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Towards Integrated Urban Flooding Risk Management in Ambo Town and Its Watershed, West Shoa Zone, Oromia Regional State, Ethiopia

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CERTIFICATION

**Ethiopian Institute of Architecture, Building Construction and City Development
(EiABC), Addis Ababa University Office of Graduate Program**

This is to affirm that the dissertation produced by Gemechu Shale Ogato, with the title **“Towards Integrated Urban Flooding Risk Management in Ambo Town and Its Watershed, West Shoa Zone, Oromia Regional State, Ethiopia”** in fulfillment of the requirements of the Degree of Doctor of Philosophy (Environmental Planning) fulfills the regulations of the University underpinned by the accepted standards relating to originality and quality.

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I. LIST OF ACRONYMS AND ABBREVIATIONS

ADPC:	Asian Disaster Preparedness Center
AHP:	Analytical hierarchy process
BAT:	Best Available Technology
BMP:	Best management practice
CSA:	Central Statistical Authority
DD:	Drainage density
DEFRA:	Department for Environment, Food and Rural Affairs
DRM:	Disaster risk management
DRR:	Disaster Risk Reduction
DEM:	Digital Elevation Model
ECE:	Economic Commission for Europe
EFDRR:	European Forum for Disaster Risk Reduction
EiABC:	Ethiopian Institute of Architecture, Building Construction and City Development
EMA:	Ethiopian Mapping Agency
FDRE:	Federal Democratic Republic of Ethiopia
FRM:	Flood risk management
GIS:	Geographic Information System
GPS:	Global positioning system
IDW:	Inverse distance weight
IFPRI:	International Food Policy Research Institute
IIED:	International Institute of Environment and Development
IPCC:	Intergovernmental Panel on Climate Change
ITDG:	Intermediate Technology Development Group
IIRR:	International institution of rural reconstruction
IUCN:	International union for conservation of nature
IUFRM:	Integrated Urban Flooding Risk Management
IWRM:	Integrated water resource management
LAS:	Land administration system
LDCs:	Least Developed Countries
LULCC:	Land Use/ Land Cover Change
MCA:	Multi-Criteria Analysis
MUDHC:	Ministry of Urban Development, Housing, and Construction

NMA:	National Metrology Agency of Ethiopia
NSMs:	Non Structural Measures
ODI:	Overseas development institute
OECD:	Organization for Economic Cooperation and Development
OPW:	Office of Public Work
SDI:	Spatial Data Infrastructures
SRTM:	Shuttle Radar Topographic Mission
SUDS:	Sustainable urban drainage systems
UCT:	University of Cape Town
UHI:	Urban Heat Island
UNDP:	United Nations Development Programme
UNEP:	United Nations Environment Programme
UNISDR:	United Nations International Strategy for Disaster Reduction
UN-HABITAT:	United Nations Human Settlements Programme
VCCCAR:	Victorian Centre for Climate Change Adaptation Research
WEF:	World Economic Forum
WLC:	Weighted linear combination
WMO:	World Meteorological Organization
WOTR:	Watershed Organization Trust

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V. DECLARATION

I, Gemechu Shale Ogato, hereby declare that this thesis entitled “Towards Integrated Urban Flooding Risk Management in Ambo Town and Its Watershed, West Shoa Zone, Oromia Regional State, Ethiopia ” which I submit for the degree of Doctor of Philosophy in Environmental Planning at The Ethiopian Institute of Architecture, Building Construction and City Development (EiABC), Addis Ababa University, is my own original work and it has not been presented in other universities, colleges or institutes for a degree or other purpose. All sources of the materials used have been duly acknowledged.

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SignatureDate.....

VI. BIOGRAPHICAL SKETCH

The author was born on May 23, 1980, in Arsi Negele, Ethiopia. He attended his elementary and secondary school education at Kuyera Adventist Primary and Junior secondary school and Kuyera Adventist Academy, Shashemene, Ethiopia, respectively. He joined the then Alemaya University and graduated with BSc in Agricultural Extension in July 2000. He joined Vrije Universiteit Brussel and graduated with Post-graduate Diploma in Human Ecology in July 2007 and MSc in Human Ecology in 2008. He worked as community development worker in Christian Children's Fund inc. Ethiopia from September 2000 to April 2002. He worked as Assistant Researcher-II in agricultural extension research and technology transfer in Oromia Agricultural Research Institute, Bako Research Centre, Ethiopia from April 2002 to September 2005. He worked as Graduate Assistant, lecturer, assistant registrar, and research team leader in Ambo University (2005-2011). He has been serving as assistant professor in Ambo University since 2013. He joined a PhD programme in environmental planning in the Ethiopian Institute of Architecture, Building Construction, and City Development (EiABC), Addis Ababa University in September 2012. He has published more than 30 scientific documents (international peer reviewed publications). He has been serving as reviewer of international journals for more than ten years (Since 2010).

VII. ABSTRACT

Towards Integrated Urban Flooding Risk Management in Ambo Town and Its Watershed, West Shoa Zone, Oromia Regional State, Ethiopia

Gemechu Shale Ogato (GSR/1993/05)

A GIS-based spatial planning and land use management is asserted to be a versatile tool in building capacities for flood disaster reduction and preparedness underpinning sustainable urban development. The purpose of the study was to analyze urban flooding hazard and risk and develop integrated urban flooding risk management strategy for Ambo town and its watershed. The study adopted a mixed research approach which combined quantitative and qualitative methods of data collection and analysis. The study confirmed that residing in flood prone area, poverty, lack of alternative livelihoods, and lack of proper drainage channels are the underlying causes of socio-economic vulnerability to urban flooding risk in Ambo town. Unwillingness of people to move away from hazard-prone areas due to the nature of their livelihoods, the high prices of properties, and a lack of awareness of the risk of hazards anticipated were identified as internal barriers to governance of urban flooding risk reduction in the study area. A strong positive association was confirmed between urban households' perception on structural and non-structural measures practiced in Ambo town and their perception on the effectiveness of the current governance of urban flooding risk reduction. A statistically significant relationship was confirmed between respondents' access to credit and their education level, total income, and employment status. A statistically significant relationship was confirmed between respondents' perception on their vulnerability to disease after flooding risk and their demographic and socio-economic characteristics. 63.04% of the watershed is moderate flooding hazard area while 52.9% of Ambo town is moderate flooding hazard area. 20.2% of Huluka watershed is moderate flooding risk area while 21% of Ambo town is high and very high flooding risk area. The IDF curves developed indicate that rainfall intensities increase with increase in return periods for all the seven stations and the Huluka watershed. High rainfall intensities were confirmed to be related to short durations while low rainfall intensities related to long durations for the same return periods. Bush and shrub land, forest, grassland, and water land use/land cover type declined with 68.2%, 59.3%, 32.7%, and 5.1% respectively between 1979 and 2017. Based on the land use/land cover analysis in the watershed, urban built-up area, cultivated land, and bare land use/land cover type increased with 351%, 105%, and 41.9% respectively between the year 1979 and 2017. Infrastructural and agricultural expansion, increased demand for wood, local environmental and biophysical drivers, rapid human population growth, economic drivers, technological drivers, policy and institutional drivers, and local socio-cultural drivers were identified as drivers of land use and

land cover changes. There should be urban disaster risk reduction policies and strategies at national level which guide local urban disaster risk reduction interventions and the principles of good governance should be properly practiced in governance of urban flooding disaster risk reduction in Ambo town. It is vital to pay attention to the coordination between urban development and flooding hazard and risk through appropriate spatial planning and land use management in Ambo town and its watershed.

Keywords: *Governance, flooding, land use/land cover, land use management, spatial planning*

CHAPTER ONE: INTRODUCTION

1.1. Background of the Study

Previous studies on urban flooding in African countries confirmed that various sociocultural activities in urban areas cause and exacerbate urban flooding (Smith, 2009; Mpofu, 2011; Alderman *et al.*, 2012; Champion, 2012; Jha *et al.*, 2012). For instance, Ologunorisa & Abawua (2005) attest that sociocultural activities in urban areas are attributable to stream or river channel encroachment and abuse, increased paved surface and poor solid waste disposal techniques underpinned by a high level of illiteracy, a low degree of community awareness, poor environmental education, ineffective town planning laws and poor environmental management. The same scholars also characterized urban flood risk as a function of the following factors: Land-use pattern, refuse disposal habits, the nature of the surrounding buildings, distance of building from the course of the streams, rainfall amount and duration, the relief or the terrain, slope, gradient, and other stream basin parameters.

For Champion (2012) and Fura (2013) the impact of urbanization and climate change in urban areas of developing countries are converging in dangerous ways causing extreme environmental and socio-economic deterioration. The same scholars also contend that urbanization degrades and fragments natural habitats which in turn cause climatic hazards like urban flooding. The urban flooding caused by climate change and other factors in these urban areas are claimed to increase vulnerability of the people and their properties (Wilby & Keenan, 2012; Fura, 2013; Santato *et al.*, 2013; Hall *et al.*, 2014).

Fura (2013) and Praskievicz & Chang (2009) characterize urban land use/land cover change as a change process resulting in increase in impervious land surface covers contributing to increase in surface run-off. Moreover, a combination of increasing urbanization and increasing per-capital land consumption in urban areas leads to unprecedented rate of land cover conversion (Jha *et al.*, 2012; Berggren *et al.*, 2013; Dodman *et al.*, 2013; Fura, 2013; Santato *et al.*, 2013).

Land use/land cover change in urban areas of developing countries like Ethiopia is claimed to result from complex interaction of different actors, driving forces, and the land itself (Zeleeke, 2000; Bewket, 2003; Fura, 2013; Hall *et al.*, 2014). It is mostly seen as the result of the complex interaction (due to the interaction of decision making at different levels) between

changes in social and economic opportunities linked with the biophysical environment (Tucci, 2007; Jha *et al.*, 2012; Dodman *et al.*, 2013; Fura, 2013).

Many previous studies in Africa confirmed flood risks in large cities. However, there are little information on causes and effects of urban risks in sub-Saharan Africa and in smaller urban centers worldwide (Kamal-Chaoui & Robert, 2009; Berggren *et al.*, 2013; Dodman *et al.*, 2013; Uddin *et al.*, 2013). This is particularly true for inland towns in Ethiopia like Ambo. Despite limited information, there is wide recognition of the importance of local-level risk and vulnerability assessments involving households and community organizations (Achamyeleh, 2003; Bewket, 2003; Alemu, 2011; Mpofu, 2011; Dodman *et al.*, 2013). Hence, the proposed study is motivated to understand the causes and effects of urban flooding risk in Ambo town and its watershed and propose integrated urban flooding risk management strategy.

1.2. Statement of Research Problem

Recent reviews of disasters in urban areas (Few *et al.*, 2004; Tucci, 2007; UNISDR 2009, 2011b) assert a rapid growth in the number of disasters in urban areas, with most of these being associated with extreme weather, including heavy winds and rains, floods, landslides and fires (Parkinson, 2003; Vasquez, 2004; Birkinshaw *et al.*, 2010). They also attest that the number of locations where such disasters are happening is expanding geographically (Mpofu, 2011; Mngutyo & Ogwuche, 2013). Although the factors that underpin these vary, as do their relative importance, in most instances they are claimed to be linked to increases in the urban population in informal settlements, increases in run-off due to urban growth and poor land-use and watershed management, and chronic underinvestment in drainage (Bewket, 2003; Mpofu, 2011; Berggren *et al.*, 2013; Alemu, 2015). In other words, urban expansion and development are claimed to generate new patterns of hazard, exposure and vulnerability that did not exist before (Few *et al.*, 2004; Dodman *et al.*, 2013; Santato *et al.*, 2013; Parikh *et al.*, 2014).

According to UN-HABITAT (2008) and Ogato (2013), high level of solid waste; water and air pollution; lack of adequate water and sanitation; and lack of legal access to land are some of the urban challenges for Ethiopian cities and towns. Despite the aforementioned major urban challenges in those cities and towns, the capacity of local government is affirmed to be weak and cities and towns have been shaped by national economic development policies and

rampant market forces (Abebe, 2013; Achamyeleh, 2003; Watson, 2009; Alemu, 2011; McCarney, 2012). Furthermore, their urban planning system is characterized by frequent corruption and clientelism. As a result, the ability to manage growth and deliver services equitably is lacking (Watson, 2009; Measham *et al.*, 2001; Fünfgeld, 2012; Abebe, 2013).

Previous studies undertaken on the environmental problems of Ambo town identified: low infiltration of rain Water, storm water occurrence, inundation of low gradient areas, incidence of sheet and gully erosion, inefficient and uncoordinated utilization of potential site and resources; sanitation problem associated with lack of waste collection system and disposal site for both solid and liquid waste, mixed waste disposal in open spaces and rivers, water stress, urban heat island effects, wind storms, dust storms, flash flood, growing water and air pollution, and unplanned expansion and deforestation as critical environmental challenges for urban development in Ambo town (Ambo Town Administration, 2013; Ogato, 2013).

UN-HABITAT (2008) affirms that the environment of Ambo town has been in a constant decline characterized with most of the solid waste not properly collected, lack of enforcement in implementing environmental regulations and sanitation, absence of sewerage system in place, lack of sanitary dumping site, and half of all houses without toilet facility. UN-HABITA (2008) further contends that the municipality of Ambo town is not in a position to address the aforementioned problems due to resource and capacity limitations. Ogato (2013) asserts that Ambo town and its dwellers are vulnerable to the negative impacts of climate change related hazards and mainstreaming climate change adaptation into urban planning is vital. The same scholar also identified urban flooding risk as priority climatic hazard for urban communities of Ambo town based on their priority ranking of climatic hazards in their town.

Localized flooding due to inadequate drainage; flooding from small streams; and flooding from major rivers are asserted as the three types of urban flooding in Ambo town and its watershed. However, causes and effects of these types of urban flooding risk were not studied in a comprehensive manner and integrated urban flooding risk management strategy is missing. Hence, it was worth investigating causes and effects of urban flooding risk in Ambo town and its watershed and proposing integrated urban flooding risk management strategy.

1.3. Research Objectives

The study has general and specific objectives. The general objective of the study is to analyze urban flooding hazard and risk and propose integrated urban flooding risk management strategy for Ambo town and its watershed.

The specific objectives of the study are:

1. To explore socio-economic vulnerability to urban flooding risk in Ambo town;
2. To examine governance of urban flooding risk reduction in Ambo town;
3. To analyze changes in land use/land cover in Ambo town and its watershed for the time period 1979-2017;
4. To analyze urban flooding hazard and risk from Geographic Information System(GIS)-based multicriteria perspective in Ambo town and its watershed ;
5. To establish Intensity-Duration-Frequency (IDF) relationship for Ambo town and its watershed; and
6. To propose integrated urban flooding risk management strategy for Ambo town and its watershed.

1.4. Research Questions

The study answered the following research questions:

Objective one: To explore socio-economic vulnerability to urban flooding risk in Ambo town. To achieve this objective, the following research question was answered:

- What are the characteristics of socio-economic vulnerability of urban environment to urban flooding risk in Ambo town?

Objective two: To examine the current governance of urban flooding risk reduction in Ambo town. To achieve this objective, the following research question was answered:

- To what extent good is the current governance of urban flooding risk reduction in Ambo town?

Objective three: To analyze changes in land use/land cover in Ambo town and its watershed for the time period 1979-2017. To achieve this objective, the following research question was answered:

- What is the dynamics of land use/land cover change in Huluka watershed for the period of 1979-2017?

Objective four: To analyze urban flooding hazard and risk from Geographic Information System(GIS)-based multicriteria pererspective in Ambo town and its watershed. To achieve this objective, the following research question was answered:

- What are the severity calssses for uran flooding hazard and risk in Ambo town and its watershed?

Ojective five: To establish Intensity-Duration-Frequency (IDF) relationship for Amo town and its watershed. To achieve this objective, the following research question was answered:

- What kind of intensity-duration-frequency (IDF) relationship exist in Ambo town and its watershed?

Objective six: To propose integrated uran flooding risk management strategy for Ambo town and its watershed. To achieve this objective, the following research question was answered:

- What strategic measures must be included in integrated uran flooding risk management strategy at watershed, town, community, and building levels?

1.5. Scope and Limitation of the Study

The study had content, geographic and methodological scopes. The content scope of the this study was that it dealt with the causes and effects of urban flooding risk in Ambo town and its watershed and proposed strategic measures for mainstreaming integrated urban flooding risk management into spatial planning and land use management. The geographic scope of the study was that it covered Ambo town and its watershed in West Shoa Zone, Oromia Regional State, Ethiopia. The methodological scope of the study was that it combined socio-economic study of causes and effects of urban flooding risk and GIS-based multicriteria analysis of flooding hazard and risk in Ambo town and its watershed.

While the findings of the study will be very much helpful in proposing integrated uran flooding risk management strategy for the town and its watershed, the author does not claim that the findings of this study are panaceas for urban environmental and developmental problems of Ambo town and its waterhed. In other words, there are possibilities of designing and implementing integrated research and development projects and programs in Ambo town and its watershed to address problems of households and communities in a sustainable manner.

1.6. Significance of the Study

The findings of the study will be helpful for both development and scientific communities. With regard to the significance of the findings of the study to development communities, the empirical findings on land use/land cover change dynamics, comprehensive analysis of flooding hazard and risk, exploration of socio-economic vulnerability to urban flooding risk, governance of urban flooding risk reduction, establishment of intensity-duration-frequency curve for the watershed, and the proposed integrated urban flooding risk management strategy will have great contribution for developing and implementing sustainable local development projects and programmes in Ambo town and its watershed. Moreover, the scientific communities will learn from the empirical evidences and the innovative methodological applications demonstrated in the study to address the aforementioned issues. More specifically the application of GIS-based multi-criteria analysis of flooding hazard and risk can be replicated in small urban areas and the comprehensive research approach of integrating socio-economic study and bio-physical research is of great value contrary to previous approaches of focusing only on socio-economic study or bio-physical study of urban flooding hazard and risk analysis.

1.7. Organization of the Dissertation

The PhD dissertation is organized into ten chapters. The first chapter is introduction. In the introduction chapter, background of the study, statement the problem, research objectives, research questions, scope and limitations of the study, and significance of the study are presented. The second chapter deals with the theoretical and empirical review of literature on the quest for mainstreaming integrated urban flooding risk into spatial planning and land use management. The third chapter deals with materials and methods (the description of the study area, research design, sampling methods and procedures, types and sourcesof data, methods of data collection, methods of data analysis, and ethical considerations). The fourth chapter deals with socio-economic vulnerability to urban flooding in Ambo town. The fifth chapter deals with governance of urban flooding risk reduction in Ambo town. Chapter six deals with the dynamics of land use/land cover changes in Huluka watershed. Chapter Seven deals with analysis of flooding hazard and risk in Ambo town and Huluka watershed. Chapter eight deals with intensity-duration-frequency (IDF) relationship in Ambo town and its watershed. Chapter nine deals with integrated urban flooding risk strategy for Ambo town and its watershed. The last chapter (Chapter ten) deals with conclusion.

CHAPTER TWO: REVIEW OF LITTERATURE

2.0. Introduction

This chapter presents theoretical and empirical review of literature on the quest for mainstreaming integrated urban flooding risk into spatial planning and land use management. The review themes for theoretical review include: definition and concepts of urban flooding, and urban flooding risk management. The review themes for empirical review include: types of urban flooding, aspects of urban flooding, causes of urban flooding, effects of urban flooding, responses to urban flooding, governance of urban flooding risk reduction, urban flooding risk management approaches, sustainable urban flooding risk management practices, and case studies on sustainable urban flooding risk management practices. This chapter also presents the conceptual frameworks adapted to address the specific objectives of the study.

2.1. Theorotical Review

2.1.1. Definitions and Concepts of Urban Flooding and Urban Flooding Risk Management

2.1.1.1. Urban Flooding

According to Balaban (2009), floods are temporary inundation of normally dry land areas from the overflow of inland or tidal waters, or from the unusual and rapid accumulation or runoff of surface waters from any source. Young *et al.* (2004) characterize floods as excessive and often unexpected overflow of water into areas that are not normally submerged. Flooding is asserted to be a global phenomenon which causes widespread devastation, economic damages and loss of human lives. In other words, floods are claimed to be one of the most threatening natural hazards for human settlements (Barua, 2008; Balaban, 2009; Cordaid & IIRR, 2011; Jember, 2014). For instance, Floods affect urban settlements of all types, from small villages and mid-size market towns and service centers (Young *et al.*, 2004; Kamal-Chaoui& Robert, 2009; Alderman *et al.*, 2012; Jha *et al.*, 2012; Fadairo, 2013). Santato *et al.* (2013) and Kamal-Chaoui& Robert (2009) affirm that flood hazard increases for different reasons and several of them are correlated as a result from the confluence of both meteorological and hydrological factors, exacerbated by human actions.

Urbanization is asserted to become the defining feature of the world's demographic growth, with the populations of cities, towns and villages swelling, particularly in developing countries. As a result, floods are confirmed to affect and devastate more urban areas, where unplanned development in floodplains, ageing drainage infrastructures, increased paving and other impermeable surfaces, and a lack of flood risk reduction activities all contribute to the impacts experienced (Genovese, 2006). These problems are attested to be compounded by the effects of a changing climate (Satterthwaite *et al.*, 2007; Barua, 2008; Alderman *et al.*, 2012; Jha *et al.*, 2012). More importantly, African flooding has been characterized as: frequent localized slum flooding due to poor drainage; Small stream flooding due to inadequate culverts and blocked culverts; Major river flooding exacerbated by land use change, expansion of populations into the floodplain and inappropriate upstream engineering; Wet season flooding in lowland and coastal cities made worse by dumping of waste beneath dwellings, reducing storage (Few *et al.*, 2004; Douglas & Alam, 2006; Satterthwaite *et al.*, 2007; Alderman *et al.*, 2012; Thomas & López, 2015).

