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Flood Exposure Mapping and Social Vulnerability to Flood using Multi-Criteria Evaluation: A Case of Awash Fentale Woreda, Afar regional State, Ethiopia

By

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THESIS SUBMITTED TO CENTER FOR ENVIRONMENT AND DEVELOPMENT STUDIES, COLLEGE OF DEVELOPMENT STUDIES IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF ARTS IN DEVELOPMENT STUDIES (ENVIRONMENT AND SUSTAINABLE DEVELOPMENT)

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DECLARTION

I, the undersigned, declare that this thesis is my original work, completed under the supervision of my research advisor, Dr. Shimele Damene, and has not been submitted for consideration for any other degree at any other university. All sources of material used in this thesis have been acknowledged, and information obtained from outside sources has been properly cited.

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Acronyms

AHP	Analytical Hierarchical Process
ACF	Action Against Hunger (or Action Contre La Faim)
AFWEPEO	Awash Fental woreda's emergency, preparedness, and early warning office
CSA	Central Statistical Agency
CSS	Center for Security Study, ETH Zürich
DEM	Digital Elevation Model
DFID	Department for International Development
DRMFSS	The Disaster Risk Management and Food Security Sector
EPA	United States Environmental Protection Agency
ESA	European Space Agency
GIS	Geographic Information Systems
IFRC	The International Federation of Red Cross and Red Crescent Societies
IOM	International Organization for Migration
IPCC	Intergovernmental Panel on Climate Change
MCE	Multi-criteria evaluation
NBRO	National Building Research Organization
NDRMC	National Disaster Risk Management Commission
NDWI	Normalized difference water index
QGIS	Quantum Geographic Information Systems
SoVI	Social Vulnerability Index
UNESCHO-IHE	United Nations Educational, Scientific and Cultural Organization Institute for Water Education (UNESCO-IHE)
UN/OCHA	United Nations Office for the Coordination of Humanitarian Affairs
UN-ISDR	United Nations Office for Disaster Risk Reduction

Abstract

Recent evidence shows that flooding is one of the most common and severe hazards disrupting people's lives and livelihoods in the world. Flood risk in Ethiopia is increasing both in intensity and coverage, particularly in lowland areas crossed by major rivers. However, the effects of flood disasters are not equal for every region, society, and community. Context-based studies on social vulnerability are very essential to identify major driving factors and address vulnerable people. It is the intention of this thesis to analyze spatial variations of social vulnerability driving factors, vulnerable groups and its impact of the 2020 kirmet season flood in Awash Fentale Woreda of Afar Regional State. GIS and remote sensing methods for exposure mapping trough selected elements at risk, AHP methods of multi-criteria evaluations along with the survey result used to identify, rank and weight the major drivers of social vulnerability, survey method was used to identify the most socially vulnerable groups in the study area.

The result shows that the study area was exposed to the 2020 kirmet season flood with an impact on land use, settlements, roads and populations. Housing structure, nearness to flood sites, source of income, access to information about flood, access to evacuation centers, education level, flood experience, access to road, access to health facilities, household compositions, training on flood preventions and preparedness and support were the major driving factors of vulnerability in the study area. From which the housing structure ranked as the most important factor in contributing (15%) for households' vulnerability to flooding, followed by nearness to flood sites (13%). Households with dependent family members, live close to the major rivers, far from the main road, not able to access basic amenities, evacuation center, transport services, no social or PSNP assistance, receive less than 3,000 ETB mean monthly income, those depends on weak livelihood base, no-flood related training, no flood experience, not able to get flood information, as well as no formal educational background, are found to be the most vulnerable groups in the study area.

The study result shows that the importance of a combined method of GIS, multi-criteria evaluations and survey for identifying, weighting and ranking of driving factors for social vulnerability to flooding. It also shows that context-specific nature of social vulnerability to flooding.

Keywords: Flood, Social Vulnerability, GIS and Remote Sensing, AHP and MCE

1. INTRODUCTION

1.1. Background

Natural hazard and natural disaster, according to Maskrey, (1989) are two separate terms that are commonly misunderstood and used interchangeably. When a natural hazard directly or indirectly impacts people, their activities, and their property, it is called a disaster. It means a natural disaster occurring in an uninhabited desert cannot be classified as a disaster, regardless of the magnitude of the impacts. Natural disasters are defined as a combination of natural hazards (such as floods, cyclones, earthquakes, and droughts) and vulnerable situations. When one or more natural disasters strike in a vulnerable area, there is a high risk of disaster.

Natural disasters today have more impact on people than they did in the past. According to DFID, (2004) the number and seriousness of disasters, people they affect and the property losses they cause is increasing, and that poor countries and poor communities are disproportionately affected. Recent evidence shows that flooding is one of the most common and severe hazards disrupting people's lives and livelihoods on the world (World Bank, 2020). It often causes unavoidable damage and suffering, particularly in those countries whose income is low and infrastructure systems such as drainage and flood protection less developed.

Several studies (e.g., Hall et al., 2014; Lins and Slack, 1999; Cousineau, 2021) also found that floods are increasing and expected to increase in frequency and intensity due to climate change such as changes in precipitation characteristics, along with temperature, wind patterns, atmospheric pressure, cloudiness and humidity. This fact also ascertained by Deepak et al., (2020) frequent flood factors were attributed to climate change impacts on the hydrologic cycle, land-use changes, and increased density of habitation activities in flood-prone areas. According to Rentschler and Salhab, (2020) land subsidence, increased coastal urbanization, and climate change have made flooding a global reality, reversing years of gains in poverty reduction and development. They warn that individuals and their livelihoods will be put at greater risk in the coming years. In relation to this, Laurent Cousineau, (2021) also underlined that flood can cause drinking water to become contaminated by disease-carrying animals, expose people to waterborne illnesses and infections, spills of chemicals, and other hazardous materials. As it has been evidenced by World Bank (2020) report, vulnerability and exposure vary across spatial and temporal scales depending on economic, social, geographic, demographic, cultural, institutional, governance, and environmental factors. This means the effects of disasters are not equal for every region, society, and community.

According to studies by Rolfe et al. (2020) and Williams and Webb (2019), flood vulnerability is not the same for everyone and varies based on coping capabilities. According to Wisner et al., (2004) and Tate et al., (2021), most residents in flood-prone areas are among the poorest, disadvantaged, and most vulnerable. These studies also demonstrate that they are vulnerable because they have few alternatives for a living or low income, forcing them to put their lives at danger. In this regard, Tate et al., (2021) stated that floods exacerbate the situation of socially vulnerable populations who disproportionately inhabit in flood-prone locations.

According World Bank (2020) report, flooding has been high for people that live in low- and middle-income countries of the world, i.e., which account 89% of the world exposed people to flooding. Studies by Rentschler and Salhab, (2020) conducted in 189 countries revealed that 1.47 billion people, or 19 % of the world population, are directly exposed to substantial risks during once in 100-year flood events, where the majority of which (about 1.36 billion) is located in South and East Asia.

During the previous three decades, the African continent alone has seen over 2,000 significant di saster events, the most of which were caused by extreme weather and climate change, such as fo od insecurity, droughts, floods, flash floods, landslides, storms, and cyclones (IFRC, 2021).
According to Rentschler and Salhab (2020), 55 % of the 132 million people living in extreme poverty (under $1.9 per day) in high flood risk locations live in Sub-Saharan African countries. In addition, the International Fund for Relief and Development (IFRC) estimates that over 71 million people in Sub-Saharan Africa live in extreme poverty and are at risk of flooding (IFRC, 2021).
According to Shumie, (2019) floods have occurred in different parts of Ethiopia for several years and caused deaths of dozens of people and property loss. Flood risk in Ethiopia is increasing both in intensity and coverage, where the incidences have been occurring frequently in main rainy season, particularly in lowland areas crossed by major rivers like Awash, Genale Dawa, Wabe Shebele and Baro Akobo.

The 2020 main rainy season flood is the most recent flood event that affected 1,017,854 people, of which 292,863 were displaced from their home across Ethiopia (NDRMC, 2020). Afar region stand second to the Oromia region was highly hit by this disaster (NDRMC, 2020). However, no sufficient studies that investigate flood exposure and social vulnerability using spatial analysis of elements at risk exposed to floods. Geographic Information System (GIS) and remote sensing techniques have been becoming powerful tools in analyzing exposure to flood by combining it with other techniques.

Therefore, this research will apply GIS and remote sensing techniques used to map selected elements at risk exposed to the 2020 Ethiopian rainy season floods in Awash Fentale Woreda of the Afar Regional State. Sample surveys of selected kebele's households that have been affected by this particular flood event were also used and the result of the survey was analyzed using Analytical Hierarchical Process (AHP) of the Multi-criteria evaluations (MCE) techniques.

1.2. Statement of the problem

As evidenced by De Britol., (2018) the majority of vulnerability research and analysis is focused on physical vulnerability to various hazards, with the purpose of determining the resistance of various structures and materials in diverse situations. The human ecology of hazards has arisen in parallel with this research. It aims to explain why hazards have a different impact on people, their economic activities, and social interactions than on physical structures. However, in assessing flood potential impacts, a society's ability to anticipate, cope with, and recover from disasters (social vulnerability) is also critical.

Natural hazards, according to Maskrey A., (1989) may receive less consideration in disaster studies. Instead, far more focus should be placed on the social contexts in which vulnerability (re)produced. These social dynamics have an impact on who is most vulnerable to hazards, as well as where they live and work, the types of settlements in which they live, their level of hazard preparedness, income, health, information access, and other spatially observable aspects of their lives.

Hence, context-based studies on social vulnerability to flood are very essential to address which groups of people are vulnerable, identify major social vulnerability factors that drive these groups of people vulnerable to hazards as there is variation in social vulnerability drivers from global to national and national to specific local areas. It is the intention of this thesis to empirically show context-based social vulnerability and indirectly measures exposure using elements in danger of floods using GIS technique and AHP techniques of MCE alongside survey tools in Awash Fentale Woreda of Afar Regional State.

1.3. Objective of the study

1.3.1. General Objective

The general objective of this study is to map flood exposure and analyze the spatial variations of social vulnerability to the 2020 *kiremt* season flood in Awash Fentale Woreda of Afar Regional State using GIS, survey tools and AHP techniques of multi-criteria Evaluation.

1.3.2. Specific Objectives:

- To map flood exposure and identify the foremost socially vulnerable groups within the study area
- To identify and rank the major causes of social vulnerability to the flooding in the study area

1.4. Research Questions

- What were the major social vulnerability drivers to flood in the study area?
- What were the foremost exposed elements to floods in the study area?
- What level did the flood affect the study area?
- Which groups of people in the study area were vulnerable to flooding?

1.5. Scope of the Study

The scope of this research is to identify the exposure level of the study area through selected elements at risk using geographic information system, and identify dominant social vulnerability factors that make them socially vulnerable to flood in the study area using survey result, expert opinion, comparative studies and Analytical Hierarchical Process techniques of multi-criteria evaluations. Not all, but Selected Theoretical Social Vulnerability (STSV) indicators were used as a proxy indicator in the survey tool for assessing and see their impact on the social vulnerability to flood in the study area. Only those selected proxy social vulnerability indicators and selected elements at risk (road, land use, population, and settlements) exposed to the 2020 Ethiopian rainy season flood of the study area were studied in time and finical constraints.

1.6. Significance of the study

The results of this study could be used to replicate the use of the methodology (GIS and MCE/AHP) for similar application both for development and research. It helps to facilitate decision making in planning out programs and projects with respect to flood preparedness, response, recovery and mitigation. Furthermore, the research finding can be used to identify priority locations where interventions can mitigate both physical and social aspects of flood vulnerability of the study area. The identified social vulnerability drivers to flood could be contributing to developing an indicator set of social vulnerability to flood exposure at larger scale. Understanding who is most exposed to floods and where are often used to adapt mitigation strategies to focus on those most in need. It can give an alternate way of seeing vulnerability without going deep into complex monetary evaluations.

1.7. Limitation of the study

This study might be challenged by introducing subjectivity to the criteria selections, weighting of the criteria as it involves experts' opinions on criteria selections and determination of criteria weight. Bedsides sensitive data such as religion, poverty, race /ethnicity, and politics were intentionally disregarded as they may mislead the respondent and the interviewee. So, this thesis is restricted to selected social vulnerability indicators, besides exposure was measured indirectly through measuring selected elements at risk to the flooding events under the GIS environment. This study uses indicator-based social vulnerability to flood and limited by not applying various complex flood analysis methods and modeling like hydraulic modeling for showing in-depth analysis of floods within the study area.

1.8. Organization of the thesis

The thesis is arranged into five chapters. Chapter one is about the background of the study, a statement of the problem, objective of the study, and significance of the study, the scope of the study, limitation of the study and organization of the thesis. Chapter two is about review of related literature, empirical review of the floods and theoretical framework of the study. Chapter three is about methods and materials used for the study and general description of the study area. Chapter four is about results and discussion of the study and Chapter five is about conclusion and recommendations based on the finding of the study.

2. REVIEW OF LITERATURE

2.1. Definitions and Concepts

How term defined influences how it is addressed. Various terminologies have been in use to elucidate hazard, vulnerability, risk, exposure, elements at risk. As stated in Mustafa, (2005) different authors use those terms differently because of variation in epistemological orientations and methodological practices as explained/defined hereunder.

RISK - can be related directly to the concept of disaster, given that it includes the total losses and damages that can be suffered after a natural hazard: dead and injured people, damage to property and interruption of activities. There is a high risk of disaster when one or more natural hazards occur in a vulnerable situation. It is the potential loss of life, injury, or destroyed or damaged assets that could occur in a system, society, or a community in a specific period, which is determined probabilistically (UN-ISDR, 2009). And it is estimated as:

RISK = (Hazard + Vulnerability)/ Coping capacity

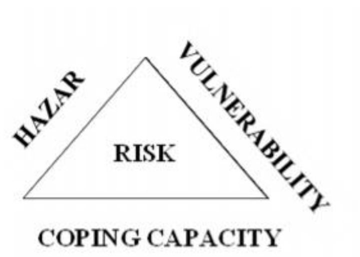


Figure 1:risk triangle

Natural disasters are generally considered as a coincidence between natural hazards (such as flood, cyclone, earthquake and drought) and conditions of vulnerability.

HAZARD - is the probability that in a given period in a given area, an extreme potentially damaging natural phenomena occurs that induces air, earth or water movements, which affect a given zone. The magnitude of the phenomenon, the probability of its occurrence and the extent of its impact can vary and, in some cases, be determined. It refers to the possible, future occurrence of natural or human-induced physical events which will have adverse effects on vulnerable and exposed elements (Birkmann, 2013).

VULNERABILITY - It is one term with many meanings, concepts and methods to various people, agencies and organizations and can be conceptualized in several ways. As noted in, Dewan, (2013) the conceptualization of vulnerability varies with the topic, discipline, organization, and/or researcher, reflecting different ideological and disciplinary perspectives.

More precise definitions of vulnerability can be operationalized in the literature on food insecurity, or famine, and natural hazards. Food insecurity vulnerability, according to Watts and Bohle (1993) defined in terms of: exposure to stress and crises; ability to manage with stress; and the severe impacts of stress and the likelihood of delayed recovery.

In terms of natural hazards, Blaikie et al., (1994) define vulnerability as having two components exposure and vulnerability. According to them, vulnerability is influenced substantially by socioeconomic structure and property relations. They clearly separate what we may term the biophysical and the social dimensions, defining vulnerability in terms of the human dimension alone as 'the capacity to anticipate, cope with, resist, and recover from the impact of a natural hazard' *(*Wisner et al., 2004*)*. The biophysical component, the exposure or measure of the hazard, is formally outside their definition of the concept of vulnerability.

In general vulnerability can be defined in different ways from different perspectives. For instance, Cutter, (1996) defined vulnerability to environmental hazard as a 'potential for loss. The term vulnerability has been used by UN-ISDR, (2009) to refer the characteristics and circumstances of a community, system, or assets that make it susceptible to the damaging effects of a hazard. A report by Save the Children (2017) defined vulnerability as a set of prevailing or consequential conditions that adversely affect people's ability to prevent, mitigate, prepare for and respond to hazardous events. Research finding by DFID, (2004) indicate that there is a high, but not overlapping correlation between poverty and vulnerability. Accordingly, poorer people are generally both more exposed and more susceptible to hazards, suffer greater relative loss of assets, and have a lower capacity to cope and recover. Furthermore, disasters can induce poverty, making better-off people poorer and the poor, destitute through their vulnerability to disaster and inability to avoid impacts. Vulnerability is considered in the study of Flood Vulnerability Index (FVI) as the extent of harm, which can be expected under certain conditions of exposure, susceptibility and resilience (Balica & Florina, 2007).

Exposure: Exposure is defined as the predisposition of a system to be disrupted by a flooding event due to its location in the same area of influence. It can also be understood as the values that are present at the location where floods can occur. These values can be goods, infrastructure, cultural heritage, agricultural fields or mostly people. The indicators for this component can be separated in two categories; the first one covers the exposure of different elements at risk and the second one give details on the general characteristics of the flood (Balica & Florina, 2007). Exposure as it is defined by Burton, Rufat and Tate, (2018) is the degree to which people and built-up environment elements intersect the spatial extent of a hazardous event. It can also be understood, according to IPCC, (2014) as the values that are present at the location where floods can occur which can be goods, infrastructure, cultural heritage, agricultural fields, or most people (elements at risk). This means having it not things were not located in (exposed to) potentially dangerous settings no problem of disaster risk would exist. However, there is confusion in using exposure instead of vulnerability, which is a distinct term. According to the IPCC, (2014) exposure is a necessary, but not sufficient, determinant of risk, for instance, it is possible to be exposed but not vulnerable (by living in a flood plain but having sufficient means to modify building structure and behavior to mitigate potential loss). But Cardona et al., (2012) argue that to be vulnerable to an extreme event, it is necessary to also be exposed.

Susceptibility: is defined as the elements exposed within the system, which influence the probabilities of being harmed at times of hazardous floods. It relates to system characteristics, including the social context of flood damage formation. Especially the awareness and preparedness of affected people regarding the risk they live with (before the flood), the institutions that are involved in mitigating and reducing the effects of the hazards and the existence of possible measures, like evacuation routes to be used during the floods (Balica & Florina, 2007).

Resilience: defined as the capacity of a system to endure any perturbation, like floods, maintaining significant levels of efficiency in its social, economic, environmental and physical components. Resilience to flood damages can be considered only in places with past events, since the main focus is on the experiences encountered during and after the floods (Balica & Florina, 2007).

The vulnerability of a system to flood events can be expressed with the following general equation:

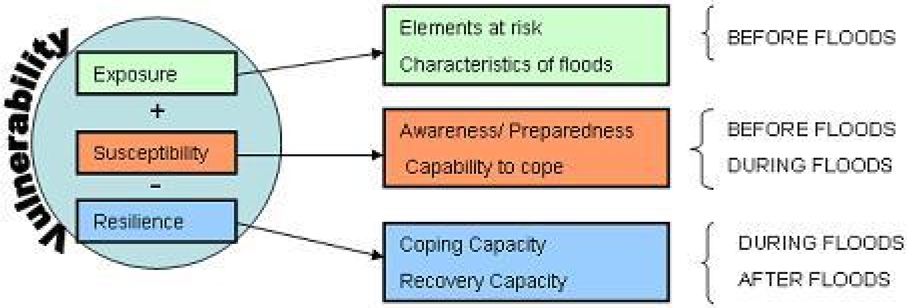


Figure 2: Factors of Vulnerability

Adapted from UNESCHO-IHE ,2021

Elements at Risk: The elements at risk are defined as the level of exposure concerning agricultural fields, buildings/infrastructure, population, economic activities, public services, and utilities, etc., which can be impacted by the flood (Dewan, 2013). It is a population, property, economic activity, including public services, or other definite values that are exposed to hazards in an area (UN-ISDR, 2009).

Studies by Anderson and Woodrow, (2019) argue that vulnerability preceding disasters, contribute to their severity, impede disaster response, and may continue to exist long after a disaster has struck. Categories of vulnerabilities as classified by Anderson and Woodrow, (2019) are given hereunder.

Physical vulnerability: People's vulnerability varies according to their material possessions. According to IGAD, (2019) poor people with limited physical/material resources are more vulnerable to disasters than rich people. This is because poor people frequently live on marginal lands, lack savings and insurance, and have poor health. These factors make them more vulnerable to disaster, and they have a more difficult time surviving and recovering from a disaster than people who have a better economic situation.

Social vulnerability: There is also a difference in vulnerability between organized and divided communities. Experience has shown that people who have been marginalized in social, economic, or political terms are more vulnerable to disasters, whereas groups that are well organized and have a strong commitment to one another suffer less when disaster strikes (IGAD, 2019). Social Vulnerability is defined by W Neil Adger et al., (2005) as the exposure of groups of people or individuals to stress as a result of environmental change's impacts.

Attitudinal Vulnerability: A community that is resistant to change and lacks initiative in life becomes increasingly reliant on outside assistance. They are unable to act independently. Their sources of income are undiversified, lack entrepreneurship, and lack the concept of collectivism. This leads to societal disunity and individualism. As a result, they become victims of conflicts, hopelessness, and pessimism, reducing their ability to cope with a disaster (M&E Studies, 2019).

Coping capacity is the means by which people or organizations use available resources, skills and opportunities to face adverse consequences that could lead to a disaster (Parsons et al., 2016). It is divided into themes of social character, economic capital, infrastructure and planning, emergency services, community capital and information and engagement.

