



ADDIS ABABA UNIVERSITY
**ETHIOPIAN INSTITUTE OF
WATER RESOURCES**



SCHOOL OF GRADUATE STUDIES

**TEMPORAL CHANGES OF FLOOD SENSITIVITY
IN AWASH BASIN**

By: Tinsae Seboka Debel GSR 7749/10

MSc. RESEARCH SUBMITTED
TO
ETHIOPIAN INSTITUTE OF WATER RESOURCES
WATER RESOURCES ENGINEERING AND MANAGEMENT

September, 2021
ADDIS ABABA

Researcher's Declaration

I, the undersigned, certify the following conditions of authorship I am responsible for the work submitted in this Master Thesis entitled "TEMPORAL CHANGES OF FLOOD SENSITIVITY IN AWASH BASIN", and that the original work is my own. I have not submitted this work to any other institution for the award of a degree. All information (including Figures and Tables) or other information which is copied from, or based on, the work of others has its source clearly acknowledged in the text at the place where it appears.

Declared By

Tinsae Seboka

RESEARCHER's NAME

SIGNATURE

DATE

Confirmed By

This thesis has been submitted for examination with my confirmation as advisor of the thesis.

Alemseged Tamiru

NAME OF ADVISOR

SIGNATURE

DATE

TEMPORAL CHANGES OF FLOOD SENSITIVITY IN AWASH BASIN

Tinsae Seboka GSR 7749/10

Master's Thesis Submitted

To

Ethiopian Institute of Water Resources (EIWR)

Water Resources Engineering and Management specialization in surface water management

Approved by Board of Examiners:

_____	_____	_____
Main Advisor	Signature	date
_____	_____	_____
Internal Examiner	Signature	date
_____	_____	_____
External Examiner	Signature	date
_____	_____	_____
Chairperson	Signature	date
_____	_____	_____
EIWR Education Coordinator	Signature	date
_____	_____	_____
EIWR Director	Signature	date

ABSTRACT

Flooding is a natural disaster that causes considerable damage. Awash basin is susceptible to flooding due to physical characteristics. Therefore, sensitivity mapping are essential for comprehensive management to reduce the harmful effects of flooding. This research aims to assess flood sensitivity in the Awash basin. The sensitivity maps use geographical information systems (GIS). Indicators for Land use, soil type, river buffer and slope determine the sensitivity of the area. There were significant temporal changes in flood sensitivity in three years which had five time interval for each. Based on the flood sensitivity, the slope, soil, river buffer and land use type were classified into 5 classes which include least sensitive, limited sensitive, moderate, and sever and critical sensitive. Most parts of the basin were found highly sensitive to flood when scores of the criteria were aggregated based on experts' weight than using equal weight. The flood maps show that the upper part of the basin is highly sensitive due to slope and land use factor but there the flood sensitive areas are expanding to the downstream part of the basin due to increased urbanization. The output of the study can contribute to flood sensitivity management in the Awash basin; it can be used by different institutions like the local disaster management authority, researchers, land use planners, government, and for others who working with flood management. It helps watershed managers to decide based on more informed data for flood mitigation. The most important output of this research is that by using the flood sensitivity indicators, land use, slope and soil, it is possible to obtain a temporal change of sensitivity to flood using a method that uses readily available data instead of more complex flood risk methods.

KEY WORDS: FLOOD SENSITIVITY, GIS, INDICATORS, AWASH BASIN

ACKNOWLEDGEMENT

I would like to express my sincere gratitude to my advisor, Dr. Alemseged Tamiru, for nonstop guiding advising and supervising in my entire work from proposal time up to final thesis and providing me with important reference materials.

I would like to acknowledge the Dilla University for financial support and to all staff members of Ethiopian institute of water resources. Ethiopian geospatial agency, Ministry of water resources, Ethiopian geological survey and Awash basin authority also helped me by providing maps of the basin, land use maps and soil data.

I would also like to thank of Dr. Azage Gebreyohanes who was (Assistant Professor in Transboundary Water Management and also the late Education Coordinator of Ethiopian Institute of Water Resources) for facilitating and advising all the necessary activities.

“All praise and thanks be to GOD”, the Lord of existence, the most Gracious, and Merciful”
I also would like to express my deepest indebtedness to my parents, as always they were there, right beside me in my sorrow and joy, and may GOD reward them all with his highest blessings.

TABLE OF CONTENTS

ADVISORS APPROVAL SHEET	i
ABSTRACT	i
ACKNOWLEDGEMENT	iv
List of table	vii
List of figures	viii
CHAPTER ONE: INTRODUCTION	- 1 -
1.1. Background	- 1 -
1.2. Statement of the Problem	- 2 -
1.3. Objectives of the Study	- 4 -
1.4. Significance of the Study	- 4 -
CHAPTER TWO: LITERATURE REVIEW	- 5 -
2.1. Definition of Terms	- 5 -
2.2. Approaches.....	- 7 -
2.2.1. Exposure.....	- 7 -
2.2.2. Sensitivity.....	- 8 -
2.2.3. Vulnerability	- 8 -
2.3. Indicators to Estimate Vulnerability	- 9 -
2.3.1. Exposure.....	- 9 -
2.3.2. Sensitivity.....	- 10 -
2.4. Assigning Scores to Indicators to Estimate Vulnerability.....	- 10 -
2.5. Aggregation to Establish Composite Index.....	- 10 -
2.6. Weakness in Conceptualization and Aggregation.....	- 11 -
2.7. Temporal Changes of Flood Exposure and sensitivity.....	- 11 -
2.8. Flood Vulnerability in Awash Basin	- 12 -
2.9. National and global Data on flood vulnerability	- 13 -
CHAPTER THREE: METHODS	- 14 -
3.1. General Description of the Study Area	- 14 -
3.1.1. Location.....	- 14 -
3.1.2. Climate	- 15 -
3.1.3. Land use and soils	- 16 -
3.2. Data Collection methods	- 16 -
3.2.1. Data sets for catchment characteristics	- 16 -
3.2.2 Data Analysis Methods	- 18 -

CHAPTER FOUR: RESULTS AND DISCUSSIONS	- 22 -
4.1 Results	- 22 -
4.1.1 Analysis result.....	- 23 -
4.2 Contribution of various factors for flood sensitivity.....	- 25 -
CHAPTER FIVE: CONCLUSIONS AND RECOMMENDATION.....	- 32 -
References.....	- 34 -

LIST OF TABLE

Table 3. 1 Major data and their sources.....	- 17 -
Table 3. 2 Indicators of Sensitivity of flood (Adopted from Vulnerability and adaptation).....	- 19 -
Table 3. 3 A sample of the questionnaire.	Error! Bookmark not defined.
Table 4. 1 sensitivity score based on expert’s opinion	- 23 -
Table 4. 2 sensitivity class for equal and experts’ weight	- 25 -

LIST OF FIGURES

Figure 3. 1 Ethiopian river basins and location map of the study area.....	- 15 -
Figure 3. 2.Methodological framework to develop and evaluate the first order vulnerability map	- 18 -
Figure 4. 1 Drainage map of the study area.....	- 22 -
Figure 4. 2 Flood sensitivity map of Awash Basin(taken from GSE).....	- 24 -
Figure 4. 3 Flood sensitivity based on expert’s weight	- 24 -
Figure 4. 4 flood sensitivity based on equal weight	- 24 -
Figure 4. 5 Flood sensitivity based on Slope of Awash Basin	- 26 -
Figure 4. 6 flood sensitivity based on land cover of Awash basin 2008	- 27 -
Figure 4. 7 Flood sensitivity based on land cover of Awash Basin 2013.....	- 27 -
Figure 4. 8 flood sensitivity based on land cover of Awash basin 2018	- 27 -
Figure 4. 9 Flood sensitivity based on soil class of Awash Basin.....	- 28 -
Figure 4. 10 Temp_profile curvature of slope on Awash Basin.....	- 29 -
Figure 4. 11 Flood sensitivity based on River Buffer of Awash Basin.	- 29 -
Figure 4. 12 Flood sensitivity in 2008.....	- 31 -
Figure 4. 13 Flood sensitivity in 2013	- 31 -
Figure 4. 14 flood sensitivity in 2018.....	- 31 -

ABBREVIATIONS AND ACRONYMS

AWBA	Awash Basin Authority
DEM	Digital Elevation Model
DPPC	Disaster Prevention and Preparedness Commission
FAO	Food and Agricultural Organization
GIS	Geographic Information System
IPCC	International Panel on Climate change
NDRMC	National Disaster Management Commission
NDVI	Normalized Difference Vegetation Index
NMA	National Meteorological Agency
NOAA	National Oceanic and Atmospheric Organization
OECD	Organization for Economic Cooperation and development
SRTM	Shuttle Radar Topographic Mission
UN	United Nation
UNISDR	United Nations International Strategy for Disaster Reduction
USAID	United States Agency for International Development
USGS	United States of Geological Survey

CHAPTER ONE: INTRODUCTION

1.1. Background

The drivers of climate change are affecting the hydrological system by climatic (e.g. Rainfall) and non-climatic (e.g. Land-use pattern) factors. The developing countries are more vulnerable to the climatic adversities due to the fact that their economies being largely dependent on agriculture (Bhatt & Mall, 2015). Crop production in developing countries of Africa is highly dependent on rainfall. Excessive rain during the rainy seasons causes most of river flooding, at times, threatening the livelihood of the people. Appropriate land use, including crop production, calls for thorough and scientific flood mapping, creates easily readable, rapidly accessible charts and maps which facilitates the administrators and planners to identify areas of risk and prioritize their mitigation/response efforts (IPCC, 2010).

Flood is a relatively high flow of water that overtops the natural and artificial banks in any of the reaches of a stream. When banks are overtopped, water spreads over flood plain and generally causes problem for inhabitants, crops and vegetation. During extreme flooding event it is important to determine the severity of flooding and land use under water (Wang, et al., 2002).

Nowadays GIS has emerged as a powerful tool for the assessment of vulnerability and the control of Natural disasters. Due to these approaches, natural hazard mapping could be developed to delineate flood risk areas on the map. This kind of maps will contribute for the immediate assessment of probable impact of a natural hazard and implementation of necessary measures for mitigating the impact. So, it will help the decision-makers to take informed decision. It will also help during post disaster activities for the assessment of damages and losses occurring due to flooding. Moreover, GIS provides a broad range of tool for determining areas affected by floods or forecasting areas likely to be flooded due to high discharge of the river. When spatial and temporal data are used in an information system, one tends to speak of a spatial and temporal information system. Spatial data has a physical dimension and geographic location. With the help of sequential images of certain area, we

can find out the behavior of the flood routing and damages (Ahmad, et al., 2018; Hardmeyer, 2007).

Ethiopia is one of the countries that are affected by flooding. Ethiopia has mountainous and lowland geographical which consists of twelve main river basins, the drainage originates from the central highlands and flow down to outlying lowlands. Especially during the rainy season (June-September), the major perennial rivers beside their several tributaries forming the country's drainage systems carry their peak discharges (Kefyalew, 2003).