Flood events are asserted to take many forms, including slow-onset riverine floods, rapid-onset flash floods, accumulation of rainwater in poorly-drained environments, and coastal floods caused by tidal and wave extremes. Both inland and coastal floodings are affirmed to be associated with windstorm events. Floods are also attested to vary greatly in magnitude and impact, according to depth, velocity of flow, spatial extent, content, and speed of onset, duration and seasonality. According to Jha *et al.* (2012) and Uddin *et al.* (2013), a flood event that has severe consequences (variously defined) may be termed a flood disaster, and the human impact of flood disasters is concentrated disproportionately in developing countries.

Disaster is affirmed to be a serious disruption of the functioning of a community or a society resulting in widespread human, material, economic or environmental losses exceeding the ability of the affected community or society to cope using its own resources (Balaban, 2009). An extreme natural event is attested to become a disaster when it has a large impact on human settlements and activities (Barua, 2008; Balaban, 2009; Santato *et al.*, 2013). Flood exposure is attested to be a measure of the human population, land uses and investment located in flood zones and at risk of flooding, and increasing exposure is a prime, contributory cause of flood hazards and disasters (Genovese, 2006). Flood hazard is characterized as flood event with the potential to cause harm to humans or human systems (Few *et al.*, 2004; Akukwe, 2014).

2.1.1.2. Urban Flooding Risk Management

Disaster management may be defined as “the organization and management of resources and responsibilities for dealing with all humanitarian aspects of emergencies in particular preparedness, response and recovery in order to lessen the impact of disasters (Young et al., 2004; Mngutyo & Ogwuche, 2013). With regard to natural disasters, risk is defined as “the probability that natural events of a given magnitude and a given loss will occur.” In simple terms, it is defined as “a probability that a hazard will turn into a disaster” (Balaban, 2009). In other words, flood risk and consequent damage is attested to be a function of hazard with exposure and vulnerability to the hazard (Barua, 2008; Balaban, 2009; Mngutyo & Ogwuche, 2013).

The concept of risk management approach is affirmed to provide wider scope that includes systematic and harmonized implementation of both structural and non-structural measures (Barua, 2008; Balaban, 2009; Richardson & Otero, 2012). Risk management may be defined as “a system which aims to identify and quantify all risks to which the business, project or planning stages are exposed so that a conscious decision can be taken how to manage the risks” (Balaban, 2009; Mngutyo & Ogwuche, 2013; Santato *et al.*, 2013). In other words, risk management is defined as “the systematic approach to minimize disaster impact at all levels and locations in a given society.” It is also asserted to be a fundamental input geared to the evaluation of schemes for reducing but not necessarily eliminating the overall risk, as in many cases risk cannot be entirely eliminated.

According to Balaban (2009), the shift to proactive management of natural disasters involves the identification of the risk (hazard potential and vulnerability), the assessment of the risk whether it is tolerable or not, the development strategies to reduce that risk and implementation of policies and programs to these strategies into effect. It is claimed to be normally based on a comprehensive strategy for increased awareness, assessment, analysis/evaluation, reduction and management measures (Genovese, 2006; Richardson & Otero, 2012). In addition, the framework is attested to include legal provisions defining the responsibilities for disaster damage and longer-term social impacts including spatial planning actions. It is also vital to understand the concept of integrated risk management. Scholars contend that integrated risk management stresses the equal implementation of all possible measures and includes risk communication and dialogue as relevant elements of risk management (Genovese, 2006; Richardson & Otero, 2012).

2.2. Emperical Review

2.2.1. Types of Urban Flooding

According to Tucci (2007:25), storm water runoff can lead to flooding and impacts in urban areas by means of the following two processes, separately or in combination:

- 1. Flooding of riverside areas:** natural flooding that occurs in the flood plains of rivers owing to temporal and spatial variations in precipitation and runoff in the catchment area; and
- 2. Flooding due to urbanization:** flooding from the urban drainage system due to the effect of soil impermeabilization, canalization or obstruction of water flow.

There are four different types of flooding identified: localized flooding due to inadequate drainage; flooding from small streams; flooding from major rivers; and coastal flooding from the sea (Few *et al.*, 2004; ADPC, 2005; Douglas & Alam, 2006; Satterthwaite *et al.*, 2007). Jha *et al.* (2012) identified River or fluvial flood, pluvial or overland flood, coastal flood, groundwater flood, urban flooding caused by failure of artificial systems, flash flood, and semi-permanent flooding as the seven types of urban flooding.

2.2.2. Aspects of Urban Flooding

Flooding is claimed to have several aspects, such as climatic, social, economic, institutional, and technical, that are differently addressed for rural and urban conditions (Andjelkovic, 2001; Balaban, 2009; Mngutyo & Ogwuche, 2013). The climatic aspect of flooding is attested to deal with the climatic conditions that may lead to the occurrence of floods. (Andjelkovic, 2001; Few *et al.*, 2004; Kamal-Chaoui & Robert, 2009; Jha *et al.*, 2012). The social aspect of flooding is affirmed to deal with the way the floods occur in different settings (Andjelkovic, 2001; Few *et al.*, 2004; Kamal-Chaoui & Robert, 2009; Jha *et al.*, 2012). The economic aspect of flooding is contended to deal with the issues of financing the capital improvement, operation, and maintenance of flood protection schemes (Andjelkovic, 2001; Few *et al.*, 2004; Jha *et al.*, 2012; Fadairo, 2013). The institutional aspect of flooding is affirmed to deal with the role of governments in the process of decision making (Genovese, 2006; Jha *et al.*, 2012; Mngutyo & Ogwuche, 2013; Richardson & Otero, 2012). The technical aspect of flooding is attested to deal with the concepts and works usually applied in flood protection (Alderman *et al.*, 2012; Jha *et al.*, 2012; Mngutyo & Ogwuche, 2013; Uddin *et al.*, 2013).

2.2.3. Causes of Urban Flooding

Urban areas are affirmed to be flooded by rivers, coastal floods, pluvial and groundwater floods and artificial system failures. In cities and towns, areas of open soil that can be used for water storage are claimed to be very limited (Merz *et al.*, 2010; Fadaïro, 2013; Santato *et al.*, 2013; Hall *et al.*, 2014). Flooding is attested to be caused by the meteorological and hydrological conditions. The hydrological conditions leading to flooding may be natural or artificial. The natural conditions (relief, precipitation type, vegetation cover, and drainage capacity) are characterized as those occurring as a result of the watershed in its natural state (Few *et al.*, 2004; Tucci, 2007; Djordjevic *et al.*, 2011). WMO (2012) identified existing soil moisture, groundwater levels, extent of impervious surface, natural channelization of water courses, and tidal impacts on runoff as hydrological factors.

An urban watershed is attested to have impervious surfaces such as roofs, streets and paved areas, and accelerates runoff by means of canalization and surface drainage. In relation to this increased peak flow and surface runoff, reduced peak time and lower base time are identified as the effects of urbanization on runoff (Merz *et al.*, 2010; Hall *et al.*, 2014). In other words, urbanization and deforestation increase the frequency of flooding from small and medium flood events. The meteorological factors are claimed to include rainfall frequency and intensity, storms and temperature. In relation to these factors human actors are claimed to complicate matters through land use changes, occupation of the flood plain, inadequate maintenance of drainage infrastructures, and obstruction of drainage channels (WMO, 2012).

Scholars assert that the two main causes or drivers of flood events are extreme precipitation and increased vulnerability to natural disasters due to growing urban population, environmental degradation and a lack of planning, land management and preparedness (Smith, 2009; WMO, 2012; IPCC, 2007; Djordjevic *et al.*, 2011; Santato *et al.*, 2013). According to IPCC (2007) and Li *et al.* (2009), some climate projections point to more extreme flooding as a consequence of extreme weather events in the future. Furthermore, human encroachment into unsafe areas are affirmed to increase the potential for damage and for that societies to become more exposed, developing flood-prone areas (maladaptation) (Santato *et al.*, 2013). However, there are also other causes of urban flooding like population growth and settlement pattern and governance failure (Djordjevic *et al.*, 2011; Santato *et al.*, 2013). Four important drivers of urban flooding (land use/land cover change, climate change,

population growth and settlement pattern, and governance failure) are discussed in this section of the literature review chapter.

2.2.3. 1. Land Use/Land Cover Change and Urban Flooding

Land use is attested to be closely related to the urban development process of rapid urbanization that takes place in most developing countries. In other words, the ways in which land has to be allocated to a variety of functions such as roads, utilities, housing industrial estates, shopping centers, offices, schools, hospitals and other elements of the physical organization of a city are affirmed to have far-reaching socio-economic, cultural, political, technical and ecological implications (Claes *et al.*, 2012).

Urban floods are attested to be caused by the effects of deficient or improper land use planning (Innocenti & Albrito, 2011; Claes *et al.*, 2012; Santato *et al.*, 2013). For instance, many urban areas are claimed to face the challenge of increased urbanization with rising populations and high demands for land (Tucci, 2007; Jha *et al.*, 2012). Moreover, uncontrolled urban growth and provisions of development plans which neglect flood hazards are contended to be main causes of life and property losses in cities and towns of developing countries (Tucci, 2007; Balaban, 2009; Mngutyo & Ogwuche, 2013; Santato *et al.*, 2013). In other words, land use change is affirmed to underpin change of flood frequency, base flow, and annual mean discharge (Pottier *et al.*, 2005; Li *et al.*, 2009; Mngutyo & Ogwuche, 2013; Hall *et al.*, 2014).

Poorly planned and managed urbanization is also attested to contribute to the growing flood hazard due to unsuitable land use change (Tucci, 2007; Kamal-Chaoui & Robert, 2009; McGranahan *et al.*, 2009; UN-Habitat, 2014). In other words, as cities and towns swell and grow outwards to accommodate population increase, large-scale urban expansion often occurs in the form of unplanned development in floodplains, in coastal and inland areas alike, as well as in other flood-prone areas (Tucci, 2007; Jha *et al.*, 2012). According to Jha *et al.* (2012), the accelerating urbanization and urban development could also increase significantly the risk of flooding independent of climate change. The impact of future urban growth on flood risk is claimed to be influenced by the policies and choices of urban dwellers as they may or may not occupy areas at risk of flooding, or adopt suitable urban planning and design (Tucci, 2007; McGranahan *et al.*, 2009; Jha *et al.*, 2012). In other words, better planned and

managed urban development is affirmed to mitigate the expected growth in future flood risk (Tucci, 2007; Jha *et al.*, 2012; Mngutyo & Ogwuche, 2013).

Land use is attested to change considerably in many areas of both developed and developing countries, for example due to deforestation, urbanization, and the construction or the abandonment of terraces in hilly landscapes (Li *et al.*, 2009; Hall *et al.*, 2014). In addition, wetland drainage and agricultural practices have dramatically affected water flow paths (Few *et al.*, 2004; Hall *et al.*, 2014). Such land use and management changes have been shown to affect evapotranspiration, water infiltration into the soil and surface and subsurface water storage and therefore flood-generating processes (Li *et al.*, 2009; Hall *et al.*, 2014).

The continued high rate of urbanization in general is affirmed to underpin urban poverty, a lack of urban services, especially to the urban poor, poor provision of urban services, considerable strain on existing urban infrastructural facilities, street children, urban unemployment, urban transportation problems, displaced persons, urban crime, a proliferation of slums and squatter settlements, and urban environmental degradation (Balzerek *et al.*, 2003; Owuor, 2006).

The most obvious direct consequence of urbanization is attributed to the altered hydrology and water balances that control the flows of energy and matter in watershed ecosystems (Wheater & Evans, 2009; Berggren *et al.*, 2013). In relation to this, urbanization is attested to elevate peakflow rates as a result of increased impervious surfaces that promote quick surface runoff (Allan, 2004; Wheater & Evans, 2009; Berggren *et al.*, 2013; Santato *et al.*, 2013; Hao *et al.*, 2015). Urban development is also claimed to create obstructions to runoff, such as sanitary landfills, bridges, inadequate drainage, obstructions of runoff and conduits, and clogging (Andjelkovic, 2001; Parkinson, 2003; Few *et al.*, 2004; Tucci, 2007; Santato *et al.*, 2013).

Flooding in Africa has been attributed to inadequate drainage causing overland flow and poor waste collection which can block drainage and water channels causing overland and river (fluvial) flooding (Few *et al.*, 2004; Tucci, 2007). Africa is identified as the world's fastest urbanizing region exhibiting a large informal sector of jobs but also of poor quality unplanned housing; Informal settlements located on sites at risk from floods and other

hazards; lack of infrastructure and services including drainage; ineffective local governments; and limited wealth in the population to invest in better housing as similar characteristics (Few *et al.*, 2004; Pelling *et al.*, 2004; Tucci, 2007).

2.2.3. 2. Population Growth and Settlement Pattern and Urban Flooding

The growth of populations in cities is underpinned by rural-urban migration and natural growth (births minus deaths). Their relative importance is affirmed to vary greatly between cities and nations. For instance, in many African countries, natural change outweighs migration. The physical and statistical growth of cities is also claimed to occur through the incorporation of peri-urban settlements as the built-up area of the city expands and administrative boundaries are enlarged (UN-Habitat, 2014).

Population growth and settlement pattern related to urbanization is claimed to be an important factor for urban flooding (Few *et al.*, 2004; Owuor, 2006; Lindfield & Steinberg, 2012; Santato *et al.*, 2013). Few *et al.* (2004) contend that human vulnerability to floods is affected by drivers of change like population growth and settlement pattern. In other words, as cities become larger and larger, and as populations become more and more urbanized, urban environmental effects will increase (Botkin, 1997; Andjelkovic, 2001; Few *et al.*, 2004; Santato *et al.*, 2013).

Dewan *et al.* (2007) affirms that increasing population pressure may force many people to enter the vacant land of cities and towns of least developed countries by filling up of natural channels and floodplains which may result in increased flood risk. Moreover, settlement of watersheds and valley bottoms is affirmed to greatly alter drainage patterns and destabilized slopes, increasing the risks of flooding and landslides (Diagne, 2007; Dewan *et al.*, 2007; Few *et al.*, 2004; Santato *et al.*, 2013). Reported global economic losses from natural hazards such as storms, tropical cyclones and floods are claimed to increase underpinned by growth in populations, and the amount of capital at risk. Sadly, patterns of development in areas of flood risk combined with changing demographics (including rapid urbanization in developing countries and ageing populations in developed countries) are confirmed to increase overall vulnerability (Dewan *et al.*, 2007; Wilby & Keenan, 2012; Santato *et al.*, 2013).

2.2.3. 3. Governance Failure and Urban Flooding

Governance failure is identified as one of the causes of urban flooding in developing countries (Andjelkovic, 2001; Pelling *et al.*, 2004; Satterthwaite *et al.*, 2007; Jember, 2014). Urban areas are claimed to always present some risk of flooding when rainfall occurs (Few *et al.*, 2004; Tucci, 2007; Jha *et al.*, 2012; Santato *et al.*, 2013). For example, buildings, roads, infrastructure and other paved areas prevent rainfall from infiltrating into the soil – and so produce more runoff (Allan, 2004; Wheeler & Evans, 2009; Berggren *et al.*, 2013). Heavy and/or prolonged rainfall are attested to produce very large volumes of surface water in any city, which can easily overwhelm drainage systems (Jha *et al.*, 2012; Berggren *et al.*, 2013; Santato *et al.*, 2013; Hao *et al.*, 2015). Scholars affirm that in well-governed cities, good provision for storm and surface drainage is easily built into the urban fabric, with complementary measures to protect against flooding (Andjelkovic, 2001; Satterthwaite *et al.*, 2007; Jha *et al.*, 2012; Porse, 2013).

Under the pressure of rapid urbanization, good urban governance is claimed to be missing (Andjelkovic, 2001; Few *et al.*, 2004). For instance, enforcement of standards and regulations is claimed to be often incomplete or even absent. Regulatory frameworks are affirmed to often demand unrealistic minimum standards while at the same time there is lack of adequate mechanisms for the enforcement of regulations. Funding is confirmed to often be limited too (Andjelkovic, 2001; Few *et al.*, 2004; Kamal-Chaoui & Robert, 2009; Cordaid & IIRR, 2011; Jha *et al.*, 2012). The institutional environment of flood control in developing countries is generally attested to be not conducive to a sustainable solution. In other words, there are only a few isolated measures by a few professionals. In general, flooding receives attention only after it occurs (Tucci, 2007). For Wilkinson & Peters (2015) and Mcgranahan *et al.* (2016), land-use planning and management should help ensure the availability of legal land plots with infrastructure that low-income households can afford. In other words, the failures of policy and practice by city and municipal governments is claimed to produce the large proportions of their populations living in informal settlements (Andjelkovic, 2001; Satterthwaite, 2011; Santato *et al.*, 2013; Wilkinson & Peters, 2015; Mcgranahan *et al.*, 2016).

2.2.3. 4. Climate Change and Urban Flooding

Land use/land cover change and climate change are attested as the two main factors directly influencing catchment hydrology and separation of their effects is of great importance for land use planning and water resources management (Li *et al.*, 2009; Smith, 2009; Claes *et al.*, 2012; Santato *et al.*, 2013). For instance, climate variability is affirmed to change the flow routing time, peak flows and volume (Li *et al.*, 2009). Moreover, the effects of the anthropogenic climate change are claimed to appear at an increasing speed and affect the development of an increasing number of countries and people (Claes *et al.*, 2012). Scholars contend that there is no doubt in the scientific community that human-induced change of land use, such as urbanization or deforestation, increase flooding (Parkinson, 2003; Few *et al.*, 2004; Tucci, 2007; O'Driscoll *et al.*, 2010; Santato *et al.*, 2013). Projections are also affirmed to show that more extreme weather events, such as flash floods, that will become more frequent and intense are expected (Balzerek *et al.*, 2003; Balaban, 2009; Santato *et al.*, 2013; Wilkinson & Peters, 2015).

The primary cause of urban flooding is identified to be a severe thunderstorm or a rainstorm proceeded by a long-lasting moderate rainfall that saturates the soil. Floods in urban conditions are confirmed to be flashy in nature and occur both on urbanized surfaces (streets, parking lots, yards, parks) and in small urban creeks that deliver water to large water bodies (Andjelkovic, 2001; Balzerek *et al.*, 2003; Balaban, 2009; Jember, 2014). Flood regime changes are attested to be brought about by natural climate variability at different timescales as well as by anthropogenic induced climatic change (Few *et al.*, 2004; Hall *et al.*, 2014). Changes in the global climate and individual climatic variables are attested to affect floods in various ways, together with soil moisture and snow storage. Generally, a warmer atmosphere is affirmed to hold more water vapour, which may increase heavy precipitation and therefore floods. Similar to floods, rainfall extremes are affirmed to exhibit temporal clustering at multi-decadal timescales (Hall *et al.*, 2014). According to Few *et al.* (2004) and Anderson & Bausch (2006), more extreme rainfall means more likelihood of floods, particularly flash floods. Moreover, flooding is identified as one of the most widespread of climatic hazards and poses multiple risks to human health (Andjelkovic, 2001; Few *et al.*, 2004; Innocenti & Albrito, 2011).

Climate change is attested as the other large-scale global trend perceived to have a significant impact on flood risk (Few *et al.*, 2004; Anderson & Bausch, 2006; Kobayashi & Porter, 2012; Hall *et al.*, 2014). For instance, the alterations in meteorological patterns which are associated with a warmer climate are potentially drivers of increased flooding, with its associated direct and indirect impacts. In other words, observed and projected patterns of climate change can have an amplifying effect on existing flood risk. Moreover, changing local rainfall patterns may lead to more frequent and higher level of floods from rivers and more intense flash flooding (Anderson & Bausch, 2006; Balaban, 2009; Jha *et al.*, 2012; Berggren *et al.*, 2013; Hall *et al.*, 2014; Linnekamp *et al.*, 2011). The impact of urbanization on flood management is affirmed to be significant for now and the future (Li *et al.*, 2009; Innocenti & Albrito, 2011; Claes *et al.*, 2012; Santato *et al.*, 2013). Flood risk managers need therefore to consider measures that are robust to uncertainty and to different flooding scenarios under conditions of climate change (Andjelkovic, 2001; Anderson & Bausch, 2006; Satterthwaite *et al.*, 2007; Jha *et al.*, 2012; Hall *et al.*, 2014).

Climate change is affirmed likely to have implications for today's urban flood risk management decisions, but is one of many drivers that must be considered (e.g. urbanization, aging infrastructure, and population growth) (Andjelkovic, 2001; Few *et al.*, 2004; Satterthwaite *et al.*, 2007; Keim, 2008; Balaban, 2009). For Berggren *et al.* (2013) and Hall *et al.* (2014), long-term infrastructure is an area where planning decisions are likely to be sensitive to assumptions about future climate conditions. This is claimed to lead to indecision, delay in investment and higher damages from flood events in the short term. It is asserted that it is crucially important to explore the implications of climate change for future flood hazard and to look for ways to build those implications into decision making processes (Andjelkovic, 2001; Few *et al.*, 2004; Anderson & Bausch, 2006; Balaban, 2009; Jha *et al.*, 2012).