Vulnerability vs. Exposure: Vulnerability and exposure are dynamic; varying across temporal and spatial scales, and depends on economic, social, geographic, demographic, cultural, institutional, governance, and environmental factors (Cardona et al., 2012). Vulnerability can vary significantly across both social and geographic space (Rufat et al, 2018). Social space refers to who is vulnerable, and is defined by the political, economic, and institutional capabilities of individuals at a selected time and place. By contrast, geographic space describes the location and scale at which people and places are vulnerable (Rufat et al., 2018).

2.2. Approaches to Vulnerability Studies

Maskrey A., (1989) proposed two approaches of examining vulnerability: The dominant approaches vs the alternative political economy approaches. The dominants approaches examine vulnerability through concepts such as maladaptation, the inability to incorporate hazards within living patterns and irrational human response to hazard. This approach assumed that disaster as a characteristic of hazard. Disaster is seen as a function of hazard which, as causal agent, acts on passive, vulnerable conditions. Only with the interruption of an unscheduled hazard does disaster occur. According to this approach, people are said to be vulnerable because of their own lack of information about hazards, erroneous risk perceptions, or ineffective decision-making and management processes in their community. However, the approach is unable to explain how individual decisions are affected or influenced by social and economic constraints.

The political economy approach looks at vulnerability in terms of social, economic, and political processes. It starts with the premise that dangers are inherent physical features of the places where they occur. And vulnerability is the result of certain social, economic, and political processes, not of hazard. A disaster is a severe condition that occurs as a result of these processes. This approach in contrast to the dominant approach, presents an analysis capable of addressing social process, organization, and change. Unequal economic relationships, which deny people access to basic resources such as land, food, and shelter, are seen as crippling large numbers of people on the social and territorial periphery of the global economic and political system. The empirical evidence from a wide number of case studies indicates that these people are the ones who are most likely to suffer disaster. Vulnerable circumstances are more common in the developing world than in the industrialized world. People and social groups, according to Maskrey A., (1989) may have very limited freedom in terms of how and where they live. Low-income people, for example, are commonly forced to live in high-risk places like flood plains. This is due to market forces regulating land, preventing low-income people access to safe building land, rather than a lack of information or an incompetent land use planning system.

2.3. Multi-Criteria Evaluation

MCE as defined by Malczewski, (2006) is a set of methods and procedures for evaluating decision alternatives based on multiple conflicting criteria and selecting the best. According to Abdulrahman & Bwambale, (2021) it is a decision-making procedure used when there is inadequate qualitative ground data availability to solve complex problems with multiple variables and alternatives, high degree of uncertainty, and scientific and socioeconomic challenges. It as an expert-based modeling approaches that includes techniques that allow for a better understanding of social vulnerability within a hierarchical structure. It helps to assess what and who is in danger, and where targeted impact-reduction strategies should be implemented. For instance, Cabral et al., (2012) recommend MCE as an effective method to arrange the conceptual understanding of social vulnerability since it decomposes its complexity into a hierarchical structure and proposed a three-level disaggregation hierarchy that aimed to comprise the social vulnerability dimensions. According to Abdulrahman & Bwambale, (2021) Analytical Hierarchical Process (AHP), which is used for decomposing complex problems into their components, is one of the best and most frequently used approaches among all multicriteria evaluation methods for its accuracy, flexibility, and less data requirement.

Analytical Hierarchy Process in combination with field survey results was used to identify and rank factors or criteria that influence a household's vulnerability to the 2020 Ethiopian *Kirmet* season floods and to what extent. The methodological process for assessing social vulnerability using MCE as suggested by Malczewski, (2006) is composed of the following steps: (1) The hierarchical structure of the social vulnerability model, (2) standardization of the factors/criteria, (3) criteria weighting, and (4) decision rules

2.4. Application of Geographic Information System in risk assessment

Generally accepted use of the term GIS as stated by Bolstad, (2016) refers to a computer-based system to aid in the collection, maintenance, storage, analysis, output, and distribution of spatial data and information. Researcher like Dewan, (2013) and Milenković and Kekic, (2016) described GIS as a tool that is capable of identifying objects spatially and have been employed in each of the emergency management phases (mitigation, preparedness, response, and recovery) that are deemed suitable to enhance one's knowledge of risks caused by natural hazards.

According to World, (2010) the most common application of GIS in hazard assessment is the creation of hazard maps. Furthermore, the study indicated that GIS can be used for risk assessment (identification of hazards, determination of new hazards through overlay of hazard data sets, storing hazard and vulnerability data in GIS databases; evaluating potential damages and risks) and, finally, GIS decision makers can take preventive actions by displaying the potential damages that can be caused by natural hazards. Hazard maps depicting hazardous areas are useful in determining whether a piece of land is located in a specific hazardous area. NBRO (2015). As a result, geographic information systems (GIS) have become almost indispensable in the risk assessment process. As per Demir and Kisi, (2021) GIS has been successfully used in floods and related issues to visualize the extent of flooding, analyze flood maps to produce a flood damage estimation, and flood risk maps. However, in this study, GIS is only used to show the study area's exposure through mapping of selected elements at risk.

2.5. Social Vulnerability

According to *Wisner et al., (2004)* social vulnerability is defined as "*the characteristics of a person or group and their situation that influence their capacity to anticipate, cope with, resist and recover from the impact of a natural hazard (an extreme natural event or process*". Cardona et al., (2012) explained it as *individuals* and communities are differentially exposed and vulnerable to disasters based on factors such as wealth, education, race/ethnicity/religion, gender, age, class/caste, disability, and health status. Social systems generate unequal exposure to risk by making some people more prone to disaster than others and these inequalities are largely a function of the power relations (class, age, gender, and ethnicity among others) operative in every society (Deborah et al., 2013).

According to W Neil Adger et al., (2005) social vulnerability is a negative state endured by groups or individuals. In the broadest sense, vulnerability occurs because livelihoods and social systems are exposed to stress and are unable to cope effectively with that stress. Though most evident in times of crisis, vulnerability is a chronic and pervasive state related to the underlying economic and social situation, not only in terms of lack of income and resources but also with respect to a range of factors determined by government policies, societal trends, and so on.

According to Prior et al., (2017) Social vulnerability refers to the susceptibility of human beings to harm in their physical and social environments. The concept of social vulnerability focuses on the processes and structures in society that might negatively affect the likelihood that "some socially defined group in society will suffer disproportionately" from a hazard. Social vulnerability, which embraces demographics, socioeconomic, infrastructures, and lifelines, defines the vulnerability of people, particularly marginal groups (Dewan, 2013). And high vulnerability and exposure are generally the outcomes of skewed development processes, such as those associated with environmental mismanagement, demographic changes, rapid and unplanned urbanization in hazardous areas, failed governance, and the scarcity of livelihood options for the poor (Cardona et al., 2012).

Social Vulnerability is defined by W Neil Adger et al., (2005) as the exposure of groups of people or individuals to stress as a result of environmental change's impacts. In the social sense, stress refers to the disturbance of a group's or individual's livelihoods as well as the forced adaptation to a changing physical environment. As a result, social vulnerability includes disruption of livelihoods and loss of security. Such pressures are generally common among disadvantaged groups and are linked to the underlying economic and social situation, including a lack of income and resources, as well as war, civil strife, and other factors. Social vulnerability and resilience are determined by a host of complex social processes and economic factors, from access to resources through to informal and formal social security, insurance and social capital. In essence, these determinants are related to the concept of entitlements and access of individuals or groups to resources. Resilience and vulnerability can be observed at different scales, but they are essentially relative concepts.

According to W Neil Adger et al., (2005) vulnerability is socially differentiated. Vulnerability to environmental change is not the same for different populations living under different environmental conditions or faced with complex interactions of social norms, political institutions and resource endowments, technologies and inequalities. Moreover, it has been demonstrated that the social causes of vulnerability often evolve on much more rapid temporal scales than the environmental changes that interact with these processes.

2.6. Social Vulnerability indicators

As stated in de Brito et al., (2018) several methods have been proposed to estimate vulnerability such as damage curves, fragility curves and vulnerability indicators, as vulnerability is not directly measurable. Of these indicators-based methods are transparent, easy to use, and understand and do not require detailed data as the other methods. An indicator is a quantitative or qualitative measure derived from observed facts that can simplify and explain a complex reality (Rufat et al., 2018).

Regardless of how scholars define social vulnerability, the approaches and indicators they use remain contested (Kuhlicke et al., 2011). The vast majority of social vulnerability indices employ equal weighting and additive models based on the same leading indicators, regardless of context. However, according to Mustafa et al., (2011) there is a large gap between the contextual complexity revealed through qualitative studies and generalized quantitative metrics produced by social vulnerability indices.

Through a meta-analysis of 67 flood disaster case studies (1997–2013), Rufat et al., (2015) profiled the leading drivers of social vulnerability to floods and found that demographic characteristics, socioeconomic status, and health are the leading empirical drivers of social vulnerability to damaging flood events.

Table 1: Theoretical indicators of social vulnerability

Coping Capacity	Individual Capacity
	Household Capacity
	Social Capital
Demographic Characteristics	Age
	Race and Ethnicity
	Family Structure
	Gender
	Functional Needs
	Language Proficiency
Health	Access
	Stress
	Disease
	Mortality
	Sanitation
Land Tenure	Owners
	Renters
	Squatters
Neighborhood Characteristics	Transportation
	Population Density
	Housing
	Resource Dependency
Risk Perceptions	Awareness
	Prior Experience
	Knowledge of Flood protection measure
	Risk Denial/Acceptance
	Trust in Officials
Socio Economic Status	Income
	Wealth
	Education

Source: Rufat et al., (2015)

Balica and Florina, (2007) identified overall flood vulnerability indicators, which are also presented here.

Table 2: Over all flood vulnerability indicators

Overall Indicators			
Flood vulnerability	**Exposure**	**Susceptibilities**	**Resilience**
Social Component	Population density	Past experience	warning system
	Population in flood area	Education (literacy rate)	evacuation routes
	Closeness to inundation areas	Preparedness	institutional capacity
	Population Close to coastlines	Awareness	emergency services
	Population under poverty	Trust in institutions	shelter
	% Of urbanized area	Communications penetration rate	
	Rural population	Hospitals	
	Cadaster survey	Population with access to sanitations	
	Cultural Heritage	Rural Populations who access to WS	
	% of young and elder	Quality of water supply	
	slums	population growth	
		Human health	
		urban planning	
Economic component	Land use	unemployment	investment in counter measure
	proximity to river	income	Infrastructure management

	Closeness to inundation areas	inequality	Dams and storage capacity
	% Of urbanized areas	quality of infrastructure	flood insurance
	Cadaster survey	years of sustaining health life	recovery time
		Human health	past experience
		urban growth	Dikes/Levees
		child mortality	
Environmental component	Ground water level	Natural reservations	Recovery time to flood
	Land use	years of sustaining health life	Environmental concern
	Over used areas	quality of infrastructure	
	Degraded areas	Human health	
	unpopulated land area	urban growth	
	types of vegetation	child mortality	
	% Of urbanized areas		
	Forest change rate		
Physical component	Topography(slope)	Building codes	Dams and storage capacity
	Geography		Roads
	Geology		Dikes/Levees
	Heavy rainfall		
	Flood duration		
	Return periods		
	proximity to river		
	soil moisture		
	evaporation rate		
	Temperature (yearly average)		
	River discharge		
	Frequency of		

	occurrence		
	Flow velocity		
	Storm surge		
	Tidal		
	Flood water depth		
	Sedimentation load		
	Coastline		
	Coastal bathometer		

Source: UNESCHO-IHE ,2021

Selected Social Vulnerability Indicators

Due to the multidimensionality of social vulnerability, as argued by Rufat et al., (2018) it is difficult or impossible to represent the concept of social vulnerability with a single equation or universal set of metrics across scales and hazards. And he recommended proxy measures must be chosen to convey the overall capacity of populations to prepare for, respond to, and recover from damaging events (Rufat et al., 2018). As a result, some of these indicators were chosen for this thesis and discussed further below.

Demographic Characteristics

According to Walker and Burningham, (2012) floods affect different population groups differently, and the phrase "vulnerable groups" should be used with caution because not all members of the group are equally vulnerable, and vulnerability is a dynamic rather than a static quality (people can move in and out of vulnerability). Despite differing views on some of the demographic characteristics that can contribute to social vulnerability to floods, as explained by Rufat et al., (2015) this study took into account household compositions such as age, family size, and gender.

Age was selected as a proxy indicator of social vulnerability to floods because studies show that vulnerability to floods varies among age groups. Studies by Rufat et al., (2015) stated that children less than 14 years of age, persons aged 65 years and above were considered as the most vulnerable section of the society for children lack knowledge and experience, very limited risk perception from warning signals, media information and deciding on evacuation. As Vink,

(2014) stated the failure of parents to continuously look after their children also lead to children's exposure to flood vulnerability as children spend a great deal of their time in infant care facilities and schools, and playing with their friends on the streets.

According to Vink, (2014) adult vulnerability is mostly understood in the context of their health conditions and social networks. This is because older adults are more likely to have impaired physical mobility, diminished sensory awareness, and chronic diseases, which, when combined with a lower income, can make it difficult to take appropriate action throughout the flood disaster management cycle. This is due to the fact that older adults frequently have difficulty receiving disaster information and warning signals; second, older adults are known to be less likely to comply with suggestions or orders issued by local governments for evacuation; this means that they frequently do not leave their homes due to psychological, medical, or economic conditions; however, their compliance with evacuation orders has not yet been generalized (Vink, 2014).

As a result, the elderly and children face increased social vulnerability (Fernandez et al., 2016). This means that people who are very young or very old are more physically vulnerable and dependent.

Gender is also used to distinguish between male and female vulnerability. When it comes to risk perception and disaster recovery, men and women have different perspectives. Women, for example, can have a more difficult time recovering than men owing to sector-specific employment, lower wages, and family care responsibilities (Cutter et al., 2003). However, according to Fekete et al., (2010) females have a higher risk perception and readiness for action than men.

Family size is another important demographic factor. According to ACF, (2010) an outsized family has difficulty evacuating due to their large size.

Socioeconomic status:

These indicators were also chosen to assess the ability to absorb losses and improve resilience to flood impacts. According to Cutter et al., (2003) wealth allows communities to absorb and recover from losses more quickly as a result of insurance, social safety nets, and entitlement programs (high status may increase or decrease social vulnerability while low income or status increase social vulnerability).

Mean monthly household income/earnings, level of educational attainment, access to (road, health facilities, schools, and elevated areas), source of income, and employment status were chosen as socioeconomic dimensions of vulnerability for this study because they could disadvantage people in the in pre, during, and post-disaster management cycles.

Household income has an impact on replacing lost/damaged property and on post-disaster recovery in a variety of ways. This means that people with lower incomes are less likely to replace their lost property, making them vulnerable. According to Hebb and Mortsch, (2007) low-income people lack the financial resources to recoup their lost resources. The poor are less likely to have the income or assets needed to prepare for or recover from a disaster, and even high-income populations may suffer higher household losses in absolute terms if their overall position is not mitigated by insurance policies, financial investments, and stable employment (Flanagan et al., 2011).

The level of education about natural hazards like floods assesses people's ability to comprehend and learn. According to (Müller et al., 2011; Kumpulainen, 2006) the assumption about educational level is that people with a low educational level do not find, seek, or understand information about risks and are thus vulnerable. Cutter et al., (2003) confirm this assumption by stating that "lower education increases vulnerability, while higher education decreases vulnerability and lower education limits the ability to understand warning information and access to recovery information."

In their studies (Kuhlicke et al., 2011) state that unemployed individuals may not have money to protect themselves; and affected disproportionately in terms of post-disaster recovery and coping mechanisms.

Risk perceptions

Knowledge of flood protection measures, prior experience, and flood awareness were used as proxies for risk perceptions because they influence overall risk reduction efforts. Messner and Meyer, (2005) found that regions with low levels of flood risk perception and a low level of preparedness for coping with flood events have higher flood damage levels than the average – their vulnerability to flood events is usually high. Their perceptions may also be influenced by the frequency of flood events and the level of flood protection. This means that if flood events are rare and flood protection in the form of dykes and levees is strong, many laymen, experts, and politicians do not believe they will ever be affected by flooding in their area.

Coping Capacity

Although social vulnerability analyses typically focus on the social characteristics that influence susceptibility to adverse effects, social vulnerability is also a function of individuals' ability to deal with hazard impacts in the short term and adapt in the long term (Rufat et al., 2015). In this study, the household's preventative actions taken before, during, and after the flood were used as a proxy indicator of coping capacity.

Access to roads, health care, and elevated areas were also used as proxies for socioeconomic dimensions of social vulnerability. These indicators describe the socioeconomic and institutional properties that increase or decrease the society's vulnerability to flood hazards. Weights were assigned to subclasses of social vulnerability indicators based on their influence on flooding vulnerability in the study area.

2.7. Floods in Ethiopia

According to NBRO, (2015) a flood is defined as a rising body of water overflowing on to lands that are not normally under water, and it occurs in well-defined areas when rivers or canals are unable to contain runoff from catchments. Flood types differ depending on the location and cause of the flooding. Low-lying areas and valleys of waterways are vulnerable to natural or seasonal flooding caused by riverine floods induced by river overflow. Studies by IFRC, (2021) indicate that flooding is among the most prevalent natural hazards affecting people around the world. In the past three decades, the average number of climate and weather-related disasters has increased by nearly 35 per cent. Over the past decade alone, 83 per cent of all disasters were caused by extreme weather and climate related events that killed 410,000 people and affected 1.7 billion people. The African continent alone experienced over 2,000 major disaster events during the last three decades with most of them being extreme weather, climate-induced disasters such as food insecurity, droughts, floods, flash floods, landslides, storms and cyclones. The study also shows that over 71 million people in Sub-Saharan African are estimated to live in both extreme poverty and significant flood risk.

In the analysis of Kron, (2015) argue that major driving factors for risk from water related events like tsunamis, storm surges, river floods, flash floods, mass movements and droughts attributed to the unabated increase in global population, the concentration of people in high-risk areas like coasts, flood plains and hillsides, the increase in vulnerability of assets, infrastructure and social systems, and the consequences of environmental and climatic changes.

In Ethiopia, flooding is that the country's second major hazard next to Drought. As indicated in, Muluneh, (2013) that like drought, flood disasters have shown a marked increase in both their frequency and coverage of affected areas. Studies on flood by Swiss NGO, (2015) found that major floods in Ethiopia experienced in 1988, 1993, 1994, 1995, 1996, 2006, and 2012 caused significant loss of life and property. Recently, nearly 1.1 million people are suffering from floods, including over 313,000 people displaced, with Afar, Amhara, Gambella, Oromia, Somali and Southern Nations, Nationalities, and People's (SNNP) regions most-affected (UN/OCHA, 2020). Based on this study, settlements and croplands in lowland areas along the basins of major rivers like the Awash, Wabe Shebelle, Omo and Gibe River basins are highly susceptible to flooding, which usually occurs following intense rainfall within the highlands. Annual flooding is additionally experienced in urban areas, notably in Addis Ababa and Dire Dawa, causing property damage. Incidents of flash floods are reportedly common in most parts of the country, especially when rain occurs following prolonged dry seasons. Besides property damage flooding could create good opportunities for the proliferation of water-borne diseases. Recorded flood disasters between 1999 and 2020 affected over 2 million people in Ethiopia, as shown in Table 2.

Table 3: Recorded flood disasters in Ethiopia

Date	Number of people affected
October 1999 (two flood disasters)	124,000
April 2003	110,000
April 2005	235,418
August 2006	38,000
October 2006	361,600
July 2007	239,586
October 2020	1,100,000
Total	2,208,604

Source: World Bank, GFDRR, and ISDR, (2011) and UN/OCHA, (2020)

As UN/OCHA, (2011) report showed in table 2 that flood hazards in Ethiopia became more frequent and of accelerating severity. For example, floods in 2006 have battered huge portions of eastern, southern, and northern Ethiopia. Floods that have also occurred in 2007 and 2008 have caused huge havoc on the livelihoods of the many rural people. Recently, repeated flash floods within the northern and eastern parts of Ethiopia have led to the loss of the many lives and therefore the destruction of household property and environmental resources. The flood hazards in Afar are the combined results of its topography, land cover, runoff from highland, and intensive torrential rainfall conditions. Generally, the rise within the destructive nature of floods within the Afar Region is often partly attributed to climate change/variability and unsustainable practices from increased population (livestock and human) pressures on the environment. The vulnerability of the population living along the Awash River and within the marshlands has also been exacerbated thanks to seemingly inappropriate settlement patterns in these flood-prone areas in recent years. During the season, the riverside areas are the sole places with pasture and are essential for the survival of humans and livestock.

This fact is supported by NDRMC (2020) report, which shows in year 2020 alone, heavy rainfall has been reported across Ethiopia during the seasonal June to September rains. This has caused flooding in six of the ten regions. Around 1,017,854 people were affected and 292,863 people were displaced by floods across Ethiopia (NDRMC, 2020). Oromia region has been the worst hit with over 447,565 people suffering from the floods followed by Afar Regional State around 162,921 people affected. The floods have killed livestock, destroyed crops, and damaged homes and public infrastructure to an extent not seen in decades (MDRET023, 2020). Following this incident, there was a better risk of the spread of COVID-19, cholera outbreak, favorable conditions for mosquito breeding, and another water-borne disease (NDRMC, 2020). Awash Fentale woreda was one among the woredas within the Afar region identified by the National Meteorological Agency as flood risk areas and suffering from the Ethiopian 2020 *kiremt* season flood (NDRMC, 2020).