The country encounters two major types of flooding: flash floods and river floods. Flash flood is caused by excessive rainfall on the upstream watersheds and gush downstream with concentration, speed and force (AWBA, 2017). Often, this incident is sudden and usually unnoticed. So, these floods frequently result in a significant damage it becomes catastrophic when they pass across or along human settlements and infrastructure concentration.

1.2. Statement of the Problem

Literatures suggest that climate change increases the frequency and magnitude of river flood (IPCC, 2012). In the last decade, the recurrence of flash floods obviously increased all over Ethiopia, which caused several mortality and substantial property loss (Paolo, et al., 2013). These studies indicated that the whole country is prone to the risk of flash floods due to climate change, intense monsoon rainfall in short time during rainy seasons. In addition to climate change, land clearing for agricultural use undoubtedly has increased the magnitude of flooding which in turn has increased the damage to the properties and life. Further, intensive agricultural activities on steep slope areas of the catchment and its expansion decrease the abstraction of rain water and there by changes quickly to flood (NMA, 2015).

As the landform of the country is rather rough with distinctly defined watercourses, extensive flooding is limited to the lowland flat parts of the country. However, intense rainfall in the highlands causes flooding of settlements in a number of river basins (Kefyalew, 2003).

The vulnerability of the population persist in the Awash River and in the marshlands has been aggravated due to outwardly inappropriate settlement patterns in flood sensitive areas in recent years. Rapid development, which includes urbanization in centers such as Addis

Ababa, Adama and Dire Dawa, will expand this sensitivity. This increases the probability of water scarcity at particular points in time and space as well as potential adverse impacts from flooding (Guinand, 1999).

Studies on the exposure and sensitivity to flood are limited in Ethiopia. The assessments are mostly related to only the excessive rainfall event. Though the reason of flooding is not only related to climatic factors, other considerations are also important. Vulnerability assessment considers many dimensions. To create vulnerability map, it requires the simplification of the diversified dimensions. Scholars used different methods to simplify and aggregate indicators of exposure and sensitivity without providing justifications (Luh, et al., 2015). There are also gaps in assigning scores since they are highly subjective. In literature, the accuracy of many vulnerability maps is not presented through validation against flood observations despite the many associated uncertainties in generating such maps.

Most vulnerability studies provide assessments only for specific time ignoring temporal changes in vulnerability. However, there are scientific evidences that show vulnerability of a community may change over time due to changes in climatic and non-climatic factors (IPCC, 2012).

Therefore, this research is necessary to fill gaps in:

- i. Flood vulnerability studies for climate change in Ethiopia,
- ii. Validation of flood sensitivity maps, and
- iii. Temporal changes in flood sensitivity.

1.3. Objectives of the Study

The general objective in this study is to assess the temporal changes of flood sensitivity of Awash basin.

The Specific objectives are:

- to compare simple additive and expert knowledge based weighting in flood sensitivity assessments
- to evaluate the accuracy of flood sensitivity map using national data and
- to assess the temporal change of sensitivity to flood hazard in the study area

The following research questions are identified based on the objectives of this study

- How can we best aggregate indicators for sensitivity?
 - Which of the weighting method is more recommendable to produce sensitivity map in Awash River basin?
- Is the vulnerability affected by sensitivity?
 - Which parts of the Awash Basin is more sensitive for flooding?
 - Is the accuracy of the flood sensitivity map acceptable to use the map for flood risk management?
- Is there any significant temporal difference in flood sensitivity of Awash Basin?

1.4. Significance of the Study

The major significances of this study;

- ✓ To provide information to the stakeholders about the sensitivity of flood in Awash River basin in order to prevent catastrophic flood damage.
- ✓ To provide information about the stakeholders the spatial and temporal change of flood sensitive areas in Awash Basin in order to use effective land use planning.

1.5 Scope of the study

The study covers Awash basin and flood sensitivity assessments restricted to five sensitivity indicators.

CHAPTER TWO: LITERATURE REVIEW

Under this section, key concepts related to: vulnerability, sensitivity, and exposure are reviewed. The role of GIS and remote sensing in vulnerability assessment are presented. Generally, the reviews are focused on assessing the existing scientific knowledge and gaps that are related to the subject of this study.

2.1. Definition of Terms

Vulnerability: it has diverse definition in literature; such diversity result from the specific aspects of the vulnerability which depend on the type of study, on the results required (damage evaluation or urban planning project), on the kind of flood hazard (flash flood or slow-flood), on the spatial and temporal scale of study, on the specificity of the study area and on the temporality (prevention, crisis, post crisis). Some definitions focus on the protection of individuals, others on the maintenance of economic activities or the protection of the environment. Finally, vulnerability definition is also linked to the particular system functions analyzed (Parent, et al., 1999).

Vulnerability describes a set of conditions of people that derive from the historical and prevailing cultural, social, environmental, political, and economic contexts. For instance vulnerability in the context of disaster risk management, it is defined as a degree of damage to a certain object at flood risk with specified amount and present scale from 0 to 1 (no damage to full damage) (UN, 1997). The United Nations office for disaster risk reduction define Vulnerability as a condition which is influenced by physical social, economic and environmental factors that raises the susceptibility of people to the impact (UNISDR, 2009). Vulnerability refers to the propensity of exposed elements such as human beings, their livelihoods, and assets to suffer adverse effects when impacted by hazard events (Liverman, 1990; 2006).

Vulnerability in the context of climate change defined as "...the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes (Parry, 2007). Intergovernmental panel for climate change defined vulnerability as the degree to which the socio-ecosystems of the case study region may be unable to cope with or susceptible to the adverse effects of climate change. One of the most

prominent definitions is the one reflected in the IPCC Fourth Assessment Report, which describes vulnerability as a function of exposure, sensitivity, and adaptive capacity (IPCC, 2001), as also reflected by, for instance, (McCarthy, 2001; Brooks, 2003; Fussel and Klein, 2006).

The definitions seem similar in defining vulnerability as the degree to which a system is susceptible to adverse effects of any hazard. However, some of them are different in correlating vulnerability as exposure and /or sensitivity, some of them completely related to hazard and risk. And the other one is the function of exposure, sensitivity and adaptive capacity.

It is argued that Vulnerability is the inability to resist a hazard or to respond when a disaster has occurred. For instance, people who live on plains are more vulnerable to floods than people who live higher up.

Exposure: is defined as the magnitude, spatial extent, and rate of change of an area due to climate change. Adger (2006) viewed exposure as the degree to which an area is in contact with a perturbation. Flood hazard exposure describes who and what might be harmed by the flood hazard. Thus, it requires a description of where the flooding occurs and what exists in that area (Nelitz, et al., 2013).

Sensitivity: is defined as a measure of the extent to which human communities or ecosystems will be affected by a given change (Fussel and Klein, 2006). While Gallopin (2006) stated Sensitivity is a degree to which a system likely to be affected by a perturbation.

Indicator: Indicator is defined as single measure of a characteristic (e.g., water temperature), the units of which can be described by a particular metric (e.g., annual maximum temperature) (Nelitz, et al., 2013). According to OECD (2002) an indicator is a quantitative or qualitative factor or variable that provides a simple and reliable means to measure achievement, to reflect changes connected to an intervention, or to help assess the performance of a development actor. USAID explained indicator as variable, which purpose is to measure change in a phenomena or process (USAID, 2001).

2.2. Approaches

Vulnerability assessment is separated into two: first order and second order vulnerability assessment. This is helpful to avoid misunderstandings caused by different conceptualization. For instance, to distinguish between the natural and social perspectives, climatic and non-climatic factors and the socio economic consideration with the potential to adapt the changing condition. In addition to this it is important to improve the knowledge on complex socio ecological system.

Fussler and Klein (2006) Stated that a range of approaches is available for assessing vulnerability for instance; a “first order vulnerability assessment” is an impact assessment with the addition of socio-economic considerations and non-climatic factors (i.e., all elements of exposure and sensitivity. Sensitivity of an area to flood hazard is mainly related to the soil condition, the deforestation rate and erosion potential of the watershed.

A “second order vulnerability assessment” includes the first order vulnerability assessment and adds an assessment of adaptive capacity (i.e., all elements of exposure, sensitivity, and adaptive capacity. This approach perceives that human and ecological systems will have some capacity to respond to the effects of flood hazard which needs to be considered.

2.2.1. Exposure

The vulnerability of a watershed will be forced massively by its exposure to climate change. Different approaches are available to estimate exposure. For instance, lumped model, semi distributed model, fully distributed model and indicator based model (Nelitz, et al., 2013). The approaches have similarities because they are useful to determine the exposure of a watershed to climate change. The main difference is the type and quantity of data requirement. From these approaches, the indicator indices and statistical models are better to characterizing patterns variability or trends related to climate conditions. The limitation of this approach is that it is not geographically transferable.

Pandey (2010) analyzed the exposure for drought hazard by using seasonal and annual rainfall for the assessment of vulnerability to drought relating with the rainfall deficiency. Luh (2015) used historical data on the frequency of droughts, floods, and cyclones from 1950 to 2012 as measures of hazard exposure. The exposure was normalized and minimum value was set to 0.1 to avoid the final vulnerability score of 0. Finally, they classified in to

intervals using the junk's natural breaks classification method in Arc GIS and map accordingly their score.

2.2.2. Sensitivity

Sensitivity is mainly related with the physiographic factors such as Topographic features, soil type, and land use. For instance, as the lower elevation has the time to retain water, the flooding effect will be higher. The soil water holding capacity and antecedent moisture content also highly related with the sensitivity to flood hazard (Liu, 2014). On the other side, the land use factor for instance barren land and improper cultivation of land also make the flooding effect severe. Pandey (2010) classified watershed geography as lower, middle and upper reach watershed areas. Accordingly, the land use factor as water body, barren land, forest, agricultural and habitation. In this study, the area was estimated under various classes of physiographic factors and calculated and then weighted based on different factors.

Sensitivity is represented in three ways, as sensitivity of watershed, sensitivity of human communities and fresh water ecosystems.

In sensitivity of watershed, two wide approaches are used that quantitatively model that connect climate and watershed reaction in vulnerability estimation. A first approach contains linked or coupled modeling (Bhaduri, et al., 2000) With this approach watershed are divided into distinct sub models, where each sub-model is built separately of the others. Each sub-model, even so, designed with the aim that the predictions or outputs from one sub-model will serve as inputs to another sub-model.

A second modeling approach includes integrated watershed models; these models are distinct from the linked modeling in a manner that the watershed form and use are characterized in an integrated modeling framework that can simulate feedback responses and process linkages. This approach has coincidences; even so, a number of standardized frameworks that are applicable to assess the vulnerability of watersheds to climate change e.g., (Nunes, 2007; Ficklin, 2009; Johnson, 2009).

2.2.3. Vulnerability

The vulnerability assessment approaches are diverse in literature. This diversity is resulting from the methods they used to aggregate exposure, sensitivity and adaptive capacity. Based

on this, different equations are developed 1. $V = E + S + AC$ (Borden, 2007; Neilsen, 2010) here adaptive capacity considered as the positive correlation with vulnerability, 2. $V = E * S * AC$ (Ferrier and Haque, 2003), it creates overlapping of the indicators 3. $V = (E * S) / AC$ (Balica, 2009) and 4. $V = (E - AC) * S$ (Hahn, et al., 2009) 5. $V = (E + S) - AC$ (Ageyei, et al., 2012; Simha, 2017) Where $V =$ Vulnerability, $E =$ Exposure, $S =$ Sensitivity and $AC =$ Adaptive capacity. The last equation considers the high adaptive capacity reduces the vulnerability. The vulnerability which is expressed as $(E - AC) * S$ did not correlate with other model and There is absence of justification in literatures when they are choosing the aggregation method (Luh, et al., 2015).

