3.2. Normalization of indicators using functional relationship

The study adopted the method of [22] in normalizing the indicators. In order to use this method, the functional relationship between the indicators and vulnerability was identified. There exist two relationships: positive and negative relationships. Indicators have a positive relationship when they tend to increase vulnerability of a community to flood, while indicators with negative relationship decreases vulnerability of a community to flood [23].

When the variables have positive functional relationship with vulnerability to flood, the normalization is done, using the formula (1):

$$V_{jc} = (Y_{jc} - MinY_j) / (MaxY_j - MinY_j) \quad ..... (1)$$

When the variables have negative functional relationship with vulnerability to flood, the normalization is done, using the formula (2):

$$V_{jc} = (MaxY_j - Y_{jc}) / (MaxY_j - MinY_j) \quad ..... (2)$$

Where; V_{jc} refers to the standardized vulnerability score with regard to vulnerability component j, for community c; Y_{jc} stands for the observed value of the same component for the same community $MaxY_j$; and $MinY_j$ for the maximum and minimum value of the observed range of values of the same component, for all settlement of the index.

3.3.3. Constructing Vulnerability Index

There are several ways of estimating vulnerability indices but for the purpose of this study, equal weights (simple average of the scores) is used. This is found to be simple and relatively reliable [22]. Each index is obtained by averaging the variable within each component of vulnerability following the formula (3):

$$AI = \frac{1}{N}\sum_{i=1}^{n} C_i \quad .... (3)$$

Where AI is the average index of each of the sources of vulnerability, N is the sum of the index and C_i is the value of the index.

3.4. Geographic Information System (GIS) and Flood Vulnerability Mapping

Application of GIS in risk and vulnerability mapping is very important in disaster risk reduction. Once normalization of indicators and calculation of vulnerability indices was done, the excel spreadsheet containing the indices of exposure, susceptibility, capacity and the overall vulnerability of the communities was saved in .dbf format and imported into the GIS (10.1) platform and joint to the shapefiles (.shp) of the communities. Maps of the exposure, susceptibility, capacity and the overall vulnerability were generated and reclassified into three (3) classes or levels (Low, Moderate and High Vulnerability). The processes involved in the creation of the maps are summarized in fig. 2. (below).

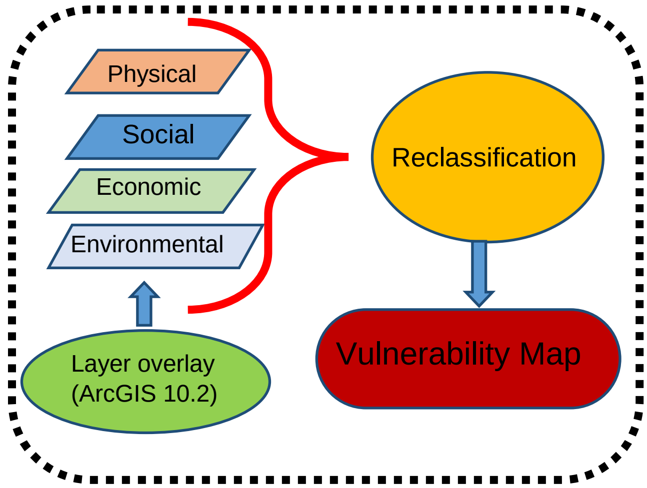

Fig.2. Methodological process for creating vulnerability map

4. RESULTS AND DISCUSSION

In this section of the study, the perception of the communities on the causes of flooding, flood duration, local indicators used as early warning systems, ranking of flood vulnerability indicators at community level, and discussion of the maps of communities' exposure, susceptibility, capacity and the overall vulnerability mapping are presented.

4.1. Floodwater Depth (Recorded in 2010)

The duration of floods and the depth of floodwater are very crucial factors in planning rapid response against flood disaster. The perception of communities and their ability to create visible marks (on walls, trees, etc.) of the floodwater levels during 2010 flood disaster was gathered, organized and analyzed. The summary is given in the table 2.