2.8. Theoretical Framework of the Study

Multicriteria evaluation (MCE) through techniques of Analytical Hierarchical Process by Malczewski, (2006) and Velasquez, (2003) “Quantifying social aspects of disaster vulnerability” and IGADS (2019) hazard assessment using earth observation and GIS were used as a theoretical framework for this study.

MCE as defined by Malczewski, (2006) is a set of methods and procedures for evaluating decision alternatives based on multiple conflicting criteria and selecting the best. Cabral et al., (2012) recommend MCE as an effective method to arrange the conceptual understanding of social vulnerability since it decomposes its complexity into a hierarchical structure and proposed a three-level disaggregation hierarchy that aimed to comprise the social vulnerability dimensions.

Analytical Hierarchic Process is one of the multi-criteria evaluation techniques, was first developed by Saaty (1980). It provides a chance to evaluate judgment consistency, selects priorities among criteria and alternatives, and simplifies preference ratings among decision criteria using pairwise comparisons. An increasing number of studies have found that the AHP technique involves four steps: -decompose the problem into a hierarchy, criteria weighting (pairwise comparisons and establish priorities among the elements in the hierarchy), Evaluate and check the consistency of judgments, and Decision making. Criterion weights are assigned using a simple pairing procedure called pairwise comparison using Saaty's 9-points Continuous rating scale 1–9 which indicates the relative scale of importance, as shown in Table (3). A pairwise comparison matrix is used to compare two alternatives at a time by assigning values of relative importance from one alternative over another alternative. The scale of relative importance has a range between one and nine in which one is equal importance and nine is extreme importance.

Table 4: Saaty's 9-points continuous rating

1/9	1/7	1/5	1/3	1	3	5	7	9
Extremely	Very Strongly	strongly	Moderately	equally	Moderately	strongly	Very Strongly	Extremely
Less important				Standard	More important			

Source: Fernandez et al., (2016)

Velasquez, (2003) developed a similar procedure in this case to quantify the multidimensional nature of vulnerability using a single composite index called the social vulnerability index. In his paper "Quantifying the Social Aspects of Disaster Vulnerability," he demonstrated the difficulties of comparing social vulnerability among different vulnerable groups using qualitative (descriptive/categorical) data because such methods of measuring vulnerability do not show the circumstances under which a person or community becomes vulnerable or not, nor do they show whether the distinction is clear or fuzzy. Hence, he comes up with a framework for the quantification of social vulnerability to a natural disaster. This involves

- standardization using the equation [Xi = (Ri – Rmin)/ (Rmax - Rmin)],

- normalization of scores to make comparison among factors driving for social vulnerability,
- Providing weights for these driving factors.

He proposed that individuals or communities be assigned to a specific decision set as a means of decision-making. A scale of issues can be created based on a damage reports, interviews, surveys, and observations, and the elements considered can be categorized and scored. Individual responses are then scored after being evaluated using the study's criteria. By assigning weights to each factor, a weighted linear combination of factors can be created. The outcomes provide a social vulnerability index for a specific physical vulnerability. The usefulness of the index's stems from the weights assigned to each criterion used to show which aspect is contributing to the community's social vulnerability.

In this framework, the rater chooses a factor and assigns it a value of one (1) to it as a standard-issue, as shown in the table (3). Then, using the scale provided, each individual or group attempts every possible pairing with the standard-issue. By dividing each score by the highest rated factor considered, a normalized scale of importance is obtained. This gives each factor a normalized score in relation to the most important factor (having a score of 1). The sum is used to establish a weight among the normalized scores, and the weights are obtained by dividing the normalized scores by their sum.

IGADS (2019) hazard assessment using earth observation and GIS were used as a framework for analyzing and mapping the elements at risk (exposure) in the study area. This framework involves the acquisition of sentinel-2 satellites images from Copernicus Open Access Hub for the study area, preprocessing of the satellites images, computation of Normalized Water Difference Index (NWDI), and identification of flooded and non-flooded areas based on NWDI results. This process resulted in the flood extent map or flood map of the study area. A flood extent map is about the spatial boundaries of the flooded area. This framework was chosen because the use of satellite data, such as Sentinel-2, greatly simplifies the determination of flood extent for large areas and eliminates the need for time-consuming and labor-intensive fieldwork. Furthermore, it is critical for rapid damage assessment following flood events, and it can provide disaster management and planners with a cost-effective and practical method of identifying flooded areas, flood-vulnerable areas, and the extent of flood disaster impacts.

The spatial interaction between the elements at risk and the flood hazard footprints is depicted in this framework using ArcGIS 10.5 by simply overlaying of the flood hazard map (flood extent map) with the elements at risk map.

Because obtaining data on all elements at risk was difficult, the study area's land use, human settlements, populations, and road network were used to demonstrate the extent of the impact of the 2020 Ethiopian *kirmet* flood on the study area.

2.9. Conceptual framework

As illustrated in figure (3), the conceptual framework of the study is illustrated below. Flood exposure mapping was done through those elements at risk with spatial dimensions such as land use, settlements, population and road networks. These element at risk were overlayed on flood extent map so as to determine the extent of each element at risk being exposed to the 2020 *kiremt* season flood.

The social groups that were vulnerable to flooding were identified through the survey that was conducted in 120 households. Analytical hierarchical process of multicriteria evaluation has been applied to weigh, compare, rank and determine the extent to which each criterion contributed to social vulnerability to flooding in the study area through the following process and workflows.

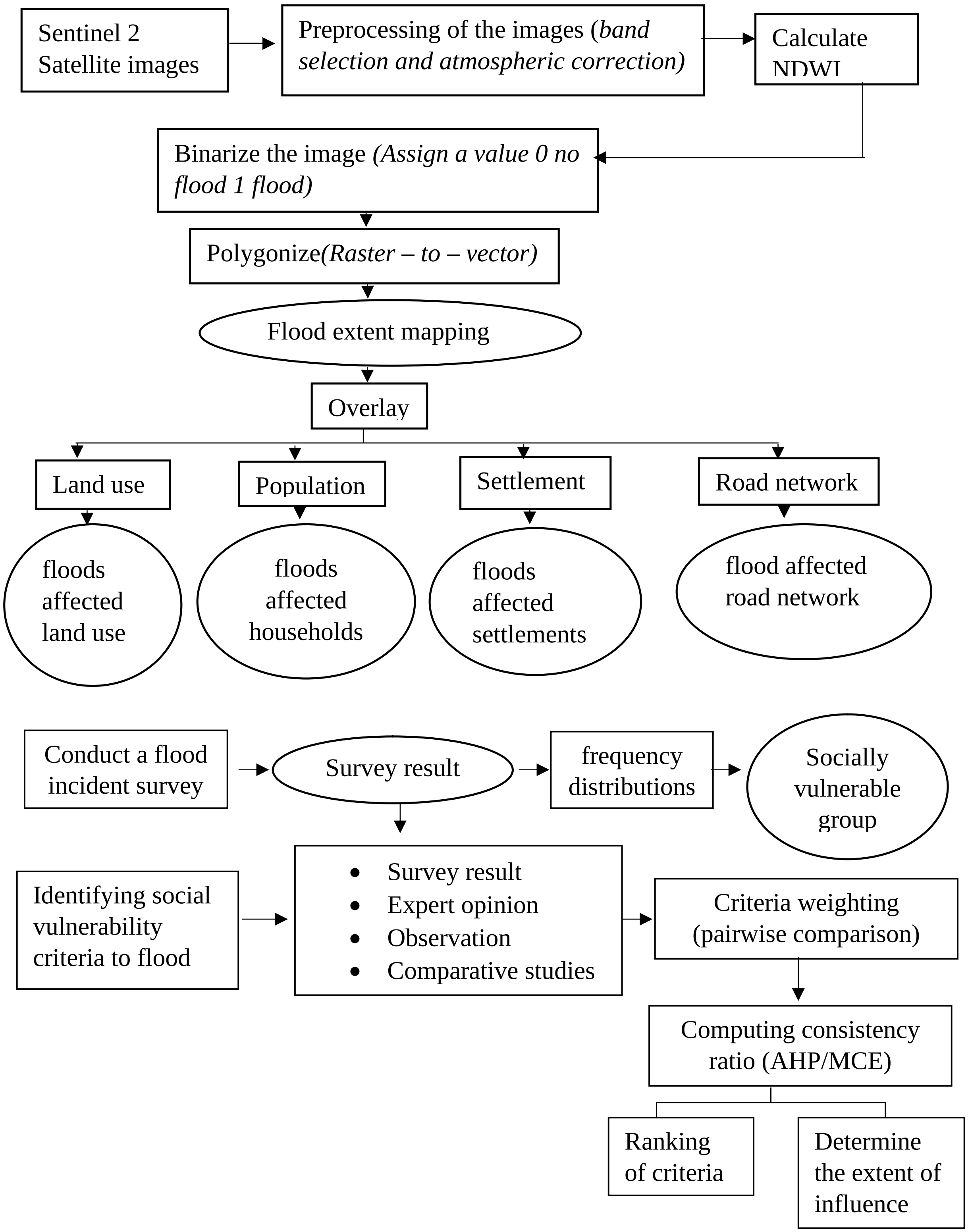


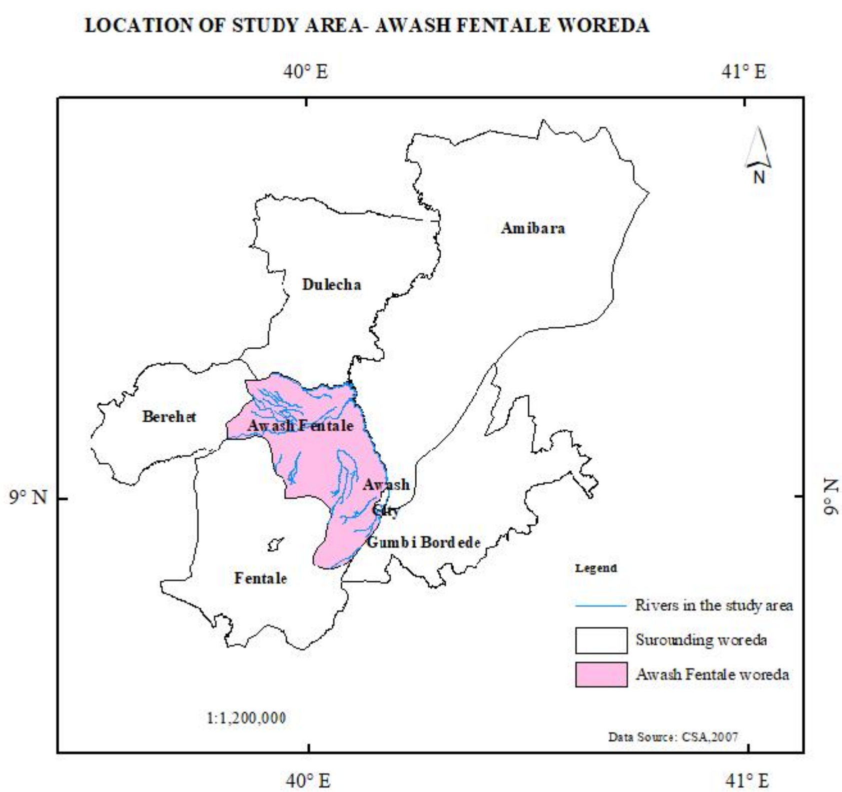
Figure 3:conceptual Framework of Exposure mapping and Social Vulnerability Analysis

3. METHODS AND MATERIALS

3.1. Description of the study area

3.1.1. Location and Demography

Awash Fentale woreda is located in Afar Regional States of Zone 3 administration and is bordered on the north by Dulecha, on the east by Amibara woreda of Afar Region, on the west by Fentale, on the south east by Gumbi Bordede woreda of Oromia Region, and on the north west by Berehet Woreda of Amhara Regional State as shown in Figure 3. The woreda is divided administratively into five rural kebeles (Kebena, Boloyita, Doho, Diduba, and Awash Biherawi park) and two towns (Sabure and Awash Sebat kilo). It is located at the foothills of the eastern mountains of the Amhara region, where the Kesem and Kebana rivers that cross the woreda originate. The woreda is traversed by the rivers Kebena, Bulga (kesem), Awash, and its tributary Germam, which contribute to annual flooding (both beneficial and damaging) by providing water for irrigation, daily economic and social life.



Data source: CSA, 2007

Figure 4: Map of study area

The Kesem dam is also located in this woreda, and its primary purpose, according to Kibret et al., (2017), is to irrigate sugarcane crops that cover 20,000 hectares of floodplain downstream of the dam. The Awash National Park occupies a sizable portion of the woreda's aerial extent, which is 1,046 km2.

The administration office of the Awash Fentale Woreda estimated the woreda population for 2020 at 39,429, of which 21053 males and 18373 females, with a sex ratio of 87 F/100 M. With a population density of 37.69sqkm, urban areas have 55 % of the population and rural areas have 45 %. According to (CSA, 2007), the average household size in the study area was 4.0 person, and the population was made up of 68.26 % Muslims, 25.75 % Orthodox Christians, and 5.21 % Protestants.

3.1.2. Topography, climate, and Vegetation

The woreda's topography is generally flat, with elevations ranging from 750 to 1050 meters above sea level and a mean slope of 1.75 %. The area's climate is hot and semi-arid, with an average annual temperature of 27.9°C. According to Degefu et al., (2020), the mean annual total rainfall and evapotranspiration are estimated to be 573.4mm. Precipitation is generally scarce, irregular, and unpredictable, with a bimodal pattern that appears to occur in February-April and July-August. Rainfall fell below the long-term average in 20 of the last 35 years (Degefu et al., 2020).

According to Rettberg, (2010) the area is further characterized by frequent drought and flood episodes, which have an impact on the ecosystem and livelihoods. Based on DRMFSS, (2014) the flood resulted in the loss of lives and property, as well as an increase in the prevalence of diseases (malaria and diarrhea) among those living in the area. According to IOM (2018) reports on displacement tracking matrix, 365 households and 2,190 people from Awash Fentale Woreda were displaced as a result of climate-related factors such as drought and flooding. Cambisols on hilly slopes and Fluvisols on flatter areas and along river courses are the main types of soils in the study area (Haregeweyn et al., 2013).

The average road density (all types included) in the study area is 24.45 % (DRMFSS, 2014). The landscape is covered by grassland, open bushland, and forest along perennial river courses. An invasive species, *Prosopis Juliflora*, has affected vast areas of native grasslands, shrublands, and woodlands (Bekele et al., 2018). The Afar ethnic group constitutes the majority of the population in the Middle Awash Valley.

3.1.3. Livelihoods

According to Abdulahi, (2019) pastoralism is a culture, livelihood system, and extensive use of rangelands, and pastoralists live in areas that are frequently described as marginal, remote, conflict-prone, food insecure, and associated with high levels of vulnerability.

Pastoralism and Agropastoralism are the major source of livelihood in the region as described in Nega, (2010) 85 % of the total population are pastoralists and the others 15% are agro-pastoralist. Camel, cattle, goats, and sheep are the most common animals raised for milk, milk products, meat, offspring sales, and sociocultural purposes. However, pastoral livelihoods in this area are severely hampered by grazing land scarcity caused by both climatic and anthropogenic factors (Deressa et al., 2009).

However, as stated by Nega, (2010) pastoralists in Ethiopia have recently faced new challenges such as competition for water and pasture, being underrepresented in socioeconomic and political activities, ethnic-based conflicts, poverty, and uneven drought and climate change, despite the constitutional right of pastoral communities to free land grazing, fair use of natural resources, market access and a fair price, and not being displaced from their lands. "Since the 1950s, some of the customary communal grazing lands have been converted into large-scale state-owned irrigated agriculture, including export-oriented sugarcane plantations and the associated Kessem Sugar Factory, which was established in 2010 in Awash Fentale woreda" (Degefu et al., 2019).

3.2. Research Method

To address the specific objectives stated in chapter one, this study used a combination of AHP techniques of MCE, GIS, and Remote sensing, as well as survey methods. The use of geographic information systems (GIS) was used to address the exposure and extent of flood impacts through selected elements at risk. To decompose, identify, and rank the major drivers of social vulnerability in the study area, AHP of multi-criteria evaluations were used. The survey method was used to identify the most socially vulnerable groups in the study area, and the results were used to select and weight social vulnerability criteria.

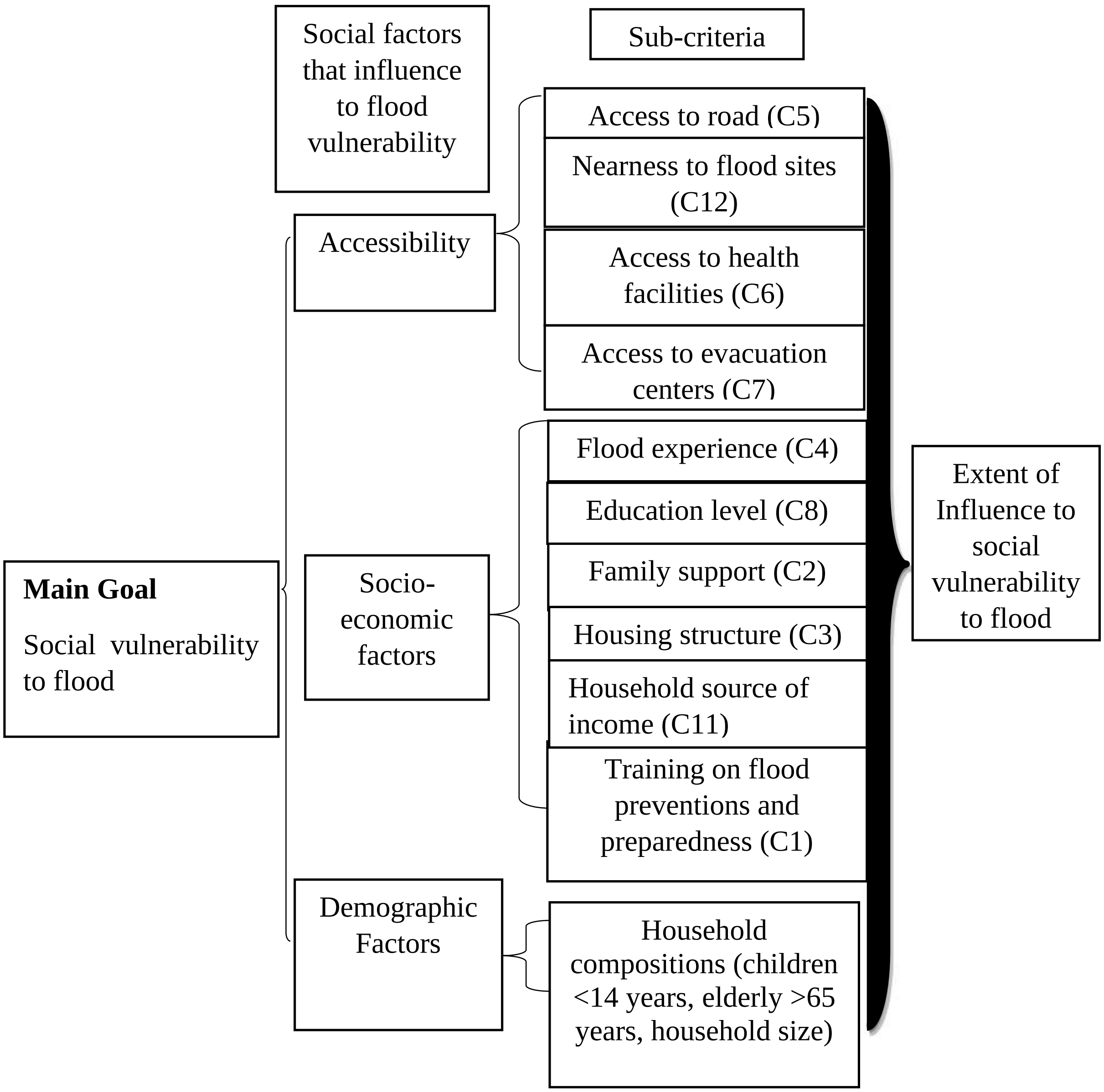
3.2.1. AHP Methods

According to Malczewski, (2006) the Analytical Hierarchical Process(AHP) method employs hierarchical structures to deconstruct a problem and assign priorities to alternatives based on user judgment on paired comparisons. AHP techniques were primarily used to decompose the problem into a hierarchy, weight criteria (pairwise comparisons and establishing priorities among the elements in the hierarchy), evaluate and check the consistency of judgments and decision making. The weights were then calculated using a pairwise comparison table based on rankings determined by the relative influence of each factor on flood vulnerability. The pairwise comparison chart was created using survey results and expert opinions from the study area, field observations, and a review of literature from comparable studies.

3.2.1.1. Selection of criteria

AHP assists in selecting the best alternative among various options and criteria, in this case the major factor contributing to social vulnerability to flooding in the study area, by decomposing the problem under investigation into its criteria and sub-criteria, as shown in figure 3. Detailed data on demographic, socioeconomic, risk perceptions, coping mechanisms, and vulnerability factors were collected using EPI collect, an opensource data collection tool (details of the questionnaires Annexed here).

However, for ease of AHP computation, the study's findings were summarized into three major social factors that influence flood vulnerability, namely socioeconomic, accessibility, and demographic characteristics. Field observations, survey results, and key experts from the study area were used to select and weight social vulnerability criteria.