2.3. Indicators to Estimate Vulnerability

Indicators are used in most vulnerability assessments. Different indicators were used by different studies for instance indicators as physical dimension, economic dimension and social dimension (Pandey, 2011); Technical, socio-economic and population-environmental indicators (Pouyaa, et al., 2017); Economic and biophysical (Ntajala, 2017); Exposure, sensitivity and adaptive capacity (Luh, et al., 2015; Liu, 2014; Yang, 2018; Nelitz, et al., 2013).

Indicators, indices, and statistical models differ extensively in their structure, information needs, and output. Inputs / outputs model requirements. For instance, input files addressing meteorology (annual mean precipitation, temperature), water resource variation and coefficient of variation of precipitation (Nelitz, et al., 2013).

2.3.1. Exposure

One of the indicators in vulnerability assessment is exposure which is mainly driven by climate change. The precipitation data (magnitude, duration, frequency...), and temperature data are widely used. These data indicates how the stream flow is affected by the changing condition (Nelitz, et al., 2013; Shabbir & Ahmed, 2015; Luh, et al., 2015).

In contrast with this, Liu (2014) considered the flood exposure as a combination of the probability affected by flood and potential damages. So the flood exposure was assessed based on two indicators: (1) the distance to the river/lake (2) The impact (or consequence) caused by flood events.

2.3.2. Sensitivity

Indicators for Land use, soil type and slope determine the sensitivity of the area. The land use system within the communities for instance forest and agricultural land response differently for the same flood event. Soil type clay and sandy loam has different reaction and the same thing for steep and flat areas as outlined by (Pandey, 2011; Luh, et al., 2015; Simha, 2017).

2.4. Assigning Scores to Indicators to Estimate Vulnerability

Qualitative and quantitative scores are assigned and a five point scale is often used (Pandey, et al., 2010). However could be noted that there is no standard qualitative scoring in literature. Accordingly, literature does not document consistent numerical scale. For instance, the higher score is assigned to a less vulnerable situation and vice versa (Pouyaa, et al., 2017). Whereas Pandey et al., (2010) used lower score assigned to less vulnerability class.

Pouyaa (2017) used indexing method to assess the vulnerability to flood by evaluating the indices. Simha (2017) transformed all indicators to dimensionless parameters by expressing as a ratio of thresholds. In order to be able to perform the arithmetical operations producing the index values the simple indicator values must have the same scale and unit of measurement (OECD, 2002) Pandey (2011) used the value of weight depends on the relevance of attributes of a given indicator. The study used uniform weighing scheme based on the assumption of relative influence of overall vulnerability. Weighted averaging methods assign inconsistent weights to each indicator by statistical means (e.g., z-scores, and Principal Component Analysis).

2.5. Aggregation to Establish Composite Index

Shabbir (2015) applied Analytical Hierarchical Process (AHP) to allow comparison between indicators. Indexing methods assign values to selected variables based on past experience and professional judgment. These values are then operated by some combination of arithmetic functions to make a single value (Nelitz, et al., 2013). Then this single value can be compared to other assessments and standards. But the most common method for calculating and aggregate index an easy averaging technique. Equal value, or weights, assigned across all indicators are assumed Averaged; the assumption being that all elements

contribute equally to vulnerability (Nelitz, et al., 2013). Accordingly, relative vulnerability score was calculated by these indices. Even so, weighted averages recognize the distinctive contribution of each component to overall vulnerability, assigning weights involves a subjective assessment of importance.

In the context of decision support applications and vulnerability quantification, Szlafsztajn & Stern (2007) suggest that it is often useful to choose a relatively simple method. This can promote both method transparency and visualization of the results.

2.6. Weakness in Conceptualization and Aggregation

Though different studies have been done on vulnerability assessment, conceptualizations take various forms. As vulnerability includes several dimensions (social, cultural, economic, ecological etc...) (Birkmann, 2006; Ahmad et al., 2018; Brooks, 2003; Adger 2006; Fernandez, 2016), It cannot be described in a simple way. The complexity arises from various scales, which can be used, do not refer to the same damages, and hence do not have an impact of same intensity. In the case of flooding, water level, immersion velocity, flow, water quality and frequency of events are example criteria used to evaluate the 'hazard'. Lack of clear guidelines to identifying indicators also the other challenge. The method for identification of indicators was taken from literature review without clear justification. Accordingly, the authors' views on aggregations of indicators are quite different and highly subjective.

2.7. Temporal Changes of Flood Exposure and sensitivity

Lui (2014) stated that the general trends of the increasing residential areas, industrial areas and commercial areas results in an increasing number of people and valuable economic resources exposed to flooding. The impact of land-use changes on storm runoff generation, which has been confirmed by several studies showed that land-use changes are most susceptible to convective storms with high precipitation intensities and rapid flood runoff production (Brath, 2000; Naef, 2002). Camarasa and Bescós (2004) focused on analyzing effects of the land-use changes on the geomorphology, hydrology and hydraulics of floodplain areas. Wegehenkel (2002) states that the afforestation has a significant effect in reducing the flood runoff discharge. Similar analysis was performed by Costa et al., (2003) find that the deforestation can increase the flood runoff discharge, particularly in small scale

and high intensity rainfall events. According to Hardmeyer and Spencer (2007) the use of floodplains has increased exposed property and population which results in more casualties and economic losses from flooding.

2.8. Flood Vulnerability in Awash Basin

Awash Basin faces unevenness and uncertainty over water availability and is greatly vulnerable to extreme events. With a total Gross Domestic Product (GDP) accounting for around 30 percent of national production, the Awash basin involves a major part of Ethiopia's economy (AWBA, 2017). So, any vulnerability is probable to be highly economically significant for the country as a whole.

The geographical pattern of development in the basin may further aggravate its vulnerability. The economic activities in Awash basin is mostly located in upstream side of the basin including industrial production. Flooding along Awash River was mainly caused by heavy rainfall in the eastern highlands and escarpment areas of North Shewa and Welo and not because of heavy rain in the upper watershed areas. Over the years soil and water run-off in the escarpment areas has steadily increased as a result of deforestation, the most serious environmental degradation in the escarpment areas being caused by overpopulation in the highlands (Dagnachew, 2003). Tributaries to Awash river such as Kesseme, Kebena, Hawadi, Ataye Jara, Mille and Logiya rivers contributed most to the lowland flooding in Afar. In August 1996, flooding damage was estimated at \$9 million and affected 75,000 residents (DPPC, 1997).

According to Dagnachew et al. (2003), Land-use change due to the expansion of urban areas also affects the ground infiltration rate which in turn gives the way flooding to occur. Land-cover change has one of the causes of flooding phenomenon of the Awash Basin, which resulted in millions worth of resources lost nearly every main rainy season. Low level vegetative cover could also affect infiltration and could lead to reduced groundwater levels and the base flow of streams. It is obvious that land-cover can affect both the degree of infiltration and increases runoff following rainfall events (Dagnachew, 2003).

2.9. National and global Data on flood vulnerability

National and global data are useful for the validation and comparison of vulnerability maps. Climate change studies, Intergovernmental Panel on Climate Change From global disaster database show the vulnerable areas (IPCC, 2012).

Daily rainfall maps acquired from the US Agency for International Development (USAID). Hydrological data and maps based on Shuttle Elevation Derivatives at multiple Scales (HydroSHEDS), based on SRTM spatial resolution: 90 m Conditioned DEMs, Flow direction and Flow accumulation grids <http://icesat.gsfc.nasa.gov/icesat2/index.php>. Land use/ land cover maps from FAO, river flow data from global runoff data center. NOAA national flood and National Meteorology agency 2018 also provides current and past flood maps http://due.esrin.esa.int/page_globcover.php (FAO, 2006; USAID, 2001; Paolo, et al., 2014; Mearthy, 2001).

CHAPTER THREE: METHODS

3.1. General Description of the Study Area

3.1.1. Location

Awash River originates over the highlands of Central Ethiopia; about 150 km west of Addis Ababa. Its basin has an elevation that varies from 4195 to 207 m above mean sea level and pass through north-eastwards, where it finally drains into the Lake Abe (figure 3.1). The river travels a distance of 1,280 km (AWBA, 2017). It is the most consumed and advantageously utilizable river basin in Ethiopia. It covers a total of 110,000 km² area (Bekele et al., 2017).

The basin contains major tributaries such as Akaki, Mojo, Keleta, Kesem, Kebena, Borkena, and Logia can be listed. The Awash River Basin has been divided into three distinct zones: Upper Basin, Middle Basin, and Lower Basin (AWBA, 2017).

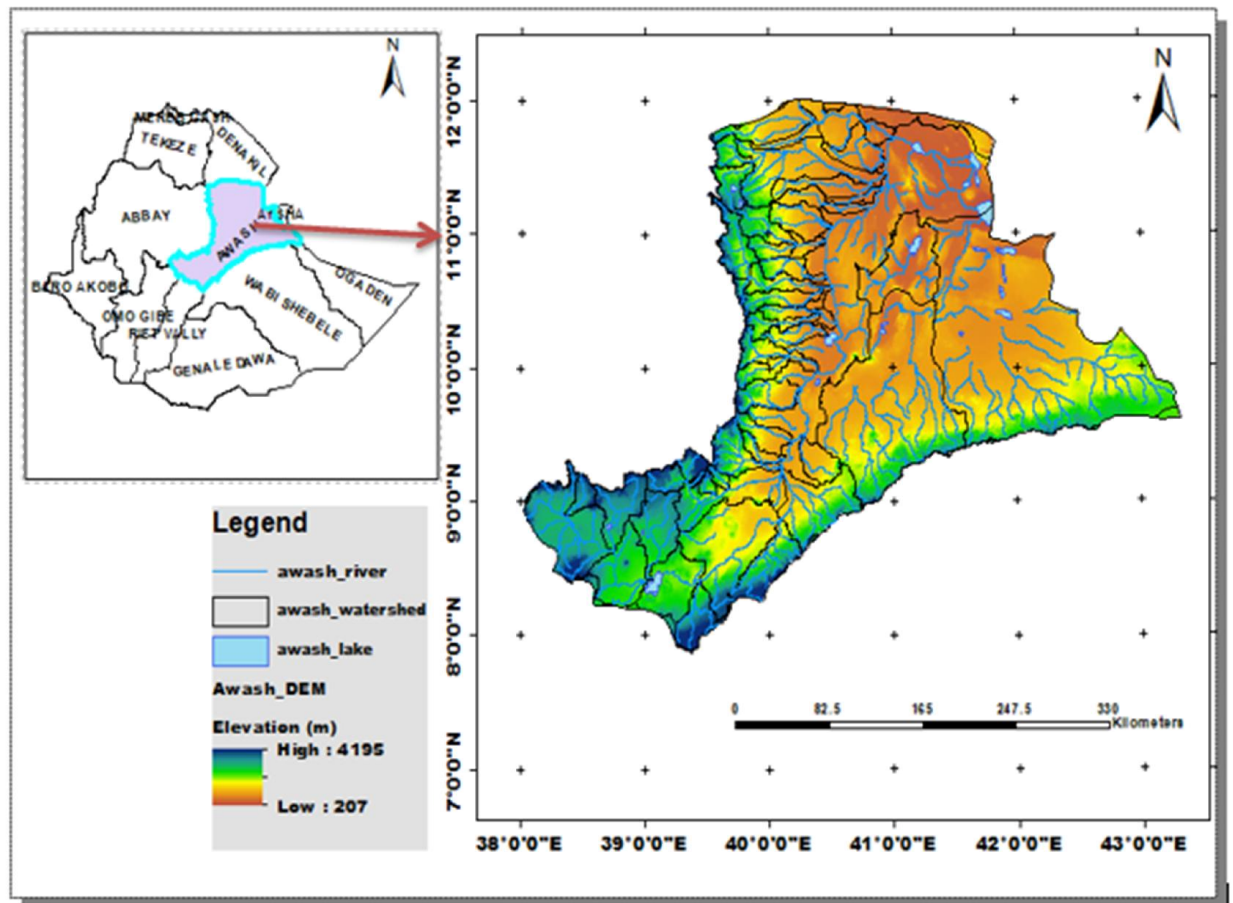


Figure 3. 1 Ethiopian river basins and location map of the study area (by Tinsae Seboka)