2.2.4. Effects of Urban Flooding

A vulnerability assessment is claimed to be a structured process for identifying the vulnerability of human and natural systems to climate change and natural disasters (Surjan & Shaw, 2008). For instance, the more exposed and sensitive an individual or community is to climate change or natural disaster, the higher its vulnerability (Pelling *et al.*, 2004). Vulnerability is also affirmed to be a function of adaptive capacity and the higher a

community's capacity to undertake adaptive actions, the less vulnerable it is (Pelling *et al.*, 2004; Richardson & Otero, 2012). Flooding is contended to have the potential to cause harm in many different ways, and these impacts can be considered as consisting of physical, social, institutional, economic, and environmental dimensions (Few *et al.*, 2004; Government of Ireland, 2009; Smith, 2009; M'uller *et al.*, 2011; Vojinovic *et al.*, 2016).

Urban settlements are affirmed to contain the major economic and social attributes and asset bases of any national population (Few *et al.*, 2004; Smith, 2009; Jha *et al.*, 2012). A very high proportion of urban population growth and spatial expansion are claimed to take place in the dense, lower-quality informal settlements of least developed countries (Few *et al.*, 2004; Smith, 2009). These are attested to be located in both city-center and peripheral, suburban or peri-urban locations and are frequently at highest risk. The concentration of the poor within these areas, which typically lack adequate housing, infrastructure and service provision is claimed to increase the risk of flooding and ensures that flood impacts are worst for the disadvantaged (Few *et al.*, 2004; Smith, 2009; Jha *et al.*, 2012).

The increased impacts of urban flooding are attested to be underpinned by development outside the protection of existing flood defenses; an increase in paving and other impermeable surfaces; overcrowding, increased densities and congestion; limited, ageing or poorly maintained drainage, sanitation and solid waste infrastructures; over-extraction of groundwater leading to subsidence; and a lack of flood risk management activities (Li *et al.*, 2009; Jha *et al.*, 2012; Mngutyo & Ogwuche, 2013; Hall *et al.*, 2014).

The impacts of flooding are affirmed to be widespread in the tropical countries and the poor are asserted to be most susceptible and most vulnerable (Few *et al.*, 2004; Siegrist & Gutscher, 2006; Fadairo, 2013). In other words, the environmental health impacts of flooding are asserted to be compounded in poor communities. In other words, the consequences of flood events are attested to be devastating for these communities. Moreover, the poor are affirmed to have fewer resources available for rebuilding and they are claimed to generally receive little external support to recover from flooding. Furthermore, their livelihoods are contended to be more vulnerable to the risks associated with flooding and are more susceptible to disruption (Few *et al.*, 2004; Sohail *et al.*, 2005). The location of poor neighbourhoods and the inferior construction materials used to build homes for the poor are also claimed to contribute to their greater vulnerability. A lack of transportation is also

asserted to prevent poor households from moving themselves and their possessions out of harm's way. More affluent communities are claimed to often contribute to the flood problem by investing in drainage infrastructure which exacerbates flood problems elsewhere (Parkinson, 2003; Few *et al.*, 2004; Sohail *et al.*, 2005; Innocenti & Albrito, 2011).

Floods are affirmed to continuously impact communities unequally and in different ways, with effects ranging from short to longer term, direct and indirect (Sohail *et al.*, 2005; Merz *et al.*, 2010; Cordaid & IIRR, 2011). For instance, health outcomes are attested to depend on both the characteristics of the flooding event and people's vulnerability. In other words, the risk for disease outbreaks is affirmed to increase with population displacement and poor hygiene (Few *et al.*, 2004; Noji, 2005; Cordaid & IIRR, 2011). Moreover, psychological distress in survivors is conformed to be well documented and accounts for a portion of all physical illness (Government of Ireland, 2009). Furthermore, trends in urbanization, burden of disease, malnutrition and maternal and child health globally are claimed to mean that the urban poor, women and children, the elderly and those with chronic conditions should be better protected with flood preparedness and mitigation programs (Siegrist & Gutscher, 2006; Brouwer *et al.*, 2007; Smith, 2009; Cordaid & IIRR, 2011; Alderman *et al.*, 2012). Moreover, disaster risk reduction activities should attempt to identify those who are most vulnerable, and pay particular attention to them (Government of Ireland, 2009; Smith, 2009; Cordaid & IIRR, 2011). It is vital to present further the effects of urban flooding as direct and indirect effects for better understanding and sustainable action.

2.2.4.1. Direct/Tangible Effects of Urban Flooding

All types of floods are affirmed to cause sustained damage to livelihoods, either through the immediate damage and loss of life or through the damage caused by prolonged inundation (Few *et al.*, 2004; Noji, 2005; Smith, 2009; Cosgrave, 2014). For instance, flooding is asserted to cause widespread disruption to transportation, power and communication systems, as well as structural damage to buildings and infrastructure (Kolsky & Butler, 2002; Parkinson, 2003; Few *et al.*, 2004; Government of Ireland, 2009; Cordaid & IIRR, 2011; Cissé & Sèye, 2015).

Excessive rainfall and flood are affirmed to pose adverse effects on different sectors infrastructure (road, rail, housing); industry (large, medium and small); physical and mechanical functioning; trade and commerce (through a disruption of communications);

utility services (water supply and sanitation); sewage management; and the supply of electricity and gas (Paul, 2006; Barua, 2008; OPW, 2009; Wilby & Keenan, 2012; Cissé & Sèye, 2015).

Water supply and sanitation condition are affirmed to become severely disrupted during flood when it embraces various water borne diseases (Andjelkovic, 2001; Kolsky & Butler, 2002; Noji, 2005; Shimi *et al.*, 2010). During a flood, especially water supply and sanitation system are conformed to be severely affected resulting in the spread of waterborne diseases causing stern health problems (Jayaratne & Sohail, 2005; Noji, 2005; Ness, 2007; Shimi *et al.*, 2010; Sakijege, 2013). Inundation of water sources including tube-wells, ponds and channels by contaminated flood water; disruption of access to safe water sources; and deteriorated quality of water due to pollution and high level of bacteriological contamination are identified as the general impacts of flood on water sources (Shimi *et al.*, 2010). Moreover, lack of proper sanitation facilities coupled with polluted drinking water and lack of awareness about hygiene are affirmed to lead to diarrhoeal diseases and such other water and insects borne diseases (Kolsky & Butler, 2002; Noji, 2005; Shimi *et al.*, 2010; Sakijege, 2013).

2.2.4.2. Indirect Effects of Urban Flooding

Infectious disease is affirmed to be a major flood-related health concern in the South, especially in settings where infectious disease transmission is an endemic public health problem (Parkinson, 2002; Few *et al.*, 2004; Pelling *et al.*, 2004). For instance, infectious disease outbreaks have been reported following major flood events in developing countries, and these outbreaks vary in magnitude and rates of mortality (Parkinson, 2002; Few *et al.*, 2004; Pelling *et al.*, 2004; Smith, 2009; Cordaid & IIRR, 2011).

It is confirmed that there is considerable empirical evidence to indicate that flooding and poor drainage have a significant impact on the prevalence of illness, and that large-scale flooding may disrupt watersupply and sanitation systems and result in disease epidemics. (Kolsky & Butler, 2002; Parkinson, 2002; Godfrey & Julien, 2005; Noji, 2005; Smith, 2009). Open drainage channels are confirmed to be potential sources of infection and disease, especially to children who play in them, and polluted water from drains is often used for agriculture, where water resources are scarce. Flooded septic tanks and leach pits, and blocked drains are attested to provide breeding sites for *Culex* mosquitoes, which transmit filariasis, a condition that can

lead to elephantiasis and its painful swelling of the legs (Kolsky & Butler, 2002; Noji, 2005; Waring & Brown, 2005; Smith, 2009). Also related to drainage conditions are *Aedes* mosquitoes, which transmit yellow fever, dengue and dengue haemorrhagic fever. In other words, these mosquitoes are confirmed to often breed in containers which fill with water during rain, such as domestic water storage containers, discarded cans, tyres, plastic bags and coconut shells. *Anopheles* mosquitoes, which transmit malaria, are also claimed to be a risk in urban areas, and they are asserted to lay their eggs in still, unpolluted water, for instance in wetlands and on pond surface waters, which are commonly found where drainage is poor (Few et al., 2004; Godfrey & Julien, 2005; Waring & Brown, 2005; Smith, 2009).

2.2.5. Responses to Urban Flooding

This section of the literature review chapter presents autonomous and planned responses to urban flooding risk. The researcher strongly believes that urban households and urban communities are not passive recipients of urban flooding risk and they may have good knowledge about urban flooding and experiences with urban flooding risk management strategies.

2.2.5.1. Autonomous Response to Urban Flooding

Urban households and urban communities are identified to adapt to urban flooding autonomously. In other words, they have important knowledge and skills which are relevant to be mainstreamed into planned adaptation to urban flooding risk. For instance, Smith (2009) asserts that demonstrating cultural sensitivity, and providing responses that demonstrate awareness of social and cultural beliefs and practices is vital in flood risk management. Scholars assert that priority should be given to vulnerable groups, in terms of both responses to flooding and Disaster Risk Reduction activities since they are the ones mostly vulnerable and they have better knowledge and experience both about the urban flooding risk and possible adaptation strategies (Smith, 2009; Owuor, 2006; Cordaid & IIRR, 2011).

The urban households are attested to develop a mix of livelihood sources, be it in town and/or from the rural home, plot or rural part of the household. Own food production (farming), diversification and multiple sourcing of cash incomes (non-farming income-generating activities) are asserted as livelihood sources (Owuor, 2006; Smith, 2009). They are also

asserted to have urban-rural reciprocity which is part of their social networks (Smith, 2009; Cordaid & IIRR, 2011). Livelihood sources are claimed to enable households generate a flow of income, food or other benefits (increased well-being, reduced vulnerability) and thereby improve the urban household's food security and income situation (Smith, 2009). A household combining urban and rural livelihood sources is attested to be a household with a multi-spatial livelihood (Owuor, 2006; Smith, 2009; Cordaid & IIRR, 2011). People in areas at risk of flooding are affirmed to use a range of measures to protect themselves. For example, building flood defense embankments in front of their houses or using sandbags, which are easier to move, are used as measures to protect people from flooding risk (Diagne, 2007; Owuor, 2006; Smith, 2009; Cordaid & IIRR, 2011). People are identified not to remain inactive and resigned under the circumstances. In other words, they develop a wide range of strategies before, during and after the rains to safeguard their houses, preserve their families' health and safety and their goods, develop their social capital in their communities and ensure their children's education (Diagne, 2007; Cordaid & IIRR, 2011; Cissé & Sèye, 2015).

2.2.5.2. Spatial Planning and Land Use Management for Urban Flooding Risk

Management

This sub section discusses the role of spatial planning and land use management for urban flooding risk management.

2.2.5.2. 1. Spatial Planning for Urban Flooding Risk Management

Spatial planning is identified as a strategic activity that considers what can and should happen in making decisions relating to the location around the distribution of land use activities (Roy, 2009; Ujoh *et al.*, 2010; Stead, 2014; Asrat, 2015). It is claimed to investigate the interaction of planning policies and practice across regional space strategically, and sets the role of places in a wider context (Marengo, 2008; Ologunorisa, 2009; Khailani & Perera, 2013; ADPC, 2014). It is also claimed to go well beyond traditional land use planning and sets out a strategic framework to guide future development and policy interventions, whether or not these relate to formal land use planning control (Marengo, 2008; Richardson & Otero, 2012). Spatial planning is claimed to be one vital aspect of integrated disaster risk management. In other words, its contribution in the long term disaster mitigation is asserted (Marengo, 2008; Watson, 2009; Adedeji *et al.*, 2012; Khailani & Perera, 2013; Santato *et al.*, 2013). Moreover, the spatial planning measures are preferable and given higher priority over

technical (structural) measures when it comes to long term mitigation and prevention of risks (Muller & Reinstorf, 2011; Wei, 2011; Richardson & Otero, 2012; Santato *et al.*, 2013; Boelens & de Roo, 2016).

Spatial planning is confirmed to play a significant role in integrated disaster risk management, particularly through its potential contribution to long term disaster mitigation (Basawaraja *et al.*, 2011; Watson & Agbola, 2013; UNDP, 2015). For instance, effective risk-based planning aims to minimize damages to people and assets before a disaster strikes, but its performance in disaster mitigation is asserted to require a high level of technical and political cooperation and coordination, and equally a commitment from other societal stakeholders as partners in sustainable development (Sutanta, 2012; Watson & Agbola, 2013; ADPC, 2014; Stead, 2014).

The world's population is confirmed to move to cities as one-half of the global population is already urban. By 2030 at least 61 percent of the world's populations are asserted to be living in cities (Djordjevic *et al.*, 2011; Campbell, 2016). Spatial planning is claimed to be the most effective approach to preventing the increase in flood risk, through active controls on (re)development of land and property in these areas (Elander *et al.*, 2005; Brown, 2011; Herk *et al.*, 2011; Sayers *et al.*, 2013; Bloch, 2015). In other words, spatial planning and the control of development is asserted to be the primary vehicle for managing flood risk in a sustainable manner, and works directly to reduce the increase in the future consequences of flooding (Madanipour, 2006; Government of Ireland, 2009; Tsamalashvili, 2010; Hurlimann & March, 2012; Sayers *et al.*, 2013).

Spatial planning is affirmed to increasingly being considered as an important mechanism in coping with flood risk due to climate change (Schmidt-Thomé, 2006; Mills *et al.*, 2010; Tingsanchali, 2012; Dewan, 2013; Khailani & Perera, 2013). One of the reasons for this is that engineering approaches are conformed to be increasingly expensive and cannot provide complete certainty of protection against climate-related floods. In other words, planning is considered as the regulation of physical implementation as well as the process of policy-making that guides spatial development (Majale, 2002; Ebi & Semenza, 2008; Marengo, 2008; Erkan, 2009). This process is claimed to mainly involve the interaction and collaboration between actors (both public and private) (Kazmierczak & Cavan, 2011; Jabareen, 2013; Sayers *et al.*, 2013; Lu, 2014; Wilkinson & Peters, 2015). However, spatial Planning is asserted to be absent in most developing countries due to the stronghold by the

traditional master planning approach to achieve controlled urban development and its management (Barua, 2008; Ebi & Semenza, 2008; Santato *et al.*, 2013; Wapwera, 2013; Dominic, 2014). Sayers *et al.* (2013) contend that effective spatial planning can result in new development and cities that are much more resilient to flood disasters, and can ensure that important infrastructure is outside the floodplain and will continue to function during times of flood; the risks to residential, commercial and industrial buildings can be limited through appropriate building control and regulation; and space is created to allow the natural process of flooding on the floodplains to take place.

Spatial planning is also asserted to provide the opportunity to introduce development policies that contribute to reducing flood hazard by restricting runoff (Huong & Pathirana, 2013; Wamsler *et al.*, 2013; Rivera, 2016; Rivera *et al.*, 2016). In this context, land use management and land management are often considered separately. Land use management is asserted to focus towards spatial planning which is the creation of preferential flood routes, urban development controls creation of SUDS and so on while land management is affirmed to be associated with soil husbandry, site management and the like. This is a useful distinction because, in general terms, better land use management requires action by policy-makers and planners whereas better land management requires action by farmers and others at a local level (Suriya & Mudgal, 2011; Sayers *et al.*, 2013; Cosgrave, 2014).

Agricultural and rural land management practices are affirmed to help reduce flood runoff, for example by growing buffer zones of dense vegetation along river channels, but the effects of these measures tend to be only felt locally, rather than at a catchment scale (Roy *et al.*, 2008; Wheeler & Evans, 2009; Sayers *et al.*, 2013; Cosgrave, 2014). Influencing rural management through spatial planning is therefore an important part of the flood risk management (FRM) portfolio, and has the potential to have a significant impact on lower return period flood flows (often an important component in the expected annual damages) (Calder & Aylward, 2009; Sayers *et al.*, 2013).

Spatial planning is recommended for wise flood risk management (FRM) with the aim of preventing risk from increasing in the future as a result of decisions to locate vulnerable property and people in areas that are exposed to flood risk (Schmidt-Thomé, 2006; Onyenechere, 2010; Sophronides, 2016). According to ADPC (2011) and Sayers *et al.* (2013), the problem is that such decisions are not generally made by the organizations that are

responsible for FRM, but usually by local organizations such as city councils or regional agencies that have land use responsibilities and generally have aims in favour of promoting development rather than restricting it.

The integrating capabilities of remote sensing (RS) with geographic information system (GIS) are confirmed to have opened up new opportunities for the quantitative analysis of natural hazards at all geographic and spatial scales (Suriya & Mudgal, 2011). In other words, the integrated use of GIS and RS is asserted to lead to a deeper understanding of complex natural hazards in the spatial and temporal context, which is regarded as vital for disaster and/or emergency management, particularly the management of flood risk. Moreover, GIS-based risk and vulnerability analysis is confirmed to assist in the identification of human–hazard interactions (Dewan, 2013). For instance, geospatial techniques are claimed to be applied to any phase of a disaster cycle as well as any natural or man-made hazards, including flood, earthquake, tornado, cyclone, landslide, and fire (Dewan & Yamaguchi, 2009; Dewan, 2013; Albano *et al.*, 2014).

It is also vital to appreciate the role of geographic information (GIS) and remote sensing technologies in mapping urban flooding risks. For instance, geospatial technology is asserted to provide the best potential to analyze and provide results required for prompt and effective decision-making on floods (Dewan, 2013). Moreover, remote sensing is confirmed to be an efficient tool for flood mapping and suitability analysis and can be useful for emergency response and disaster preparedness (Balaban, 2009; Uddin *et al.*, 2013). Scholars also assert that there is scope to utilize remote sensing and geographical information systems (GIS) for planning and design of urban drainage systems though this is often constrained by the expense of the technology and a lack of suitably skilled technicians (Alfasi *et al.*, 2012; Santato *et al.*, 2013; Uddin *et al.*, 2013; Cosgrave, 2014).

The most important outcome of the geospatial approach is attested to be a series of maps encompassing the spatial distribution of hazard, risk, and vulnerability, which is known to provide better representation and visualization of human–environment interaction. As hazards take place over space, the incorporation of spatial components into risk assessments is affirmed to lead to informed disaster risk reduction and hence allow the development of a disaster-resilient community (ADPC, 2011; Dewan, 2013).

Given that flood hazard is spatial phenomenon, the application of GIS and Remote Sensing techniques are asserted to be essential to the flood hazard/risk management process. More importantly, flood hazard and risk maps are identified as effective tools for reducing flood damage (Twigg, 2004; Marchi *et al.*, 2010; Wondim, 2016). For instance, flood risk maps are confirmed to be certainly excellent tools for risk assessment and planning, but they can also be valuable tools for public education and awareness (Balaban, 2009; Adedeji *et al.*, 2012; Uddin *et al.*, 2013; Petiteville *et al.*, 2015). Moreover, properly presented, flood maps are asserted to allow urban residents to see exactly where and how they may be impacted by flood waters. They are also attested to enable planners see who in the community is vulnerable to flooding and who is not (WMO, 2011b).

The flood map is identified as a multi-layered map which provides information on flooding from rivers and the sea and also has information on flood defenses and the areas benefiting from those actions (Abbott, 2003; Kobayashi & Porter, 2012; Santato *et al.*, 2013; Cosgrave, 2014). Moreover, the Flood Map is attested to be designed with the purpose of increasing awareness among the public, local authorities and other organizations of the likelihood of flooding, and encourage people living and working in areas prone to flooding to find out more and take appropriate action (Balaban, 2009; Andjelkovic, 2001; Dewan, 2013; Santato *et al.*, 2013). Moreover, hazard zoning is affirmed to provide a detailed overview of the hazard situation and a basis for communal and cantonal spatial planning processes (Balaban, 2009; Adedeji *et al.*, 2012; Sutanta, 2012; Santato *et al.*, 2013; Jalayer *et al.*, 2014). Hence, it is attested to serve as a basis for identifying hazardous zones and determining conditions for use (e.g. definition of hazard zones in development plans and formulation of building regulations) (Balaban, 2009; Andjelkovic, 2001; Santato *et al.*, 2013; Cosgrave, 2014).

Spatial multi-criteria decision assessment/analysis (MCA) or multi-criteria evaluation (MCE) is attested to receive renewed interest underpinned by the following reasons: (1) it allows improved decision making; (2) it supports developing and evaluating alternative plans; and (3) it is predominantly appropriate for spatial decision making, as the data that the decision makers rely on are mostly related to space (Dewan, 2013). Scholars affirm that without flood risk maps it is not easy to identify the areas at risk, and without a systematic way of making development decisions there will be no consistency in deciding how and where to reduce urban encroachment into at-risk areas (Zhiyu *et al.*, 2013). Moreover, the availability of the

land use plan is affirmed to give readily available guidance to developers, planners and others on which areas may be developed for which uses, and allows the incorporation of flood risk information into their decisions and judgements (Sayers *et al.*, 2013).