Source: own, June 2021

Figure 5: Social Vulnerability to flood evaluation framework

Based on a review of comparable studies, expert opinion, survey results, and field observations, twelve important sub-criteria were identified to evaluate the factors that influence the community within the study area to flood (table 4). These include flood prevention and preparedness training (C1), family support (lack of assistance) (C2), housing status (housing materials) (C3), flood experience (C4), road access (C5), access to health facilities (C6), access to evacuation centers

(C7), an education level (C8), access to flood information (C9), livelihood base (charcoal productions, livestock...) (C10), average household income (C11), and proximity to flood sites (Situated around flood areas) (C12).

Table 5: Major factors and data sources used for social vulnerability to floods analysis

Factors	**Criteria**	**Data sources**
Accessibility	Access to road(C6)	SRTM-DEM data, shape files (CSA, EMA, UN/OCHA, DRMC)
	Access to health facilities(C7)	
	Access to evacuation centers (schools, local hall, elevated areas. etc.) (C8)	
	Closeness to flood sites (situated around flood areas) (C12)	
Socio Economic	Family support (lack of assistance) (C3)	Survey results/field observations/Expert opinions
	Housing Status (housing materials) (C4)	
	Education level(C9)	
	Source of income (charcoal productions, livestock…) (C11)	
	Average household income(C11)	
Demographic	Household Compositions (Children<14 years and Elderly >65 years large family size and female headed) (C1)	Survey results/field observations/Expert opinions
Coping capacity	Training on flood preventions and preparedness(C2)	Survey results/field observations/Expert opinions
Risk Perceptions	Flood experience(C5)	Survey results/field observations/Expert opinions
	Access to Information about flood(C10)	

Source: own, June 2021

As stated in the literature section, vulnerability is context-specific; thus, the above criteria were chosen for the study area based on the survey results, expert opinion, field observations, and a review of comparable studies with justifications presented in table 5.

Table 6: Justifications given for selected criteria

Criteria	**Justifications**
C1, Household Compositions (Children<14 years and Elderly >65 years large family size and female headed	Households with a large family size and a higher number of dependents, such as children and the elderly, pose a significant challenge to a household during evacuations and recovery after a disaster because these people require special assistance.
C2, Training on flood preventions and preparedness	Flood prevention and preparedness training may result in a different level of vulnerability because those who receive the training are equipped with the knowledge of what to do in the event of a flood disaster.
C3, Support (family or social)	The level of support, whether from within the family or from outside (Social), results in a different level of vulnerability to flooding. As ties among family members in households strengthen, their level of vulnerability decreases. Strong family and social ties increase resilience to floods and other difficult situations. This is due to the fact that they share resources. Households that do not receive assistance, on the other hand, are more likely to face difficulties during and after a flood disaster.
C4, Housing structure	Housing made of different materials has varying degrees of flood vulnerability (those made of hut or Chika have a higher chance of flood vulnerability than those made of concrete or stone). Housing styles also affect the level of vulnerability to flooding, as houses built on elevated columns are more vulnerable to flooding than low-lying housing.
C5, Flood experience	The level of flood experience also resulted in a different level of vulnerability, as households with flood experience have different ways of dealing with flood events.

Criteria	Justifications
C6, Access to road	Access to the road exposes households to varying degrees of vulnerability in terms of receiving emergency assistance. It also has an impact on receiving various social services. Those who live far from the road and transportation have a higher risk of flooding.
C7, Access to health facilities	Access to health care facilities also places households at varying levels of vulnerability in terms of saving lives and treating flood-related injuries.
C8, Access to evacuation centers (schools, local hall, elevated areas. etc.)	In terms of reducing the impact of flood vulnerability and saving lives, the availability of evacuation centers contributes to a different level of vulnerability to floods.
C9, Education level	The level of education of the household's head and family members also contributes to a different level of vulnerability, as it has an impact on risk perceptions and flood mitigation strategies.
C10, Access to Information about flood	Households with access to flood information (heavy rainfall, river bank level, etc.) have varying levels of vulnerability to flood in terms of flood prevention and preparedness.
C11, Source of income	The source of a household's income has varying effects on its vulnerability. Those households that rely on charcoal production face a high risk of flooding because the ground on which they produce is prone to flooding.
C12, Nearness to flood sites	Most flood injuries and impacts are higher for those households close to the flood sites

Source: own, June 2021

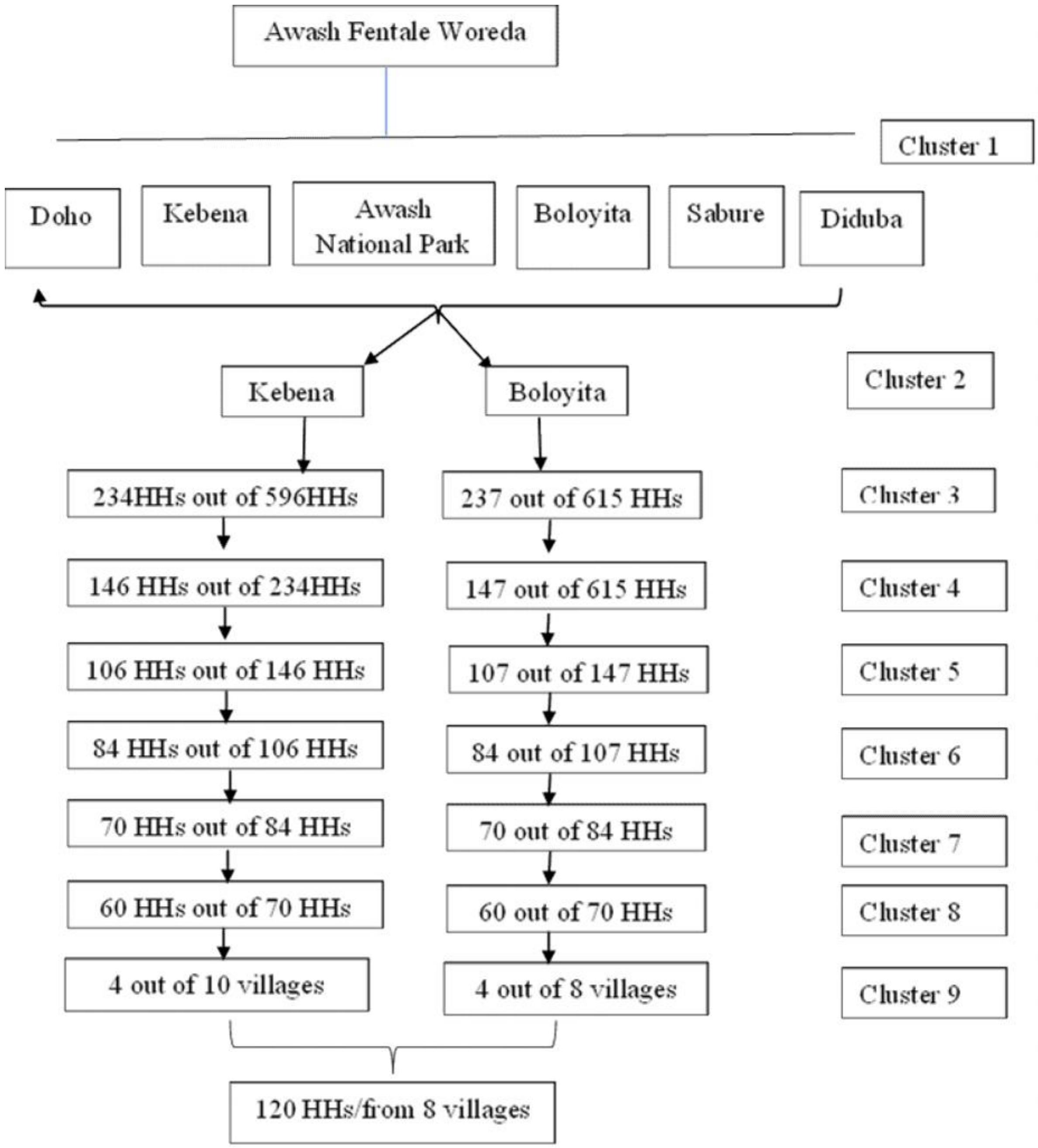
AHP techniques were used to assess the extent to which socioeconomic, demographic, and accessibility factors influence households in the study area. Furthermore, the social vulnerability index was calculated using Velasquez's (2003) "quantification of social aspects of flood vulnerability techniques." According to Velasquez (2003), the vulnerability of a community (or an individual) is rarely one dimensional, but rather consists of several aspects that compose its physical, social, economic, and reputational conditions, and necessitates a procedure for combining them into a single composite index as well as a statement of how choices are to be compared using the index.3.2.3. Survey techniques

3.2.3.1. Study area selection and Sampling techniques

This study collected data from 120 households selected using multistage and purposive sampling techniques based on whether they were heads of families, residents of the study area, and living in the area at the time of the flood event. The majority of households surveyed live near rivers that run through the woreda, such as the Kebena, Awash, and Kesem (Bulga). Furthermore, the Kesem dam, built on the Kesem river for sugar plantations, is close to the surveyed households. Those who live near to these bodies of water are likely to be more vulnerable to flooding as a result of this.

During the 2020 *kirmet* season, the kebeles of Fentale Woreda kebena, Boloyita, Doho, and Sabure were the most flood-affected of the seven administrative units found in Awash Fentale woreda (Data on the number of affected and displaced households are annexed at the end of this thesis). Kebena and Boloyita kebeles were specifically chosen for this study. These two kebeles were chosen because they are close to the kebena, Awash, and Kesem rivers, which could make households more vulnerable to flooding. According to the Awash Fentale woreda's emergency, preparedness, and early warning office (AFWEPEO), 596 and 615 households in these two kebeles were affected during the 2020 rainy season, respectively.

The kebeles and households for the study area were chosen using a multistage sampling technique in conjunction with a purposive sampling technique. Multistage sampling is a probability sampling technique in which sampling is carried out in stages, with the sample size decreasing with each stage. The following are specifics about the techniques used:



Source: own, June 2021

Figure 6: Multistage sampling techniques used in the study area

In the above figure 5, simple random sampling techniques were used until cluster 8. The study area's sample size was determined using Israel's, (2003) simplified formula for calculating sample sizes. The Equation is assumed to have a 95% confidence level and a P value of 0.05.

$n = N/1+N(e)^2$ Where n is the sample size, N is the population size, and e is the level of precision.

$n = 1211/1+1211(0.05)^2$

= 292 household

It was difficult for the researcher to distribute questionnaires to 292 households. Based on the multistage sampling techniques, the sample size was reduced to 120 households. Data on demographic, socioeconomic, risk perceptions, coping mechanisms and other relevant information were collected from these 120 households, woreda and kebele offices.

3.2.3.2. Data Sources and Data Collection techniques

This study's survey instrument was a structured questionnaire, which is commonly used in vulnerability analysis surveys. However, the instrument was modified to limit the issues as needed in this study. The survey results are used in this study to fit into a set of vulnerability criteria in order to meet the quantification procedure and criteria guide proposed by Velasquez (2003). The criteria guide was also modified to fit the need of this research. Detailed data were collected on demographic, socio-economic, risk perceptions; coping mechanisms factors of vulnerabilities using EPI collect (details of the questionnaires Annexed here). However, these data were summarized into three major social factors that influence vulnerability to flood such as socio-economic, accessibility and demographic characteristics as shown in figure (3).

Households in four kebena kebele villages (E'aba, Gurmule, Ero-Edadase, and Kudu-Ededas) and six villages in Boloyita Kebele (Sifera Malekadura, Keda Melkadura, Rifoda, and Hayukole) were purposefully selected and asked open and closed-ended questions on the selected proxy social vulnerability indicators (socioeconomic, risk perceptions, coping mechanisms, and demographic characteristics). Key informant interviews with kebele chairmen from the two kebeles and woreda's emergency, preparedness, and early warning officers supplemented data collected at the household level.

The study relied on a variety of secondary data sources. Secondary GIS data used includes collateral data (administrative shape files, road network (to show goods and people access to the road for facilitating evacuation, getting emergency services, and recovery), settlements (to show which villages are most vulnerable to their proximity to hazardous events), public facilities (schools and health-to show their resilience by showing their accessibility to these resources), socio-economic and demographic data (to show their overall economic, social and demographic status) and Remote sensing data (sentinel-2 satellite imagery, Aster-DEM -to map flood extent) of the study area. These data were obtained from CSA, Ethiopian Geospatial Information Institutes, UN-OCHA, European Space Agency (for Sentinel-2 image data), Ethiopian land use and land cover Sentinel-2 data.

Other data such as socio-economic and demographic data were obtained from Central Statistical Agency (CSA), Disaster Risk Management Commission (DRMC), Woreda risk profile, UNOCHA, relief web, the International Federation of Red Cross and Red Crescent Societies (IFRC), and from those who are working with the topic under study.

3.3.4. GIS and Remote Sensing based risk assessment

3.3.1. Identification of extent of exposure to flooding using elements at risk

According to Messner and Meyer, (2005) an element-at-risk is a social, economic, or ecological unit or system that is at risk of being affected by all types of hazards in a specific area, such as people, households, businesses, economic production, buildings, cultural assets, and public infrastructure, ecological species, and landscapes that are located in or connected to a hazardous area, and it can be measured in monetary or non-monetary units. Irrespective of its variation, every element at risk is more or less exposed to and susceptible to flood events. Hence, exposure and susceptibility are always related to element-at-risk and contribute significantly to the analysis of flood vulnerability (Messner and Meyer, 2005).

People who live near flood sites, settlements, land use, and roads that fall within flood extent areas were used as elements at risk in this study as a measure of exposure for the 2020 *kirmet* flood in the study area. Exposure is a measure of a given area's predisposition to disruption from a flooding event as a result of its location (REACH,2020). GIS and remote sensing techniques were used in this study to address flood exposure by mapping the extent of the flood and the elements that were at risk (exposed) during flooding in the study area. These techniques try to highlights those areas which were likely to experience flooding and have potential to be more severely impacted in the case of flood.

Flood extent Mapping

According to floodinfo.ie, (2018) flood extent is the area of land that has been or may be flooded. A flood map frequently depicts the extent of a flood. It is similar to a flood hazard map in that it can indicate areas of land that may be prone to flooding (flood extent map), the depth, velocity, or other aspect of flooding or flood waters for a given flood event, and it is usually prepared for either a past event or (a) potential future flood event(s) of a given probability.

Information about the extent of the flood and the elements affected by the flood is critical for relief organizations and those involved in disaster risk reduction and management. According to Eilander et al., (2015) information about the flood extent is required for damage estimation and calibrating hydrodynamic models, particularly in the post-flood phase, but obtaining this information is frequently difficult. Flood extent maps are currently derived from a few sources, including satellite images, areal images, and post-flooding flood marks (Eilander et al., 2015). Several studies, including Shen et al., 2015; NASA, 2017; Long et al., 2014; McDougall & Temple-Watts, 2012; Anderson, 2016; and Jo et al., 2018, used various satellite images and techniques to map flood extent. In this study, free sentinel2 satellite images and techniques recommended by UN-SPIDER for flood extent mapping are used, along with administrative boundaries from the study area. The flood extent in the study area was processed and mapped using ArcGIS 10.5 software. And the details of the work flow are described below.

Table 7: data used for flood extent mapping

Data	Data type	Date of acquisitions	Source
Sentinel2 satellites images	raster	2020	https://scihub.copernicus.eu/
Zone 3 shape files	Vector	2013	CSA

Source: own, June 2021

Workflow of Flood Extent Mapping

One of the most critical pieces of information required by humanitarian actors in the immediate aftermath of a disaster is the spatial distribution and estimation of the water extent (in case of flooding). The use of Sentinel-2(S2) optical data from the European Space Agency (ESA) for flood mapping and damage assessment is recommended because it acquires data in 13 spectral bands at various spatial resolutions such as 10 meters, 20 meters, and 60 meters and can be accessed through the Scientific Data Hub. Sentinel-2(S2) imagery from Afar regional state's zone 3 was downloaded from the site and processed using UN-SPIDER's flood area mapping recommendation in a GIS environment to accurately map the extent of the flood in the study area. Green and near-infrared (NIR) bands with a spatial resolution of 10 meters were recommended for flood extent mapping in the study area.

To obtain the actual reflectance emitted by objects on the earth's surface, atmospheric correction was performed in QGIS using the Semi-Automatic Classification plugin. The flood extent map was created by calculating the Normalized Difference Water Index (NDWI) using the green and near-infrared bands in the raster calculator using the (pgreen - Pnir) / (pgreen + Pnir) formula. To distinguish water from no water areas, a threshold was chosen and the NDWI image was binarized. This means that each pixel was assigned a value of 0 or 1, corresponding to flood or no flood.

Source: own, June 2021

Figure 7 : Workflow of flood extent map extractions

The threshold was determined by sampling digital number values in flooded areas and generating an average binarized *tiff* file. To obtain the flood extent shape files, the generated *tiff* file was converted to a vector file using QGIS /ArcGIS's "Polygonize (Raster-to-Vector)" process. Small polygons that may have been created as a result of wet rooftops, wet streets, or artificial water bodies such as pools or reservoirs that did not necessarily represent the actual flood extent were removed during this process to obtain the actual flood extent.

A flood extent map of zone 3 of Afar Regional State created using these work flows as it can be seen from figure 7. The flood extent maps cover an area of 457.92hectars. The map shows that the flood primarily affected Amibara, Dulecha, Awash Fentale, and Gewane woredas. This map was used to produce elements at risk in the study area. Various geoprocessing and spatial analysis tools, such as buffers, raster calculators, intersection and vector overlays, were used in conjunction with a flood extent map to compute and produce elements at risk of flooding in Afar regional State's zone 3.

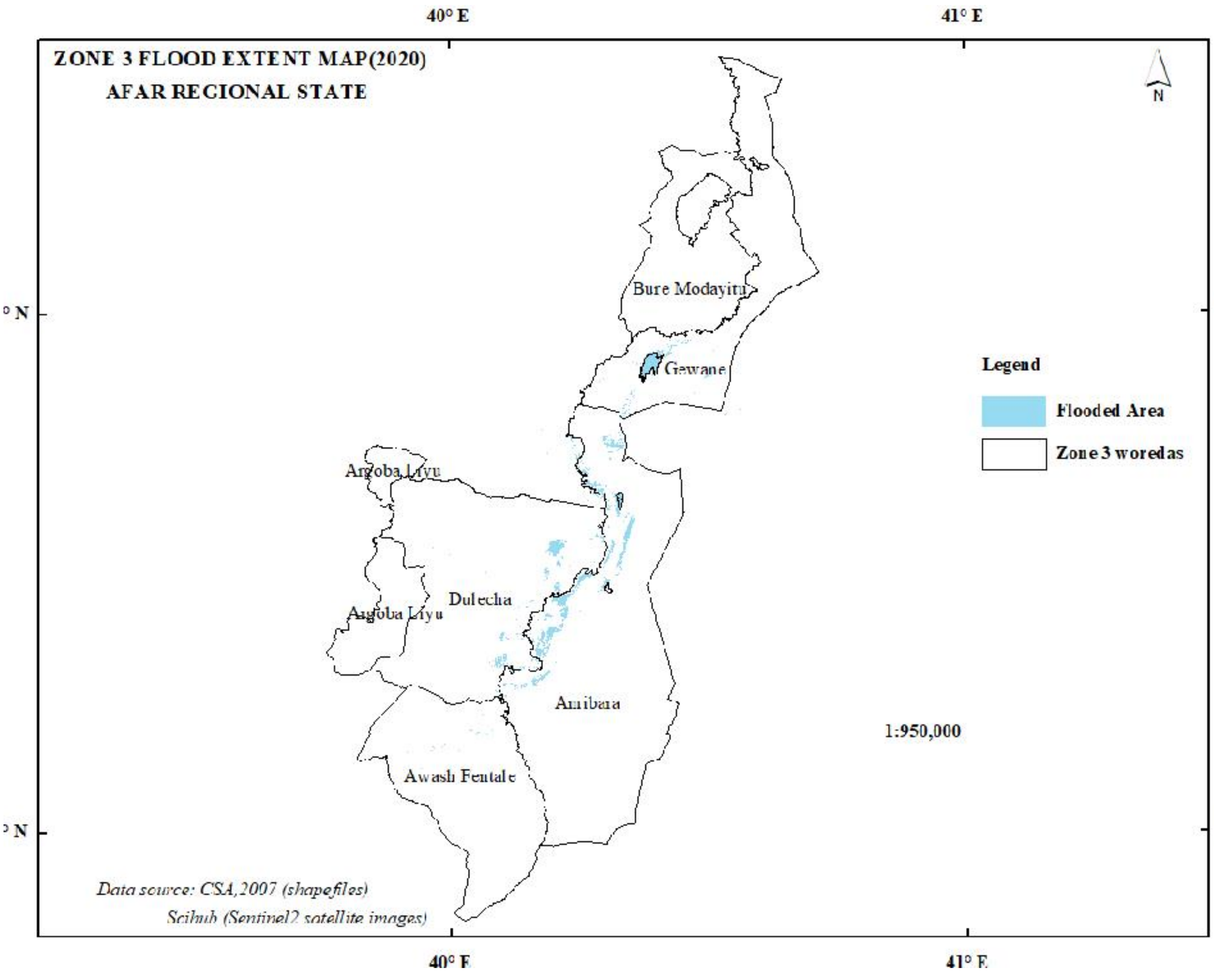


Figure 8: Zone 3 Flood extent map (2020), Afar Regional State

Elements at Risk Mapping

The population, properties, economic activities, including public services, and any other defined values exposed to hazards in a given area are examples of elements at risk (UN-ISDR, 2009). Elements at risk, according to Corominas et al., (2014) are all of the elements that may be impacted by the occurrence of hazardous phenomena, such as population, property, or the environment. Elements with a spatial characteristic, such as a road network, settlements, land use, and populations, were used to map elements at risk of flooding in order to understand the extent of exposure in the study area. The flooding risk element is based on the IGAD's, (2019) "Hazard Assessment Using Earth Observation and GIS for Ethiopian Technical Training Modules." The outcome of this exercise aids in understanding the level of exposure and extent of flood damage for post-disaster interventions in the study area. Data on land use, roads, settlements, and populations from zone 3 of Afar regional state were used to compute elements at risk of flooding in the study area, as detailed in table 6.