3.1.2. Climate

The mean annual rainfall of the basin varies from 1600 mm in the highlands north east of Addis Ababa, to 160 mm, to the low land of the basin (Taye, et al., 2018). Rainfall distribution is generally bimodal in the middle and lower Awash and unimodal in the upper Awash. Minor rains normally occur in March and April and major rains from July to August. As such the occurrence of rainfall is highly erratic (Edossa, et al., 2010).

The total amount of rain fall also varies greatly from year to year, resulting in severe droughts in some years and flooding in others. The total annual surface runoff in the Awash

Basin amounts to some $4,900 \times 10^6 \text{ m}^3$ of which some $3,650 \times 10^6 \text{ m}^3$ is currently utilized the remaining water being largely lost to Gedebassa swamp. (Edossa, et al., 2010).

3.1.3. Land use and soils

The major land use types in the Awash River Basin are cultivated land, grassland, cropland with shrub land, lake and forest land. Urbanization with in the Awash basin particularly on upper Awash, Addis Ababa and Adama city are growing faster. The Awash River Basin build up by different soil types. From this soil types Cambisols and Vertisols are common. The Vertisols are dominated by the montomorillonite clay mineral. These clay minerals have a character of expanding and shrinking when there is a wet and dry condition. Then it results cracks at the surface in the dry season (Nederveen, 2010).

3.2. Data Collection methods

3.2.1. Data sets for catchment characteristics

The major data used for this study include data on catchment characteristics. These data were obtained from relevant global data sources and national organizations such as Ministry of water resource and Ethiopian Geospatial information agency (Table 3.1). The selected flood sensitivity factors, such as slope and land cover were classified based on level of contribution to flood sensitivity. The slope was extracted from 90m resolution SRTM DEM by using Arc GIS. These data were obtained from relevant national organizations and global data sources such as Ministry of water resource and Ethiopian Geo spatial information agency.

Landsat satellite images were used to map the land cover map of Awash Basin for three different periods, which are separated by five years. The mapping was based on analysis of Normalized Difference Vegetation Index (NDVI).

Table 3. 1 Major data and their sources

No	Data	Description	Data source
1	DEM	Digital Elevation Model (90mx90m) and (30x30m)	http://earthexplorer.usgs.gov .
2	Soil	Soil type	FAO, MoWR, Harmonized world soil database
3	Land use	Land classification	Ethiopian Geo-Spatial information Agency

This study adopted a mixed quantitative (including spatial data) and qualitative (expert opinion) approach. The qualitative data was obtained from 16 experts in related fields such as hydrology, civil and environmental engineering, geology, geomorphology, and urban and regional planning.

Experts were selected based on their expertise and experience in flood management to provide meaningful and unbiased information. Expert input and literature review provided guidelines for selecting flood causative factors (slope, land use, soil type, and river buffer).

First, a pilot survey was conducted to correct ambiguities to ensure that the respondents clearly understood the questions. After multiple revisions, the final version of the questionnaire was distributed to 22 experts to obtain their relative preference rankings of the sensitivity indicator and only 16 responses were obtained.

3.2.2 Data Analysis Methods

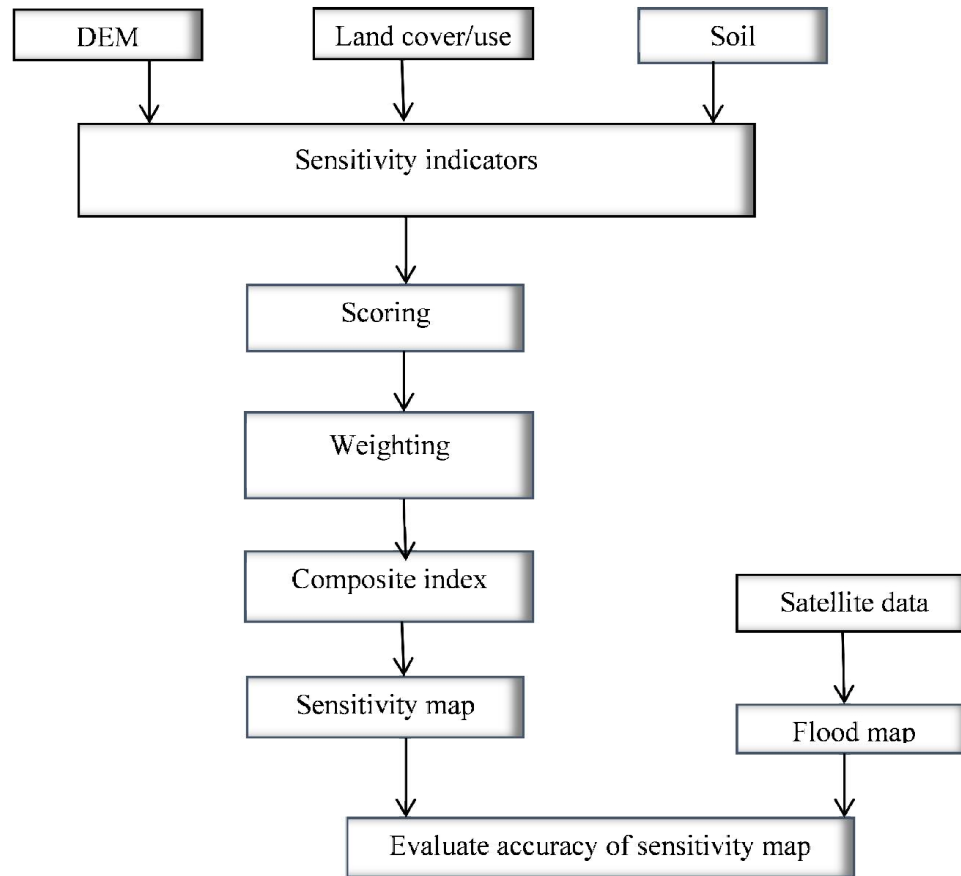


Figure 3. 2. Methodological framework to develop and evaluate the first order vulnerability map

Table 3. 2 Indicators of Sensitivity of flood (Adopted and modified from Vulnerability and adaptation Assessment of water resources sector to climate change in Ethiopia).

Indicator	Sensitivity Score				
	Least=1	Limited=2	Moderately=3	Severely=4	Critically=5
Land cover	Wetland/ water body	Forest	Grassland	Cultivated land	Urban and others
Terrain slope (%)	>15	5-15	2-5	1-2	0-1
Soil	Sandy loam	Sandy clay loam	Loam	Clay loam	Clay

3.2.2.1 Sensitivity

Based on the flood sensitivity, the slope and land use type were classified into 5 classes which include least sensitive, limited sensitive, moderate, sever and critical sensitive. The score was assigned as: the least sensitive score “1” and for critically sensitive score “5” as mentioned above in the table.

The land use classification was done by supervised classification which was classified by sixteen classes. To assign score the sixteen land use classes were reclassified in to five by using Arc GIS spatial analyst tool. The classification on the land cover which was dense, moderate, sparse forest, wood land and perennial crop, were merged to Forest Land. Since perennial crops are not harvested annually and the root and structure of the plant is strong, these are grouped under Forest land.

Closed and open grassland and also closed and open shrub land were grouped to Grass land. The shrubs are grouped with grasses because the roots of shrubs are not thick and hard like forests and on the other hand since their height is not long as a tree, the velocity which the rain comes could not much reduced. Annual crops were grouped to cultivated land. Settlement, bare soil, lava flow and rock outcrop were grouped to urban and others. Vegetation and forest canopy affect precipitation interception.

The slope of Awash Basin was done by Arc GIS spatial analyst tool by surface analysis. The minimum value was 0 and maximum value 78.76%. These values were reclassified with a range of 0-1, 1-2, 2-5, 5-15 and > 15% which is adopted from (Gallant, 2018 and FAO,

2006) slope classification. The gentle slope was classified in detail based on their high flood tendency. The last slope was taken as > 15 because as the slope percent become higher the flood occurrence is much lower rather the flood is produced. Therefore, Steep slope was considered least sensitive to flooding due to less water retention.

The Curvature function displays the shape or curvature of the slope. A part of a surface can be concave or convex; which tell the curvature value. This was done by using Arc GIS 3D analyst tool. A positive curvature shows that the surface is upwardly convex at that cell. A negative curvature shows that the surface is upwardly concave at that cell.

In the profile output, a negative value indicates the surface is upwardly convex at that cell. A positive profile indicates the surface is upwardly concave at that cell. A value of 0 indicates the surface is flat. In the plan output, a positive value shows the surface is upwardly convex at that cell. A negative plan shows the surface is upwardly concave at that cell. A value of 0 shows the surface is flat. The profile curvature has an impact on the acceleration and deceleration of flow and, therefore, it affects erosion and deposition.

The other indicator of flood sensitivity is Distance from the river. Before working with Euclidean distance flow direction, flow accumulation and stream network were extracted from DEM 90. Euclidean distance was used in spatial analyst tool to determine how much each place is close to the stream. The minimum distance starts from 0 and maximum 219 km. This value was reclassified with a minimum range of 0-2 km and maximum > 8 km.

The soil factors influencing the rate of infiltration are: the total amount of pores (soil porosity), the particle size distribution and the structure of pores (grain size distribution), organic matter content of the soil, and soil structures (size distribution and structure of aggregates). Due to the larger pore space between the soil particles, sandy soils have higher saturated hydraulic conductivities than finer textured soils. Therefore, the clay soils infiltration rate is much lower than that of sandy soils. Porous soils with stable soil aggregates have more saturated hydraulic conductivity values than soils that are compact and dense.