Table 2. Floodwater Depth and Flood Duration

Name of Com'ty	Floodwater depth (m)	Flood Duration (Days)
Aveve	1.01	40-46
Aklakou-Zongo	1.01	40-50
Adame	1.7	50-60
Azime Dossou	1.34	80-90
Agbanakin	1.46	90-95
Togbavi	1.5	90-95

Obviously, it is visible from table 2 that the highest floodwater level of 1.5 m and 1.45 m was recorded at Togbavi and Agbanakin. This confirms the fact that the areas have relatively lower elevation, flat slope angles and clay soil (60%), which donot permit rapid infiltration of water. The lowestfloodwater depth was 1.01 m, which was recorded at

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Aveve and Aklakou-Zongo. Deeper floodwater increases the vulnerability of communities and pose great challenge to human security

4.2. Communities' perception on the causative factors of Flooding

Communities perceived that the main cause of flooding in the lower part of the basin is extreme high rainfall. The next probable causative factor is the opening of the Nangbeto dam in the middle course of the River. Sedimentation of the Mono River is also seen as a cause of flooding. Surface runoff, which carries sediments from farmlands, bear grounds and untarred roads into the main channel of the river, which reduces the actual depth of the river channel hence, a reduction in its ability to contain all the recharge water. This compels the extra water to overflow the banks of the river during periods of extreme high rainfall. Deforestation is perceived as the least important factor, which is contrary to the findings of [23], in Nyando River basin in Kenya, where deforestation is the major cause of flooding. The catchment characteristics of the basin gives an explanation of the activities of the communities and the expected future modifications to hydrological systems of the River.

4.3. Flood duration and floodwater depth (in 2010)

The highest floodwater level of 1.5 m and 1.45 meters (m) was recorded at Togbavi and Agbanakin. The depth of floodwater and flood duration are positively related in the communities. Areas with higher floodwater depth also experienced longer flood duration: thus 93 days each. The duration of flooding at Azime Dossou was 85 days while 43 days was recorded at Aveve during the 2010 flooding. The lowest floodwater depth of 1.01 m, was recorded at Aveve and Aklakou-Zongo.

This explains the fact that the areas lie in relatively lower elevation with flat slope angles characterised by clay soil (60%), which does not permit rapid infiltration of water.

Longer flood durations and deeper floodwater likely lead to negative impacts on humans and ecological systems but in some communities (Azime Dossou and Togbavi), longer flood duration aids in rapid breeding of fishes, which increases their fish catch.

4.4. Local indicators identified in the communities as flood early warning systems

Capacity to anticipate, cope and recover from a disaster is very crucial in disaster risk management. The communities have identified some local indicators, which serve as a flood early warning system. Some of the indicators are widely used in allthe communities, whiles others are considered not very reliable. The selection of the local indicators is based on the perception of the communities. A few of the local indicators are given in table 3.

Table 3. Local indicators used as flood early warning system

Nameof Com'ty	Birds	Frogs	Ants	Snails	Total (%)
Aveve	**21**	**59**	**9**	**11**	**100**
Aklakou-Zongo	**37**	**47**	**11**	**5**	**100**
Adame	**23**	**64**	**9**	**4**	**100**
Azime Dossou	**34**	**51**	**11**	**4**	**100**
Agbanakin	**29**	**55**	**10**	**6**	**100**
Togbavi	**25**	**58**	**10**	**7**	**100**

From table 3, all the communities have identified frog croaks as the most common and relatively reliable indicator of flooding. Croaking of the frogs signifies a likely heavy rainfall, which might lead to flooding. Also, birds such as swans change their direction of movement with respect to heavy rainfall. When ants begin carrying their eggs, it is a sign of a likely heavy rainfall and serves as a local indicator of flooding. It was again identified that when snails are observed climbing trees, it is a sign of an expected extreme high rainfall but this was not widely used in all the communities. Similar local indicators are identified in the Oti River Basin, northern part of Togo, where Frog croak is widely used as sign of an extreme high rainfall, which could result into flooding [6]. Local knowledge has been in existence since antiquity but not given the required attention in scientific studies. In this era of increasing disasters, it is very important to integrate it into empirical studies.