Table 8 : Data and data source for mapping of elements at risk

Description	Data Type	Date of data source	Data Source
Administrative boundaries	Vector(polygon)	2020	DRMC
Flood extent map (Sentinel-2(S2) image data	Raster(images)	2020	https://scihub.copernicus.eu/
Road Network	Vector(polyline)	2011	UN-OCHA
Settlements	Vector(point)	2011	UN-OCHA
Land Use	Raster(images)	2017	Ethiopia Sentinel2 Land Use Land Cover 2016
Gridded Population of the World (GPW), V4	Raster(images)	2020	SEDAC

Source: own, June 2021

These data were processed and analyzed with the ArcGIS/QGIS software. The following is a description of the major workflow used in identifying and mapping elements at risk of flooding as stated in IGAD's 2019 hazard assessment manuals: First, the extent of the flooded surface is delineated. The second human settlements, land use, road network, and population affected by the 2020 Ethiopian rainy season flooding will be delineated. Third, import the two layers mentioned above into ArcGIS 10.5 and perform spatial analysis to obtain relevant results.
The extent of the flood surface for zone 3 of Afar Regional State, which includes the study area, has already been produced. The elements exposed to the 2020 *kirmet* season flood, such as the road network, settlements, populations, and land uses, as well as the impact level to these elements, were produced using the flood extent map of zone 3.

Road Network

Road networks are widely acknowledged to be critical for economic, social, environmental, and security reasons. However, the road has been jeopardized by a number of man-made and natural hazards. According to the World Bank, (2016) flooding is a major threat to roads because it can cause massive traffic jams and damage to road structures, with long-term consequences. Flooding causes significant repair costs for road control authorities, access difficulties for emergency services, and disruption for road users and the community at large (Versini et al., 2010). The ramifications for businesses and the economy as a whole can be severe (Brabhaharan et al., 2006). When road networks are disrupted by a hazardous event, the consequences for emergency management can be disastrous. Transportation lifelines are widely regarded as the most critical in an emergency due to their critical role in the restoration of all other lifelines (Cova and Conger, 2004).

The extent of flood-affected roads was calculated by overlaying roads in zone 3 of Afar regional state on a flood extent map, and the parts of the road that intersected with the flood extent maps were clipped out, resulting in flooded roads, as shown in figure 8. A total of 151 kilometers of road were found to be flooded. This means that approximately 151 kilometers of road were exposed to flooding during the 2020 *kirmet* (rainy season). According to the map, the types of roads that were at risk of flooding were trails, dry and all-weather roads. From the map approximately 5 kilometers of dry weather roads and 2 kilometers of trails leading to Boloyita kebele were vulnerable to flooding during the 2020 rainy season. Melka Werer-Berehet asphalt roads served as evacuation areas during field observations and discussions with respondents because most infrastructures in the study areas were flooded and there were no ready-made evacuation centers in place.

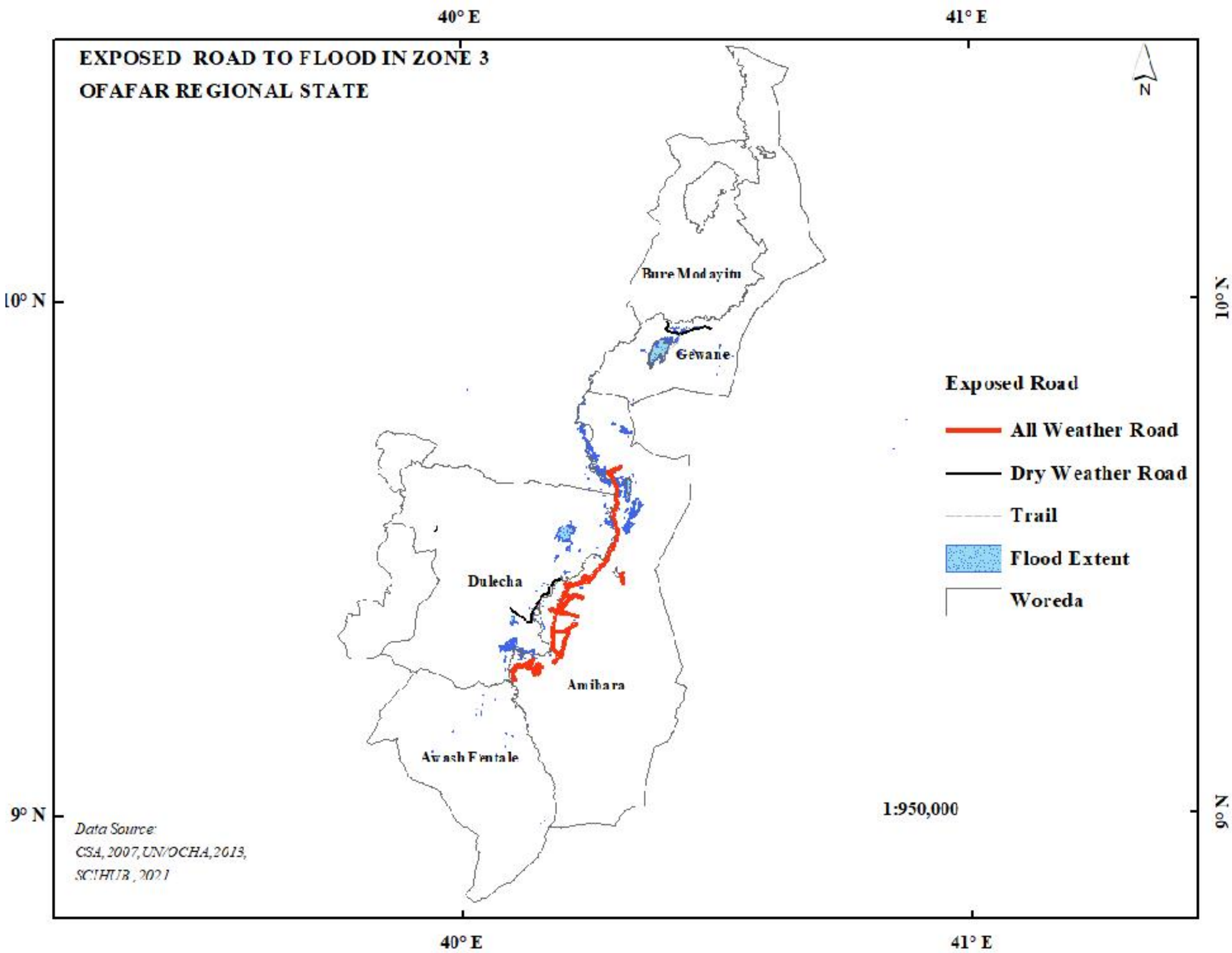


Figure 9 : Maps of roads exposed to flood in zone 3 of Afar Regional States

Settlements

Settlement information is critical for identifying settlements that were highly vulnerable to flooding. Settlements that do not have immediate access to dry or elevated areas are considered highly vulnerable to flooding. Flood-prone settlements impede people's ability to work, disrupt economic activity, and obstruct humanitarian aid access. The flood extent map was overlaid with villages located in zone 3 of Afar Regional states. And those villages that were within 1.5 kilometers of the flood extent map were extracted, resulting in 67 localities in zone 3 of Afar Regional State, of which 16 villages were from Awash Fentale Woreda, being at risk to the 2020 Ethiopia *kirmet* (rainy) season as shown in figure 9. As a result, the flood events affected 16 settlements in the study area.

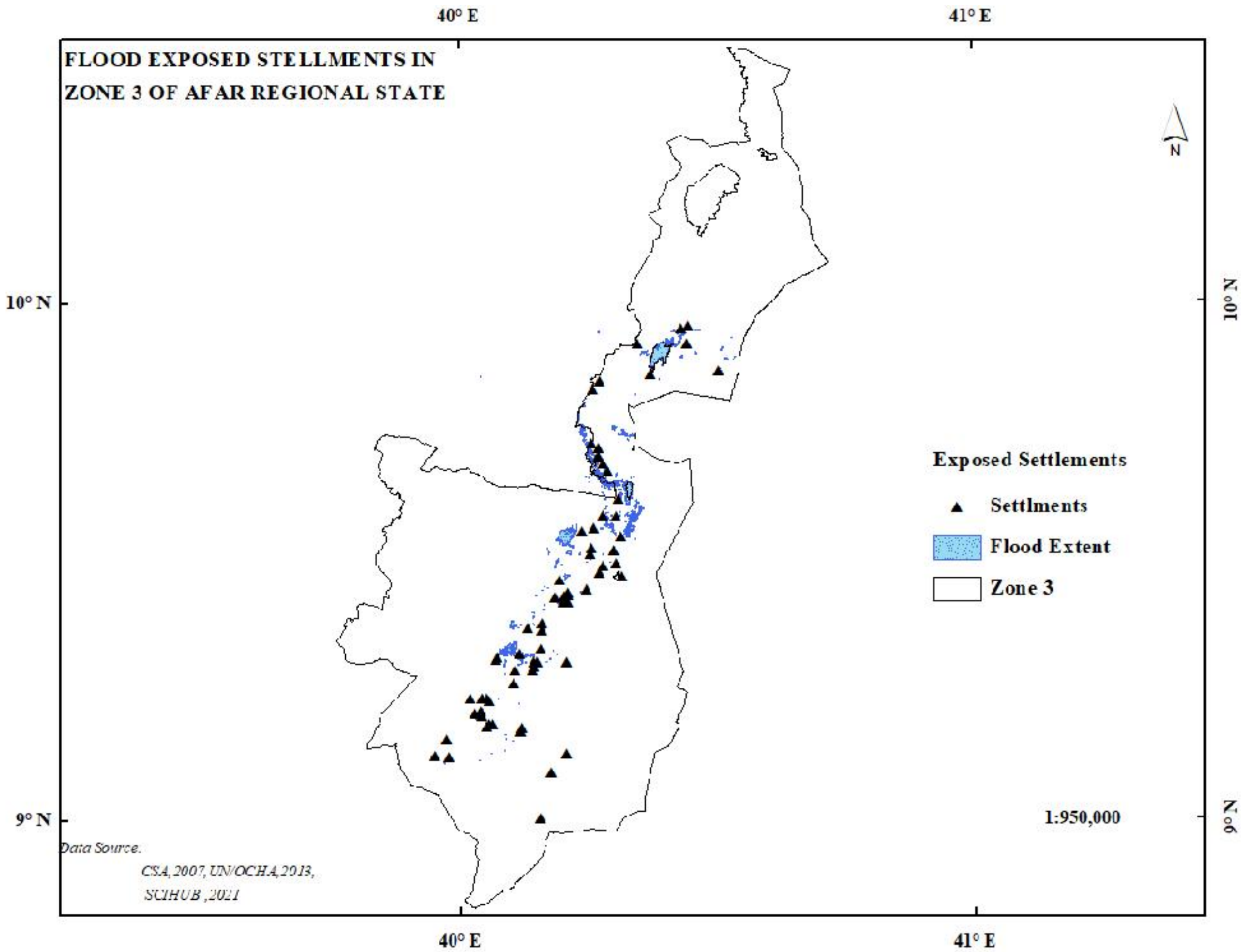


Figure 10: Maps of settlements exposed to flood zone 3 of Afar regional states

Source: AFWEPEO, September 2020

Figure 11: part of flooded settlements in kebena kebele

Land Use

Land is important in society for a variety of economic activities. Certain global development trends, such as population growth and rapid urbanization, however, result in land use conflicts, increased vulnerabilities, and disaster risks. This uncontrolled development has an impact on water flow, either by accelerating runoff or obstructing the natural drainage system, which could lead to large-scale flooding or landslides with serious human and economic consequences. According to Apollonio et al., (2016) land use type has a significant impact on flooding because of its impact on infiltration and runoff generation. Also, according to NBRO, (2015) inappropriate EPA

and management practices, as well as human interventions, can change the scale and extent of flooding and worsen its consequences.

Mapping land use in the study area that has been adversely affected by the 2020 *kirmet* season flood could aid in distinguishing between land use that has been exposed to flood and land use that has not been exposed to flood. This allows for better planning and a better understanding of what motivates people to locate themselves in high-risk areas. Because humans have significantly altered natural landscapes, land-use change has the potential to have a significant impact on floods. Large areas have been deforested or drained, resulting in either increased or decreased antecedent soil moisture or erosion. During floods, however, various land use categories, such as cropland, would be affected. This, in turn, has an impact on household food security and makes them more vulnerable.

According to Ethiopia's sentinel2 land use and land cover 2016 data, the land use in the study area was classified into eight categories: settlements, tree cover and sparse vegetations, cropland (primarily sugar cane plantations), water areas, shrubs, and grassland, regularly flooded areas, and bare areas. While data obtained from the Awash Fentale Woreda Office five categories such as arable land (55,000 hectares), grazing land (113,000 hectares), forest cover (2000 hectares), grassland (9000 hectares), and water body (1000 hectares) with a total area of 180,000 hectares. These differences may be due to the methods used by the two offices to classify land use and land cover. By superimposing the flood extent map on Ethiopia's Sentinel2 land use and land cover 2016 of zone 3 of Afar Regional States, land use categories that fall within the flood extent map were clipped out using ArcGIS 10.5 and resulted in the type and extent of the land use and land cover affected by the flood as shown in figure 10.

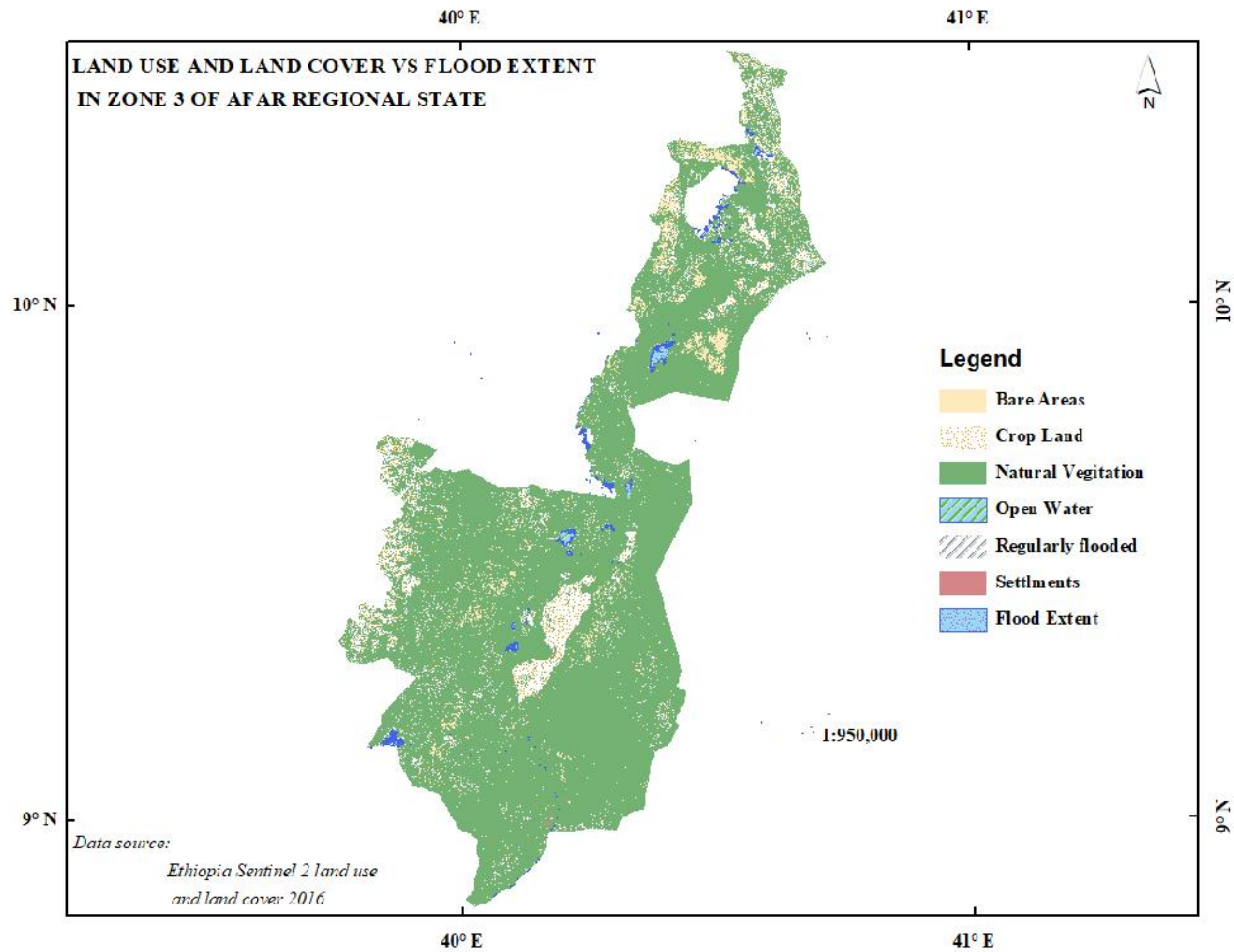


Figure 12 : Map of exposed land use and land cover in zone 3 of Afar Regional state

Awash Fentale woreda's land area is primarily used for Kesem sugar plantations, settlements, grassland and shrub. crop land, grass land, shrub and tree cover are among the types of land use and land cover affected by the 2020 *kirmet* season flood in the study area.

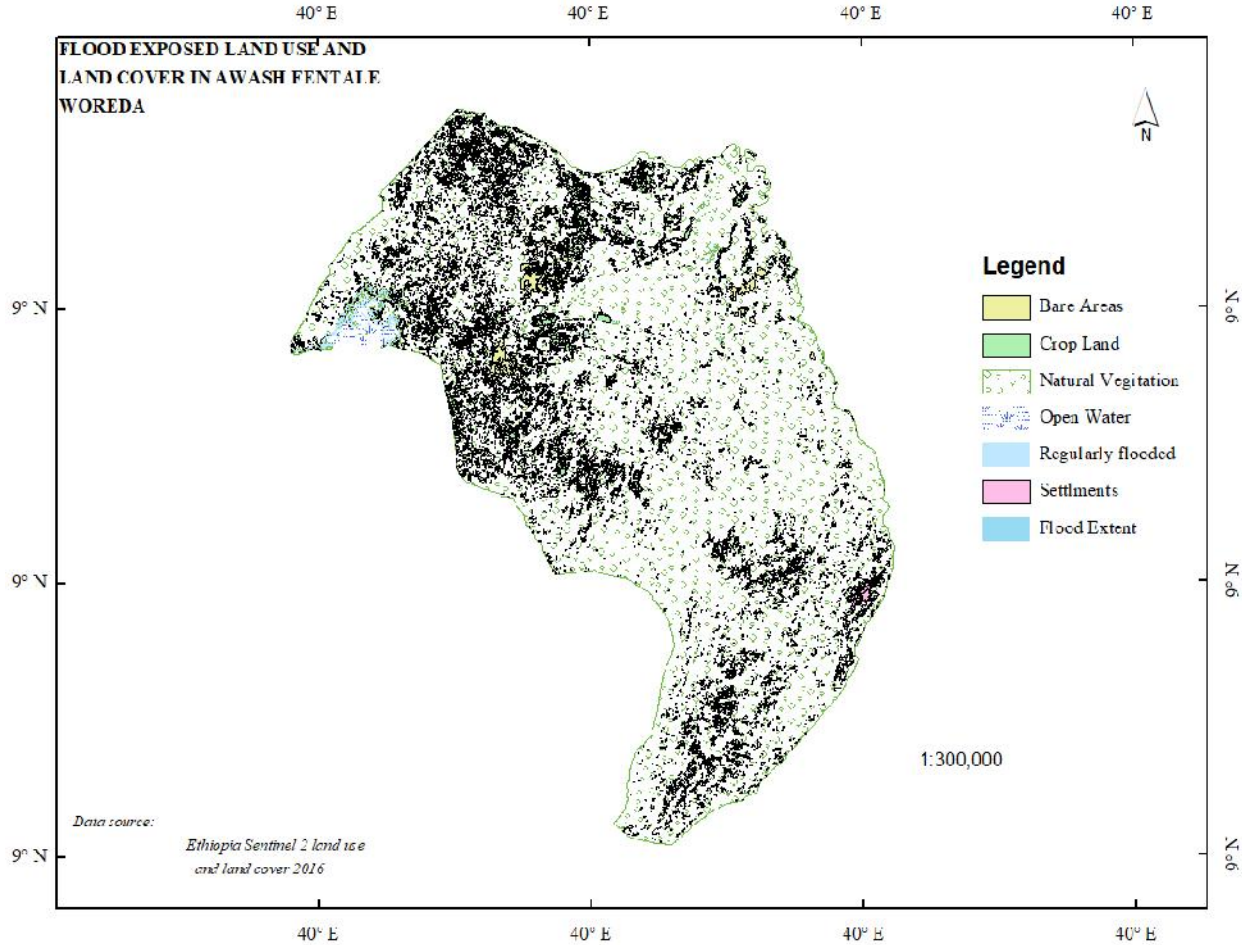


Figure 13 : Map of exposed land use and land cover in Awash Fentale woreda.