Assessment of risks is identified as the fundamental step in planning for flood management (Parkinson, 2002; Balaban, 2009; Prabhakar *et al.*, 2009). It is asserted to involve a cataloguing of potential risks that the community is facing. It is asserted to be site specific. Prioritization is affirmed to involve taking into account risks and vulnerable groups and areas in order to determine which hazards present the greatest threats to people, property and essential services. After giving priorities to hazards, the strengths and weaknesses of plans regulations and policies are encouraged to be reviewed to see if they adequately address all identified hazards. Development of mitigation measures are claimed to involve an identification of actions to address identified weaknesses in policy, plans and regulations (Balaban, 2009; Parkinson, 2002; Mngutyo & Ogwuche, 2013). Effective flood risk management is affirmed to require geo-spatial data representing accurate representations of the flood area, post flood and flood plain reference marks. Sources of this data include geological survey maps, satellite imagery and the local community (Andjelkovic, 2001; Richardson & Otero, 2012; Jabareen, 2013; Mngutyo & Ogwuche, 2013).

Contemporary cities are highly encouraged to develop a greater awareness of the need for policies that might eventually enhance resilience and reduce vulnerability to expected climate change impacts (Jabareen, 2013). However, environmental risks and hazards are asserted not to be always evenly distributed geographically, and some communities may be affected more than others. In other words, mapping the spatial distribution of risks and hazards is attested to be critical for planning and management at the present and for the future (Brown & Damery, 2002). For example, the communities that are most vulnerable to climate change impacts are calimed to be usually those who live within more vulnerable, high-risk locations that may lack skills, adequate infrastructure and services (Prabhakar *et al.*, 2009; Jabareen, 2013).

Uncertainty-oriented planning is encouraged to be uncertainty-oriented rather than adapting the conventional planning approaches (Ziervogel *et al.*, 2010; Jabareen, 2013). In other words, planning is confirmed to have a wider role to play that is closely associated with uncertainties. For example, planning means, essentially, is controlling uncertainty -either by

taking action now to secure the future, or by preparing actions to be taken in case an event occurs (Deng *et al.*, 2013; Friend & Moench, 2013; Jabareen, 2013; León & March, 2016).

2.2.5.2. 2. Land Use Management for Urban Flooding Risk Management

Land use management is affirmed to employ two principal options: zoning control and development/building control. Zoning control is asserted to include designating, by the responsible authority, the type of activity that can be undertaken within the flood-prone area (Cissé & Sèye, 2015; José *et al.*, 2016). Most of the physical, social and economic problems associated with flooding, soil erosion and water pollution stormwater are claimed to be attributable to inappropriate urbanization of the floodplain, unwise land use within the city, insufficient attention to drainage in urban planning, ineffective updating of existing stormwater control facilities and lack of enforcement of zoning ordinances (Andjelkovic, 2001; Richardson & Otero, 2012; Mngutyo & Ogwuche, 2013).

Sound land management is attested to require operational processes to implement land policies in comprehensive and sustainable ways. Land tenure rights and land use opportunities are affirmed not to be separated as this is vital to link planning and land use controls with land values and the operation of the land market (Swan, 2010; Profice, 2010; ADPC, 2011; Balaban, 2012; Enemark, 2012). A Land administration system (LAS) is attested to provide a country with the infrastructure to implement land-related policies and land management strategies. Land-use planning and policies will, of course, determine and regulate future land development (Neuman, 2005; Enemark, 2012; Dewan, 2013; León & March, 2014).

The land management paradigm is affirmed to provide a conceptual framework for understanding and innovation in land administration systems. The paradigm claimed to be the set of principles and practices that define land management as a discipline. The principles and practices are attested to relate to the four functions of LAS, namely land tenure, land value, land use and land development, and their interactions. These four functions are attested to underpin the operation of efficient land markets and effective land use management (Enemark, 2012; Abdulaal, 2012; Qian, 2013).

Efficient and effective land administration systems that support sustainable development are affirmed to require a spatial data infrastructure to operate. For instance, the spatial data

infrastructure (SDI) is the enabling platform that links people to information. It is attested to support the integration of natural (primarily topographic) and built (primarily land parcel or cadastral) environmental data as a pre-requisite for sustainable development (Jabareen, 2013; Santato *et al.*, 2013; Cosgrave, 2014). The SDI is also affirmed to permit the aggregation of land information from local to national levels. Successful LAS are claimed to be measured by their ability to manage and administer land efficiently, effectively and at low cost. The success of LAS is affirmed not to be determined by complexity of legal frameworks or sophisticated technological solutions. Success is attested to lie in adopting appropriate laws, institutions, processes and technologies designed for the specific needs of the country or jurisdiction (Enemark, 2012; Dominic, 2014; Chelleri *et al.*, 2015; Wilkinson & Peters, 2015).

2.2.5.3. Structural Response to Urban Flooding

This section deals with structural response to urban flooding. Flood management measures are claimed to be typically described as either structural or non-structural. Scholars affirm that structural flood management measures are any physical construction to reduce or avoid possible impacts of hazards, or application of engineering techniques to achieve hazard resistance and resilience in structures or systems (Parkinson, 2003; Santato *et al.*, 2013). They are asserted to range from hard-engineered structures such as flood defenses and drainage channels to more natural and sustainable complementary or alternative measures such as wetlands and natural buffers (Jha *et al.*, 2012; Sitas *et al.*, 2013). It is asserted that structural measures aim to reduce flood risk by controlling the flow of water both outside and within urban settlements (Tucci, 2007; Jha *et al.*, 2012). They are affirmed to be complementary to non-structural measures that intend to keep people safe from flooding through better planning and management of urban development (Tucci, 2007; Jha *et al.*, 2012; Santato *et al.*, 2013).

Structural measures are affirmed to be those measures that alter the river system by means of structures in the watershed (extensive measures) or in the river (intensive measures) to prevent flood water overflowing into the flood plain (Andjelkovic, 2001; Parkinson, 2003; Tucci, 2007; Jha *et al.*, 2012). They are asserted to be engineering works implemented to reduce the risk of flooding. These measures are declared to be extensive or intensive. Extensive measures are affirmed to be those that act in the watershed, aiming to change the relationships between precipitation and flow, like changing the vegetation cover of the soil,

which reduces the negative impacts of flood in the watershed. Intensive measures are declared to be those that react in the river and may be of three types: (a) accelerating flow: construction of dykes and polders, increasing discharge capacity and cutting meanders; (b) delaying flow: attenuation reservoirs and basins; c) diverting flow: structures such as diversion canals (Tucci, 2007).

According to Jha *et al.* (2012), well-designed structural measures can be highly effective when used appropriately. However, they are claimed to characteristically reduce flood risk in one location while increasing it in another. Urban flood managers are encouraged to consider whether or not such measures are in the interests of the wider catchment area (Andjelkovic, 2001; Cordaid & IIRR, 2011; Jha *et al.*, 2012). Structural flood management measures often are claimed not to be an adequate answer. The disadvantage of this strategy confirmed to be its finiteness of effectiveness (Parkinson, 2003; Santato *et al.*, 2013).

Schars affirm that the flood management approach that is only based on the structural measures may seem to solve problem in the short term, however it leads to even more severe impacts in the long-run (Andjelkovic, 2001; Barua, 2008; Balaban, 2009; Cordaid & IIRR, 2011). Scholars also attest that there is always unknown but predictable mechanisms that require wider scope than that of the structural measures provide (Parkinson, 2003; Tucci, 2007; Balaban, 2009; Jha *et al.*, 2012).

2.2.5.4. Non-Structural Response to Urban Flooding

This section deals with non-structural response to urban flooding. The structural measures are affirmed to require a complementary part which includes interventions based on mechanisms leading to measures indirectly influence human behavior (Jayaratne & Sohail, 2005; Balaban, 2009; Santato *et al.*, 2013). Non Structural Measures (NSMs) are affirmed to be any measures not involving physical construction that uses knowledge, practice or agreement to reduce and prevent risks and impacts, in particular through policies and laws, public awareness raising, training and education (Balaban, 2009; Santato *et al.*, 2013). Regulations, such as city codes and subsidies, are encouraged to promote implementation of non structural measures such as means for rainwater storage, infiltration and runoff control in an integrated manner at the urban and basin scale (Jayaratne & Sohail, 2005; Balaban, 2009; Santato *et al.*, 2013).

Non-structural measures, such as preparedness, response, legislature, financing, environmental impact assessment, reconstruction and rehabilitation planning, and their component techniques, are affirmed to contribute directly towards reducing losses of life and damage to property (Andjelkovic, 2001; Tucci, 2007; Balaban, 2009; Jha *et al.*, 2012). This policy approach is attested to include regulations (zoning and other land-use regulations like land acquisition, permanent property relocation; elevation and other flood-proofing of buildings), education, a variety of financial incentives (flood insurance), and also technical assistance of capacity building tools (flood warning systems, disaster preparedness, and response planning). In short, this approach is claimed to be an attempt to reduce the flood hazard for people and property, with a commitment to long-term risk management of all factors that affect flood risk (Tucci, 2007; Balaban, 2009; Jha *et al.*, 2012; Santato *et al.*, 2013). Engineered infrastructures are highly encouraged to be well integrated with non-structural approaches to manage flooding and other related environmental and socio-economic problems in sustainable manner. As these rely predominantly on behavioural changes to be effective, a participatory approach is recommended within a strategic framework of urban stormwater planning (Parkinson, 2003; Jayaratne & Sohail, 2005; Paul & Hossain, 2013).

Non-structural stormwater management strategies for mitigation of flood impacts are attested to focus upon preventative action and rely predominantly on behavioral changes in order to be effective (Parkinson, 2003; Satterthwaite, 2011; Paul & Hossain, 2013). They are asserted to work well, provided the municipal authorities are receptive to the involvement of community groups in project implementation. Collaboration between government agencies and non-governmental organizations, in conjunction with communities, is claimed to be essential but often challenging. Many of these constraints are affirmed to be overcome if there is a political and institutional commitment to overcoming problems and, specifically, a consideration of and concern with the needs of the urban poor (Parkinson, 2003; Satterthwaite, 2011; Paul & Hossain, 2013; Santato *et al.*, 2013).

Amongst the non-structural responses, land use planning is attested to be the more crucial components in managing flood risks (Wheater & Evans, 2009), especially as a preventive measure (Santato *et al.*, 2013). Preventive land use is attested to mean stopping building development in flood basins and discourages any construction or works likely to form an obstacle to the natural flow of waterways that cannot be justified by the protection of densely

populated areas (Santato *et al.*, 2013). The challenge with many non-structural measures is affirmed to lie in the need to engage the involvement and agreement of stakeholders and their institutions (Jha *et al.*, 2012; Santato *et al.*, 2013). Flood management is attested to hugely benefit by the involvement of stakeholders (Satterthwaite, 2011; Jha *et al.*, 2012; Paul & Hossain, 2013).

2.2.5.5. Integrated Urban Flooding Risk Management Response

This section deals with integrated urban flooding risk management response. Scholars assert that the management of urban flooding risk has recently been recognized as a complex problem facing Local Governments and Urban areas all over the world. This is asserted to call for a more integrated approach to urban storm water management for urban areas and for all cities (Kobayashi & Porter, 2012; Santato *et al.*, 2013; Migosi, 2014). In other words, an improved approach to watershed and flood management is encouraged that integrates watershed and land-use management in the highlands with land-use planning, engineering measures, flood preparedness, and emergency management in the affected lowlands while taking into account the social and economic needs of communities in both the highland, often source areas, and also the lowland flood-prone affected communities (Calder & Aylward, 2009).

Flood disaster management in developing countries is identified to be mostly reactive responding to prevailing disaster situations (emergency response and recovery). However, reactive responses are encouraged to be changed to proactive responses to increase effectiveness of management and reduce losses of life and properties. Proactive disaster management is attested to require more participation from various governments, non-governmental and private agencies and public participation (Plate, 2002; Tingsanchali, 2011; Sutanta, 2012). A primary goal of the urban flood management is affirmed to be having a unified conceptual program for stormwater drainage and flood control, in order to mitigate future flood damages while systematically reducing annual flood damages (Schmitt *et al.*, 2004; Balaban, 2009; Zhiyu *et al.*, 2013; UNISDR, 2015). Integrated urban flood risk management is asserted as a multi-disciplinary and multi-sectoral intervention that falls under the responsibility of diverse government and non-government bodies (Jha *et al.*, 2012; Berkes & Ross, 2013; Sakijege, 2013; Bahadur & Tanner, 2014; Islam *et al.*, 2016). In other words, flood risk management measures are encouraged to be comprehensive, locally specific,

integrated, and balanced across all involved sectors (Jha *et al.*, 2012; Berkes & Ross, 2013; Sakijege, 2013; Kim & Kakimoto, 2014).

Integrated urban flooding risk management is identified as an important process that promotes a holistic approach to risk management (Mpofu, 2011; Jha *et al.*, 2012; Berkes & Ross, 2013; Sayers *et al.*, 2013). Integrated Urban Flooding Risk Management (IUFMR) is attested to explicitly recognize the interrelationships between all sources of flooding and the effectiveness and cost of flood risk management measures, within changing social, economic and environmental contexts (Balaban, 2009; Berkes & Ross, 2013). In other words, an integrated flood risk management approach is attested to be a combination of flood risk management measures which, taken as a whole, can successfully reduce urban flood risk. Moreover, a comprehensive integrated strategy is encouraged to be linked to existing urban planning and management policy and practices (Mpofu, 2011; Satterthwaite, 2011; Jha *et al.*, 2012; Batica & Gourbesville, 2014). Furthermore, a well-coordinated and balanced combination of both structural and nonstructural measures is recommended as part of the long-term flood mitigation strategies (Parkinson, 2003; Sayers *et al.*, 2013; Chelleri *et al.*, 2015; Rimal *et al.*, 2015; Wilkinson & Peters, 2015).

Flooding is attested to be controlled by a combination of structural and non-structural measures enabling the riverside population to minimize its losses and continue to live in harmony with the river (Ward *et al.*, 2013). These are asserted to include engineering and social, economic and administrative measures (Hallegatte *et al.*, 2010). Planning of protection against flooding and its effects is affirmed to involve research into the ideal combination of these measures (Parkinson, 2002; Few *et al.*, 2004; Tucci, 2007; Berkes & Ross, 2013; Rimal *et al.*, 2015). Moreover, integrated urban flooding risk management strategies are attested to be naturally designed to fit in with water-related planning issues and can be part of a wider agenda such as urban regeneration or climate change adaptation (Hallegatte *et al.*, 2010; Prior & Roth, 2013). In other words, action to reduce flood risk are encouraged to be carried out through a participatory process involving all those stakeholders that have an interest in flood management, including those people at risk or directly impacted by flooding (Ologunorisa, 2009; Mpofu, 2011; Solecki *et al.*, 2011; Jha *et al.*, 2012).

Structural and non-structural measures are affirmed not to preclude each other, and most successful strategies will combine both types. Recognizing the level and characteristics of existing risk and likely future changes in risk to achieve the balance between the required long and short term investments in flood risk management is also claimed to be important (Jha *et al.*, 2012; Satterthwaite, 2011; Berkes & Ross, 2013; Santato *et al.*, 2013; Migosi, 2014).

Incorporation of non-structural measures into any urban flood management strategy is highly encouraged. For example, there is always a role for non-structural measures which manage risk by building the capacity of people to cope with flooding in their environments. Moreover, non-structural measures such as early warning systems are encouraged as a first step in protecting people in the absence of more expensive structural measures. Furthermore, non-structural measures are affirmed usually not to require huge investments upfront, but they are often claimed to rely on a good understanding of flood hazard and on adequate forecasting systems (WMO, 2009; Jha *et al.*, 2012; Santato *et al.*, 2013; Migosi, 2014).

Management or control of floods is attested to be achieved through hard engineering, soft engineering, and behavioral response options (Tucci, 2007; Balaban, 2009; Jha *et al.*, 2012; Berkes & Ross, 2013; Santato *et al.*, 2013; Migosi, 2014). The hard engineering option is attested to include dam constructions and river engineering, while the soft engineering option is asserted to include afforestation and managed flooding such as channeling the river flow away from settlements to flood non-settled areas and urban planning (Tucci, 2007; Balaban, 2009; Jha *et al.*, 2012). Planning is affirmed to involve the conversion of vulnerable areas into agricultural and other purposes instead of development purposes, the use of development control to enforce strict compliance to zoning, and provision of drainage in line with the natural topography of the place (Satterthwaite, 2011; Santato *et al.*, 2013; Cosgrave, 2014). The behavioral responses are attested to involve residents adopting different coping strategies to flood management, and these include accepting the loss, public relief funds in terms of emergency response, flood insurance, monitoring and prediction, flood plain zoning and flood proofing (Mngutyo & Ogwuche, 2013; Santato *et al.*, 2013; Koks *et al.*, 2015).

Urban planning and management which integrates flood risk management is affirmed as a key requirement, incorporating land use, shelter, infrastructure and services (Roy *et al.*, 2008; Roy, 2009; Collier *et al.*, 2013; Sitas *et al.*, 2013). The rapid expansion of urban built up

areas is also affirmed to provide an opportunity to develop new settlements that incorporate integrated flood management at the outset. Adequate operation and maintenance of flood management assets is also claimed to be an urban management issue (Jha *et al.*, 2012; Mngutyo & Ogwuche, 2013; Santato *et al.*, 2013). The changing paradigms in urban planning are asserted to represent pro-active management of floods in urban areas through disaster risk reduction (DRR) that requires geospatial information (Waring & Brown, 2005; Mngutyo & Ogwuche, 2013). For instance, changing paradigms in flood control and management are confirmed to be skewed in the direction of behavioral responses because they tend to conserve crucial natural ecosystems and hence are sustainable. Furthermore, options for management of flood disasters are claimed to be limited for countries in developing countries because of poor economy and low technological development. However, effective flood management strategies are encouraged to be economically, environmentally and socially sustainable (Waring & Brown, 2005; Mngutyo & Ogwuche, 2013).

Achieving effective flood management and disaster risk response is affirmed to require improving technology in early warning systems, using geo-spatial information from satellites to create Data bases at the national level for disaster management information systems (Satterthwaite, 2011; Mngutyo & Ogwuche, 2013; Santato *et al.*, 2013). Moreover, the need to improve communication network and infrastructure is encouraged. Furthermore, a need for education and public enlightenment of the public at fora such as conferences, seminars, workshops and focus group discussions are recommended. Improved community action is also relevant for communities to know that they have to initiate action for disaster risk reduction (DRR) because natural disasters are site specific and impacts are felt by them and so can be best mitigated by them (Mngutyo & Ogwuche, 2013; Satterthwaite, 2011; Santato *et al.*, 2013; Cosgrave, 2014).

In managing flood risk today, and in planning for the future, a balance between common sense approaches that minimize impacts through better urban management and the maintenance of existing flood mitigation infrastructure, and far-sighted approaches which anticipate and defend against future flood hazard by building new flood mitigation infrastructure or by radically reshaping the urban environment is of paramount importance (Waring & Brown, 2005; Posthumus *et al.*, 2008; Fadairo, 2013; Kim & Kakimoto, 2014; Klijn *et al.*, 2015; Su, 2016).

An integrated approach is affirmed to be difficult to achieve where municipal managements suffer from a lack of technical capacity, funding or resources (Waring & Brown, 2005; Mpofu, 2011; Fadairo, 2013; Rimal *et al.*, 2015). Its implementation is claimed to require wider participation and a change in traditional management methods to be successful. For instance, at political and institutional levels, actions to reduce flood risk are encouraged to employ tools and techniques to extrapolate current trends and drivers into the future, to assess alternative scenarios, and to build strategic, integrated approaches (Jha *et al.*, 2012; Fadairo, 2013).

Integrated flood risk management is affirmed to require greater coordination between city governments, national governments, ministries, public sector companies, including utilities, along with meteorological and planning institutions, civil society, non-government organizations, educational institutions and research centers, and the private sector (Barua, 2008; Chatterjee, 2010; Asrat, 2015; Tompkins & Cogswell, 2016). Government decisions about the management of risk are asserted to be balanced against competing, often more pressing, claims on scarce resources as well as other priorities in terms of land use and economic development (Mpofu, 2011; Jha *et al.*, 2012; Fadairo, 2013). For effective integrated urban flood risk management, especially in low-cost settlements, understanding the hazardscape and human vulnerability is encouraged (Benjamin, 2008; Merz *et al.*, 2010).

The linkages between flood management, urban design, planning and management, and climate change initiatives are affirmed to be beneficial (Brown, 2011; Sayers *et al.*, 2013). For example, the greening of urban spaces has amenity value, enhances biodiversity, protects against urban heat island and can provide fire breaks, urban food production and evacuation space (Jim & Chen, 2006; Colding & Barthel, 2013; Wamsler, 2015). Moreover, improved waste management is asserted to have health benefits as well as maintaining drainage system capacity and reducing flood risk (Parkinson, 2002; Few *et al.*, 2004; Genovese, 2006; Tucci, 2007; Convery & Bailey, 2008; Jha *et al.*, 2012; Fadairo, 2013).

There is no single best response that reduces flood risk substantially and that is completely sustainable (Genovese, 2006; Convery & Bailey, 2008; Tucci, 2007; Jha *et al.*, 2012). Measures which can be implemented more quickly (such as operations and maintenance, greening of urban areas, improved drainage, building design and retrofitted protection measures) are also asserted to enable occupation of flood risk areas while minimizing the

expected damage from flooding (Parkinson, 2002; Merz *et al.*, 2010; Jha *et al.*, 2012). Scholars affirm that policies are expected to address factors contributing to vulnerability, such as urbanisation, poverty, poor environmental management and uncontrolled development. These factors can also contribute to flood risk. Therefore, flood risk reduction policies must be integrated into development planning to ensure flood risk is considered in the development process (Parkinson, 2002; Merz *et al.*, 2010).