4.5. Community-based flood risk factors

During focus group discussion, members of each of the various communities listed flood vulnerability factors that are relevant in their communities and ranked them according to their level of influence on flooding. The rank of 1 is given to the most important factors, while the rank of 6 is given to the least important factors. The summary is given in table 3, where the most important factor in one community is the least important factor in another community. While proximity to river channel is ranked first at Adame, low elevation is ranked as the most important factor at Togbavi, which is the least influential factor of flooding at Adame (See table. 4).

Table 4. Community's perception on flood risk factors

Agbanakin	Adame	Aveve	Aklakou	Azime Dossou	Togbavi	Rank
Elevation	**Proximity to active water channel**	**No access to financial aid**	**Elevation**	**Surrounded by water**	**Elevation**	**1**
Proximity to active water channel	**No access to financial aid**	**Proximity to active water channel**	**Poor building materials**	**Elevation**	**Surrounded by water**	**2**
Poor building materials	**Poor building materials**	**Poor building materials**	**Proximity to active water channel**	**Poor building materials**	**No disaster mgmt. plan**	**3**
No access to Meteo. data	**No flood mgmt. committee**	**No "Balise"**	**No flood mgmt. committee**	**No flood mgmt. committee**	**Poor building materials**	**4**
No flood mgmt. committee	**No disaster mgmt. plan**	**No flood mgmt. committee**	**No access to financial aid**	**No access to Meteo. data.**	**No means of evacuation**	**5**
No "Balise"	**Elevation**		**No disaster mgmt. plan**	**No means of evacuation**	**No access to financial aid**	**6**
Poor drainage system of the River						**7**

4.6. Flood Vulnerability Mapping

The vulnerability mapping considered the exposure, susceptibility, capacity and measures of the communities to prepare, cope and recover from flood disaster in the Lower Mono River Basin. Vulnerability maps are useful as they represent the physical extent of an event or hazards. Flood vulnerability maps give a more direct and stronger impression of the spatial distribution of the flood vulnerability than other forms of presentations

4.6.1. Flood Exposure

Exposure is an important factor of vulnerability pending on how it is conceptualized. It looks at the physical location and display of human systems with time. Details of communities' exposure to flood hazard is presented in figure 3