Figure 12 depicts a flooded farm and Kesem Sugar plantations in the Awash Fentale woreda of kebena kebele. The Awash, Kebena, and Bulga (kesem) rivers supply enough water to the kesem sugar plantations in this kebele.

Source: AFWEPEO, September 2020

Figure 14: flooded farm in the study area

Populations (Grid) Data

People are one of the elements at risk exposed to flooding. The majority of the time, what is exposed to flooding is understood based on local post-disaster studies. According to a number of studies (Lee and Jung, 2014; Rolfe et al., 2020; Tate et al., 2021) flood exposure is higher for socially vulnerable populations.

As stated in Dulal and Thomas, (2014) population data with appropriate format and resolution is required for a variety of applications such as spatial planning, processes, disaster and emergency management, and risk and vulnerability assessment. It was indicated the importance of a high-resolution gridded data for spatial vulnerability and risk assessment, especially at a local or community level.

The 2020 World Grid Population IV data were used and computed for mapping populations in the study area that were at risk (exposed) to flooding. Elements at risk (exposed) populations were obtained by computing a zonal statistics table in a GIS environment for Grided Population data, resulting in 934 households estimated to be affected by the 2020 Ethiopian rainy season flood in the study area. This calculation only applies to households that were not displaced but were directly impacted by the flood events at their residence. Assuming a household size of four, this translates to 3739 people directly affected by the flood.

Thus, the roads (151km in zone 3, of which the study area is a part), settlements (16 localities in the study area), land use (crop and grassland, shrub cover areas, and tree cover), and populations (3739 people) in the study area were all vulnerable to the 2020 *kirmet* flood. However, there is a discrepancy in these figures when compared to AFWEPEO data. For example, according to AFWEPEO, the number of affected localities is 24, but in these calculations, it was found to be 16. (Data on affected localities, kebeles and population are annexed at the end).

3.4. Data Analysis tools and materials

ArcMap 10.5/QGIS3.12 were used to perform mapping and data analysis (overlay operations) to show the study area's exposure through mapping of the elements at risk based on the IGAD, (2019) Hazard Assessment using Earth observation and GIS for Ethiopian technical training techniques. The flood extent area, road network, settlements, land use, and Gridded Population were processed, analyzed, and mapped to demonstrate the level of exposure through mapping of the elements at risk.

Table 9: Software's and instruments used in the study area

Types of software's	Descriptions
ArcGIS10.5	For data editing, data analysis, visualizations, and presentations
QGIS 3.12	For data editing, data analysis, visualizations, and presentations
Rhino Garmin GPS	For the collection of household coordinates in the study area
GPS utility software's	To transfer GPS coordinates from a handheld GPS to a computer
Micro Soft Office excel	Used to import coordinate data into ArcGIS/QGIS.

Source: own, June 2021

3.4.1. Identification of the major causes of social vulnerability to flood

Identifying major causes of vulnerability is critical for reducing flood impacts and implementing priority-based interventions. According to REACH, (2020) multi-criteria evaluation using AHP provides a consistent method of judging diverse criteria, reducing bias through weight normalization, and evaluation criteria and their weights must be determined based on their importance. As stated in section 3.2.1.1, twelve important sub-criteria were identified based on a review of comparable studies in the literature, expert opinion, survey results, and field observations. And an AHP method of multi-criteria evaluations was used to assess the relative importance of these identified causes of vulnerability in their contribution to social vulnerability to flood in the study area, and to see if it corresponded to the weights and opinions provided by experts.

Criteria Weighting

As stated in previous sections, AHP employs hierarchical structures to represent a problem and then develops priorities for alternatives based on the user's judgment via paired comparisons. Weighting the 12 identified criteria based on their level of contribution to flooding was accomplished using Analytical Hierarchical Process (AHP) techniques. Two AFWEPEO experts and two kebele chairpersons from surveyed kebeles participated in weighting each vulnerability factor using key informant questionnaires (The questionnaires appendix). While comparing two criteria (factors) in AHP, these vulnerability factors were given weights based on Saaty's 9-point Continuous rating scale (table 3) and scale of preferences (table 8).

Table 10: Scale preference comparing two parameters in AHP

Level of influence to vulnerability	Numerical Expressions	Definitions
Standards	1	Children under the age of 14 and people over the age of 65 were considered the standard or most vulnerable groups, and other criteria were weighted in relation to them
Moderate Influence to social vulnerability to floods	3	In terms of its contribution to social vulnerability to floods, experience and judgment strongly favor one criterion over another
Strong Influence to social vulnerability to floods	5	One Criteria's contribution to social vulnerability to floods is strongly favored by experience and judgment over another.
Very Strong Influence to social vulnerability to floods	7	Criteria influence is strongly favored, and its dominance is evident in practice.
Extreme influence to social vulnerability to floods	9	The evidence in favor of one criterion over another is of the highest level of confirmation.
Intermediate influence to social vulnerability to floods	2,4,6,8	Intermediate influence

Source: modified and adapted from Rufat et al, 2015

Computation of pairwise comparison

A consistency ratio (CR) was calculated after a pairwise comparison based on survey results and expert opinion weighting. The first step in the AHP procedure is to perform pairwise comparisons between each criterion as shown in table 9.

Table 9: Pairwise comparison matrix for each criterion

C	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12
C1	1	1/2	2	1/2	1/3	1/3	1/3	1/3	2	1/2	1/3	1/3
C2	2	1	2	1/2	1/2	1/2	1/2	1/2	1/2	1/2	1/2	1/2
C3	1/2	1/2	1	1/5	1/7	1/7	1/3	1/2	1/2	1/3	1/3	1/7
C4	2	2	5	1	2	2	2	2	2	2	2	2

C5	3	2	7	1/2	1	1	1/2	1/2	1/2	1/2	1/2	1/2
C6	3	2	7	1/2	1	1	1	1/2	1/2	1/2	1/2	1/2
C7	3	2	3	1/2	2	1	1	1	1/2	1/2	1/2	1/2
C8	3	2	2	1/2	2	2	1	1	1	1/2	1/2	1/2
C9	1/2	2	2	1/2	2	2	2	1	1	1	1/2	1/2
C10	2	2	3	1/2	2	2	2	2	1	1	1	1/2
C11	3	2	3	1/2	2	2	2	2	2	1	1	1
C12	3	2	7	1/2	2	2	2	2	2	2	1	1
Sum	**26**	**20**	**44**	**6.2**	**16.98**	**15.98**	**14.67**	**13.33**	**13.5**	**10.33**	**8.67**	**7.98**

Source: own, June 2021

The factors are then normalized before calculating the criteria weight. Normalization is accomplished by dividing each column entry by the sum of the columns. This yielded a normalized score. The criterion weight is calculated by dividing the sum of each normalized score row by the number of criteria, which in this case is 12 as shown in the table (10).

Table 10: Normalized pairwise comparison and criteria weight

C	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	Normalized Value Sum	Criteria Weight
C1	0.04	0.03	0.05	0.08	0.02	0.02	0.02	0.03	0.15	0.05	0.04	0.04	0.55	0.05
C2	0.08	0.05	0.05	0.08	0.03	0.03	0.03	0.04	0.04	0.05	0.06	0.06	0.59	0.05
C3	0.02	0.03	0.02	0.03	0.01	0.01	0.02	0.04	0.04	0.03	0.04	0.02	0.3	0.03
C4	0.08	0.10	0.11	0.16	0.12	0.13	0.14	0.15	0.15	0.19	0.23	0.25	1.8	0.15
C5	0.12	0.10	0.16	0.08	0.06	0.06	0.03	0.04	0.04	0.05	0.06	0.06	0.85	0.07
C6	0.12	0.10	0.16	0.08	0.06	0.06	0.07	0.04	0.04	0.05	0.06	0.06	0.89	0.07
C7	0.12	0.10	0.07	0.08	0.12	0.06	0.07	0.08	0.04	0.05	0.06	0.06	0.89	0.07
C8	0.12	0.10	0.05	0.08	0.12	0.13	0.07	0.08	0.07	0.05	0.06	0.06	0.97	0.08
C9	0.02	0.10	0.05	0.08	0.12	0.13	0.14	0.08	0.07	0.10	0.06	0.06	0.99	0.08
C10	0.08	0.10	0.07	0.08	0.12	0.13	0.14	0.15	0.07	0.10	0.12	0.06	1.2	0.1
C11	0.12	0.10	0.07	0.08	0.12	0.13	0.14	0.15	0.15	0.10	0.12	0.13	1.38	0.11

C12	0.12	0.10	0.16	0.08	0.12	0.13	0.14	0.15	0.15	0.19	0.12	0.13	1.57	0.13
														1.00

Source: own, June 2021

The consistency was then calculated by multiplying the matrix value of the criteria in table (9) by the weight of the criteria in table (10). This yielded a consistency value for each row, and the sum of the consistency values yielded a weighted sum. The weighted sum was then divided by the Criteria Weight to yield a weighted average in table (11).

Table 11: Weighted Average of the criteria

C	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	Weighted Sum	Weight Average
C1	0.05	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.09	0.02	0.02	0.02	0.32	7
C2	0.10	0.05	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.39	8
C3	0.01	0.01	0.01	0.01	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.00	0.1	3.83
C4	0.30	0.30	0.15	0.15	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	3.31	22
C5	0.21	0.14	0.04	0.04	0.07	0.07	0.04	0.04	0.04	0.04	0.04	0.04	0.78	11
C6	0.22	0.15	0.04	0.04	0.07	0.07	0.07	0.04	0.04	0.04	0.04	0.04	0.85	11.5
C7	0.22	0.15	0.04	0.04	0.15	0.07	0.07	0.07	0.04	0.04	0.04	0.04	0.97	13
C8	0.24	0.16	0.04	0.04	0.16	0.16	0.08	0.08	0.08	0.04	0.04	0.04	1.17	14.5
C9	0.04	0.17	0.04	0.04	0.17	0.17	0.17	0.08	0.08	0.08	0.04	0.04	1.11	13.5
C10	0.20	0.20	0.05	0.05	0.20	0.20	0.20	0.20	0.10	0.10	0.10	0.05	1.66	16.5
C11	0.34	0.23	0.06	0.06	0.23	0.23	0.23	0.23	0.23	0.11	0.11	0.11	2.18	19
C12	0.39	0.26	0.07	0.07	0.26	0.26	0.26	0.26	0.26	0.26	0.13	0.13	2.61	20
∑Weighted Average														159.83
λmax =∑Weighted Average/n - where n is number of criteria (12)														13.32
Consistency Index (CI) = (λmax-12)/ (12-1)														0.12
Consistency Ratio= CI/RI where RI =1.48														0.08

Source: own, June 2021

To confirm the consistency of the response and rating, the consistency ratio (CR) should be computed. According to Saaty, (1980s) response reliability can be maintained only if the consistency ratio is less than 0.10. The consistency of judgments in the AHP process can be checked by calculating the consistency ratio (CR), which is defined as:

$$CI = \frac{\lambda max - n}{n-1}$$

Equation 1: Consistency Index

n is number of criteria CI is consistency index

λmax ∑Weighted average/n

=159.83/12

=13.32 CI= (13.32-12)/ (12-1) = 0.12

The CR defines the likelihood that the matrix ratings were generated at random, and Saaty (1980) recommends that matrices with CR ratings greater than 0.10 be re-evaluated.

$$CR = \frac{CI}{RI}$$

Equation 2: Consistency Ratio

CI 0.12 CR 0.12/1.48 which is 0.08

RI 1.48

CR consistency ratio

RI random index

Average random inconsistency index (RI)

Table 11: Random Index for 15 criteria

(n)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
RI	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49	1.51	1.48	1.56	1.57	1.59

Source: adapted from Zabihi et al., 2019

The value of CR 0.08 is less than 0.1. As a result, the consistency ratio of 12 selected social vulnerability criteria was computed and found to be 0.080, which is less than 0.1, indicating that the inconsistency is acceptable.

3.4.2. Ranking of major factors of social vulnerability to flood

Ranking the major factors contributing to social vulnerability to flooding is critical for identifying, prioritizing, and intervening on the factors that primarily contribute to the vulnerability of households to flooding in the study area. As a result, to better understand which factors respondents consider to be the most important factors contributing to social vulnerability to flood in the study area, the criteria weights in the table (10) were multiplied by 100 to convert to percentage. As a result, those factors are arranged in table (10) in order of their level of influence, from most influential to least influential. According to the results of the analytical hierarchical process for 12 selected criteria, the housing structure was the most important factor in contributing (15 %) to households' vulnerability to flooding, followed by proximity to flood sites (13 %). Household income is ranked third with a contribution of (11 %) to household vulnerability to flooding, and access to flood information is ranked fourth with a contribution of (10 %) to household vulnerability to flooding. In terms of vulnerability to flooding in the study area, access to evacuation centers and education level ranked fifth with (8 %) equal contributions, respectively. Access to the road, access to health care, and flood experience were also ranked sixth with equal (5%) contributions, and household compositions and flood prevention and preparedness training also contribute equally (5%) to social vulnerability to flood. The least important factor in determining social vulnerability to floods was support from family and friends. Campanero, (2017); Munyai, (2019) used rank to identify factors that influence households' social vulnerability to flooding. The researcher believes that respondents' rankings may be influenced by the study area's social, environmental, cultural, and economic conditions.

Table 12: Extent of each criterion influence to social vulnerability to flood in the study area

Criteria's	Influence (%)
C4, Housing structure	15%
C12, Nearness to flood sites	13%
C11, Source of income	11%
C10, Access to Information about flood	10%
C8, Access to evacuation centers (schools, local hall, elevated areas. etc.)	8%
C9, Education level	8%

C5, Flood experience	7%
C6, Access to road	7%
C7, Access to health facilities	7%
C1, Household Compositions (Children<14 years and Elderly >65 years large family size and female headed	5%
C2, Training on flood preventions and preparedness	5%
C3, Support (family or social)	3%
	100%

Source: own, June 2021

Computation of social vulnerability Index

To better illustrate the vulnerability of the study area, a social vulnerability index for 12 criteria was computed using Velasquez (2003)'s techniques for computing the social vulnerability index to flooding. The following steps are involved in this method:

Step 1: Calculates scores for each factor (criterion)

Step 2: Perform aggregation techniques using simple means (average)

Step 3: The average score is ranked in order to provide weights.

Step 4: The standardized score is then calculated using the equation [$X_i = (R_i - R_{min}) / (R_{max} - R_{min})$].

Step 5: Normalize the score by dividing the weight of each factor by the maximum factor weight.

Step 6: To calculate the weighted score, divide each normalized score by its sum.

Step 7: Compute the social vulnerability index by adding the products of the weighted and normalized scores.

Four experts, two from AFWEPEO and two from the kebele (local) administrator of the surveyed area, were asked to assign a score from 1 to 9 to the selected criterion based on its level of influence on social vulnerability to flood. The scores of each expert for each criterion were then added up. By dividing the total by the number of experts, an average for each criterion was calculated. The average is then ranked and weighted based on their level of influence. The scores from 1 to 9 were then converted to a scale of 0 to 5 using the formula [$X_i = (R_i - R_{min}) / (R_{max} - R_{min})$, where 5 is the maximum and 0 is the minimum, X_i is the standard score, and the average score is used as R_i (raw score). The normalized score was calculated by dividing each factor weight by the factor weight with the highest weight. The result of each normalized score was divided by its sum to obtain the weighted score for each criterion. Finally, the social vulnerability index for the study area was calculated by adding the product of the weighted score to the normalized score. A Likert scale of 0 to 1 was used to calculate the social vulnerability index to flooding as shown in table 11.

Table 13: Scales for measuring social vulnerability index

Weighted Rating	Description
0.0	Extremely safe
0.01 - 0.25	Hardly ever unsafe
0.26 – 0.50	Slightly unsafe
0.51 – 0.75	Moderately unsafe
0.76 – 0.99	Highly unsafe
1.0	Extremely unsafe

Source: adapted from: Campanero, (2017)

According to Valquesz's, (2003) quantification of social vulnerability to flood techniques, the social vulnerability index for flood vulnerability in the study area is 0.81, which falls into the highly unsafe categories as shown in the table (15). Hence, the study area was in a highly unsafe condition during the 2020 Ethiopia's *kirmet* flood.

Table 14: Social vulnerability index to flood calculated for 12 criteria

Vulnerability Measure	Expert's weight				Aggregation			Standardized and Normalized index of Vulnerability				
	Ex1	Ex2	Ex3	Ex4	Sum	Average	Rank	Standardized score	weight	Normalized score	Weight	Vulnerability Factor index (Social Vulnerability Index)
C1	7	6	4	3	20	5	4	1	1	0.14	0.02	0.00
C2	5	5	4	4	18	4.5	8	0.9	5	0.71	0.08	0.05
C3	8	5	3	5	21	5.25	2	1.05	7	1.00	0.11	0.11
C4	3	5	4	3	15	3.75	11	0.75	3	0.42	0.05	0.02
C5	7	4	5	3	19	4.75	5	0.95	5	0.71	0.08	0.05
C6	5	2	6	6	19	4.75	5	0.95	7	1.00	0.11	0.11

C7	6	5	5	7	23	5.75	1	1.15	6	0.85	0.10	0.08
C8	5	6	3	4	18	4.5	8	0.9	5	0.71	0.08	0.05
C9	3	4	3	5	15	3.75	11	0.75	4	0.57	0.07	0.03
C10	5	3	5	5	18	4.5	8	0.9	5	0.71	0.08	0.05
C11	7	6	5	3	21	5.25	2	1.05	6	0.85	0.10	0.08
C12	5	6	5	3	19	4.75	5	0.95	7	1.00	0.11	0.11
sum						56.5			Sum	8.71	Social Vulnerability Index	0.81

Source: own, June 2021

4. Results and Discussions

4.1. Socioeconomic characteristics of the survey households

According to the Geographical Association, (2021) flood hazard has a varied impact on people, which is partly controlled by the socioeconomic system in which they live, and there is variation in levels of vulnerability within a country, region, community, and individual. Those most vulnerable to flooding may be unable to evacuate due to a lack of resources (money, knowledge, work flexibility etc.). The survey results from the study area were used to identify socially vulnerable groups.

Those households with a low capacity to cope with the flood disaster (weak livelihood base and low mean monthly income), no access to social services (health facilities, schools, and evacuation centers), near flood sites, households not receiving SafetyNet and relief, large family size, dependent family member (Age 14 years and Age >65 years), structurally poor housing condition, no access to flood information, no flood experience, those with health problems were taken as socially vulnerable. It should be noted, however, that the vulnerability of households to flooding is caused by a combination of factors rather than a single factor.

The average household size in the surveyed households is six, with 46.0 % of children under the age of 14 and 4.2 % of people over the age of 65. According to ACF, (2010) young and elderly family members will have a more difficult time evacuating during disasters. Furthermore, an outsized family has difficulty evacuating due to their large size. Females make up a slightly higher proportion of household members (51 %) than males, as per the survey results (49 %).

Table 15: Demographic characteristics of the surveyed households

	Number	percent
Average Household Size	6	
Sex		
Male	357	49.00%
Female	372	51.00%
Age Group		
Less than 14 years	336	46.00%
14 to 65 years	363	49.70%

Greater than 65 years	31	4.20%

According to Munyai et al., (2019) the level of resilience and recovery is influenced by resource availability. Adequate resources such as money, knowledge and time reduce vulnerability, whereas a lack of them increases exposure and vulnerability to floods because it takes a long time to recover from damage. According to Rufat et al., (2015) higher flood exposure is associated with poverty (in relative terms, not absolute terms), a lack of land ownership, and income inequality.

In terms of average monthly household income and source of income, the majority of households (82.5 %) reported an average monthly household income of less than 3000 ETB, while 17.5 % reported a monthly income ranging from 3,000 to 4,999 ETB. According to table 18 and figure 13, 61.3 % of total survey households are engaged in livestock production, while the remaining 33.3 % earn income from charcoal production, 3.2 % from crop production, and 2.1 % from employment including casual labor work. Income and poverty, as explained by Rufat et al., (2015) are important indicators of a household's social vulnerability to flooding because income is associated with other factors such as employment status (livelihood base). This is frequently due to a household's wealth, which determines its capacity to recover and return to normal life because the household has sufficient resources to mobilize for rebuilding destroyed homes and lost property.

According to ACF, (2010) studies the extent of household income is one factor that contributes to flooding vulnerability because households with low income do not have enough resources to mobilize in order to cope with pre- and post-disaster impacts. Studies on wealth by Sevillano et al., (2020) indicated that the Afar region consists among the poorest households in Ethiopia.

Table 16: Average household monthly income

Income Group	Number of Respondents	Percent
Less than 3000	99	82.50%
3000 to 4999	21	17.50%
above 5000	0	0.00%

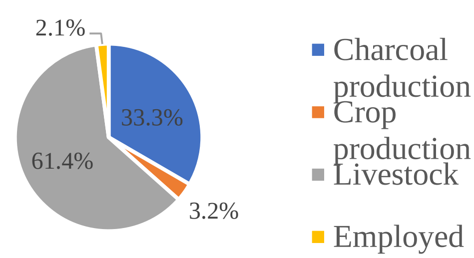


Figure 15: Household Source of income

The main source of income for the surveyed households, as shown in figure 14, is low-productivity livestock herding and charcoal production. Animal husbandry has long been a popular source of income in many Afar communities. However, according to Thrive's, (2019) report these livelihood practices have recently been challenged by extreme weather events such as floods and drought, resulting in less food availability for animals and increased insecurity and risk to pastoralist livelihoods.