2.2.6. Governance of Urban Flooding Risk

This section deals with governance of urban flooding. The word ‘governance’ is affirmed to mean to steer and to pilot or to be at the helm of things. Governance for sustainable development is claimed to involve participation; rule of law; transparency; responsiveness; consensus orientation; equity; effectiveness and efficiency; accountability; and, strategic vision as the criteria (Merz *et al.*, 2010; Sayers *et al.*, 2013; Sandhu *et al.*, 2016). Governance is defined as the different ways in which governments, the private sector and in general all individuals and institutions in a society organize themselves to manage their common affairs. Within this broader governance concept, disaster risk governance is defined as the specific arrangements that societies put in place to manage their disaster risk (UNISDR, 2015).

Scholars attest that governance can be analyzed on a global, regional, national as well as on a local level (Vasquez, 2004; Barua, 2008; Enemark, 2012). Urban governance is affirmed largely to be unprepared for the scale of change to come and the need to adopt more sustainable practices. However, sustainable urban development is claimed to require major changes, starting with the way cities are governed and managed (Knox & Pinch, 2010; Enemark, 2012; Wapwera & Egbu, 2013; Ward *et al.*, 2013). Strengthening urban governance, recognizing the importance of local leadership, utilizing local networks, involving local communities and leveraging local resources are encouraged to promote sustainable urban development and manage urban disasters like urban flooding in developing countries (Pelling & Holloway, 2006; Ness, 2007; Wei, 2011; Jabareen, 2013).

Good governance is claimed to do with the efforts of all stakeholders to balance the interests of governments (municipality councils) to initiate policies; the implementation of these decisions by civil servants (or the management of public utilities) and the impact of these decisions on the society (or on the customers of the public utilities) (Vasquez, 2004; Enemark, 2012; Wapwera & Egbu, 2013). For instance, effective water governance is

attested to require changes in attitudes and behavior amongst individuals, institutions, professionals, and decision-makers (Pelling *et al.*, 2004; Vasquez, 2004; Bulkeley, 2010; Porse, 2013).

Good governance in the form of a capable, accountable and responsive government working together with civil society and at-risk communities is claimed to be one of the single most important factors determining progress in reducing disaster risk (Pelling *et al.*, 2004; Enemark, 2012; Jabareen, 2013; Pasquini *et al.*, 2014). In other words, governance is claimed to be the way states and people manage their affairs and are central to the solution to natural hazard risks. For example, the relationship between people, the natural and built environment is attested to be influenced by social, political and economic systems, and these in turn are affirmed to be mediated and regulated through the “governance” process (Oxley, 2011).

Disaster risk management is affirmed to require the ability of government officials to interact effectively with each other and the broader community (Lassa, 2010; Wilkinson, 2013; Rivera & Wamsler, 2014). For instance, improved networking, cooperation, collaboration and cooperation has the potential to deliver a range of benefits in both disaster management and climate change contexts relating to the building of interagency trust, improved information exchange, collaborative decision-making, risk sharing and pooling limited resources to achieve common goals (Pelling *et al.*, 2004; Howes *et al.*, 2013; Lu, 2014; Rivera, 2016; WEF, 2016). Governance for disaster risk reduction has economic, political and administrative elements (Pelling *et al.*, 2004).

Appropriate governance for disaster risk management is affirmed to be a fundamental requirement if risk considerations are to be factored into development planning and if existing risks are to be successfully mitigated (Rivera, 2016; WEF, 2016). For instance, good governance is attested to be a prerequisite for flood risk management. In other words, without good governance and strong leadership, the government or other leading organizations are claimed not to have the legitimacy or support to carry out flood risk reduction measures (Bulkeley, 2010; Porse, 2013). Moreover, many aspects of flood risk reduction, such as early warning systems or relocation programmes are attested to require participation and trust between a decision-making body and its citizens (Jha *et al.*, 2012). Community participation in decision-making for flood risk reduction measures is attested to be essential for project planners to understand the dynamic interactions between people and their natural and built

environment. Moreover, multi-stakeholder participation in programming is attested to enable a host of people with vested interests to discuss and review strategies, and explore new methods for reducing flood risk (Chatterjee, 2010; UNDP, 2015).

Empowerment and mutual ownership of the flood problem by relevant bodies and individuals are asserted to lead to positive actions to reduce risk (Parkinson, 2002; Chatterjee, 2010; Jha *et al.*, 2012; Asrat, 2015; UNDP, 2015). For instance, effective engagement with the people at risk at all stages is affirmed as a key success factor. Moreover, engagement is claimed to increase compliance, generate increased capacity and reduce conflict. This is encouraged to be combined with strong, decisive leadership and commitment from national and local governments (Kamal-Chaoui & Robert, 2009; Bulkeley, 2010; Mpofu, 2011; Jha *et al.*, 2012). Many of the measures that mitigate urban floods and that help adapt to its effects are asserted to make also cities more livable and therefore potentially more competitive (Parkinson, 2002; Sohail *et al.*, 2005; Thomalla *et al.*, 2006; Kamal-Chaoui & Robert, 2009).

2.2.6. 1. Challenges of Governance of urban flooding risk management

An integrated approach to flood risk management set within urban planning processes is now seen as an effective way of minimizing risk, although this has not always been recognized in practice and empirical guidance on its implementation is still lacking (Mills *et al.*, 2010; Corfee-Morlot *et al.*, 2011; Herk *et al.*, 2011). Managing the risk of flooding is identified as a significant challenge for many cities, and the magnitude of such challenge is expected to grow even further with an ever-continuing urbanization, population growth, climate change, and economic growth (Lindley *et al.*, 2007; Khailani & Perera, 2013; Vojinovic *et al.*, 2016). A critical governance issue is that most urban growth in low- and middle-income nations is claimed to happen without “good local governance” and so without the provisions needed to reduce risks (Satterthwaite *et al.*, 2007; Bulkeley, 2010; Archer *et al.*, 2014).

Local level organization and the establishment of systems of governance that allow voice and influence to the poorer groups are of paramount importance for adaptation policies (Collier *et al.*, 2013; Jabareen, 2013; UN-Habitat, 2014). Scholars also attest that sustainability can not be left to spontaneous mechanisms or to market forces. Urban planning practices are also encouraged to be changed to reflect a new awareness and to integrate environmental, health, economic and social concerns in the 21st century. For example, new city master plans and

new neighborhood plans are encouraged to be guided by a set of community values and a new community vision involving the citizens (Pelling & Holloway, 2006; Bajec, 2011; Olorunfemi, 2011).

Poor adaptive capacity of a city and its dwellers is asserted to be one of the governance issues of urban flooding risk management. In other words, there is lack of adaptive capacity and the very large backlogs in provision for infrastructure and services in most urban centres in low- and middle-income nations (Pelling *et al.*, 2004; Sohail *et al.*, 2005; Ness, 2007; UN-Habitat, 2014). For instance, most city and municipal governments in least developed countries are asserted to have almost no investment capacity at all. However, improved competence, capacity and accountability within city and municipal governments almost by definition are attested to increase adaptation capacity and increase the possibilities of it being “pro-poor” (Parkinson, 2002; Satterthwaite *et al.*, 2007; Kamal-Chaoui & Robert, 2009; Cordaid & IIRR, 2011; Godden & Kung, 2011).

For any well governed city, land-use management (and management of changes in land use) is affirmed to be an important part of risk reduction as it should serve to guide urban expansion and development away from areas or sites at risk and ensures new land is available for housing and urban development with needed infrastructure (Twigg, 2004; Satterthwaite, 2011). In other words, ineffective urban planning is claimed to be one of the governance issues of urban flooding risk management (Parkinson, 2002; Sohail *et al.*, 2005; Ness, 2007; Satterthwaite *et al.*, 2007; Erkan, 2009; ADPC, 2011; Satterthwaite, 2011; Alfasi *et al.*, 2012). Erkan (2009) asserts that the new approach to make urban planning more effective should have components like community participation, involvement of all stakeholders in the city, coordination, interaction of urban and economic planning, sustainability, financial feasibility, and Subsidiarity. The political and institutional constraints on national and local governments being able to develop appropriate policies and measures for urban flooding risk management are claimed not to be recognized in much of the literature on urban flooding risk management (Satterthwaite *et al.*, 2007; Jabareen, 2013; Buyana *et al.*, 2014).

One of the critical problems of urban drainage is urbanization and new housing and commercial developments. This problem is claimed to exacerbate urban drainage problems by increasing urban runoff from impermeable areas. For instance, in many cities in the

developing world, there is often no real control over new developments due to deficiencies in the administrative systems for urban planning and control. Moreover, buildings are constructed with no consideration for drainage of stormwater and the situation is claimed to be exacerbated for buildings in floodplains or natural drainage pathways underpinned by downstream flow constrictions (Sohail *et al.*, 2005; Erkan, 2009; Satterthwaite, 2011; Alfasi *et al.*, 2012).

Another critical problem of urban drainage is that urban drainage systems cannot be designed in isolation from the communities that they serve (Pelling *et al.*, 2004; Sohail *et al.*, 2005; Erkan, 2009; Satterthwaite, 2011; Buyana *et al.*, 2014). Effective drainage area and catchment planning is asserted to require careful coordination between the relevant institutions responsible for water supply, sewerage, drainage and solid waste management (Parkinson, 2002; Erkan, 2009; Alfasi *et al.*, 2012). The financing and cost-recovery of urban drainage systems is claimed as one of the challenges and developing an appropriate system to pay for these services is encouraged (Parkinson, 2002; Fünfgeld, 2010; Jabareen, 2013; Buyana *et al.*, 2014; UN-Habitat, 2014).

2.2.6. 2. Governance Challenges for Integrated Urban Flooding Risk Management in Ethiopia

The current level of urbanization in Ethiopia is claimed to be only 17 per cent, although 55 per cent of GDP is generated in urban areas and the urban economy is growing very strongly. Consequently, the urban population is claimed to grow at approximately 3.6 per cent per annum and another 42 million people are expected to reside in urban areas by 2050 (UN-Habitat, 2014). This is asserted to be one of the largest absolute increases in Africa and makes it vital to prepare for large-scale urban population growth. In addition, 79 per cent of the population is affirmed to live in “slums” and there is a pressing need to upgrade urban conditions (UN-Habitat, 2014).

Ethiopia is confirmed to be located in north east Africa between 3⁰ and 18⁰ North latitude and 33⁰ and 48⁰ Eastlongitude. Elevations are asserted to range between 100 meters below and 4600 m. above sea level. It has a land area of about 1,100,000 sq. km (Achamyeleh, 2003). The rainy season in Ethiopia is affirmed to be concentrated in the three months between June and September when about 80% of the rains are received. Torrential down

pours are claimed to be common in most parts of the country. As the topography of the country is rather rugged with distinctly defined watercourses, large scale flooding is attested to be rare and limited to the lowland areas where major rivers cross to neighboring countries. However, intense rainfall in the highlands are claimed to cause flooding of settlements close to any stretch of river course (Achamyeleh, 2003; Chibssa, 2007; Dessie & Tadesse, 2013; Alemu, 2015; Getahun & Gebre, 2015). The worst floods were reported to be experienced in 2005 and 2006. For instance, in August 2006, the rivers in the east, north and south of the country burst their banks after 12 days of heavy rains causing loss of 364 lives in south Omo, 256 in the east and 6 in northern part of the country. Floods are also confirmed to destroy productive assets and infrastructure including sanitation facilities thereby compromising health of affected population (Cordaid & IIRR, 2011).

The low-level per capita for an urban local government is affirmed to be a serious constraint to funding investment in infrastructure and service provision. In other words, many urban local governments are asserted to depend on special grants or transfers to finance certain capital investments (FDRE-MUDHC, 2014). Increased solid waste generation; prevalence of wasteful practices and waste generating habits; lack of recycling habit and technology, lack of waste segregation by type, lack of awareness of environmental hazards, etc., lack of minimum standard for sanitary provisions and inappropriateness of onsite sanitation facilities for dense settlements; inadequate sanitation facilities for residents; lack of public bathing facilities; lack of public toilets in central areas; lack of awareness about environmental hygiene; and limited capacity of municipalities and minimal participation of private sector operators in sludge collection are identified as some of the critical issues that are encouraged to be addressed in the future urban agenda of Ethiopia (Achamyeleh, 2003; FDRE-MUDHC, 2014; Getahun & Gebre, 2015).

Many parts of Ethiopia, and much of the more densely populated regions, are confirmed to be blessed with breath-taking landscapes, vistas and other natural endowments (Chibssa, 2007; Dessie & Tadesse, 2013; Alemu, 2015). Many other towns are asserted to be surrounded by rich agricultural lands (Ogato *et al.*, 2017). These natural resources can provide significant amenity to the urban population, again compensating for other deficiencies and the hardship of daily life. However, the planned urban structures generally appear to be imposed on their natural environment, failing to respond to them, let alone to utilize and incorporate their riches in the urban structure and fabric. Sadly, urban planning and development in Ethiopia

often appears to ignore these elements. Moreover, the preservation of many of these assets (woodlands, water-courses, etc.) is claimed to be ignored particularly in the urbanized districts (Gebremichael *et al.*, 2014; FDRE-MUDHC, 2014; Ogato *et al.*, 2017; Ogato *et al.*, 2021).

Environmental degradation and climate change are claimed to hamper Ethiopia's economic growth. Weak capacity in environmental management and enforcement are attested to be key challenges. There is a lack of skilled human resources in key sectors and prioritized initiatives. Pollution control is attested to be lacking and monitoring, reporting and verification of abatement measures is identified to be weak (FDRE-MUDHC, 2014; Ogato *et al.*, 2017; Ogato *et al.*, 2021).

Consideration needs to be given to the relative priority of providing drainage to those existing neighborhoods most subject to seasonal flooding and problems with standing water, to do away with its attendant health hazards (Gebremichael *et al.*, 2014; Ogato *et al.*, 2017). Urban centers with their overall capital spending constraints are encouraged to consider whether to give more priority to covering open channels and, as a policy, avoid constructing them in the future. Site planning standards to minimize and better channel storm water runoff are encouraged to be incorporated into urban land use planning and regulation of new development—with an eye to reducing the volume of storm water that needs to be accommodated by expensive, built drainage structures (FDRE-MUDHC, 2014).

Urban areas in Ethiopia are asserted to always present some risk of flooding when rainfall occurs. Moreover, buildings, roads, infrastructure and other paved areas are asserted to prevent rainfall from infiltrating into the soil and so produce more runoff. Heavy and/or prolonged rainfall produces very large volumes of surface water in any city, which can easily overflow drainage systems (Alemu, 2011; Alemu, 2015; Ogato *et al.*, 2017). For instance, flooding in urban settlements in Ethiopia, especially in Addis Ababa, annually causes damages to property along streams coming down from the nearby hills (Achamyelch, 2003; Alemu, 2011; Collier *et al.*, 2013; Gebremichael *et al.*, 2014).

Integrated Water Resources Management in Ethiopia is affirmed not to be at an advanced stage. While the country's water and land resources endowments are abundant, very little has been accomplished in the way of proper exploitation for the economic benefit of the people

(Achamyeleh, 2003; Gebremichael *et al.*, 2014; Ogato *et al.*, 2017). A previous study conducted in Adigrat town, Ethiopia demonstrates that the current flood disaster coping strategies in Ethiopian cities and towns are not effective (Achamyeleh, 2003; FDRE-MUDHC, 2014; Ogato *et al.*, 2017). The study further identified challenges for integrated urban flooding risk management in Ethiopia. Poor drainage infrastructure; inadequate enforcement of land use and zoning plans and other rules and regulations; poor early warning systems and flood risk preparedness; inadequate financial and skilled human resources; and poor coordination among different stakeholders were identified as the major challenges for integrated urban flooding risk management in Ethiopian cities and towns. The study also attests that lack of a national policy on flood risk management in Ethiopia underpins the presence of the aforementioned critical problems. Therefore, Ethiopia is encouraged to formulate a comprehensive and integrated approach that includes developing a policy as well as streamlining coordination and awareness-raising measures (Achamyeleh, 2003; FDRE-MUDHC, 2014; Alemu, 2015; Getahun & Gebre, 2015; Ogato *et al.*, 2017).

2.2.6. 3. The Role of Good Urban Governance in Mainstreaming Integrated Urban Flood Risk Management into Urban Spatial Planning and Land Use Management

Recent paradigms of urban flooding risk management are affirmed to call for a participatory process in which the different stakeholders are involved early in the urban flooding risk assessment procedure and urban good governance has vital role in the process (Merz *et al.*, 2010; Mpofu, 2011; Jha *et al.*, 2012; Santato *et al.*, 2013). On the one hand, the knowledge of the research community is encouraged to be communicated to users and the uptake by end-users has to be facilitated. Moreover, the expertise, the perspectives and values of the stakeholders are encouraged to be taken into account (Parkinson, 2002; Bulkeley, 2010; Mpofu, 2011; Jha *et al.*, 2012; Santato *et al.*, 2013).

The implementation of flood map and flood risk management plans is attested to require multi-stakeholder cooperation and communication is necessary to raise awareness and reinforce preparedness (Corfee-Morlot *et al.*, 2009; Mpofu, 2011; Jha *et al.*, 2012; Santato *et al.*, 2013). For instance, the flood map is designed to increase awareness among the public, local authorities and other organizations of the likelihood of flooding, and to encourage people living and working in areas prone to flooding to take appropriate action (Parkinson, 2002; Santato *et al.*, 2013). It is attested that good urban governance has vibrant role in the multi-stakeholder coordination and communication process for mainstreaming integrated

urban flooding risk management into urban land use planning and management of cities and towns of least developed countries (Satterthwaite *et al.*, 2007; Steinberg & Lindfield, 2012; Buyana *et al.*, 2014). For instance, applying climate science and ecosystem management and restoration in disaster risk reduction activities to an urban area is confirmed to be possible with a proper mindset; inclusive and transformative partnerships with key stakeholders from different tiers of governance; political leadership; and the effective use of science (Hurst *et al.*, 2012; Lehmann, 2012; Wright, 2012; Arcilla & Lagdameo, 2015).

Good communication and co-operation between different agencies (national and international) when responding to floods are attested to be important so that responses are well co-ordinated, and information and resources can be shared during and after the emergency (Cordaid & IIRR, 2011). Furthermore, effective integration of emergency preparedness planning and implementation of the plan when responding to an emergency is asserted to be crucial for sustainable urban flooding risk management (Parkinson, 2002; Smith, 2009; Sayers *et al.*, 2013; Jember, 2014; UN-Habitat, 2014; Arcilla & Lagdameo, 2015).

At the national level, mainstreaming disaster risk reduction with development policy is attested to be a key challenge. A more integrated approach is claimed to call for collaboration between government agencies responsible for land-use planning, development planning, agricultural and environmental planning and education as well as those organizations responsible for disaster management (Sayers *et al.*, 2013; Wamsler *et al.*, 2014; UN-Habitat, 2014). This approach is affirmed to require decentralized disaster risk planning strategies that can empower communities and open the window for local participation. Enabling participation in these circumstances is asserted to require a long-term commitment to social development as part of vulnerability reduction programmes (Cordaid & IIRR, 2011). The importance of a gendered perspective on risk and the opportunities raised by risk reduction for a gender-sensitive approach to development is encouraged from encouraging experiences of civil society groups active in risk reduction and disaster recovery (Pelling *et al.*, 2004; Cordaid & IIRR, 2011).

Legislation is often affirmed to be vital to ensure a solid ground for other focal areas like institutional systems, sound planning and coordination, local participation and effective policy implementation. However, the road of legal reform is attested to have many challenges. Monitoring and enforcement are affirmed to be relevant and good urban

governance is vital to realize effective monitoring and enforcement of urban planning legislations (Pelling *et al.*, 2004).

The concept of social capital is affirmed to provide additional insights into the ways in which individuals, communities and groups mobilize to deal with disasters (Pelling *et al.*, 2004; Cavill & Sohail, 2005; Nyakundi *et al.*, 2010; van Buuren *et al.*, 2014). Social capital is attested to be those stocks of social trust, norms and networks that people derive from membership in different types of social collectives. Local level community response is attested to be the most important factor enabling people to reduce and cope with the risks associated with disaster (Pelling *et al.*, 2004). Cavill & Sohail (2005) attest that the role of face-to-face communication promotes the establishment of trust and cooperation and service providers are encouraged to establish credibility in communities in order to build trust. Hence, one of the mechanism through which good governance assist the mainstreaming process is building trust in communities (Pelling *et al.*, 2004; Cavill & Sohail, 2005; Asrat, 2015).

The successful integration of adaptation to climate change and natural disasters like flood into local development processes is attested to depend on a number of enabling conditions. For instance, there is a need for broad and sustained engagement with and participation of local stakeholders, including local governments, communities, civil society and businesses. Moreover, greater awareness raising and targeted messaging on climate change are required as local actors need to know why they might have to take different decisions or call on different or additional resources in shaping their livelihoods (Corfee-Morlot *et al.*, 2009; Faling *et al.*, 2012; Christine *et al.*, 2013; Uittenbroek *et al.*, 2013).