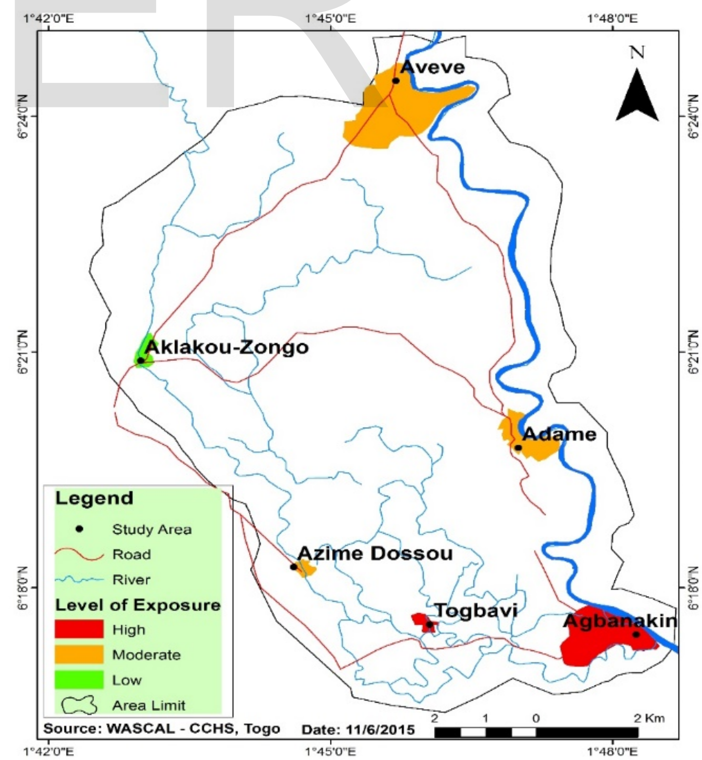

Fig. 3. Flood exposure map

It is visible in Fig. 1 that all the communities are exposed to flooding but the level of exposure was classified. Communities such as Agbanakin and Togbavi are mostly exposed. This is explained by the fact that nearly 98% of the people are found in the flood zones and are located 10 m from the river channel. Relatedly, Adame, Azime Dossou and Aveve are othercommunities, which are moderately exposed to flooding. Thecommunities are largely dependent on agriculture as a source of livelihood but their field crops are located in flood zones as well. Deeper floodwaters and longer flood durations are experienced at Agbanakin and Togbavi, which further explained the high levels of exposure. This conforms the findings of [10] that factors such as proximity to the Water bodies, longer flood duration and location of field crops in flood zones tend to increase the exposure of communities.

4.6.2. Susceptibility to flooding

Susceptibility of communities to flooding is largely influenced by complex and independent characteristics of human systems. The levels of communities' susceptibility to flooding is present in fig. 4.

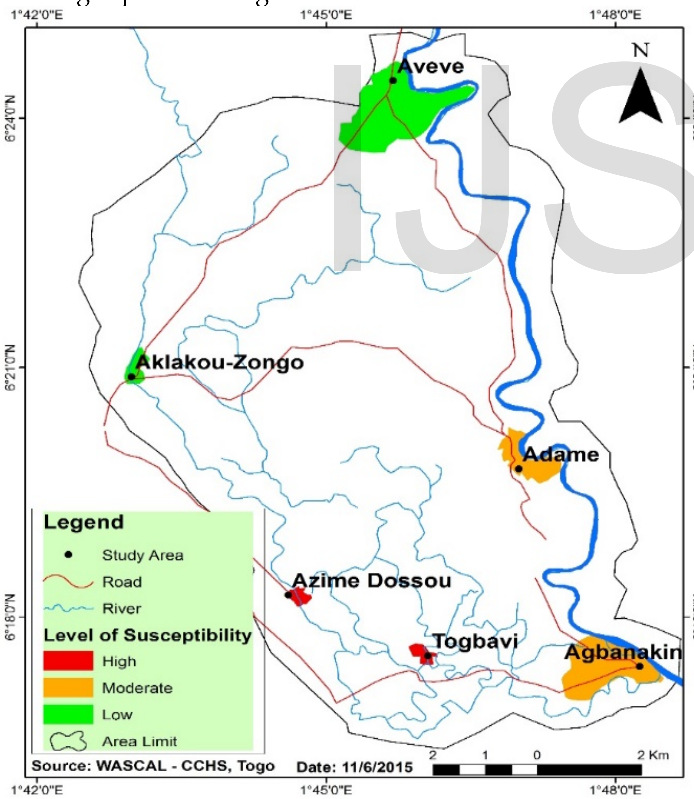

Fig. 4. Flood Susceptibility Map

Communities such as are Azime Dossou and Togbavi are seen to have a high level of susceptibility to flooding, though Agbanakin and Adame are equally susceptible. Azime Dossou and Togbavi are largely characterized by houses that are constructed with mud and roofed with thatches and "Bamboo sticks". The floors of the building are also made with a mixture of mud and concrete.

Poor building materials and building codes increases the susceptibility of communities. They are also engaged in vegetables and maize farming, which is highly influenced by extreme high rainfall, conforming the findings of [15]. Aveve and Aklakou-Zongo are less susceptible to flooding probably due to the fact that their houses are mostly made of concrete. Members of Aklakou Zongo are into animal raising, where farm animals are easily quarantined in safe places, when severe flooding is anticipated.

4.6.3. Capacity and Measures

The capacity of social-ecological systems to anticipate, cope and bounce back well is very crucial in dealing with hazards and disasters. The capacity assessment considered availability of flood disaster training programs, early warning systems, and availability and accessibility of evacuation facilities among others (see Fig. 5).