After all sensitivity indicators are collected, map of each sensitivity factor was organized by Arc map. The sensitivity map was prepared by using Arc GIS raster calculator. All

indicators were combined to give one flood sensitivity map. By using simple additive weighting method, the weight of each indicator was calculated by dividing the sum score of the indicators by the number of indicators. For the sensitivity there are five indicators namely terrain slope, soil, Land use, Curvature and river buffer.

Finally, analysis was performed on the sensitivity indicators according to their degrees of sensitivity and the spatial pattern of the different sensitivity levels was mapped.

In this study, considering the straightforwardness and simplicity of equal weighting over other methods, the weights of the indicators are assumed equal.

Using equal weighting (EW) method, the same weight is assigned for each indicator using

Equation 1.
$$W_j = \frac{1}{k}$$
 (Anowar, et al., 2021).

Where w_j is a weight for k indicators ($j = 1 \dots k$) for each factor.

Experts were requested to respond regarding flood sensitivity by the question listed below. Sorting was based on the contribution of these indicators to the flood sensitivity in a given area.

Awash Drainage Basin

Modjo, Boru, Keleta and Arba are the major perennial streams in the Awash drainage basin. Only small portion of Kesem River, another perennial tributary, flows in the map sheet. The Awash drainage basin consists of three sub-basins: the first basin covers the area drained by Mojo River having Wedecha, Belbela and Dobi perennial tributaries. The second sub-basin covers the area drained by Kesem river tributaries. The area drained by Tebo River and its tributaries forms the third sub-basin. The tributaries are intermittent.

CHAPTER FOUR: RESULTS AND DISCUSSIONS

4.1 Results

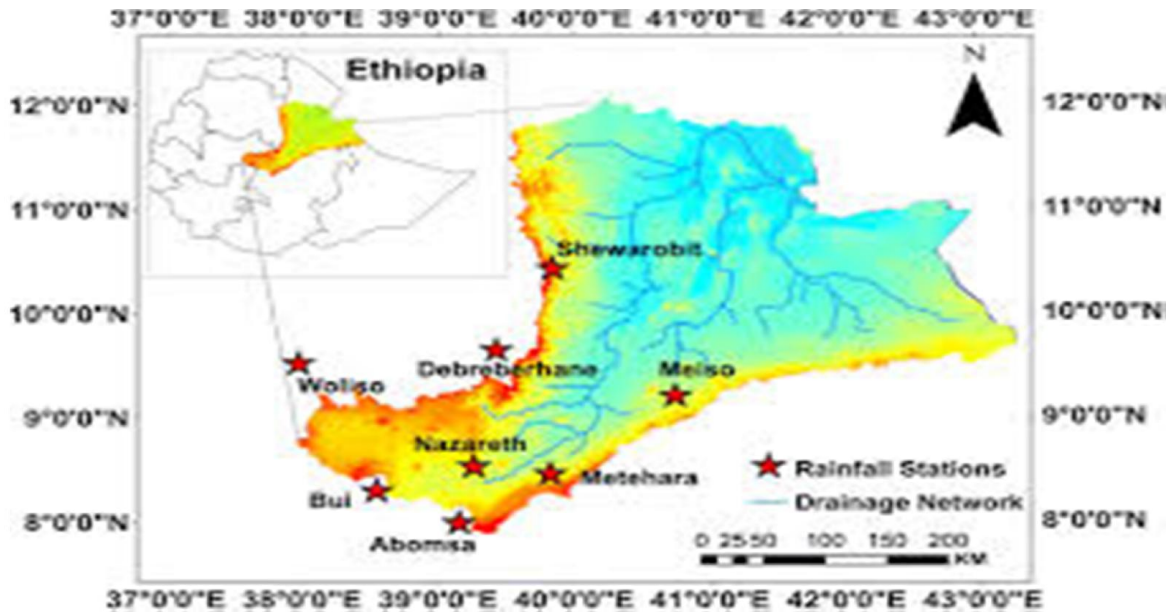


Figure 4. 1 Drainage map of the study area (source research gate. net)

The results showed that by equal weighting method weights are assigned based on the equal contribution of each sensitivity indicator to flood sensitivity. Experts also ranked each sensitivity factor based on the knowledge on selected area and weight assigned. Two methods were applied (i) equal weight for all factors (0.2 for each of the five factors), and weight assigned by experts, which is 0.3 for river buffer, 0.25 for slope, 0.2 for land cover, 0.15 for soil and 0.1 for curvature of surface.

4.1.1 Analysis result

Descriptive and statistical method of analysis was used in this work. In the Awash flood, most of the respondents 31.25 % of the respondent said buffer has highest contribution to flood sensitivity. Hence, buffer is ranked 1st in this study. Slope is identified as the highest contributor to flood sensitivity. As a result, slope is ranked second in terms of contribution. Similarly, land cover, soil and slope curvature are ranked 3rd, 4th and 5th based the experts' opinion. These ranked were used to guide the weight assigned to each factor (Table 4.1). Therefore, this study's findings indicate that slope and river buffer has more weight in experts' opinion and the rest land cover, soil and curvature of surface has minimum weight. This implies that when areas are more close to the river the sensitivity become higher.

Table 4. 1 sensitivity score based on expert's opinion

Experts response	Rank	Weight
Curvature of slope	1	0.1
Soil	2	0.15
Land cover	3	0.2
Slope	4	0.25
Buffer	5	0.3

The analysis result shows that the methodology is effective to identify the flood sensitive area as a result the summative magnitude of flood sensitivity at Awash basin figured below. It shows the flood sensitive of Awash basin. The green part shows areas which are least sensitive, the light green shows limited sensitive areas, the yellow area is under moderate sensitivity , and the light red part reached severe flood sensitivity and finally the red part of the basin flood sensitivity map scores very high flood sensitive part.

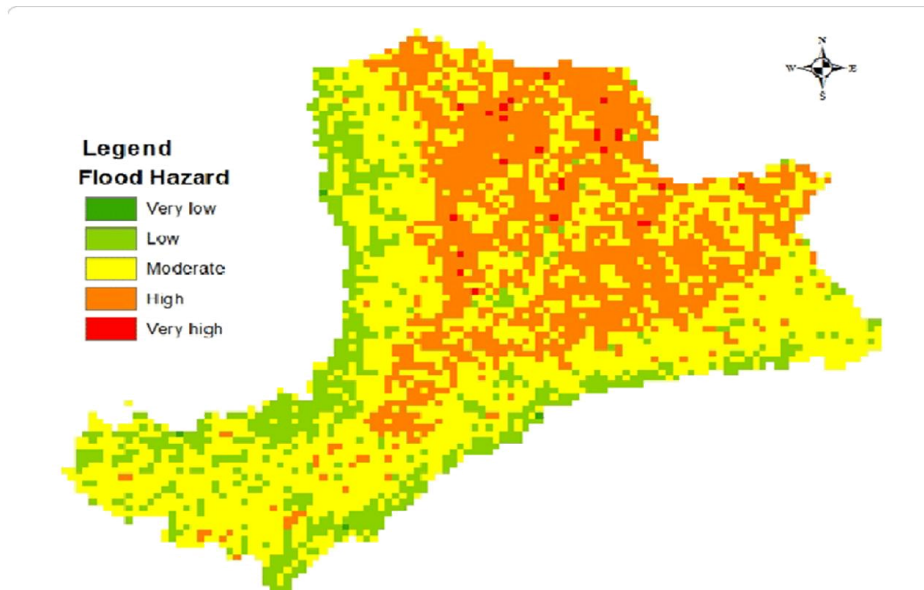


Figure 4. 2 Flood sensitivity map of Awash Basin(source GSE)

On the above figure the flood sensitive part listed on the legend as shown. Hence the green one shows least sensitive, the light green the limited sensitive, the yellow and broad part of the basin under map scores very high flood sensitive part and difficult to sustain on that area.

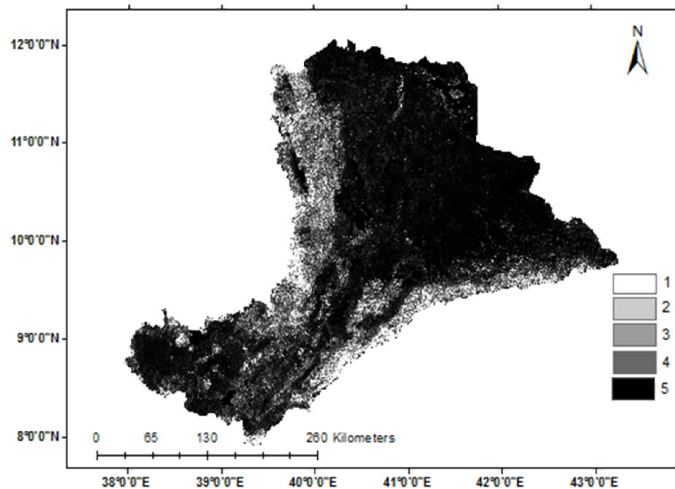


Figure 4. 4 Flood sensitivity based on expert's weight

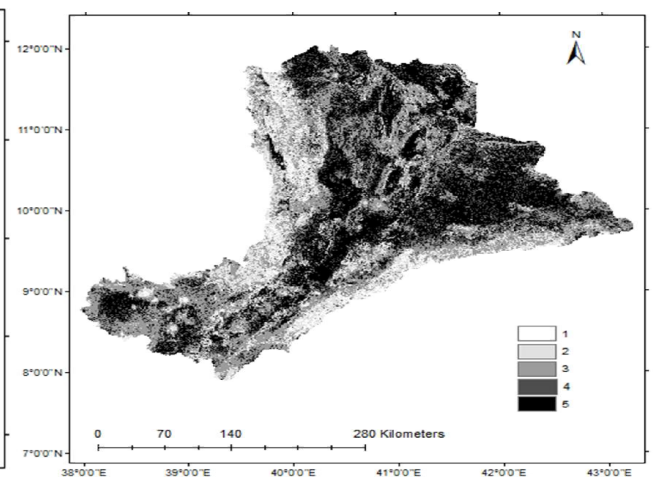


Figure 4. 3 Flood sensitivity based on equal weight

Table 4. 2 sensitivity class for equal and experts' weight

Sensitivity class	Area (km ²) for equal weight	Area (km ²) for expert weight	Area difference (km ²) from equal to expert weight
1	920	1510	-590
2	3100	2258	842
3	5010	45412	-40402
4	9100	24582	-15482
5	90100	31674	58426

4.2 Contribution of various factors for flood sensitivity

Land use practices, particularly urbanization, can play a significant role in water infiltration, concentration, and runoff behavior. Slope and basin geometry, type of soil, land cover, curvature of slope, river buffer determine such behavior as the speed and concentration of runoff. The land cover of Awash basin was changed from year to year depending on this, it is noticeable how the sensitivity was affected by this factor. Sensitivity indicators are listed below.

Indicator 1: Slope of the Basin

Slope plays a major role in flood sensitivity of the Awash basin. It has a significant impact on flood assessment because it directs the amount of surface runoff generated the precipitation rate and displacement velocity of water over the surface. Practically, high rating is assigned to low slopes whereas low rating is assigned for high slopes.