Improved science-policy integration and decision support systems for organizational learning are asserted as first steps forward in assisting city authorities to (further) incorporate mainstream adaptation into urban planning practice (Christine *et al.*, 2013; Ogato *et al.*, 2017).

In summary, appropriate governance is asserted to be fundamental if risk considerations are to be factored into development planning and if existing risks are to be successfully mitigated. Moreover, development is attested to be regulated in terms of its impact on disaster risk (Tajima *et al.*, 2014). According to UN-Habitat (2014) and Arcilla & Lagdameo (2015), the greatest challenges for mainstreaming disaster risk into development planning are political will and geographical equity. These are claimed to be problems shared through

environmental management and environmental impact assessment (Pelling *et al.*, 2004; Olorunfemi, 2011; UN-Habitat, 2014; Arcilla & Lagdameo, 2015).

2.2.7. Urban Flooding Risk Management Approaches

2.2.7.1. A Holistic Approach to Urban Flooding Risk Management

A holistic approach is attested to be needed in order to achieve a comprehensive and global vision that is able to fit with the expectations of each urban society under the constraints of climate change. The experiences of many cities around the world affirm that a “no-regrets” approach to mitigation and adaptation initiatives can be highly effective and sustainable. This approach promotes the necessary changes in behaviour, technology, and policies as simply sound urban management necessary under any circumstances. When this “no-regrets” approach is supplemented with specific measures on climate change impact mitigation and adaptation and on disaster risk management, the probability of enhancing a city’s resilience capacity becomes very high (Dick, 2009; Djordjevic *et al.*, 2011; Lundy & Wade, 2011; Kim & Kakimoto, 2014; Larsen, 2014).

A holistic approach to flood risk management is encouraged to be adopted, rather than a narrow techno-centric approach (Mitchell, 2005; Akinmoladun & Adejumo, 2011). Such a holistic approach is encouraged to incorporate the views and perceptions of stakeholders, rather than merely the views of technical experts. A significant benefit of this perspective is claimed to be its ability to combine the strengths of the two approaches to risk (Vojinovic *et al.*, 2016). In other words, a holistic approach to flood risk assessment integrates physical, economic, social, and cultural vulnerabilities, along with perceived risk. This approach relies on the combination of two separate approaches. The first is a multicriteria flood risk assessment which quantifies flood risk in terms of the city’s physical, social, economic, and cultural vulnerabilities. The second approach rests on stakeholder participation to ascertain the perception of risk by local residents. These two approaches provide two alternative flood risk maps (i.e. quantitative and qualitative) (Prabhakar *et al.*, 2009; Vojinovic *et al.*, 2016).

Land use planning for cities and communities, neighborhoods and allotments is recommended to be seen as an integrated process and holistic approach of the ecosystem in urban and rural development. In other words, the holistic approach of the city as an ecosystem needs to be assessed at different scales from regional to city, urban and rural area

to district, allotment and building level (Djordjevic *et al.*, 2011; Claes *et al.*, 2012; Steinberg & Lindfield, 2012; Santato *et al.*, 2013; Kernaghan & da Silva, 2014).

It is vital to understand well the holistic and integrated urban flood management approaches to plan and implement them at all levels. The holistic approach is claimed to recognize drainage system complexity and inter-connectivity of its elements and is also known as the ecosystem approach (Millennium Ecosystem Assessment, 2005; Kobayashi & Porter, 2012; Wamsler *et al.*, 2014; Nature Uganda, 2015). For a holistic approach, three groups of objectives are recommended to be addressed on a river basin scale, such as social, economic and environmental. The solution needs to be found in a triangle of geoscientists, environmentalists and urban planners that have to be brought together at early stage of flood mitigation planning (Andjelkovic, 2001; Wertz-Kanounnikoff *et al.*, 2011; Claes *et al.*, 2012; Santato *et al.*, 2013).

Integrated approach to urban flood management is asserted to understand harmonization of relevant local and state laws dealing with urban development, environmental protection, use of water and management of communal infrastructure systems (Parkinson, 2002; WMO, 2009; Merz *et al.*, 2010; Sayers *et al.*, 2013). It is affirmed to be an approach to land and water resources planning and management. Moreover, it is asserted to imply the inclusion of physical, biological and socio-economic variables involved in natural system and human system, which addresses societal goals and functioning of the ecosystem and participation of stakeholders. It is attested to encourages participation to bring together a diverse array of knowledge of individuals as well as stakeholders include government entities, nongovernment organizations, community groups, business and industry with a particular interest in the system (Kidd & Shaw, 2007; Barua, 2008).

Integrated water resource management (IWRM) is attested to be a process which promotes sustainable development (Mitchell, 2005; Kidd & Shaw, 2007; Barua, 2008). IWRM is affirmed to be increasingly recognized globally as a way of achieving the efficient, equitable, and sustainable development of water resources. Moreover, it is attested to promote the coordinated development and management of water, land, and related resources, taking into account multiple viewpoints and development objectives (Roy, 2009; Collier *et al.*, 2013; Pegram *et al.*, 2013; ADB, 2015).

2.2.7. 2. The Three Spatial Scales of Urban Flooding Risk Management

It is asserted that there are different situations and different answers to problems with respect to flooding and living in cities prone to flooding (Cordaid & IIRR, 2011). Flood risk reduction is encouraged to be considered at a range of scales, including the whole water system. Experience has also shown that local flood protection measures can have negative effects both downstream and upstream (Claes *et al.*, 2012; Santato *et al.*, 2013). There are different approaches to manage the risk of flooding focusing on three (or four) spatial scales: the conurbation/catchment scale, (the city scale) the neighborhood and the building scale (Cordaid & IIRR, 2011; Santato *et al.*, 2013).

At the catchment scale the main goals should be to integration of green and the establishment of retention rooms (e.g. sports fields and car parks) to increase the temporary water storage capacity during flood events, which helps to reduce peak flows (Thomalla *et al.*, 2006; Baird & Esteban, 2012; Claes *et al.*, 2012; Santato *et al.*, 2013). The use of flood risk management plan is highly recommended at this level and the flood risk management plan on river basin district level is based on the flood hazard maps and the flood risk maps. It is claimed to contain common objectives for flood risk management (prevention, protection and preparedness, including land use planning, flood forecast and early warning systems). Measures are recommended to be planned to achieve these goals. They are encouraged to take into account costs and benefits, extent of flooding and overflow channels and areas potentially apt for flood retention. Land use planning which integrates flood risk management is claimed to be a key requirement as it provides an opportunity to develop new settlements that incorporate integrated flood management at the outset (ADPC, 2005; Claes *et al.*, 2012; Santato *et al.*, 2013).

The aim of land use planning is asserted to be making the best use of the catchment as a whole rather than to minimize flood losses. In other words, it is encouraged to be multi-objective in purpose and take account of multiple constraints in practice. For instance, to control land use solely with the purpose of minimizing flood losses would be inefficient and simply create other problems which might be worse (Barua, 2008; Balaban, 2009; Claes *et al.*, 2012; Santato *et al.*, 2013; Sayers *et al.*, 2013). Hence, flood risk management is recommended commonly to be based on 'holistic and dynamic' processes (Balaban, 2009; Andjelkovic, 2001; Merz *et al.*, 2010; Spaliviero *et al.*, 2011; Claes *et al.*, 2012; Santato *et al.*, 2013).

At the neighborhood scale, efforts are encouraged to focus on understanding and managing flood pathways and protecting areas at risk. For instance, well-designed adaptation can have additional benefits for water quality and resource management, and enhance public spaces. Similar solutions from catchment flood risk management strategies are recommended to be applied at the neighbourhood level and include, for example, the replacement of impermeable surfaces by Sustainable Drainage Systems (SUDS), such as permeable pavement, gravel or grass so that water can soak away (Cordaid & IIRR, 2011; Claes *et al.*, 2012; Santato *et al.*, 2013).

It is asserted that it is important to keep in mind that land use planning is used to pursue many local policy objectives, including providing affordable housing, stimulating job growth, preserving the character and heritage of a community, reducing greenhouse gas emissions, protecting biodiversity and enabling efficient transportation (Parkinson, 2003; Tucci, 2007; Balaban, 2009; Jha *et al.*, 2012). A key challenge for planners and local decision makers is identified to be how to incorporate and balance the need to prepare for climate change and urban disaster risks management through adaptation with other local development objectives. Another consideration affirmed is how to integrate (mainstream) consideration of changing climate and urban disaster risks management into the wide array of decisions made by local governments, from operating municipal services to capital spending, enforcement and inspection activities, collection of taxes, and administration of disaster response programs (Balaban, 2009; Richardson & Otero, 2012). Adaptations to flooding are encouraged to harmonize with natural processes to deliver other benefits including habitat creation, river restoration and lower carbon emissions. These are asserted to be implemented in a progressive way in response to changing information on future flood risks (Parkinson, 2003; Tucci, 2007; Balaban, 2009; Jha *et al.*, 2012; Wilby & Keenan, 2012).

It is asserted that it is possible to reduce the risks through spatial planning. For instance, many experiences in various countries and regions of the world have proved that water management that includes flood management could be strategic instrument beyond being just a regulatory task. Moreover, land use planning no longer considers the water management as an external technical exercise. Moreover, the ways to live with floods could possibly be found when the water element is considered as complementary, multi-functional area (Parkinson, 2003; Tucci, 2007; Balaban, 2009; Jha *et al.*, 2012).

The aim at building scale is attested to be minimizing the exposure to flooding whilst incorporating structural solutions, which help to reduce the vulnerability. For instance, new developments are encouraged to be carefully assessed to ensure that they are built to cope with flood risks as they change over time and that risks in adjacent areas are not exacerbated. Moreover, existing buildings are affirmed to take advantage of new materials and products to minimize flood risks (Cordaid & IIRR, 2011; Claes *et al.*, 2012; Santato *et al.*, 2013).

2.2.8. Sustainable Urban Flooding Risk Management Practices

Disaster Risk Reduction (DRR) is asserted to be the systematic development and application of policies, rules and regulations, procedures, strategies and practices to minimize vulnerabilities and disaster risks throughout the society to avoid (prevention), to limit (mitigation), or take precautions (preparedness) against the adverse impacts of hazards within the broad context of sustainable development (Jember, 2014). In other words, sustainable development cannot be achieved unless disaster risk is reduced (UNISDR, 2015).

A successful city in sustainable development terms is attested to be the one where many different goals of its inhabitants and enterprises are met without passing on cost to other people in space or time (Millennium Ecosystem Assessment, 2005; Merz *et al.*, 2010; Claes *et al.*, 2012; Steinberg & Lindfield, 2012). Prospective disaster risk management is asserted to be properly integrated into sustainable development planning. In other words, development programs and projects are encouraged to be reviewed for their potential to reduce or aggravate vulnerability and hazard (Pelling *et al.*, 2004; ADPC, 2005; Claes *et al.*, 2012; Sayers *et al.*, 2013).

The safest and most sustainable way to deal with increased risk from urban flooding is affirmed to be reducing vulnerability and exposure by moving settlements and assets out of the flood plains, flood prone areas behind protection constructions and by giving rivers their natural room for flooding (Wheater & Evans, 2009; Naumann *et al.*, 2013; Santato *et al.*, 2013). However, for many settlements and land uses this is not a feasible option and more integrated approaches are needed to come up with realistic and tailor-made solutions (Parkinson, 2002; Pelling *et al.*, 2004; Jayaratne & Sohail, 2005; Claes *et al.*, 2012).

Land use planning measures are asserted to have multiple co-benefits considering flood management and climate change. For example, the greening of urban spaces is attested to

have amenity value, enhances biodiversity, protects against urban heat islands, and can provide fire breaks, urban food production and evacuation space. Moreover, improved waste management is affirmed to have health benefits as well as maintaining drainage system capacity and reducing flood risk (Parkinson, 2002; Wheeler & Evans, 2009; Merz *et al.*, 2010; Santato *et al.*, 2013). Considering social and ecological consequences of land use planning scenarios is asserted to be of paramount importance (Starkl *et al.*, 2013; Hambati & Gaston, 2015). As some social and ecological consequences such as loss of community cohesion and biodiversity are not readily measurable in economic terms, city managers, communities at risk, urban planners and flood risk professionals are encouraged to give qualitative judgments on these broader issues (Achamyeleh, 2003; Alemu, 2011; Santato *et al.*, 2013; Migosi, 2014; Arcilla & Lagdameo, 2015).

2.2.8. 1. Sustainable urban drainage systems (SUDS) for Flood Risk Management

Drainage engineers are affirmed to notoriously unsympathetic to the use of natural drainage patterns and, all too often, engineering designs take little account of the existence of waterways and wetlands (Jember, 2014; Su, 2016). These factors are identified to lead to a re-evaluation of the conventional approach to drainage system design and the development of an alternative approach based upon the planning and design of sustainable urban drainage systems (SUDS). For instance, infiltration of relatively uncontaminated runoff from rainfall is asserted to help maintain base flows in rivers, and rainwater harvesting is claimed to reduce peak flows of stormwater runoff as well as offering benefits in terms of water supply (Merz *et al.*, 2010; Adedeji *et al.*, 2012; Sayers *et al.*, 2013; Khan *et al.*, 2014).

Sustainable Drainage System (SUDS) is asserted to be an alternative to conventional drainage with the aim of reducing flooding and improving the quality of water draining from urban surfaces (runoff) (Asrat, 2015). It is attested that the sustainable drainage systems (SUDS) may take the form of areas of vegetation like grassy banks, green roofs, or natural water storage features like ponds (Chatterjee, 2010; Adedeji *et al.*, 2012; Coutts *et al.*, 2012; Sayers *et al.*, 2013). A sustainable drainage system (SUDS) is also affirmed to constitute an approach to drainage which uses a wide range of techniques. It is further attested that the SUDS approach has the potential to reduce flood risk, where appropriate capacity has been included in the design, while achieving multiple benefits in improvement of water quality,

recharging of groundwater, and enhancing the potential for biodiversity (DEFRA, 2004; Sayers et al., 2013).

2.2.8. 2. Ecosystem-Based Adaptation for Flood Risk Management

Flood risk management (FRM) is attested to be part of the landscape, as flooding and its management is confirmed to shape the rural landscape, and continue to do so. In other words, the nature and identity of a frequently flooded landscape is asserted to shape communities and histories. Moreover, framing FRM in this way is attested to situate flooding as part of the landscape. Moreover, practical actions that work with the landscape and the protection of natural environments are emphasized within Making Space for Water (Sayers *et al.*, 2013; Twigger-Ross, 2005; ADB, 2015). Furthermore, urban green spaces are identified to have an important role to play within flood risk management (FRM). For instance, they are confirmed to provide soft surfaces which will absorb water (as opposed to hard standing such as car parks which water runs off). Developing schemes with landscaped green banks that are designed to flood and slow the flow of the water is also claimed as one approach to flood alleviation (Twigger-Ross, 2005; Sayers *et al.*, 2013).

Ecosystem-based approaches are attested to constitute a strategy for the integrated management of land, water, and living resources to promote equitable conservation and sustainable use. In other words, an ecosystem-based approach is claimed to involve applying appropriate methodologies focused on the essential structure, processes, and functions of ecosystems and the interactions among organisms (Sayers *et al.*, 2013; ADB, 2015). For instance, the adaptation of land-use patterns intended to both diminish the impacts of climate change and to improve opportunities for natural and social–economic systems to respond is essential for the future adaptive capacity of the landscape. Moreover, a conservation strategy is encouraged to be flexible and adjustable in the future when new impacts and new knowledge might ask for further adjustments. Hence, strengthening ecological networks in climate adaptation zones is asserted to be a good adaptive strategy, as ecological networks are affirmed to be flexible, are able to cope with processes on different spatial scales, and have proven to be effectively implemented in planning processes (Vos *et al.*, 2010; Pasquini *et al.*, 2014).

2.2.8. 3. Best Management Practices and Best Available Technologies for Flood Risk

Management

Best management practice (BMP) is attested to be a common name for a variety of non-structural and low cost structural measures in mitigating the flooding and pollution effects in urban settings. It is affirmed that BMP tends to reverse the impacts caused by urbanization and include a number of proven and promising measures for controlling destruction and pollution caused by urban runoff and combined sewer overflows (Andjelkovic, 2001; Cordaid & IIRR, 2011). The best urban flooding management measures are encouraged to be based on the entire watershed control, performance (target) oriented, designed to account for local characteristics, supported by local and state government, technically feasible, environmentally sustainable, economically justifiable, and politically acceptable (Andjelkovic, 2001; Sayers *et al.*, 2013; ADB, 2015).

Best available technology (BAT) is attested to be a process that determines the criteria upon which BMPs will be proposed, based on practical experience gained from the implementation and monitoring of the measures already in force, in conjunction with theoretical assessment and common sense. BAT criteria are claimed to change as they are underpinned by "learning by doing" (Andjelkovic, 2001). Best management practices (BMPs) are underpinned by several principal concepts like retaining the natural drainage system, imitating the natural drainage system, protecting land during urbanization and farming, cleaning urbanized surfaces, and protecting aquatic life (Andjelkovic, 2001).

It is also worth understanding non-structural stormwater quality best management practices. It is affirmed that non-structural storm water best management practices (BMPs) are institutional and pollution-prevention practices designed to prevent or minimize pollutants from entering stormwater runoff and/or reduce the volume of stormwater requiring management (Taylor & Wong, 2002; Parkinson, 2003). The flood management measures in pre, during and post-disaster phase are encouraged to be well planned and integrated with one phase to another. Moreover, policy makers and planners are encouraged to introduce latest and contemporary community based flood management strategies for sustainable and fruitful flood management along with the existing strategies by incorporating local knowledge to manage impending flood disaster for proper development of the country (Merz *et al.*, 2010; Paul & Hossain, 2013).

Town planning controls, strategic planning and institutional controls, pollution prevention procedures, education and participation programs, and regulatory controls are identified as the five core categories of nonstructural best management practices (BMPs) (Taylor & Wong, 2002). Cost, coverage, using in retrofit context, targeting specific pollutants of concern, application of polluter pays principle, high potential effectiveness of some measures, community participation, flexibility, and secondary benefits are identified as the benefits of non-structural best management practices (Taylor & Wong, 2002; Merz *et al.*, 2010; Paul & Hossain, 2013; Sayers *et al.*, 2013).

2.2.8. 4. Intensity-Duration-Frequency Relationship and Uran Flooding Risk

Management

Kotei *et al.* (2013) described rainfall intensity-duration-frequency (IDF) curves as “graphical representation of the quantity of water falling on the basin area.” It is also asserted to be “a mathematical relationship of rainfall intensity, duration and return period” (Okonkwo & Mbajiorgu, 2010; Akpan & Okoro, 2013; Subramani & Ravikumar, 2017; David & Nwaogazie, 2020; Barrie & Scott, 2021). It is also attested to be used to link the amount of rainfall per unit time (intensity) to the time (duration) taken for a defined event and its rate of occurrence (frequency) (Elsebaie, 2012; Suthakaran *et al.*, 2014; Agbazo *et al.*, 2016; Hamaamin, 2017).

Rainfall intensity is attested to be expressed as the rate of rainfall in inches or millimeters per hour. Moreover, it is affirmed to be an important characteristic of rainfall underpinning more soil erosion keeping other things being equal. Duration is attested to be how long time rainfall intensity lasts at a particular rate. It is confirmed that generally, the high-intensity portion of a storm has a shorter duration than the low-intensity portion. Frequency is asserted to be how often a storm of specified intensity and duration may be expected to occur (Okonkwo & Mbajiorgu, 2010).

Rainfall is an integral component in the hydrologic cycle. Engineers must be able to quantify rainfall in order to design structures impacted by or dealing with the collection, conveyance, and storage of excess rainfall. Quantification of rainfall is generally done using isopluvial maps and intensity-duration-frequency (IDF) curves. These two tools are used by engineers to design safe and cost effective structures for certain return periods, thus accepting a certain amount of risk that the capacity may be exceeded (Kotei *et al.*, 2013). The magnitude of an extreme rainfall event is asserted to have an inverse relation to its occurrence frequency.

Hence, the severe rainfall events are confirmed to have less frequency compared to moderate rainfall events (Hamaamin, 2017).

According to Gebremedhin (2017), hydrologic design of storm sewers, culverts, retention/detention basins and other components of storm water management systems are typically performed based on specified design storms derived from the rainfall intensity-duration-frequency (IDF) estimates and an assumed temporal distribution of rainfall. In other words, use of inappropriate data or design storms underpins malfunctions of the infrastructure systems (Kotei *et al.*, 2013; Hamaamin, 2017; Jefrin *et al.*, 2017). For instance, over-estimation is attested to result in costly over-design while under-estimation is confirmed to be associated with risk and human safety (Gebremedhin, 2017). Al-Wagdany (2020) also attests that development of Intensity-Duration-Frequency (IDF) curves is of paramount importance for the design of various hydraulic structures such as culverts, dams, and stormwater drainage systems.