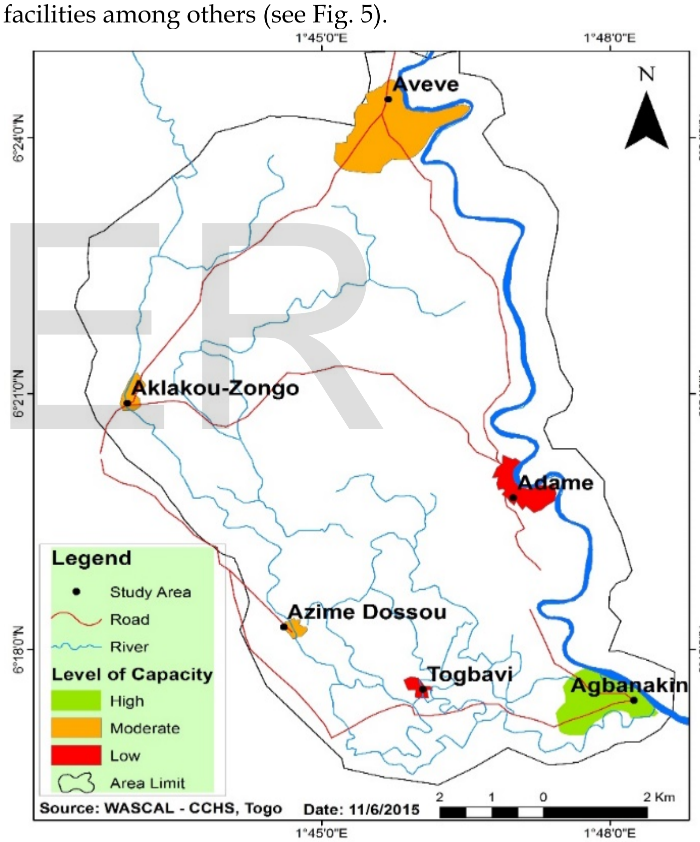

Fig. 5. Map of Capacity and Measures

It could be observed in Fig. 5 that Agbanakin has a higher level of capacity to face flooding, while Adame and Togbavi has relatively lower levels of capacity to anticipate, cope and recover from flooding. Azime Dossou, Aveve and Aklakou-Zongo also emerged with medium level of capacity to face flood disaster. This is partly explained by the fact that Azime Dossou is the only community that has a "Balise" (a flood early warning system), to alert them of an oncoming flood, though it is wrongly sited. Agbanakin community is well aware of flood hazard and are prepared to face flood disaster.

Togbavi and Adame have very poor roads and lack evacuation facilities. At Azime Dossou and Togbavi, only one canoe each was donated by the German and the Togolese Red Cross to help evacuate people during flooding.

If a community has a high level of capacity and measures to anticipate, cope and recover from the impacts of flooding, its level of vulnerability reduces. Though Agbanakin is located very closed to the river as compared to Aklakou-Zongo but notvulnerable due to its relatively high level of capacity. It is not only these communities which have low capacity but most communities in rural areas in [24]. These communities often rely on external help when hit by flood disaster.

4.6.4. Flood Vulnerability Map

It is the socioeconomic and biophysical characteristics, which influence an individual's or group's exposure, susceptibility and the ability or inability to anticipate, cope with, resist, and recover from or adapt to any external stressor extreme event such as flooding (Consider Fig. 2).