Figure 4.5 shows slope has least contribution to flood sensitivity in the North West highlands (the upper part and middle parts of the basin) due to steep slope percent. Some of south east part also shows least sensitivity to flood. On the other hand, the lower part of the basin is severely sensitive due to low slope percent.

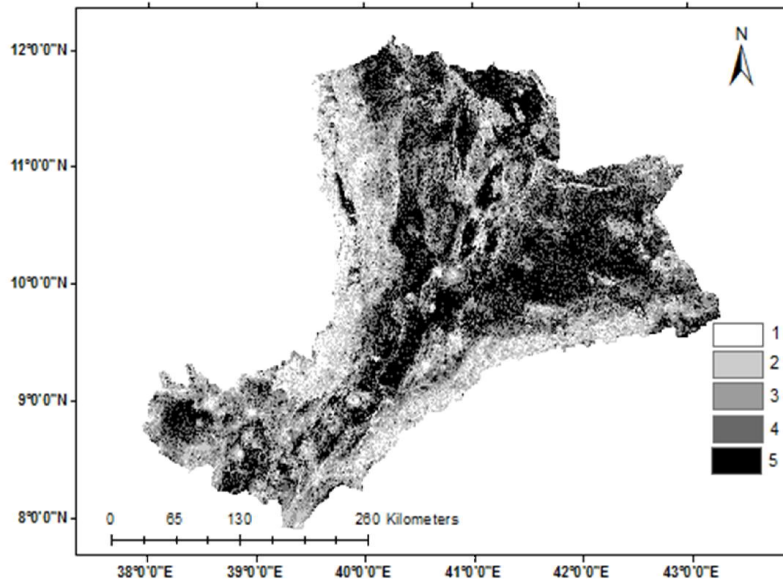


Figure 4. 5 Flood sensitivity based on slope of Awash Basin

Indicator 2: Land Coverage

Here land cover; of the Awash basin is shown for three years which are separated by five years range each. Figure 4.6 shows that the lower part and some part of middle Awash were critically sensitive due to low vegetation cover in 2008. The settlement areas which are scattered along the river course are also severely sensitive to flooding due to the impervious nature of the land cover. Hence, Addis Ababa and its surrounding are critically sensitive due to dense population with in small area this indicated that settlement without support by vegetation will expose to high flood sensitivity.

The severely sensitive areas to flooding due to land covered intensified in the lower parts of Awash basin in 2013. However, some severely sensitive areas that appeared in the 2008 map became less sensitive in the 2013 map. These areas are situated in the middle part of Awash (Figure 4.7). Some part of Awash basin is covered with forest land and some part North West part of the basin is covered with vegetation.

From the land cover map it is possible to see that the flood sensitivity was more in lower part of the basin but in 2018 large part of the basin area was become flood sensitive.

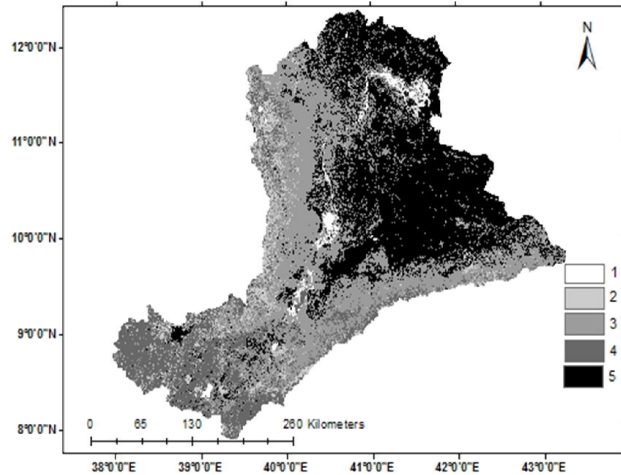


Figure 4. 7 Flood sensitivity based on land cover of Awash Basin 2008

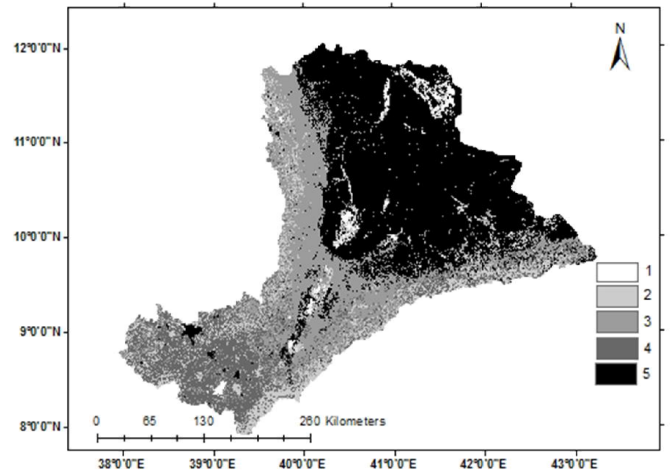


Figure 4. 6 Flood sensitivity based on land cover of Awash basin 2013

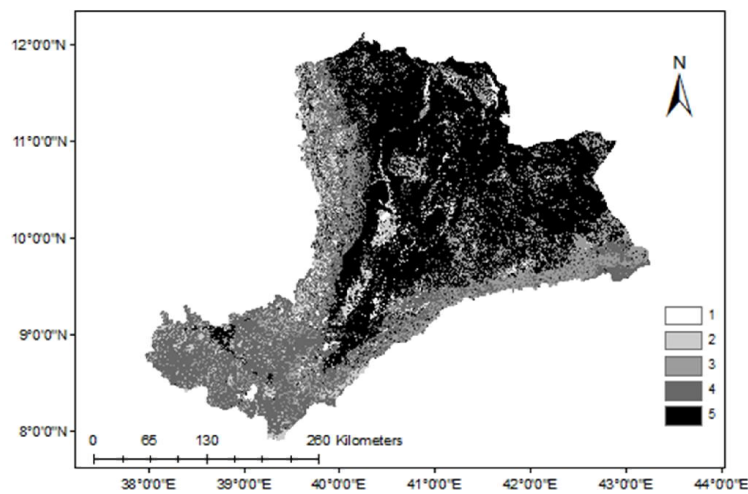


Figure 4. 8 Flood sensitivity based on land cover of Awash basin 2018

Indicator 3: Type of Soil

Different soil types have different potential to infiltrate water that significantly affects the rainfall -runoff process. The soil characteristics in general control the amount of water that is available for surface runoff after a rain storm event. The soil porosity factors influencing the rate of infiltration at the basin because, the basin covered with Sandy soils.

Because of the larger pore space between the soil particles, Sandy soils have higher saturated hydraulic conductivities than finer textured soils. Some of the basin area covered

with clays particularly, the rate of infiltration of clayey soils is much lower than that of sandy soils. Porous soils with stable soil aggregates have higher saturated hydraulic conductivity values than soils that are compact and dense.

The upper part of the basin is mainly dominated by clayey soil and which results on high flood sensitivity to flood. But the lower parts and middle Awash is relatively less sensitive based on this, most part of the basin is not sensitive to flood due to soil factor rather other indicators are contributed a lot.

By taking into consideration the above facts, soil physical properties particularly soil texture was considered to build soil type factor. The soil of Awash basin was composed of five soil types upper Awash is mainly dominated by clay loam. Different soils have different capacity to infiltrate water which depends on soil porosity, particle size and organic matter content of the soil. Based on their sensitivity to flood, score was given as 5 (critically sensitive) for clay soil and 1 (least sensitive) for sandy loam.

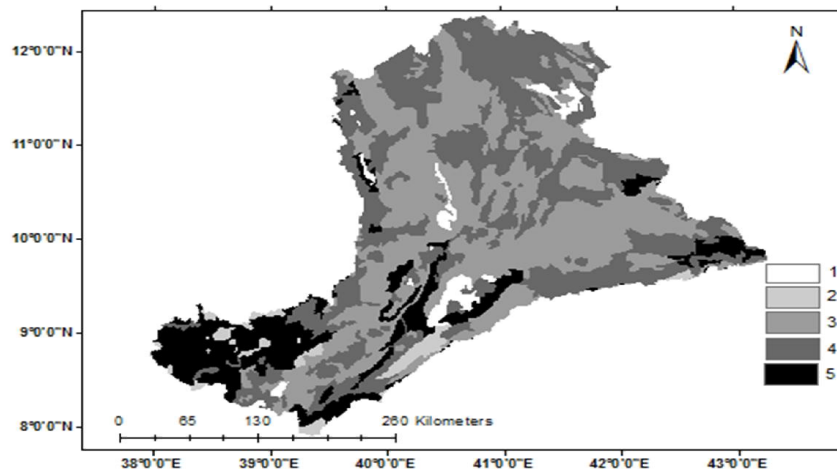


Figure 4. 9 Flood sensitivity based on soil class of Awash Basin

Indicator 4: Curvature of Slope

The curvature function map of Awash basin shows that there was high variation with in a place. All parts of the basin have upwardly concave and convex. Due to this upper, middle and lower part of the basin have critically sensitive areas and least sensitive areas as well.

As explained above, all the processes for elevation factor development are also in the slope factor development. The raster layer is then reclassified in according to their influence to

flood sensitivity. The flood line of the basin is mostly from north western part to eastern part of the basin.

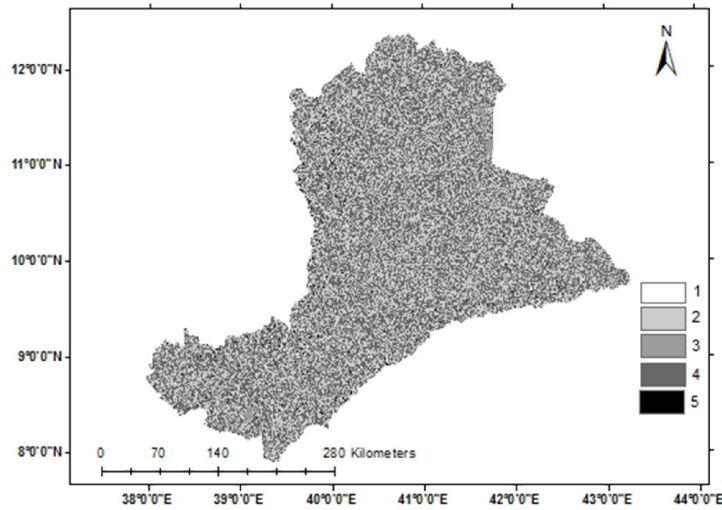


Figure 4. 10 Profile curvature of slope of Awash Basin

Indicator 5: River Buffer

River buffer has a direct and significant impact on flood sensitivity and dealing with the amount of water that are available for surface runoff. The structure of pores, soil porosity, the particle size distribution and soil structures cause effect on the river buffer.