Intensity-Duration-Frequency (IDF) relationship is affirmed to be one of the most critical tools used in the development of water resource systems and drainage works (Elsebaie, 2012; Liew *et al.*, 2014; Rasel & Hossain, 2015; Ewea *et al.*, 2017; Gebremedhin, 2017). Moreover, the IDF curve developed and the IDF parameters generated for the return periods of 2, 5, 10, 25, 50 and 100 years for all durations are asserted to be good to use for development interventions like water resource designing, and soil and water conservation practices (Agbazo *et al.*, 2016; Gebremedhin, 2017; Al-Wagdany, 2020). For David & Nwaogazie (2020), the Rainfall Intensity Duration Frequency (IDF) relationship is one of the most commonly used tools for the design of hydraulic and water resources engineering control structures. For Suthakaran *et al.* (2014), intensity-duration-frequency curves and empirical equations underpins proper calculation of peak discharge into Minor Irrigation Tanks and effective planning and designing of any water resource management projects. Akpan & Okoro (2013) and Jefrin *et al.* (2017) affirm that the availability of Rainfall Intensity Frequency Regimes underpins effective design of any hydraulic structures and other structural measures for controlling extreme rainfalls related environmental risks. Sheonty & Islam (2020) attest that the Intensity-Duration-Frequency (IDF) curve is one of the most important hydrologic tools used by engineers for designing drainage and flood control structures in urban areas.

According to Al-Wagdany (2020), IDF curves are developed through frequency analysis of annual maxima rainfall data. The frequency analysis is affirmed to be done following the most suitable theoretical probability function (PDF) to fit the annual extreme. Two methods are recommended for the frequency analysis: the graphical procedure to estimate the exceedance probabilities from the measured precipitation data and fitting theoretical probability distribution function which is then used to extract rainfall intensity values corresponding to certain duration with specific exceedance probabilities (Kotei *et al.*, 2013; Al-Wagdany, 2020).

2.2.8. 5. Storm Water Drainage Issues in Ambo Town

The storm water drainage problem in Ambo town is affirmed to be dominantly associated with urbanization that change land surface characteristic without proper coverage of drainage infrastructure. The storm water in the town runs over roads, rooftops, and compacted land posing hazard and risk to the town, different sectors, and livelihoods of residents underpinned by the increase in water velocity and volume for surface runoff water (Ambo Town Administration Office, 2013; Ogato *et al.*, 2017; and Ogato *et al.*, 2021).

The storm water drainage problem of the town was also asserted to be linked to flooding and stagnation of water because of low laying area in the town like village 3 and 2; flooding caused by negligence to clean drainage channels and construct flood protection structure; improper disposal of solid waste in open drainage channel, and natural waterways; overflow of drainage and flow channels during high rainy time; land degradation; and deterioration of existing drainage channels (Ambo Town Administration Office, 2013; Ogato *et al.*, 2017; and Ogato *et al.*, 2021). There is a need for better IDF curve for Ambo town to properly manage the storm water and other water resource related development projects (Figure 2.1).

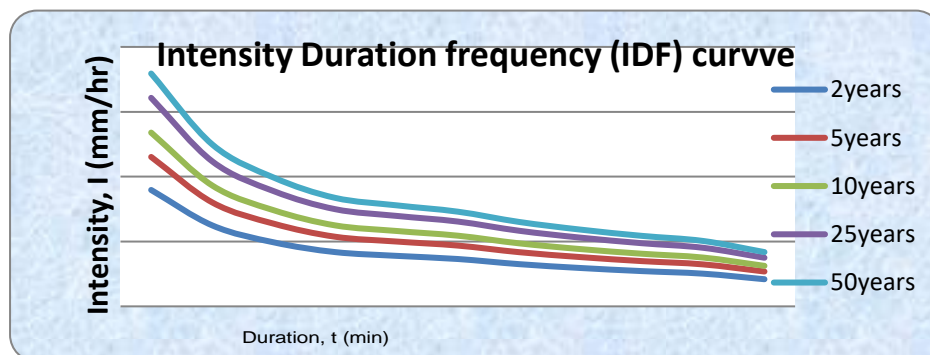


Figure 2. 1. Intensity-duration-frequency curve of Ambo town

(Source: Ambo Town Administration Office, 2013).

2.3. Synthesis and Research Gap

In this chapter, theories and concepts of flooding risk management, causes of flooding, effects of flooding, responses to flooding, and approaches and practices of flooding risk management, and intensity-duration-frequency (IDF) relationships in different parts of the world, were reviewed. It was worth to adapt the international, regional, and national experiences on urban flooding risk assessment, management, and adaptation to understanding local level challenges of urban flooding risk.

Based on the comprehensive review, it was possible to learn that comprehensive understanding on local urban flooding risk and its sustainable management strategy is missing in urban Ethiopia in general and small towns in particular. Hence, assessing socio-economic vulnerability to urban flooding risk and its governance; analyzing the dynamics of land use and land cover changes and their drivers; analyzing the severity classes of flooding hazard, and risks; establishing intensity-duration-frequency relationship; and proposing integrated urban flooding risk management strategy for Ambo town and its watershed were identified as critical research gaps of the socio-economic and biophysical components of the study. The most significant contribution of the study was the proposed integrated urban flooding risk management strategy to be utilized by Ambo town and its watershed and the possibility of replicating the comprehensive research approach and urban flooding risk strategy to other small towns and watersheds in Ethiopia and other regions.

CHAPTER THREE: MATERIALS AND METHODS

This chapter deals with, description of the study area, research design, sampling methods and procedures, types and sources of data, methods of data collection, methods of data analysis, and ethical considerations.

3.1. Description of the Study Area

This section presents description of Huluka watershed and Ambo town.

3.1.1. Description of Huluka Watershed

Huluka watershed is located in West Shoa Zone, Oromia Regional State, Ethiopia. The watershed is located between 8° 49' 26" to 8° 55' 22" N lat. and 37° 49' 50" to 38° 8' 08" E long (Fig. 3.1). The total land area of the Huluka watershed is 81237 ha and composed of villages mainly from Ambo, Dawo, Dendi, Elfeta, Jeldu, TokeKutaye, and Wonchi districts and Ambo town. The total human population of the watershed was reported to be about 303,416 in the year 2017 (projected based on CSA, 2007). Forest, cultivated land, urban built-up, bush/shrub land, bare land, grassland, and water body were identified as the seven land use and land cover types in the watershed. Forest land use and land cover in the watershed is characterized by areas covered with dense trees including Eucalyptus and Coniferous trees, and riverine trees. Bush/shrub land use and land cover is characterized by land with shrubs and bushes and scattered small trees mixed with grasses. Grassland land use and land cover is characterized by land predominately covered with grasses, forbs, and grassy areas used for communal grazing. Cultivated land use and land cover is characterized by areas used for rain-fed crop production and scattered rural settlements. Areas occupied by urban residential houses, buildings, and industrial uses. Urban Built-up land use and land cover is characterized by areas occupied by urban residential houses, buildings, and industrial uses. Water land use and land cover is characterized by areas covered by lake water in the watershed permanently. Bare land is characterized by areas with no or very little vegetation cover and characterized by shallow and rocky surface along the fooding area of the local stream valleys, over gentle and steep mountain slopes (Ogato *et al.*, 2021).

As the percentage change of transformation of urban built-up and cultivated land use and land cover types in the watershed are high currently, environmental problems like fooding, soil erosion, biodiversity loss, climate change, decrease in soil fertility and agricultural production are typical features of Huluka watershed. Rapid human population growth in the watershed and lack of sustainable watershed management strategies has exacerbated the environmental problems in the watershed and beyond (Ogato *et al.* 2017, 2020, 2021).

The highest elevation in the watershed is 3253 m above sea level while the lowest elevation of the watershed is 1834m above sea level. The highest slope in the watershed is 32.5% while the lowest slope is 0% (Fig. 3.2). Chromic Luvisols, Chromic Vertisols, Eutric Cambisols, Eutric Nitisols, Leptosols, Orthic Luvisols, and Pellic Vertisols are identified as the types of soils in the watershed. The highest mean daily annual maximum rainfall of the watershed over 32 years (1984–2015) is 43.45 mm while the lowest is 39 mm (Fig. 3.3). The rainfall of the area was identified to be bimodal, with unpredictable short rains from March to April and, the main season ranging from June to September (Ogato *et al.* 2017). The lowest and highest annual average temperature are 13 and 27°C, respectively (Atnafe *et al.*, 2015).

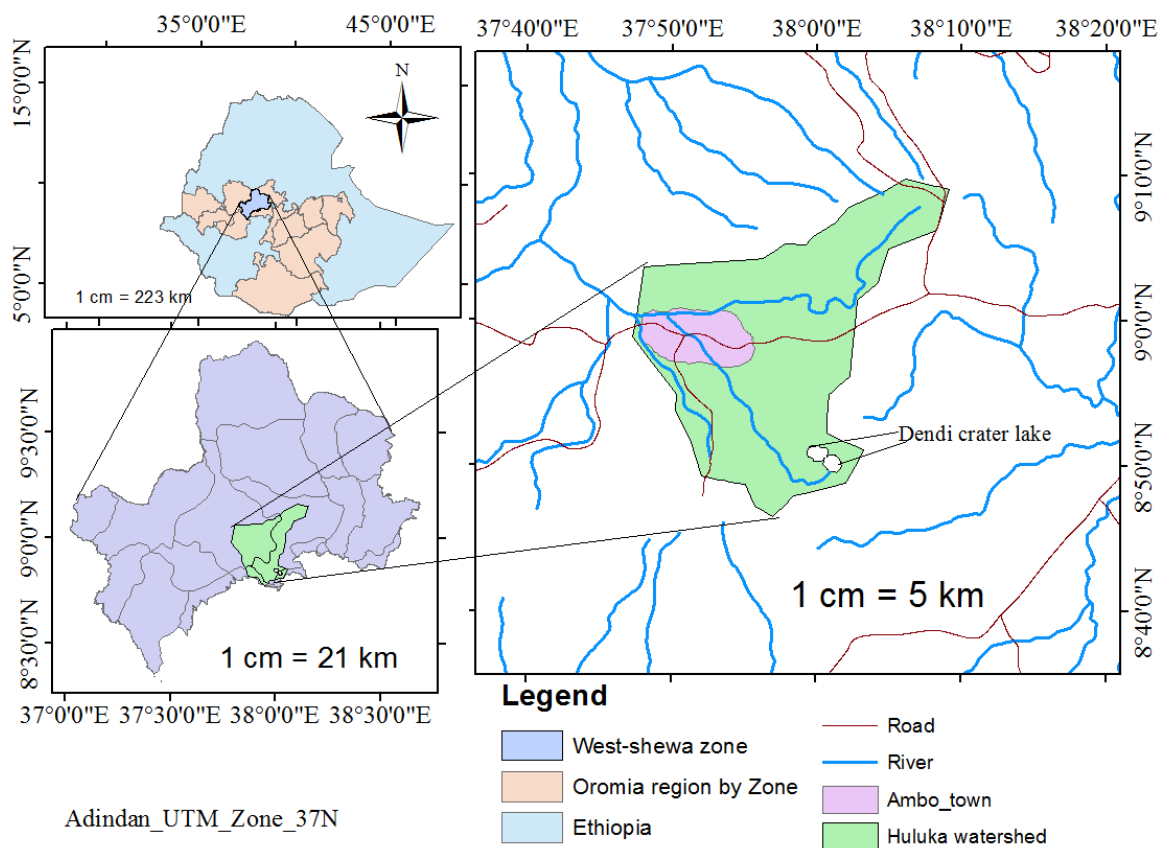


Figure3. 1 Geographical location of Huluka watershed

(Source: Ogato *et al.*, 2021).

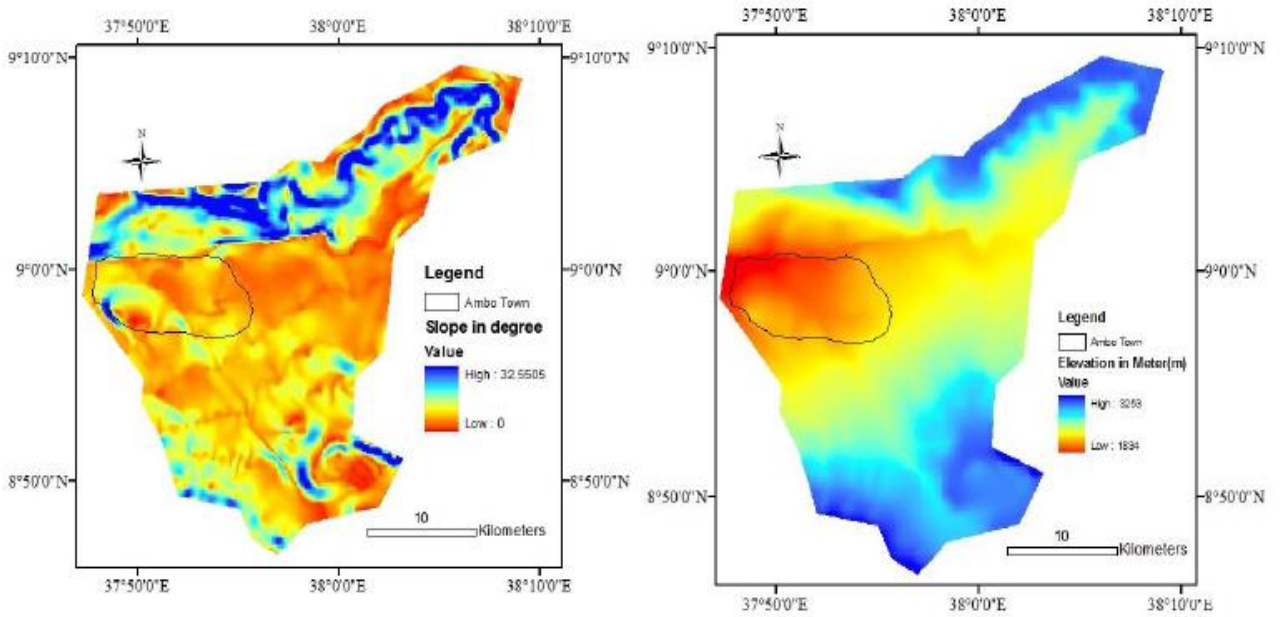


Figure3. 2 Elivation and slope of Huluka watershed
(Source: Ogato *et al.*, 2021).

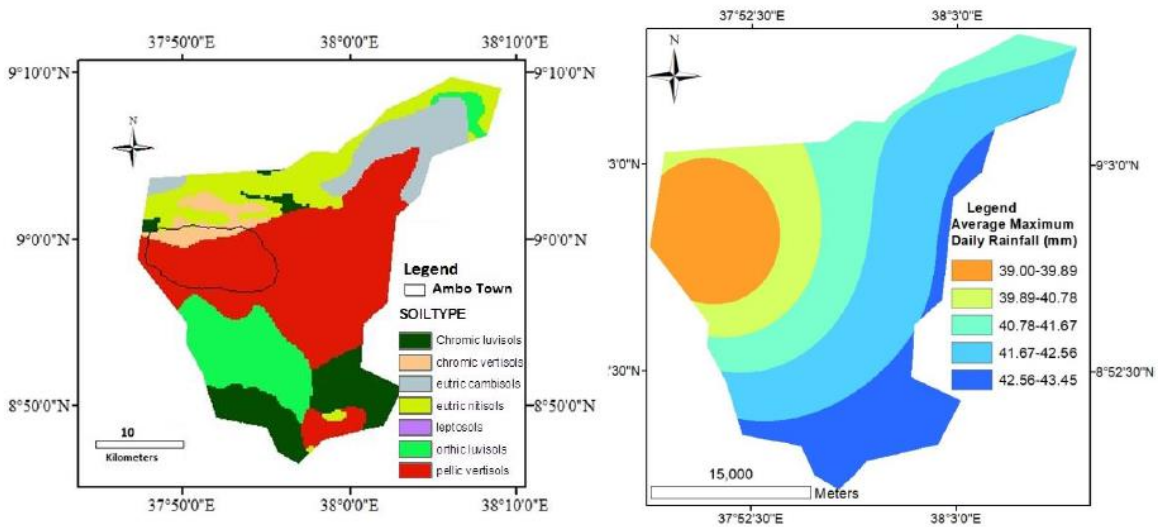


Figure3. 3 Soil type and rainfall of Huluka Watershed

In the watershed, much of natural vegetation were claimed to be destroyed by prolonged cultivation and human settlement. As a result, much of the natural forests were reported to be found in some protected areas and along rivers. Scholars identified indigenous trees like Juniperus (Gaattira), Olea abyssinica (Ejersa), Hagenia forests (Heexoo), acacia (laaftoo), podocarpus (Birbirs), Arundinaria alpine (Shimala), and Erythrina Abyssinia (Korchi). They also identified exotic tree species like Eucalyptus globulus (bargamo adii) and Eucalyptus camaldulesis (Bargamo dimaa) (Atnafe *et al.*, 2015; Ogato *et al.*, 2020, 2021). Farming system in the area is identified to be typically mixed crop-livestock system of the high lands of the country, where livestock provide the drought power needed for farming operation and a good part of crop residue are fed to livestock. The major crops identified to be grown in the watershed include barley (*Hordeum Vulgare*), wheat (*Triticum Vulgare*), oat (*Avena sativum*), Niger seed (*Guizotia abyssinica*), field pea (*Pisum Vativum*), faba bean (*Vicia faba*) and root crop like potato (*Selenium tuberosum*). Enset (*Ensete Ventricosum*) is the most popular perennial crop grown in all homesteads of midstream and upstream of Huluka watershed and serves as staple food and income source of local people (Atnafe *et al.*, 2015).

3.1.2. Description of Ambo town

The location, demographic, institutional conditions, topography, drainage basin, and climate of Ambo town area are briefly described in this section.

The geographical location of Ambo town is approximately between 8° 56'30'' N - 8° 59'30'' N latitude and between 37°47'30" E - 37° 55'15" E longitude. It is located in the Western Shoa Zone of the Oromiya region (See figure 3.4). Relatively Ambo town is located 114 kms far away West of Addis Ababa, 60kms North West of Weliso town and 12kms East of Guder town (UN-HABITAT, 2008, Shanmugham & Tekele, 2011; Ambo Town Administration Office, 2013).

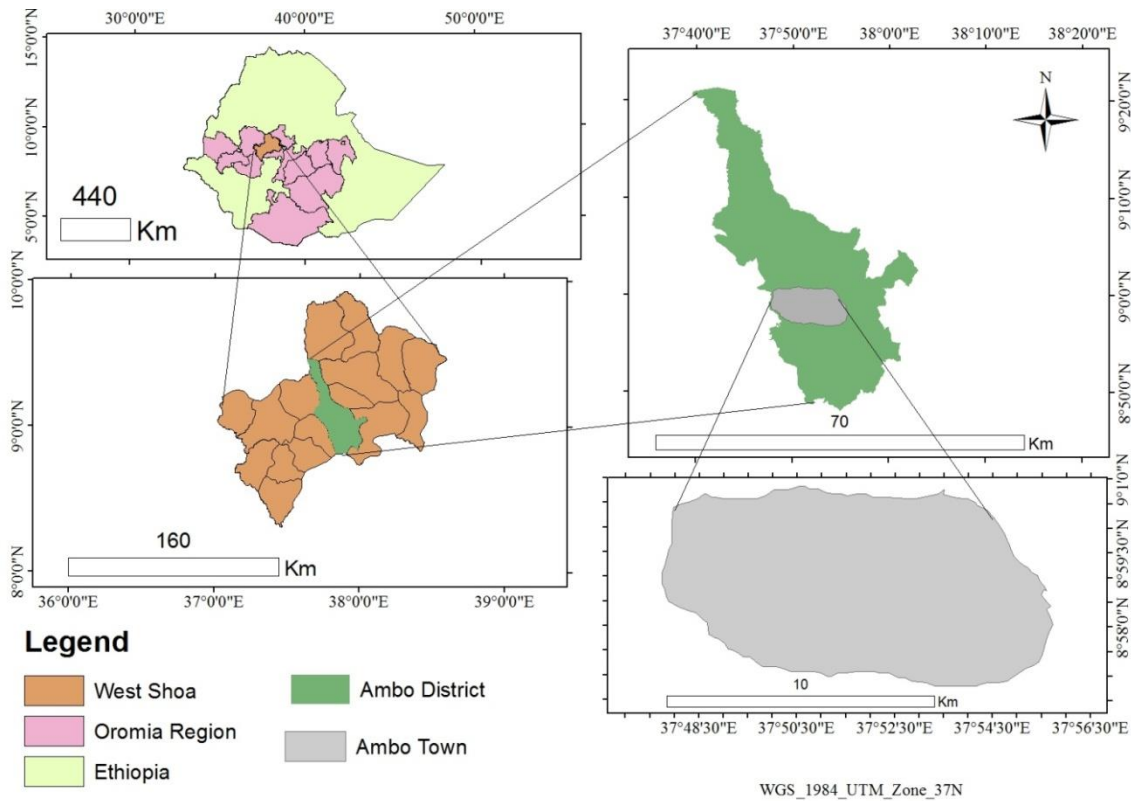


Figure3. 4 Geographic Location Map of Ambo Town.

With regard to topography, Ambo town is located on the Shoa plateau land, most of the existing built up areas of the town is almost gentle slope & undulated while some hilly slope and mountain are also seen in the town. Along the course of the rivers and streams, steep slope and gullies are also observed. Concerning the altitude of the town, the town's altitude ranges from 1924 meter above sea level (masl) to 2384 meter above sea level (masl). With regard to slope of the land surface, the slope classification of Ambo is largely dominated by terrain with flat to undulating and steep slopes. Slopes with 20%- 60% cover small area in the town whereas slopes beyond 2% up to 20% cover the majority areas of the town (Ambo Town Administration Office, 2013; Ogato, 2013).