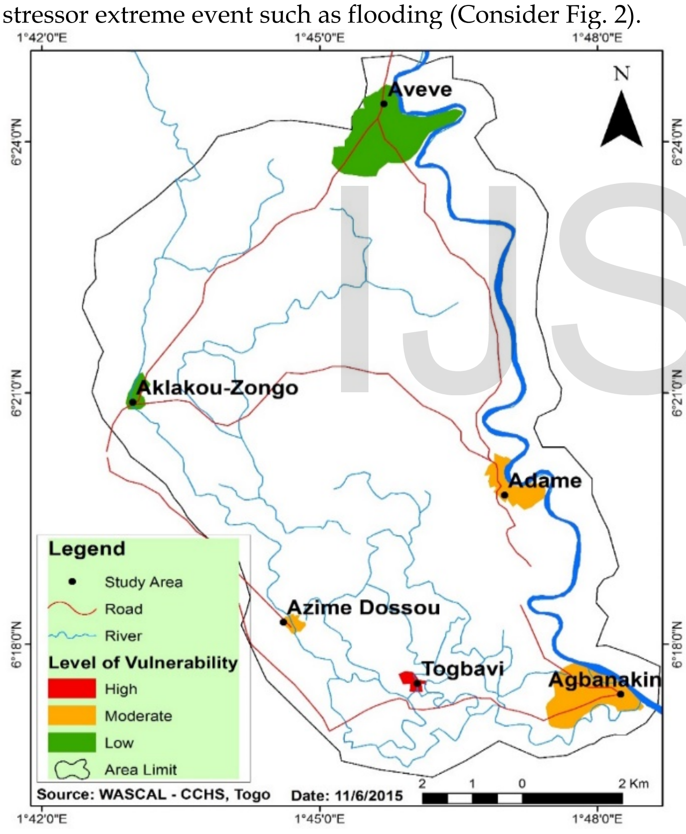

Figure 3. Flood Vulnerability Map

Vulnerability of a place is dynamic in both space and time and also on the scale of measurement. In figure 6, Togbavi is highly vulnerable, while Adame, Azime Dossou and Agbanakin are moderately vulnerability. The high level of vulnerability of the communities is partly explained by the fact that their levels of exposure and susceptibility are higher than the levels of their capacity. Agbanakin community proved to have a high level of capacity but its exposure is relatively very high.

High level of exposure and susceptibility with a low level of capacity gives rise to high level of vulnerability as in the case of Togbavi, Azime Dossou and Agbanakin. Communities suchas Aveve and Aklakou-Zongo are less vulnerability partly due to the fact that their biophysical characteristics are less susceptible. Their buildings are largely made of concrete and roofed with iron sheets, which is relatively less susceptible compared to building made with "mud and thatch" or palm branches.

Conforming the report of [22], vulnerability is a complex concept and its outcome could not be predicted through a mere mental mapping. The spatial proximity of the communities to active water channels do not woefully explain their vulnerability to flood disaster but also the use of socio-economic indicators, which revealed the underlying factors of vulnerability. Human security is people-centred therefore its analysis must include human factors to identify the source of the vulnerability and help prioritize mitigation measures.

5. Conclusion

Investigating into the perception of communities regarding their exposure, susceptibility and capacity is very found to be very important. It has been revealed that most of the communities in the Lower Mono River Basin are vulnerable to flooding. Among the communities, Togbavi is found to be more vulnerable, though, Agbanakin, Adame and Azime Dossou are equally vulnerable. It could be penned that Aveve and Aklakou-Zongo are the communities that are less vulnerable.

Vulnerability is directly related to the degree of exposure, susceptibility and inversely related to the capacity to cope and recover or adapt. The adoption of the MOVE Framework in vulnerability mapping proved very effective in capturing all dimensions of vulnerability at the local scale (community level). In disaster risk reduction processes, it is not only important to identify high risk areas, it is also critical to identify vulnerable populations, understand the underlying factors, and assess the available measures that are needed to help reduce vulnerability.

Using GIS has provided a good experience and the platform to visualize the extent of flood exposure, susceptibility, and the overall vulnerability of flood.

It is henceforth underscored that vulnerability of communities could be reduced by identifying and empowering those who are most vulnerable because vulnerability is not a predetermined state, due to the fact that it is usually socially constructed, contextual, dynamic, and driven by various causal agents and processes. hence, capturing the differential elements of vulnerability is a prerequisite for formulation and implementation of policies to promote sustainable development.

Recommendation

- collaboration among disaster relief organizations is very crucial. This will help in reducing duplication and strengthen the mitigation strategies.

- A positive attitude towards early warning systems is an effective means of reducing disaster risk in the lower basin
- Designing and location of early warning systems should be properly done. For instance, the Balise at Azime Dossou is not well sited because it was placed at 1 m above sea level. Therefore, by the time the water level reaches "Green"(Normal flow), it is already entering people's rooms. It is proper to install "Balise" at hydrographic zero.

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