The study area's majority of households rely on livestock herding and charcoal production for a living, making them vulnerable to flash flooding. As a result, their herds may be drained by flooding, and charcoals that were being prepared may also be swept away. Households may find it difficult to recover after a disaster because it took them so long to resume normal activities.

Source: AFWEPEO, September 2020

Figure 16: Charcoal prepartion

In terms of shelter type, the survey areas revealed that various materials were commonly used for housing. Huts known locally as *Ari* houses accounted for 81.7 % of the households. The *Ari* is typically made of light materials such as long wooden sticks shaped to oval and erected by women, whereas 15.8 % of the household's home is *chika* house, a type made of wood and mud, and only 2.5 % of the household home is made of stone as shown in table 18. Following consultation with the community and the appropriate government office, it was discovered that all types of houses in the surveyed households were susceptible to flooding. This could be due to the materials used and the manner in which the house is constructed, which are made of very simple materials such as wooden sticks and *chika* (mud). Houses constructed of these materials are easily flooded because mud is easily washed away by a powerful flood, and the hut (*Ari*) is also easily flooded because it is not built on an elevated column.

Table 18: Type of shelter in the study area

Shelter type	Number	Percent
Hut *(Ari*)	98	81.70%
Stone house (*Dabou*)	3	2.50%
Chika House	19	15.80%

The nature of the materials used to build the houses, as well as the conditions of the houses, result in a variation in the level of vulnerability among survey households. According to Campanero, (2017) the stronger the materials used in house construction, the more resilient the house to disasters, and building types appear to correlate with social vulnerability and individual features of a structure. Based on Martins et al., (2012) persons and households with more resources will have a higher capacity to choose and invest in safer housing solutions. According to UNICEF's (2019) Situation Analysis on Children and Women in the Afar Region, children and adults are vulnerable to health risks in their homes due to insufficient housing conditions and the inability to protect them from adverse weather conditions, health and structural hazards. According to NBRO, (2015) houses with lighter structures can be carried away in a flood if the force of the flowing water is significant. Unsuitable or poor-quality building materials, such as unburned clay bricks and poorly bonded masonry, can easily give way during a flood. Observations in the field revealed that these types of housing were defenseless, increasing their vulnerability to sudden flood events (figure 15).

Source: AFWEPEO, September 2020

Figure 17: Flooded houses

The difference in educational level can lead to a difference in flooding vulnerability because those who can read and write can read a flood warning and prepare them, whereas those who cannot will find it difficult to prepare and minimize the impact of the hazard. Figure 16 shows that nearly half of the household heads (49.5 %) have no formal education, while only about 2 % have received formal education. In the survey households, 37.8 % of family members received formal education, while 11.20 % had no formal education. Hence, it can be deduced that the education status of the surveyed households could make them vulnerable to flooding, as their ability to read and understand notifications about evacuations and post-disaster recovery is hampered.

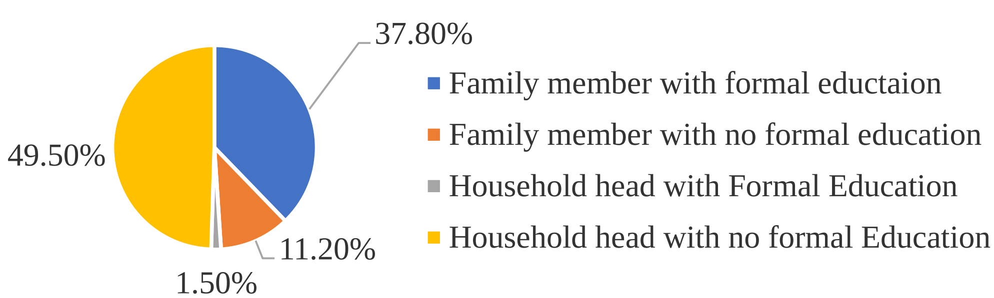


Figure 18:Household educational status

4.2. Flood causes and responsible environmental activities

The surveyed households were asked about what human and environmental activities they thought could cause flooding in their area. As a result, 41 % of survey households stated that the overflow of major rivers (Kebena and Kesem) was the cause, while 34.1 % attributed it to the overflow of the Kesem dam (Figure 17). Failure to build flood defenses (41.2 %) around flooded areas, forest clearing (38.6 %) in the mountain, and lack of attention from management (17.2%) were also mentioned as major environmental and human activities that are responsible for flooding in their area (Table 19). According to Natural Disaster, (2020) flooding is primarily man-made and can be exacerbated by a variety of human activities. This is due to the fact that if humans had not settled in the flood plain, there would have been no disaster. According to Shumie , (2019) the Kesem Kebena Dam upstream catchment flood hazard destroyed a 35m high dam on the Kesem River in 2008.

Table 17:Responsible human activities for flooding in the study area

human activities	Response	Percent
Forest clearing	95	38.60%
Failure to build flood defenses	83	44.20%
Loss of attention from management	37	17.20%

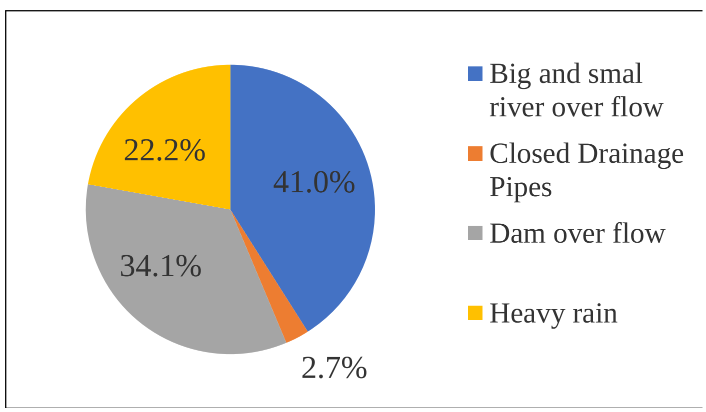


Figure 19:Responsible environmental activities for flooding in the study area

Source: own, June 2021

Kesem sugar plantation, which is primarily dependent on the Kesem dam for its water needs, covered a large portion of the surveyed kebele. The water in dam reservoirs is typically released into rivers prior to the arrival of the rainy season, causing flash flooding in the surveyed areas. Aside from flooding, the stored dam water causes bad odors in the area, and pregnant women frequently become ill as a result. During field observation and discussion with the household, kebele administration they made the dam management responsible for not maintaining public safety around dams. This is because they were not adequately notified when the dam's water was released into the rivers, and they failed to take various measures to mitigate the impact of the dam's flood. During the *kiremt* season, this dam frequently overflows, especially if heavy rains occur upstream, causing the surveyed areas to flood.

4.3. Access to Information, road, social infrastructure and services

Access to health services during and after a disaster can ensure that individuals receive the necessary attention while also limiting the possibility of health complications that increase the individual's vulnerability. The surveyed households were also asked to estimate the distance between their home and health-care facilities. As a result, the majority of participants estimated that the health facility was less than 5 kilometers away (80.9 %) (Table 20). During filed observations and discussions, respondents stated that most infrastructures, including health facilities, in the area were flooded, making getting services from these facilities difficult.

Table 20: Estimated distance between households and the nearest health care facilities

Distance to nearest Health facilities	Response	Percent
Less than 5km	89	80.9%
5km to 10km	12	10.9%
Above 10 km	9	8.2%

Flooding interferes with the learning and teaching processes by limiting access to schools. According to the survey results, 65.8 % of households said they can get to school in less than 5 kilometers, 30 % in 5 to 10 kilometers, and 4.2 % in more than 10 kilometers (Figure 18).

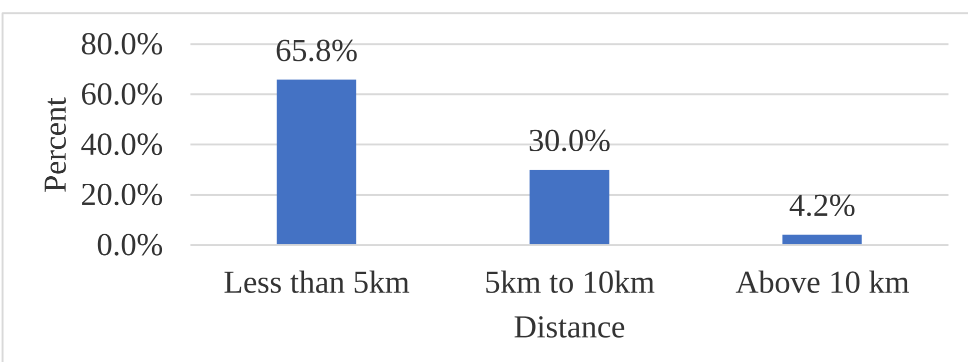


Figure 20: Distance between households and the nearest school (estimated)

According to the World Bank, (2020) flood event cause severe disruptions in segments of the transportation network, undermining access to health, education, and job opportunities while also impeding economic growth. Based on the survey findings, 70.8 % of households live less than 5 kilometers from the main road, 24.2 % live between 5 and 10 kilometers from the main road, and 5.0 % live more than 10 kilometers from the road (Figure 19).

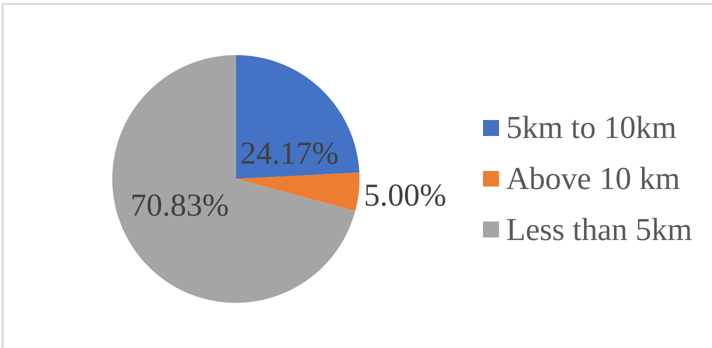
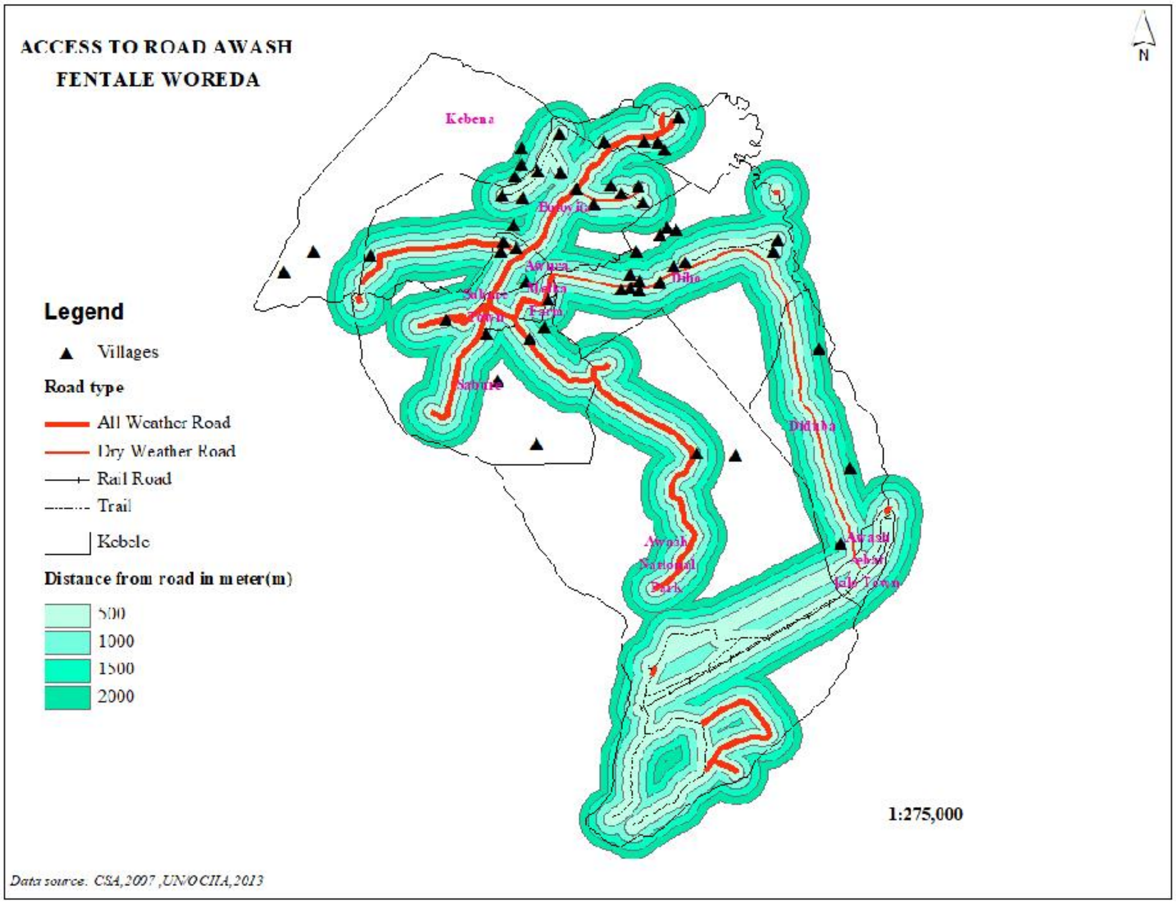


Figure 21: Households' estimated distance from main road

A buffer zone around the main road was created in ArcMap to estimate their level of accessibility to the main road, and as shown in figure 21, approximately 80% of the settlements are within 2 kilometers of the main road. The majority of the areas surveyed were dominated by feeder roads, which are rough and dusty during the dry season and muddy during the rainy season. As a result, rural areas far from the main road are the most vulnerable, as there is a greater risk of providing emergency assistance to these impoverished areas, which can easily become isolated during flooding.



Source: own, June 2021

Figure 22: Road access in the study area

As it can be seen from Table 21 about 47.5 % travel by foot, 29.2 % by tricycle (*Bajaj*), and 15.8 % by car to their destinations. Land transport is critical during a flood disaster for evacuations and emergency services. If a section of the road is closed, it will complicate these services and evacuation efforts. Because different modes of transportation differ in height, strength, and capacity, the mode of transport can also increase or decrease vulnerability to floods. It is clear from this that nearly half of the respondent's face difficulties in obtaining transportation services.

Table 18: Households' mode of transportation

Mode of transport	response	percent
tricycle(*bajaj*)	35	29.2%
motor cycle	9	7.5%
car	19	15.8%
foot	57	47.5%

During the field observations, only those living near the main road had access to these transportation options. When local roads become impassable due to flooding during the rainy season, remote households may become isolated. Furthermore, the rapidly spreading invasive acacia species *Prosopis juliflora* (Figure 21) has disrupted people and livestock mobility, in addition to the other various socioeconomic impacts in the study area. During floods, the obstruction caused by *Prosopis juliflora* is extremely severe, as people and animals are unable to escape the danger.

Source: AFWEPEO, September 2020

Figure 23: local road obstructed by *Prosopis juliflora*

Flood information is critical because it aids in the overall disaster risk management process of flood mitigation, preparedness, and recovery. As depicted in table 16 approximately 74.2 % of households received flood information from traditional communication systems known as *Dagu*. *Dagu* is the largest "wireless", so to say, traditional news network in the Horn of Africa that connects the Afar people living across three neighboring countries – Ethiopia, Eritrea, and Djibouti (Mohammed, 2016). The remaining 20.8 % of households were informed about the flood by the local administration, and 5 % were informed through modern means of communication such as radio. During field observations, it was discovered that the majority of surveyed households do not own a personal television. It has also been observed that the *dagu* system is being modernized as a result of the introduction and use of mobile phones.

Table 19: Source of flood information

Source of flood information	Response	Percent
Local Disaster Risk and Management Committee	25	20.8%
Radio	6	5.0%
Television	0	0.0%
Traditional communication System (*Dagu*)	89	74.2%

4.4. The effects of flooding on surveyed households

In terms of flood impacts at the household level within the surveyed areas, 54.1 % of the households stated that they lost their source of income, 26.1 % lost household materials, 10.8 % reported their house damaged, and 9 % experienced health problems as a result of the flood events (figure 22). Loss of a source of income and household materials could exacerbate their misery and make it difficult for them to recover and return to their previous life. Various studies (e.g., Glago, 2021; Doocy et al., 2013; and Alemu, 2007) indicated that floods have a variety of effects at various levels, one of which is damage to household income and food sources.

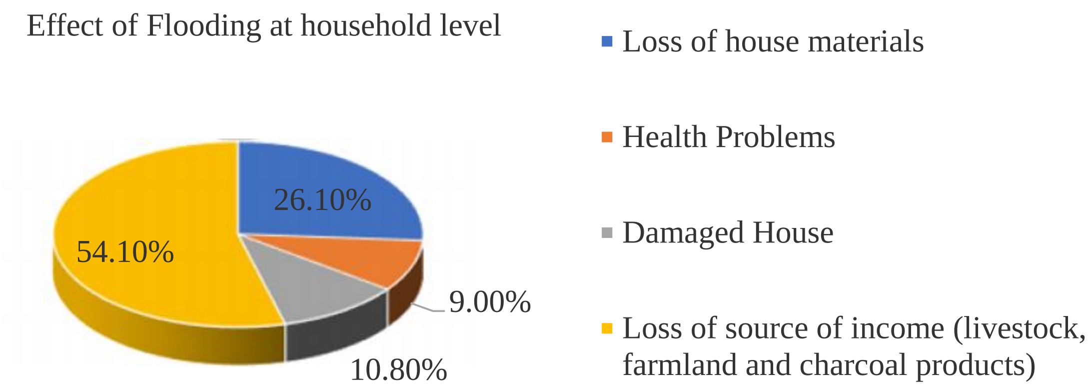


Figure 24: effect of flooding at household level

The survey revealed various health risks associated with flooding, including diarrhea, fever, malaria, headache, and common cold, which were experienced by 39.4 %, 33.3 %, 20.2 %, 5.1 %, and 2.0 % of the survey households (mostly children), respectively (Figure 23). The surveyed households did not report any deaths as a result of flooding. Flooding, on the other hand, disrupted work, school, and other normal daily activities in the surveyed areas. Similarly, Legesse Brook and Gumi Boneya (2020) found that the major health impacts of flooding include injuries, diarrheal diseases, vector-borne diseases, malnutrition, psychological state problems, and damage to infrastructure. Death due to flooding either through drowning or injuries are common in most flooding events as indicated by (WHO, 2014).

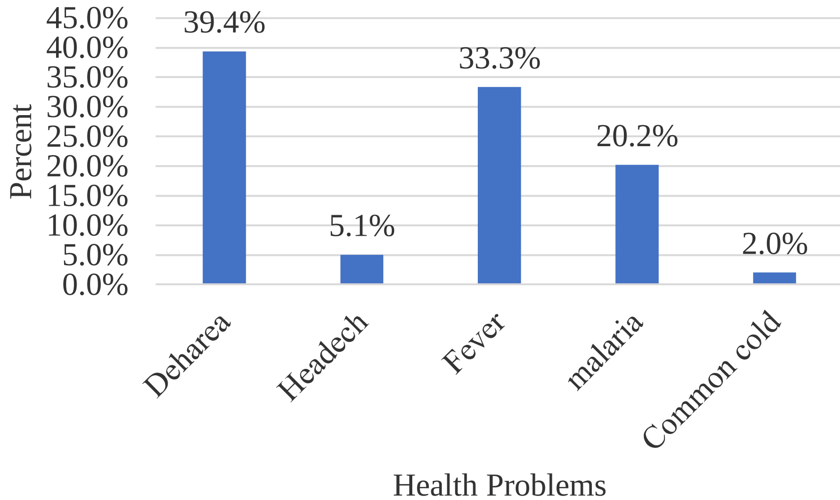


Figure 25: Household health risks during the flood disaster

Stagnant water (as shown in Figure 24) during and after flooding may exacerbate the health problem in the study areas by serving as a potential breeding site for malaria. Diarrheal diseases can be caused by drinking contaminated water.

Source: AFWEPEO, September 2020

Figure 26: Parts of the flooded areas and stagnant water

The flood of the 2020 kiremt season wreaked havoc on the local infrastructure in the surveyed areas. Flooding impacted school facilities, health facilities, farmer training centers, and local roads, according to 19.4 %, 21.9 %, 15.6 %, and 14.8 % of survey respondents, respectively. However, 28.3 % of households stated that they were unaware of the effects of flooding on local infrastructure (Table 17). Flood-affected households had difficulty obtaining services from this infrastructure or evacuating to these facilities due to the impact of flooding on this infrastructure. Hence, flooding has impacted local government infrastructure, disrupting services provided by infrastructure such as schools, farmer training centers (FTC), and health facilities.

Similarly, numerous studies (for example, Njogu, 2021; UN, 1999; WHO, 2014; Onywere et al., 2011) have described the impact of floods on infrastructure. These studies show the devastation caused by floods on physical infrastructures like roads, communication, buildings, and social amenities, as well as the disruption of services provided by this infrastructure. Infrastructure disruptions have an impact on all economic activities that rely on it, and they frequently have unintended consequences such as loss of life and livelihood, increased outages of electricity, water, and communication, and ultimately leaving communities vulnerable to floods (Njogu, 2021).