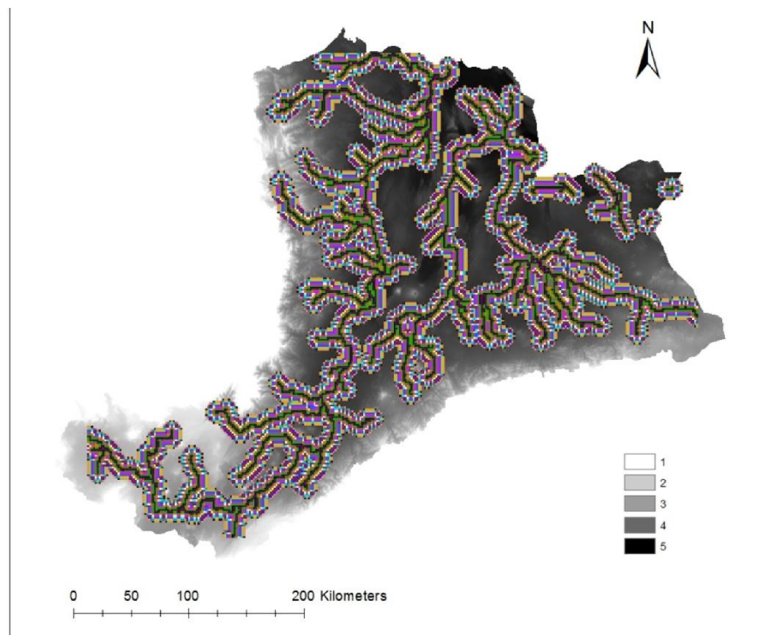


Figure 4. 11 Flood sensitivity based on River Buffer of Awash Basin.

Even though the proximity to rivers is one of sensitivity indicator, it also depends on the social factor; the way people live, their daily life activities, the material their houses made and the capability to respond to the natural disaster.

The Awash River basin has been experiencing flooding in downstream of the basin. The location and hydrological properties of the basin were relatively suitable for extensive development, but catastrophic flooding has been claiming scores of human life and property damage.

Evaluation was conducted on the basis of statistical measures, sensitivity to input data quality, space-time resolution of inputs and outputs,

Based on the land cover change due to human interruption over natural resources, flood sensitivity of Awash basin is increasing through time. Land is cleared for Settlements, as the population is increasing rapidly it creates over consumption of natural resources. This indicates that peoples are using natural resources excessively without keeping sustainability of these resources. Studies show that in developing countries land cover change is very fast. Even though there were different campaigns to compensate destructions over the resources those activities were seasonal and lacks follow up.

Therefore, Federal Democratic Republic of Ethiopia National Disaster Risk Management Commission should equally be equipped to evacuate victims during flood emergencies as well as distribute relief materials to relieve victims of sustained shocks. NDRMC had demonstrated a poor capability in managing flood disasters in Ethiopia. Awareness creation is very essential because it enhances community resilience through socioeconomic empowerment and strengthened adaptive capacity and plays a vital role in flood control.

A restriction that can be mention to this method of flood sensitivity is that the climatic factors are not included to estimating the exposure to flood. By this reason, the study is conducted without considering precipitation data. Therefore, in the future research on developing flood vulnerability map climatic factors; the precipitation data (magnitude, duration, frequency...), and temperature data should be considered for Awash basin.

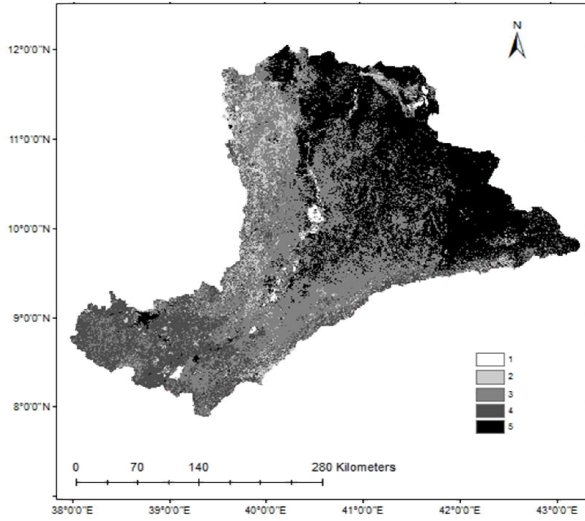


Figure 4. 12 Flood sensitivity in 2008

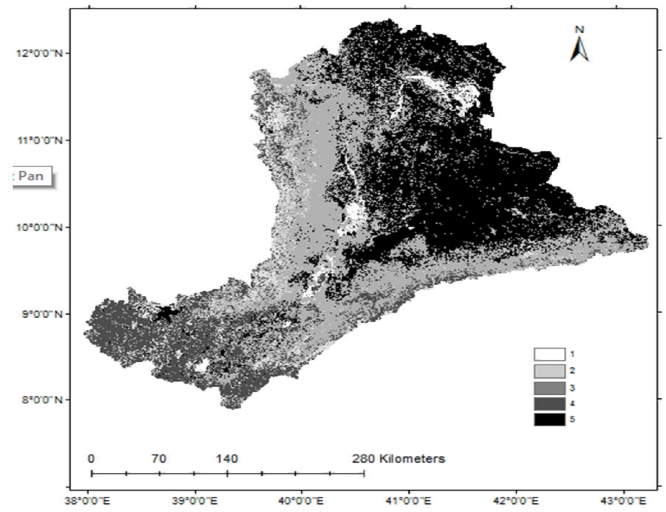


Figure 4. 13 Flood sensitivity in 2013

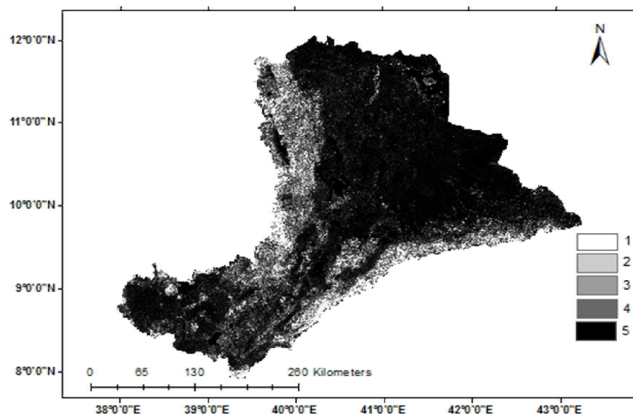


Figure 4. 14 Flood sensitivity in 2018

Table 4.3 Flood sensitivity class for 2008, 2013 and 2018

Sensitivity class	Area (km ²) in 2008	Area (km ²) in 2013	Area (km ²) in 2018	Area difference (km ²) from 2008 to 2013	Area difference (km ²) from 2013 to 2018
1	911	814	752	-97	-62
2	10100	10080	8200	-20	-1880
3	20200	15260	10030	-4940	-5230
4	31300	33510	31520	2210	1990
5	47410	49950	58760	2540	8810

CHAPTER FIVE: CONCLUSIONS AND RECOMMENDATION

Flood sensitivity assessment is important in making decisions, policies and managing floods. Community based flood warning systems can go a long way in helping rural communities, as well as flood management agencies, to prepare for flash floods. The enhancement of community resilience through socioeconomic empowerment and strengthened adaptive capacity can play a vital role in flood sensitivity management.

This study used geographical information system to map flood sensitivity area. The sensitivity classes were least sensitive, limited, moderate, severe and critical. Based on the map it is possible to see that most part of the Awash basin is subjected to critical flood sensitivity from this the lower Awash basin took a large sensitivity class. One of the reasons was that the basin slope condition and the land were more covered by bare land, rock outcrop, and open shrub land and lava flow.

The flood sensitivity map indicated that downstream plains of Awash Mille, Dubti, Afambo and Aysayta woredas were subjected to very high flood sensitivity. Most part of the basin are with in high and very high flood sensitive area. There are also towns, kebeles and settlement in upper Awash Basin areas that are subjected to high flood sensitivity.

The sensitivity map for different years shows that LULC has large effect on altering sensitivity of an area to floods. Particularly, the increase of built-up areas is expanding the most sensitive areas to the upstream of the Awash basin.

It was found that the experts' weight assigned from the total area of the basin most parts were highly sensitive than equal weight. Especially lower part of the basin had great difference on critical flood sensitivity which depends on river buffer and slope factor. Therefore those sensitive areas need actual attention to reduce potential future flood sensitivity.

Finally my recommendation is it is better to utilize water effectively by using flood control measures and take it as a resource for maximizing agricultural productivity. To minimize flood sensitivity areas, institutions shall work together. For instance land use planners with

water, Irrigation and Energy Minister and Ministry of Agriculture. Participation of all stakeholders to solve this sensitivity problem is also essential.

Flood hazard requires a serious attention to save the life of the peoples and their properties as well. Afforestation and reforestation is also essential to minimize the sensitive areas and to gain a good water balance. By retarding the flow of water over the surface and constructing a channel along root systems for water to enter the soil, it is possible to improve the Vegetation infiltration capacity

A limitation that can be mentioned to this study is that the GIS result is not integrated with suitable hydrologic method for estimating stages. By this reason, the study is conducted without flood depth inundation map. Therefore, in the future research, this consideration should be done for the Awash Basin.

References

- Adger, WN.,(2006). Vulnerability. *Global environmental change*.16: 268-280.
- Agyei AP, Dougil D (2012). Mapping the vulnerability of crop production to drought in Ghana using rainfall, yield and socio economic data. *Applied Geography* 32:324-334.
- Anowar, F., Sadaoui, S. and Selim, B.(2021): Conceptual and empirical comparison of dimensionality reduction algorithms A.: Construction of an integrated social vulnerability index in urban areas prone to flash flooding, *Nat. Hazards Earth Syst. Sci.*, 17(9), 1541–1557, 17-1541-
- Ahmad T, Pandey AC, Kumar A (2018). Flood hazard vulnerability assessment in Kashmir Valley, India using geospatial approach. *Physics and chemistry of the earth*. 105 : 59–71.
- AWBA (2017). *Awash River Basin Flood and Drought Management Strategic Plan*. Ethiopia
- Balica N. (2009). Flood vulnerability indices at varying spatial scales, *Water Science. Technologies*. 60: 2571–2580.
- Bekele, D.; Alamirew, T.; Kebede, A.; Zeleke, G.; Melesse, A.M. (2017). Analysis of rainfall trend and variability for agricultural water management in Awash River Basin, Ethiopia. *Journal of Water and Climate Change*. 8, 127–141
- Bhaduri, B., Harbor, J., Engel, B. (2000). Assessing Watershed-Scale, Long-Term Hydrologic Impacts of Land-Use Change Using a GIS-NPS Model. *Environmental Management* **26**, 643–658
- Bhatt D, Mall RK(2015).Surface Water Resources, Climate Change and Simulation Modeling. *Journal of Environment and Sustainability Delopment*. 4:730 – 738
- Birkmann J (2006). Measuring Vulnerability to Natural Hazards towards Disaster Resilient Societies. *Environmental Hazards* 7:20–31.
- Bloch R(2012). *Cities and flooding*.The World Bank, Washington.
- Borden S (2007). Vulnerability of U.S. cities to environmental hazards. *Homeland Secure Emerging Management* 4:264-285.

Brath MA(2000). Effects of the spatial variability of soil infiltration capacity in distributed rainfall runoff modeling. *Hydrol Proc* 14:2779–2794.

Bolin C, Cardenas H, Vatsa KS (2003). Natural Disasters Network: Comprehensive Risk Management by Communities and Local Governments, Inter-American Development Bank.4:38-41.