Table 20: Flood impact on local infrastructure

Damage on local Infrastructure	Response	Percent
Farmer Training Center	37	15.60%
Health Facilities	52	21.90%
School	46	19.40%
Local Road	35	14.80%
Don't know	67	28.30%

4.5. Assistance and coping mechanisms in the surveyed households

According to survey results on studied households (Table 18), 92.5 % receive both food and non-food items (typically household equipment), 5 % receive only food items, and 2.5 % receive only non-food items during flooding from communities outside of flood-prone areas, local governments, and charitable organizations. Field observations and discussions with local disaster management experts revealed that the assistance provided by these communities and organizations reduced food-related expenses, partially replaced lost household property, and partially relieved psychological stress. However, this heartfelt assistance will not provide long-term solutions for flood victims. In this regard, Wisner et al. (2004) stated that flood victims require immediate assistance because the majority of them lost property or livelihoods, albeit to varying degrees. However, as stated by Wisner et al. (2004), people's ability to cope with disaster is heavily influenced by the level of social and economic conditions.

Table 21: Recipients of local relief goods

Types of Relief	Recipient	Percent
Food items	6	5.00%
Non-food items	3	2.50%
Both food and non-food items	111	92.50%

Figure 26 shows that, in addition to receiving relief assistance, 72.5 % of the households reported being Productive Safety Net Program (PSNP) beneficiaries, indicating that the survey households had a low economic base and are vulnerable. PSNP is one of Ethiopia's government strategies for increasing household, community, and national resilience to climate shocks, and it has been implemented in chronically food insecure districts (woredas) across six Ethiopian regions, including Afar (DFID, 2015). This program could help the surveyed households with their adaptation and mitigation efforts. Figure 27 depicts flood victims receiving food and non-food items (relief support) in the study area.

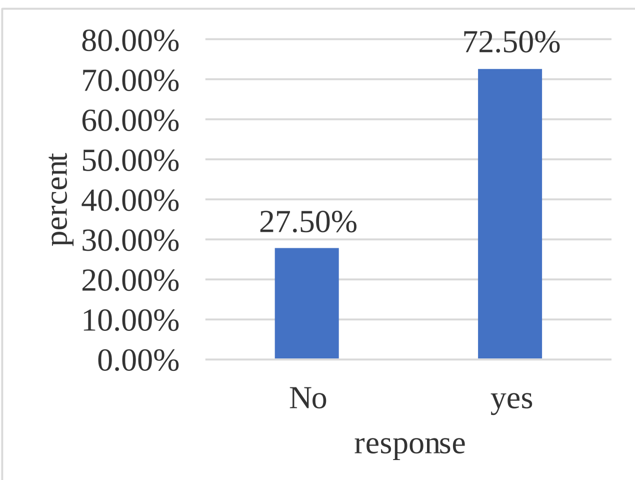


Figure 27: household SafetyNet beneficiaries

Source: AFWEPEO, September 2020

Figure 28: Flood victims while receiving food and non-food items

Households and individuals used a variety of local flood-response strategies to deal with floods. According to Habtu , (2011) disaster victims employ a variety of coping strategies at various levels (individuals/households, community, and institutional). This study took into account coping mechanisms such as selling livestock, receiving assistance from relatives, local governments, humanitarian organizations, and friends, as well as reducing expenses and food consumption. Respondents also demonstrated a variety of strategies for dealing with a flood disaster. Figure 28 shows that approximately 26.7 % reduced their food expenses and consumptions, 25 % received assistance from humanitarian organizations, 20 % received assistance from local governments, 15 % sold their livestock, and approximately 9 % received assistance from relatives and social groups as a way of recouping their losses.

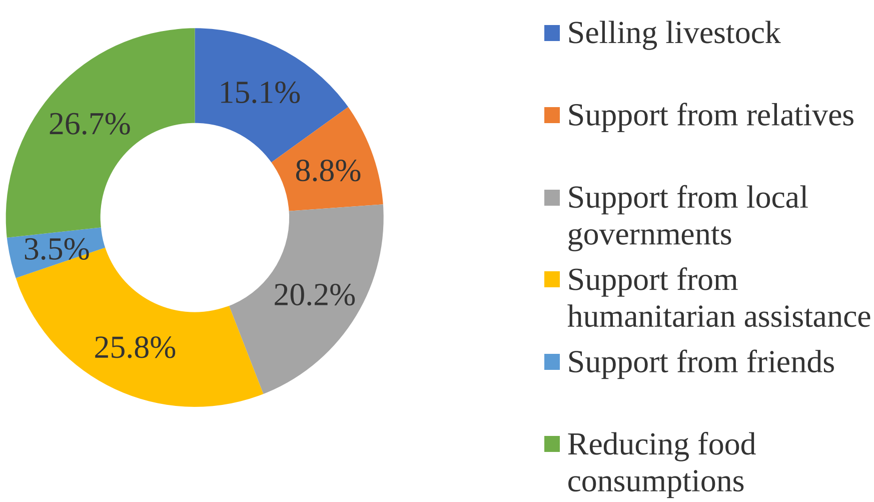


Figure 29: Household coping mechanisms to flood

As per the survey results, approximately 73 % of the households did not receive, while 27 % received flood prevention and preparedness training (table 19). This means that those who have received flood training have a better understanding of flood situations and how to protect themselves from their effects than those who have received no flood training. According to Nazli et al., (2014) disaster preparedness is an effort designed to enhance staff and community readiness and knowledge. Flood training for flood-affected communities is important as a means of preparing for potential future flood events and reducing the impact of the flood. Furthermore, Nazli et al., (2014) advocated for the prioritization of public preparedness programs aimed at disaster-prone communities through hands-on training.

Table 22: Training status before flood events

Household training on flood disasters	Response	Percent
yes	32	26.7%
no	88	73.3%

Despite differences in the types of training required, the majority of respondents in the surveyed areas require training on flood evacuation routes (34.7 %), flood warning signals (38.9 %), and flooded sites (20.8 %). Only 5.6 % were uncertain of the type of training they really want (Figure 28). According to Nazli et al., (2014) disaster training needs assessment is critical to ensuring that proper training is delivered to the right trainee at the right time.

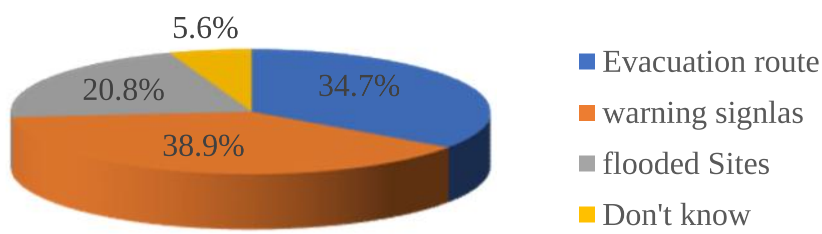


Figure 30: Household training need

4.6. Households' flood experience and proximity to flood hazard areas

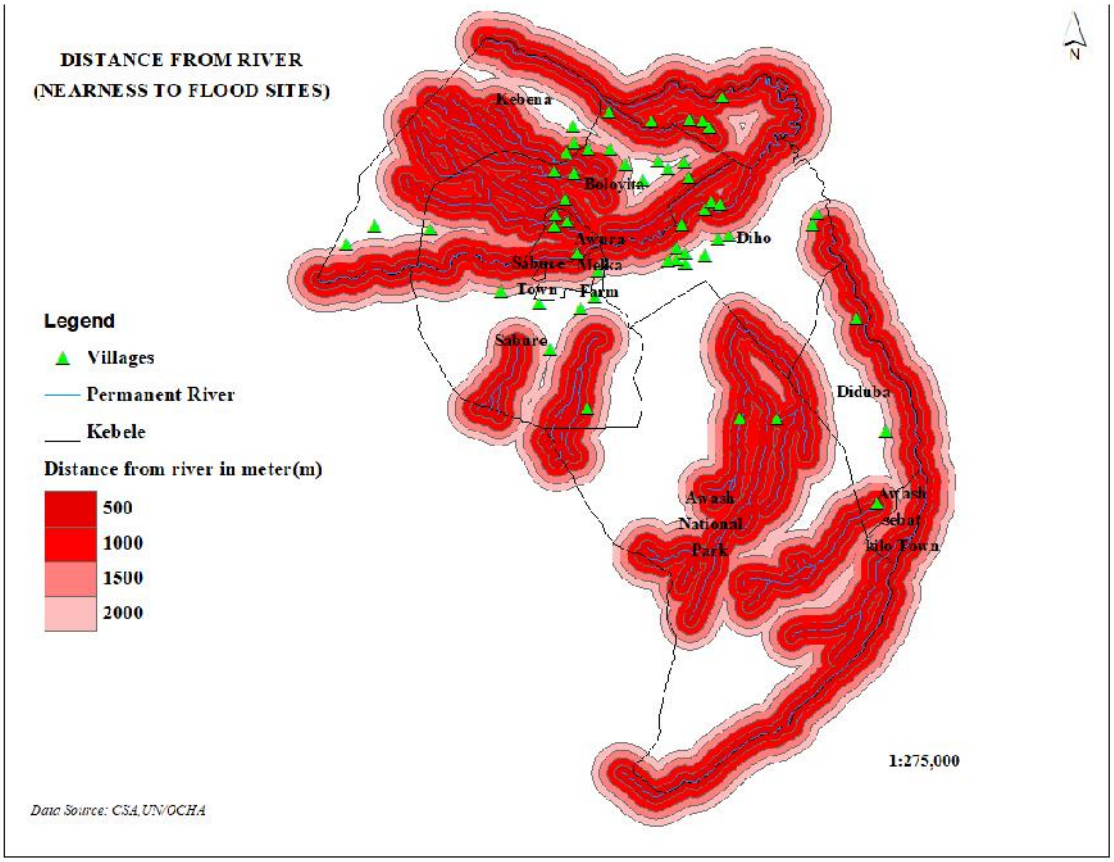
The length of stay in flood-prone areas demonstrates flood experience and how people cope with flooding as they become more exposed to it and acquire knowledge or skills to adapt to it. This means they have had sufficient exposure to flood events. Local administrators (kebele chairpersons) also confirm that flooding occurs on an annual basis. This means that the households have been subjected to varying degrees of flooding each year. According to the survey results, approximately 84.5 % of the households have had more than ten years of experience with flooding, while 12.1 % have had four to ten years of exposure to flooding in the surveyed areas (table 20).

Table 23 : Length of stay in the study area

Length of stay in the study area	Response	Percent	
Less than 3 years	4	3.4%	
4 to 10 years	14	12.1%	
above 10 years	98	84.5%	

Rivers are viewed as both a benefit and a threat in the study area. It has a variety of economic and social benefits, such as human and livestock consumption, agriculture (primarily kesem sugar plantations), and has become a threat to those who live near these rivers (Kesem, kebena, and Awash), as water levels in those rivers are not always consistent. Flooding occurs in the study areas in three ways: as a result of heavy rainfall, as a result of natural river flooding caused by upstream heavy rainfall, and as a result of dam water release (for fear of dam failures during rainy season).

Doocy et al., (2013) stated that as deforestation and the proximity of large populations to coastal areas, river basins, and lakeshores increase, so does the risk of catastrophic losses due to flooding. A 2km buffer zone was built around the study areas' major rivers and settlements, and it was found that the majority of the settlements are within 1km to 2km of the rivers. As a result, flooding in the study area became a common occurrence, resulting in household property loss and infrastructure damage, particularly for those households living close to these rivers.



Source: own, June 2021

Figure 31: Map of proximity to flood hazard sites

Thus, it can be deduced from the above results and discussion that households with dependent family members (children < 14 years, disability, health problems, elderly >65 years), those living close to major rivers, far from the main road, unable to access basic amenities (health facilities and schools), evacuation center, transport services, no social or PSNP assistance, receive mean monthly income less than 3,000 ETB and rely on a weak livelihood base (such as charcoal production), with no-flood related training, no flood experience, not able to get flood information as well as no formal educational background are found to be the most vulnerable groups in the study area.

5. Conclusion and recommendation

5.1. Conclusion

The study found that the study area was prone to floods during the 2020 kiremt season. The 2020 kiremt season flooding in the study area was caused by the overflow of rivers such as the Kebana, Kesem, and Awash, as well as heavy rain falls upstream and the study area's (low-lying) topography. And, because of their proximity to these major rivers and low-lying topography, the majority of respondents were exposed to flooding. Based on the defined categories, the social vulnerability index (0.81) highlights the study area's exposure as a high-risk area. These have exacerbated the already precarious livelihood base in the study area.

The study also revealed that households with dependent family members (children <14 years of age , disability, health problems, elderly >65 years), those living near major rivers, those living far from the main road, those unable to access basic amenities (health facilities and schools), those living far from evacuation centers, transport services, those receiving no social or PSNP assistance, those with no information about the flood, and those with a mean monthly income of less than 3,000 were more likely to be affected.

Consequently, this study demonstrated the importance of GIS for flood exposure mapping by examining risk elements with spatial dimensions such as land use, population, settlement, and road network., AHP method of multi-criteria evaluation techniques in combination with survey for identifying, weighting, and ranking of major driving factors for social vulnerability to flood. It also demonstrates that social vulnerability to flooding is context-dependent.

The findings would serve as a guide for computing, identifying socially vulnerable groups, assessing the extent of the impacts, ranking and prioritizing major driving social vulnerability factors to flooding, and making critical interventions based on the findings.

5.2. Recommendations

The following points are thematically recommended by the researcher based on the study's findings.

- Restricting the construction of houses near the Kebena, Bulga, and Awash rivers, constructing raised-column housing, installing flood barriers around the house and public infrastructure, as well as providing proper flood prevention and preparedness training prior to a flood event, will help to mitigate the flood's impact in the study area.

- Harmonizing and improving the livelihoods of the study area by diversifying their income through the introduction and cultivation of flood-resistant crops such as rice, wheat, and barley, which can strengthen their resilience to flood disasters.
- Prioritizing and intervening on identified social vulnerability driving factors, as well as addressing vulnerable groups based on vulnerability condition, such as children under the age of 14, people with health problems (including disabilities), people over 65, and pregnant women.
- The local government should implement a community-based flood forecasting system as well as a flood prevention and preparedness plan to mitigate the effects of the flood.

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Annex I Questionnaires for social vulnerability to flood survey

Introduction and consent

My name is ______________ from Addis Ababa University, college of development studies center for Environment and Sustainable development. I'm here to conduct my thesis research on topic "Exposure and Social Vulnerability to Flood using GIS and Multi-criteria Evaluation: the case of Awash Fentale Woreda, Afar Regional Sate, Ethiopia" for the partial fulfillment of MA in Environment and Sustainable development. This Study focus on social and household characteristics that expose and make households vulnerable to the 2020 Ethiopian rainy season flood. This study will contribute to flood disaster preparedness and prevention process before, during and after disasters. And the information you provide shall not be transferred to third party and will be kept confidentially. Can I proceed to the Questions? Yes No

Household code: ______________

Date of Interview ______________

Approved by ______________

Part II: Household social Vulnerability to flood questionnaires

1. Household code ______________
2. Address
   a) Region ______________
   b) Zone ______________
   c) Woreda ______________
   d) Kebele ______________
   e) Gote/villages/localities ______________
   f) Geographic coordinates in decimal degree

Latitude ______________

Longitude ______________

3. Age and gender of household head and family member

Family members						Average HH size		Female HHH	Male HHH
<14 years		14-65 years		>65years		M	F		
M	F	M	F	M	F				

4. Have you received training on flood prevention and related issues?
    a. Yes
    b. No
5. What is your training need regarding flood disasters?
6. What coping strategy did you used to temporarily alleviate the flood disaster?
7. What was the flood disaster impacts on local infrastructure during flooding? List them
8. What health problems occurred to household members during flood disaster? List them
9. How long have you been in this area?
    1. Less than 3 years
    2. 4 to 10 years
    3. above 10 years
10. Are you SafetyNet Beneficiary?
    1. Yes
    2. No
11. What type of relief have you received?
    1. Food item
    2. Non-food item
    3. Food and non-food items
    4. Others-explain
12. What mode of transport you usually use?
    1. Tricycle (Bajaj)
    2. Motor cycle
    3. Car
    4. Foot

13. How far from your home to get the main road?
    1. Less than 5km
    2. 5km to 10km
    3. Above 10 km
14. How far from your home to school around your residence?
    1. Less than 5km
    2. 5km to 10km
    3. Above 10 km
15. How far from your home to health facility around your residence?
    1. Less than 5km
    2. 5km to 10km
    3. Above 10 km
16. What is the educational status of you (Household heads) and your family members?
    1. No schooling
    2. Elementary
    3. High school
    4. College /university
    5. vocational
17. Indicate most affected family members by the flood disasters?
    1. Children
    2. Elderly
    3. Disabled
    4. Pregnant
    5. others
18. What environmental activities do you think has contributed to increase flood disasters in your area?
    1. Forest clearing
    2. Failure to build flood defenses
    3. Loss of attention from management
19. How did you get information about flood?
    1. Informed by the Local Disaster Risk & Management

2. Radio
3. Television
4. Traditional communication System (*Dagu*)

20. What is the main source of income of your household?
    1. Livestock
    2. Charcoal production
    3. Employed
    4. Crop production
    5. Daily labor
    6. others

21. what is the average monthly income of the households?
    1. Less Than 3000
    2. 3000 to 4999
    3. above 5000

22. Indicate the road condition of your area
    1. Rough dirt & muddy road when raining
    2. Gravel
    3. Asphalt
    4. Concrete

23. Indicates types of housing
    1. Hut (Ari)
    2. Stone house (Dabou)
    3. Chika Houses

24. What was the impact of the flood disaster at household level?
    1. Loss of household materials
    2. Livestock loss
    3. Health Problems
    4. Damaged house
    5. Flooded farm and pasture land
    6. Others

25. Is there an evacuation during flooding? Yes No

26. If answer to Q 25 then please describe condition of public facilities and services in your evacuation center
27. Who were most affected by disasters in your family? How?

Part II Questionnaires for Woreda Disaster and Preparedness Office

Woreda profiles

1. Name of the woreda where the study conducted ______________

   Region ______________

   Zone ______________

2.Woreda Aerial Extent (Area of the woreda) ______________

3. Woreda total populations by sex:

   Male ______________

   Female ______________

4. Topography

   Elevation ______________

   Terrain ______________

   Vegetation ______________

   Soil type _____________

5. Unemployment rate ______________
6. Woreda land use category ______________
7. Rainy Season ______________
8. Are warnings given on time to prepare your residents in flood Affected areas of the woreda? Yes No
9. Can you explain what has so far been done to mitigate the flood disaster in flood prone areas by the government or non- governmental organizations?
10. What kind of assistance provided to flood affected areas during and after flooding?
11. What plan is there to alleviate the impact of flood in the area sustainably?
12. Number of people affected by the 2020 *kirmet* season flood
13. Number of people displaced from their homes

14. Is there land zonation in flood affected areas (legal framework that protect settlements in flooded areas)

First of all, I would like to thank you for your participation in this pair-wise comparisons techniques where each criterion is compared with the other criteria relative to its influence to social vulnerability to flood in Awash Fentale on a scale from 1 to 9. So, I will appreciate if you could fill in the required information by circling.

Factor	Factor Weighting Score																	Factor
	More Important than								Equal		Less important than							
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C1
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C2
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C3
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C4
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C5
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C6
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C7
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C8
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C9
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C10
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C11
C1	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C12
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C1
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C2
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C3
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C4
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C5
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C6
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C7
C2	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C8

	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C9
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C10
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C11
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C12
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C1
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C2
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C3
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C4
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C5
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C6
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C7
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C8
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C9
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C10
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C11
C3	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C12
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C1
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C2
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C3
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C4
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C5
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C6
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C7
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C8
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C9
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C10
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C11
C4	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C12
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C1
C5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C2

	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C3
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C4
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C5
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C6
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C7
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	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C9
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C10
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C11
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	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C1
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C2
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C3
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C4
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C5
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C6
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C7
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	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C9
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C10
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C11
C6	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C12
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C1
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C2
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C3
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C4
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C5
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C6
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C7
C7	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C8

	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C9
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C10
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C11
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C12
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C1
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C2
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C3
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C4
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C5
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	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C7
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C8
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C9
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C10
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C11
C8	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C12
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C1
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C2
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C3
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	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C5
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	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C9
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C10
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C11
C9	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C12
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C1
C10	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C2

	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C3
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C4
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C5
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C6
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	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C7
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	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C10
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C11
C11	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C12
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C1
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C2
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C3
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	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C5
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C6
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C7
C12	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C8

	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C9
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C10
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C11
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C12

Thank you for your participation

2020 Flood Affected and displaced localities, and Households in Awash Fentale Woreda													
Affected Kebeles	Affected localities	Displaced Households			Displace from	Displaced to	Households affected at their home			Total displace and Affected households		
		Male HHs	Female HHs	total			Male HHs	Female HHs	Total	Male HHs	Female HHs	Total
Kebena	Yalo	79	28	107	Yalo and Ededas	Dankar and E'aba	387	102	489	466	130	596
	kudu - Ededas											
	Ero - Ededas											
	Ferese-gubi											
	E'aba											
	Gurmule											
	Fenti ilala											
	Keda-ilala											
	Hadiya-hbur											
	Hadi											
Boloyita	Rifoda	251	49	300	Teneshu-melkadura and Rifoda	Teneshu-ilala andkoma-ergid	248	67	315	499	116	615
	Sifera											
	Hayukelo											
	Teneshu-melkadura											
	Keda--melkadura											
	Teneshu-ilala											
	Mhal-											

	boloyita										
	Keda-boloyita										
Doho	Hamdas	343	57	400		China camp and ku'hala	175	35	210	518	92	610
	Arb-hara											
	Nemelyfen											
Sabure	Awessa	–	–	–			346	63	409	346	63	409
	Wasero											
	Dadiga											
Total		673	134	807			1156	267	1423	1829	401	2230

Source: AFWDRMO,2020