Brooks N(2003). Vulnerability, Risk and Adaptation: A Conceptual Framework. Tyndall Centre for Climate Change Working Paper 38,. University of East Anglia.28:293-299

Camarasa AM, Birkmann J, Fordham M (2004). A Cartografía de áreas inundables: comparación entre mapas de peligro y mapas de inundaciones concretas. *Riesgos Naturales y Antrópicos en Geomorfología* 2: 25–36.

Costa MH, Botta A, Cardille JA(2003). Effects of large-scale changes in land cover on the discharge of the Tocantins River, Southeastern Amazonia.. *Journal of Hydrology* 283:206–217.

Dagnachew LF, Coulomb VC, Gasse C(2003). Hydrological response of a catchment and land use change in tropical Africa: Case study south central Ethiopia. *Journal of Hydrology, J* 275: 67-85.

DPPC, 1997. Flood vulnerability in Ethiopia and needs for preparedness. Disaster Prevention and Preparedness Commission, Addis Ababa.

Edossa G, Babel M, Gupta G(2010). A Drought analysis in the Awash River Basin,. Ethiopia. *Water Resource Manage* 24(7):1441–1460 .

Elkhrachy L, 2015. Flash Flood Hazard Mapping Using Satellite. *The Egyptian Journal of Remote Sensing and Space Sciences*.18, 261–278.

FAO, 2006. World Reference Base for Soil Resources: A Framework for International Classification, Correlation and Communication.

Fernandez S, Paulo LP (2016). A new approach for computing a flood vulnerability index using Cluster analysis. *physics and chemistry of the earth*.

Ferrier H, Haque C (2003). Hazards risk assessment methodology for emergency managers: A standardized framework for application. *Natural Hazard* 28:271-290.

Faulkner, H., 1990. Vegetation cover density variations and infiltration patterns on piped alkali sodic soils: implications for the modelling of overland flow in semi-arid areas. In: J.B. Thornes (Editor), *Vegetation and erosion*. Wiley, Chichester, pp. 317-346. watershed using SWAT.

Ficklin DL, Luo Y, M. Zhang(2009). Climate change sensitivity assessment of a highly agricultural watershed using SWAT, *Journal of Hydrology*, Volume 374, Issues 1–2,Pages 16-29.

French J (2003). Airborne LiDAR in support of geomorphological and hydraulic modelling. *Earth Surface Processes and Landforms*, 28(3): 321-335.

Fussel HM., Klein, R.J.T. (2006). Climate change vulnerability assessments: An Evolution of Conceptual Thinking. *Climatic Change* 75, 301-329.

Gallopín, G.C. (2006). Linkages between Vulnerability, Resilience, and Adaptive Capacity. *Global Environmental Change*, 16, 293-303.

GillesD, Young N, Schroeder H, Piotrowski J, Chang Y (2012). Statewide coverage and detailed urban flooding analysis. *Inundation mapping initiatives of the Iowa flood center*.4(1):85-106.

Guinand Y (1999). Target group and development oriented participatory approach for agricultural research: the case of agroforestry in the East and Central African highlands. *Book* pp 291

Hahn N, RiedererS, Foster S (2009). The livelihood vulnerability index: a pragmatic approach to assessing risks from climate variability and change. A case study in Mozambique. *Global environmental change* 19: 74-88.

Hardmeyer MA, Spencer RS(2007). Using Risk-Based Analysis and Geographic Information Systems to Assess Flooding Problems in an Urban Watershed in Rhode Island.. *Environmental Management* 39:563–574.

IPCC (2001). *Climate Change Impacts, Adaptation, and Vulnerability*. Intehangergovernmental Panel on Climate c, Cambridge: Cambridge university.

IPCC(2007). *Climate Change 2007: The Physical Science Basis*. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change.

IPCC(2010). *Managing the risks of extreme events and disasters in Africa*. Lessons from the IPCC SREX.

IPCC (2012). *Intergovernmental Panel on Climate Change From global disaster database.Determinants of Risk: Exposure and Vulnerability*.

JohnsonTE,Weaver CP (2009). A Framework for Assessing Climate Change Impacts on Water and Watershed Systems. *Environmental Managment*. 43: 118–134.

Kefyalew A (2003). *Integrated Flood Management: Case study Ethiopia*, Ethiopia: Water Resource Consultant.

Liu Shao-yu W, Dong-mei L (2014). The Analysis of the Impact of Land-Use Changes on Flood Exposure of Wuhan in Yangtze River Basin, China. *Water Resour Manage* **28**, 2507–2522

Liverman D (1990). Vulnerability to global environmental change. In: Understanding global environmental change: The contribution of risk analysis and management. 3: 27-44.

Luh EC, Toregozhina CA, Bartram J (2015). Vulnerability assessment for loss of access to drinking water due to extreme weather events.

Mcarthy J J, Canziani O, Leary NA, Dokken DJ, White KS (2001). Impacts, Adaptation, and Vulnerability.. Cambridge University.

Mitchell, J., 1999. Crucibles of Hazard: Megacities and Disasters in Transition. United Nations University Press, Tokyo.

Morgan, P.C. et al., 1998b. The European Soil Erosion Model (EUROSEM): documentation and user guide, Cranfield University, Silsoe, Bedford.

Naef, S. S. W. M., 2002. A process based assessment of the potential to reduce flood runoff by land use change. *Journal of Hydrology* 264:.. p. 74–79.

Nederveen C (2010). Flood Recession Farming: An Overview and Case Study from the Upper Awash Catchment, Ethiopia. M.Sc Thesis, VU University..

Nelitz B, M Smith R, 2013. Tools for climate change vulnerability assessments for watersheds essa Technologies Ltd, under contract to the Canadian Council of Ministers of the Environment (CCME).

Nielsen PS (2010) The vulnerability of beach tourism to climate change- an index approach. 579-606.

NMA, 2015. Unseasonal rainfall and flood alert. 55:273–289.

Ntajala BL, Lamptey IB, Mahamadouc, Benjamin K N (2017). Flood disaster risk mapping in the lower mono river basin Togo. West Africa. *International Journal of disaster risk reduction*. 23:93-103

Nunes J (2007). Vulnerability of Mediterranean Watersheds to Climate Change: The Desertification Context. Dissertação apresentada para obtenção do Grau de Doutor em Engenharia do Ambiente pela Universidade Nova de Lisboa, 12:27–34.

OECD (2002). Organisation for economic cooperation and development. Annual report

Pandey A, Galkat R(2010). Integrating hydro-meteorological and physiographic factors for assessment of vulnerability to drought. *Water Resource Management* 24: 4199-4217.

Pandey A, Galkat R, Ravi V (2011). Indicator based approach for assessing vulnerability of freshwater resources in the Bagmati River basin, Nepal .*Environmental Management* 48: 1044-1059.

Paolo B, Rossano T, Ciampalini AY (2013). Increased frequency of flash floods in Dire Dawa, Ethiopia: Change in rainfall intensity or human impact?

Parent C, Spaccapietra S, Zimany, (1999). *Spatio-Temporal Conceptual Models: Data Structures + Space + Time*. Kansas City, Kansas,. 26-33.

Parry ML, Canziani OF, Linden JP, Hanson P.J(2007). impacts, adaptation and vulnerability. In contribution of working groups II to the fourth assessment report of the intergovernmental panel on climate change. Cambridge university press, UK.

Pouyaa N, Mansouria J , N. & Alireza, A. (2017). An indexing approach to assess flood vulnerability in the western coastal cities of Mazandaran, Iran. *Interna Journ of Disas Risk Reductio*.

Rabia S (2015). Water resource vulnerability assessment in Rawalpindi and Islamabad, Pakistan using Analytic Hierarchy process. 28:293-299.

Rivard B 2007. Determination of Flood Extent Using Remote Sensing: Department of Earth and Atmospheric Science University of Alberta .

Simha P, Mutiara Z, Gaganis P (2017). Vulnerability assessment of water resources and adaptive management approach for Iesvos island, Greece. *Journal of Sustainable water resource management*.

Szlafsztein, C. & Sterr, H (2007). A GIS-based vulnerability assessment of coastal natural hazards, state of Pará, Brazil. *Journal of Coastal Conservation*.11:53–66.

Taye, M.T.; Dyer, E.; Hirpa, F.A.; Charles, K. (2018) Climate Change Impact on Water Resources in the Awash Basin, Ethiopia.

Thornes, J.B., 1990. The interaction of erosional and vegetational dynamics in land degradation: spatial outcomes. In: J.B. Thornes (Editor), *Vegetation and Erosion* Wiley, Chichester, 41-53

Turner BL (2013). Flood modelling using a synthesis of multi-platform LiDAR data. *Water*. 5:1533-1560.

UN (1997). United Nations Commission on sustainable development. Comprehensive assessment of the fresh water resources of the world:, New york.

UNISDR (2009). (United Nations International Strategy for Disaster Reduction), UNISDR Terminology for Disaster Risk Reduction, United Nations International Strategy for Disaster Reduction (UNISDR), Geneva, Switzerland.

USAID (2001). Long term response to disasters. United states agency for international development.

Wang, Y, Colby, J. D. & Mulcahy, KA (2002). An efficient method for mapping flood extent in a coastal floodplain using Landsat TM and DEM data. *International Journal of Remote Sensing*. 18:3681–3696.

Woubet, G. A (2007). Flood hazard and risk assessment using GIS and Remotesensing.

Yamamoto, T. and Anderson, W., 1973. Splash erosion related to soil erodibility indices and other forest soil properties in Hawaii. *Water Resources Research*, 9: 336-345.

Yang K, Lian J, Ling B. Chaoma K (2018). Multiple flood vulnerability assessment approach based on fuzzy comprehensive evaluation method and co-ordinated development degree model. *environl manage*. 1-98.

Yirga WK(2016). Flood Hazard and Risk Assessment Using GIS and Remote Sensing in Lower Awash Sub-basin. *Journal of Environmental and Earth Science*.1-125.

Ziegler, A.D. et al., 2004. Hydrological consequences of landscape fragmentation in mountainous northern Vietnam: evidence of accelerated overland flow generation. *Journal of Hydrology*, 287: 124-146.

Appendix

Research Questionnaire

My name is Tinsae Seboka. I am a Master's of surface water management student at Addis Ababa University Ethiopian institute of water resource. The purpose of this questionnaire is to collect information on the Awash flood sensitivity. Kindly cooperate in filling the questionnaire as your genuine is crucial for the success of my study. Besides, I would like to assure that the data collected using this questionnaire is purely for academic requirement. Hence, the researcher kindly requests you to respond each item.

Note:

- No need of writing your name

Section I: Background Information

1. Gender 1. Male 2.Female

2. Educational Qualification

1. Degree 2. Masters 3.PhD 4.Other

3. Age _____

4. Years of experience _____

5. In which institution you are currently working?

Section II: Indicate the flood sensitivity class to which you agree with the following sensitivity indicators by using a scale of 1 to 5 where: '1' least sensitive, '2' limited, '3' moderately, '4' severely, '5'critically sensitive. Please tick (√) in the box that best reflects your answer where:

Rank	Description	Indicators	Justifications
1	Highest contribution to flood sensitivity		
2	Second highest contribution to flood sensitivity		
3	Third highest contribution to flood sensitivity		
4	Fourth highest contribution to flood sensitivity		
5	Lowest contribution to flood sensitivity		