As for the drainage basin of the town, the town is drained by Perennial and seasonal rivers and streams. The town is found within the Abay drainage basin, and it is particularly drained by major rivers (Huluka, Debis and Taltale); minor seasonal rivers (Aleltu, Awaro, Boji, Dobi, Kerise, Chafe Jara, Jalina, Maja, solbe, Jabdu and Sankale; and a number of intermittent or seasonal streams within the catchment area. The rivers and streams drain to the major Huluka river in the surrounding area of Ambo and Huluka river drains Westward to Guder river and finally Guder river drains to Abay river. The discharges of the streams are relatively small or absent during dry seasons, whereas the volume of these rivers/ streams

drastically increases during wet season (June - October) and inundates the low gradient areas close to their banks (Prabu *et al.*, 2011; Ambo Town Administration Office, 2013; Ogato, 2013).

With regard to the climatic condition of Ambo town, the mean annual temperature of the town over 30 years (1981-2010) is about 18.64°C while the mean annual rainfall of the town over 30 years (1981-2010) is about 968.7mm (Ogato, 2013). The highest rainfall concentration occurs from June to September. The mean monthly relative humidity of the town varies from 64.6% in August to 35.8% in December. The prevailing winds of Autumn (Locally Meher or Birra), Winter (Locally Bega or Bona) and Spring (Locally Belg or Arfasaa) seasons are Easterly and South Easterly Winds while that of Summer (Locally Kremt or Ganna) season is Westerly and South Westerly Winds. Generally the most dominant prevailing wind of Ambo town is Easterly Wind (Ambo Town Administration Office, 2013; ogato, 2013).

With regard to demographic conditions of the town, over the past few years the human population of Ambo town has been growing rapidly. The total human polulation of Ambo town was 77,735 in 2017 (CSA, 2017). The poor quality of housing and inability of the administration to increase supply could be taken as key indicators that a wide reform is necessary for Ambo town (UN-HABITAT, 2008; Shanmugham & Tekele, 2011).

With regard to institutional settings of the town, Ambo is one of the oldest towns in Ethiopia (Established in 1889). Ambo is among a few privileged towns of its time to have its own municipal administration since 1931, and a master plan since 1983 (UN-HABITAT, 2008). Ambo town is governed through the Oromiya region municipal establishment proclamation no. 65/95 and has two tiers of administration. The highest level is the municipal council, which is responsible for service delivery, administering funds and management of the city (UN-HABITAT, 2008, Ambo Town Administration Office, 2013).

3.2. Research Design

The proposed study adopted a mixed research approach which combines quantitative and qualitative methods of data collection and analysis. The quantitative aspect of the study design involved the collection of geospatial data, remote sensing data, and socio-economic and demographic data and the application of geographic information system and remotse sensing techniques to understand the composition, proportion, rate, and drivers of land

use/land cover change in the study area. It also involved mapping of flooding hazard and risk in the watershed. ERDAS IMAGINE10 software and ArcGIS10 software (Monkkonen, 2008; Alfasi *et al.*, 2012; Santato *et al.*, 2013; Uddin *et al.*, 2013; Cosgrave, 2014) were employed to analyze quantitative geospatial and remote sensing data while SPSS software was employed to analyze socio-economic data collected through semi-structured household survey questionnaire. The qualitative aspect of the study design involved the application of participatory data collection and analysis techniques (community mapping, observational walk, historical and seasonal calendars, and pair-wise matrix ranking) (Jabeen *et al.*, 2012; McCarney, 2012; WOTR, 2013; IIED, 2014; Stein & Moser, 2014). In other words, these qualitative tools were employed in focus group discussion, key informant interview, and personal observation to complement the quantitative data collected through the aforementioned quantitative methods.

3.3. Sampling Procedures and Techniques

With regard to sampling methods and procedures, the study employed both non-probability sampling (purposive) and probability sampling techniques for its socio-economic component.

Ambo town and Huluka watershed were purposively selected as Ambo town is located within the watershed and the main purpose of the study was to develop integrated urban flooding risk management strategy for Ambo town and Huluka watershed. The sample size for qualitative methods of data collection (key informant interview and focus group discussion) were purposively determined based on important criteria (gender consideration, age, experience and knowledge of the subject under investigation, and geographical location). To this end, respondents for key informant interview and focus group discussion were purposively selected to complement the quantitative data analysis undertaken through integrated GIS and remote sensing tools.

As one of the major method of data collection for the purpose of the study was interview schedule/household survey questionnaire, multi-stage sampling procedure was employed. First Ambo town was purposively selected. second, Ambo town was stratified into six administrative villages. Finally, sample households were selected from each village proportional to their size. The sample size for household survey was determined based on the total number of urban households in Ambo town. Accordingly, the sample size for collecting

primary data from urban households for the purpose of this study was determined by using the following formula (Yemane, 1967):

$$n = \frac{N}{1+N(e)^2} \dots\dots\dots 1$$

Where;

n =designates the sample size the study uses;

N= designates total number of households

e =designates maximum variability or margin of error 5 %;

l=designates the probability of the event occurring.

Therefore;

$$n = \frac{N}{1+N(e)^2}$$

Sample size determination aimed at selecting part of the population from which information was drawn to form conclusions about the entire population. By applying the above formula:

$$n = \frac{18156}{1+18156 (.05)^2}$$

n=391 urban households.

The sample size of each urban village was determined using the proportional method of sample size distribution as follows (see table 3.1 also):

Table3. 1 Urban Household Sample from Ambo town

Sr. No	Villages	Target Population (households)	Sample	Actual Sample
1	Village 01	6518	140	140
2	Village 02	5802	125	125
3	Village 03	3740	80	80
4	Sinkile Farisi	879	19	30
5	Awaro Kora	539	12	30
6	Kisose Edo Liben	678	15	30
	Total	18156	391	435

Remark: 457 (plus 5% of the actual sample size) household survey questionnaire were administered to manage non-response rate.

3.4. Types and Sources of Data

The types of data used to explore socio-economic vulnerability to urban flooding risk in Ambo town include: profile of urban households and communities, assets of urban households, communities and Ambo town; perceptions of urban households, communities and urban planners about urban flooding and their adaptation strategies strategic plan of Ambo town; determinants for adaptive capacity of urban communities and Ambo town; pictures of vulnerable households and communities, and sectors in Ambo town. The sources of these data were: Ambo town administration, urban households, urban communities, urban planners, watershed managers, and rural land use planners and managers.

The types of data used to examine governance of urban flooding risk reduction in Ambo town include: strategic plan of Ambo town; current land use map of Ambo town; and urban spatial planners' and stakeholders' perspective on challenges and opportunities for planning and implementation of urban floods' adaptation and mitigation strategies; and urban households' perception about the governance of urban flooding risk reduction in relation to principles of good governance (decentralization and autonomy, accountability and transparency, responsiveness and flexibility, participation and inclusion, and experience and support) . The sources of these data include: Ambo town administration; urban communities, urban

households, urban planners at local, regional, and national levels; urban disaster risk reduction offices at local, regional, and national levels; and stakeholders in Ambo town.

The types of data used to analyze changes in land use/land cover in Huluka watershed include: base map of Huluka watershed; Topographic map of Huluka watershed of 1:50,000; ground truth data; administrative boundary map of the villages in the watershed, drivers of land use/land cover change (biophysical, demographic, socio-economic, and institutional drivers) in Huluka watershed where Ambo town is located; and Landsat TM and ETM⁺ imagery for the periods 1979, 1984, 2009, and 2017(38 years). These years were chosen based on the purpose of the study and the purpose of the study was to understand the changes in land use/land cover and local residents' perceptions on its cause and negative effects in the watershed. To this end, year 1979 was chosen as a reference year representing 1970s due to the availability of good quality Landsat image for the decade for Huluka watershed. Year 1984 was considered as it was the census year in Ethiopia. 2009 was considered also as year close to the census year in Ethiopia (2007) with good quality land sat image for the study watershed. Year 2017 was chosen to represent current year. In other words, these years were chosen based on the purpose of the study and the purpose of the study was to understand the changes in land use/land cover change in the watershed over 38 years and relate the change to flooding risk in the watershed. These data were obtained from the Ethiopian Central Statistical Authority (CSA), Ethiopian Mapping Agency (EMA), Landsat website of www.glovis.USGS.gov., Urban and rural communities in Huluka watershed, urban planners of Ambo town, and land use planners in Huluka watershed.

The types of data used to analyze urban flooding hazard and risk from Geographic Information System(GIS)-based multicriteria perspective in Ambo town and its watershed include: Landsat images of 2015; digital map on shape file with the scale of 1:50,000; rainfall data (1984-2015) for the study watershed; Digital Elevation Model (DEM) of the watershed; soil types of Ethiopia; human population, disaster profile; GPS points and pictures of vulnerable areas in Ambo town; and flood points in the watershed. The sources of the aforementioned data were: Central Statistical Authority (CSA) of Ethiopia, Ethiopian Mapping Agency (EMA), Ethiopian Meteorology Agency, Landsat website of www.glovis.USGS.gov, SRTM (Shuttle Radar Topographic Mission) website; urban and rural communities in Ambo town/ Huluka watershed, urban planners of Ambo town, and land use planners and managers in the watershed.

The types of data used to establish intensity-duration-frequency relationship in Huluka watershed was daily and hourly maximum rainfall of stations in and around the watershed. The source of the rainfall data was the Ethiopian Meteorology agency.

The type of data used to develop integrated flooding risk management strategy were: information generated from review work and data analyzed in the study; views of respondents in interview schedule/ household survey questionnaire, focus group discussions, and key informant interview; maps of land use/land cover change; maps of flooding hazard and risk in the watershed and the town. The sources of these data include: strategic plan of Ambo town; urban spatial planners; urban households, experts from different disciplines; literature review, results of other specific objectives of the study.

3.5. Methods of Data Collection

The methods employed for data collection were underpinned by the specific objectives of the study and the quantitative and qualitative nature of data to be collected. The methods of data collection for each specific objective are presented in the following sections.

3.5.1. Methods of Data Collection for Socio-Economic Analysis of Urban Flooding Risk

The methods of data collection employed to explore socio-economic vulnerability to urban flooding risk in Ambo town were composed of quantitative and qualitative methods. The quantitative method was household survey questionnaire. To this end, a semi-structured questionnaire was designed, pre-tested and administered through interview schedule for 457 households (435+5%) in Ambo town to examine households' perceptions on causes and effects of urban flooding disaster risk, socio-economic vulnerability and adaptive capacities of urban communities, and local government, and autonomous local adaptation strategies to overcome challenges of urban flooding disaster risk.

The qualitative methods of data collection employed include: Focus group discussion, key informant interview, and personal observation. To this end, focus group discussion was employed to collect qualitative data from urban communities. Accordingly, a total of twelve focus group discussions (120 participants) were administered in six villages of Ambo town. Participants of the focus group discussion were members of the urban local communities' development associations who lived in Ambo town for more than 20 years and knowledgeable about flooding disaster risk in their area. Each focus group discussion participated 10 persons and the discussion in each group took about 60 minutes. Each focus

group discussion was started and closed with blessings of local elders as per the norm of Oromo culture in each urban village of Ambo town. Key informant interview was also employed to collect primary qualitative data to address the aforementioned objective. Accordingly, in-depth interview was made with 15 key informants from six urban villages (Village 1, village 2, and village 3, Sinkile Farisi, Awaro Kora, and Kisose Edo Liben) on their perception and personal experiences on urban flooding disaster risk in their area. Moreover, 15 experts were interviewed on flood causing factors. The key informants were men and women who lived in Ambo town for more than 20 years and older than or equal to 50 years of age at the time of interview. Personal observation was also employed to visually observe and document indicators of causes and effects of urban flooding disaster risk in Ambo town. The personal observation was guided by a semi-structured checklist and knowledgeable local person in each study village in the town.

3.5.2. Methods of Data Collection for Examining Governance of Urban Flooding Risk

The methods of data collection employed to examine governance of urban flooding risk reduction in Ambo town was composed of qualitative and quantitative methods. The quantitative method employed was semi-structured household survey questionnaire. Accordingly, a semi-structured questionnaire was designed, pre-tested and administered through interview schedule for 457 households (435+5%) in Ambo town to examine households' perceptions on current governance of urban flooding risk reduction. The qualitative methods employed were personal observation, focus group discussion, and semi-structured key informant interview. Accordingly, personal observation was employed to visually observe and document indicators of governance of urban flooding risk reduction. The personal observation was guided by a semi-structured checklist and knowledgeable local person in each study village in the town. Focus group discussion was also employed to complement data collected through household survey questionnaire. Key informant interview was also employed to complement data collected through household survey questionnaire.

3.5.3. Methods of Data Collection for Land Use/Land Cover Change Analysis

The methods of data collection employed to analyze changes in land use/land cover in Huluka watershed were composed of quantitative methods and qualitative methods. The quantitative methods include: online satellite imagery, collection of GPS points, and household survey questionnaire. The qualitative methods of primary data collection

employed include: focus group discussion, key informant interview, and personal observation. Accordingly, six focus group discussions, and 30 key informant interviews (15 local elders and 15 experts) were undertaken to collect qualitative data from the local communities in the watershed to complement the quantitative data collected through quantitative methods.

3.5.4. Methods of Data Collection for Urban Flooding Hazard and Risk Analysis

The methods of data collection employed to analyze urban flooding hazard and risk from Geographic Information System(GIS)-based multicriteria perspective in Ambo town and its watershed were composed of quantitative and qualitative methods. The quantitative methods employed include online Satellite Imagery while personal observation and key informant interview were employed as qualitative methods of data collection to complement data collected through online imagery and document review. Accordingly, key informant interview was conducted with 30 persons (15 local elders and 15 experts from different disciplines) to prioritize flooding hazard and risk factors using pair-wise matrix ranking.

3.5.5. Methods of Data Collection for Establishing Intensity-Duration-Frequency Relationship

The annual daily maximum rainfall data of 32 years (1984-2015) were received from the Ethiopian meteorology agency in excel sheet as secondary data. Hence, the method of data collection for this objective was secondary data provided in excel spreadsheet by the agency.

3.5.6. Methods of Data Collection for Proposing Integrated Urban Flooding Risk Management

To address the last specific objective, a mix of qualitative and quantitative primary and secondary methods was employed for data collection. To this end, online imagery and semi-structured interview schedule/household survey questionnaire were employed. On the other hand, qualitative data were collected through personal observation, key informant interview, and focus group discussion. More importantly, synthesis of literature review and results of other specific objectives was employed to carefully identify the major issues identified in the study and propose vital strategic measures in the watershed and the town.

3.6. Methods of Data Analysis

The methods employed for data analysis were underpinned by the specific objectives of the study and the quantitative and qualitative nature of data collected. The methods of data analysis employed for each specific objective are presented hereunder.

3.6.1. Methods of Data Analysis for Socio-Economic Analysis of Urban Flooding Risk

Both qualitative and quantitative methods of data analysis were employed to analyze the collected data. The qualitative data captured through focus group discussion, personal observation, and key informant interview to assess the causes and effects of urban flooding disaster risk in Ambo town, examine the socio-economic vulnerability and adaptive capacities of urban households, urban communities and local government, and assess autonomous local adaptation strategies to overcome challenges of urban flooding disaster risk in Ambo town were analyzed with the help of thematic analysis, content analysis, narrations and qualitative descriptions. The major criteria underpinning the combined application of the aforementioned qualitative methods of data analysis were: transparency, maximizing validity and reliability, comparative analysis, and reflexive approach in the process of analysis. The major steps involved in the process include: Reading and annotating transcripts; Identify themes; developing a coding scheme; and Coding the data. On the other hand, simple descriptive statistics (frequencies and percentages) were employed to analyze data collected through household survey questionnaire. To this end, SPSS software (SPSS-Version 20) was used to help the quantitative analysis of the study. Moreover, Ch-square test was employed to analyse relationship between characteristics of respondents and perceptions on negative effects of urban flooding on livelihoods of households.

3.6.2. Methods of Data Analysis for Examining Governance of Urban Flooding Risk Reduction

Both qualitative and quantitative methods of data analysis were employed to analyze the collected data. The qualitative data captured through focus group discussion, personal observation, and key informant interview on challenges of governance of urban flooding disaster risk reduction in Ambo town were analyzed with the help of thematic analysis, content analysis, narrations and qualitative descriptions. The major criteria underpinning the combined application of the aforementioned qualitative methods of data analysis were: transparency, maximizing validity and reliability, comparative analysis, and reflexive approach in the process of analysis. The major steps involved in the process include: Reading and annotating transcripts; Identify themes; developing a coding scheme; and Coding the data. On the other hand, simple descriptive statistics (mean, frequencies and percentages) were employed to analyze data collected through household survey questionnaire on the urban households' perceived governance of urban flooding disaster risk reduction in Ambo town. To this end, SPSS software (SPSS-Version 20) was used to help the quantitative analysis of the study. More importantly, the analytical framework for European Forum for Disaster Risk Reduction (EFDRR) (2014) was adapted to analyse the perceived level of urban flooding risk reduction in Ambo town (Figure 3.5). Accordingly, governance of urban flooding risk reduction was characterized by nine important factors. Description of the relationship between each factor and governance of urban flooding risk reduction is presented hereunder.

- 1. Accountability:** This is about holding actors responsible for their actions and for delivering on their commitments.
- 2. Legality:** This is about making risk management factors compatible with regulation and legislation.
- 3. Impartiality:** This about making decisions in an independent manner, free of prejudice, and with a strong, reliable process of evidence-based risk management.
- 4. Transparency:** This is asserted to require that decisions about reduction of disaster risks be made public, information on planning and projects is shared among organizations, implementation measures are transparent, regulations exist guaranteeing the right to disaster risk reduction information, and audit and monitoring procedures support the transparency principle.

5. **Participation:** This is about the contribution of all actors to the improvements in disaster risk reduction processes.
6. **Coordination:** This is about compatability and coordination among all relevant institutions and organizations charged with risk management.
7. **Effectiveness:** This is about having concern for the efficient implementation of precaution and responsibilities during risk management processes.
8. **Education/Awareness:** This is about raising awareness to engage all stakeholders in effective disaster risk reduction.
9. **Subsidiarity:** This is about taking responsibility by the nearest actor for the fastest response (EFDRR, 2014).

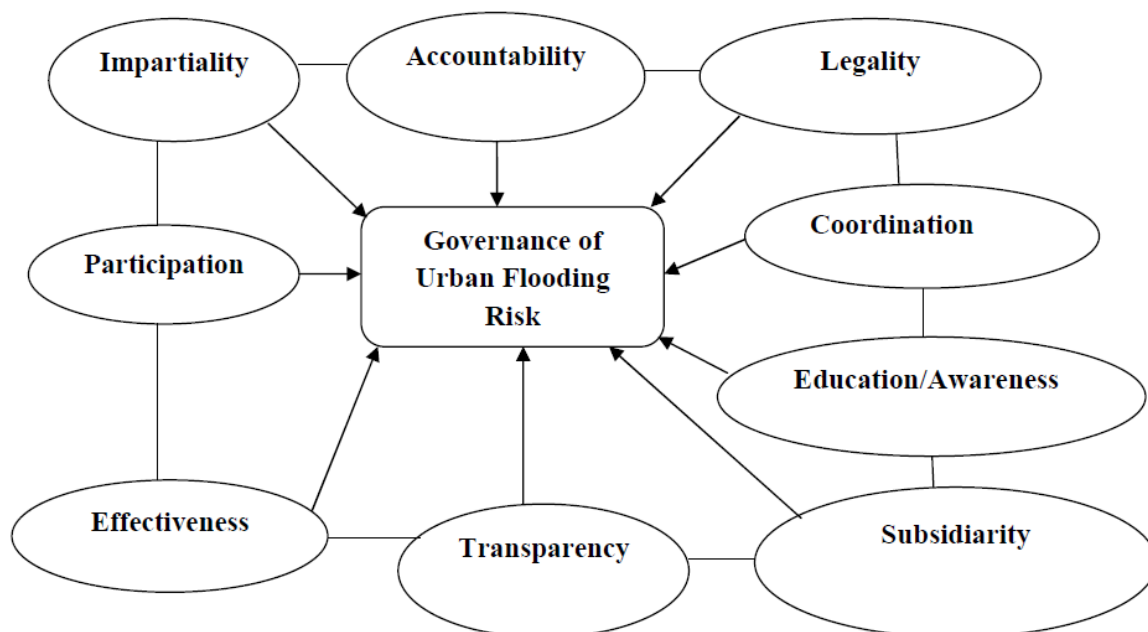


Figure3. 5 Factors characterising urban flooding risk governance

(Source: Researcher's elaboration based on EFDRR, 2014).

3.6.3. Methods of Data Analysis for Land Use/Land Cover Change Analysis

The qualitative data collected through focus group discussions, key informant interviews, and participant observation were analyzed by employing the thematic content analysis technique (Strauss, 1987; Burnard, 1991; Onwuegbuzie *et al.*, 2009; Kassie, 2017; Gardner *et al.*, 2019). The responses from the focus group discussions and the key informant interviews

were recorded by hand on the notebook as the participants preferred not to be recorded by any audiovisual tools. However, relevant environmental events were recorded through audiovisual tools and hand during participant observation and transect walk sessions. As the number of focus group discussions (six) and key informant interviews (15) were manually manageable and the researcher is familiar with the data, no software was employed to analyze the qualitative data. The major criteria underpinning the application of thematic content analysis were: transparency, maximizing validity, maximizing reliability, comparative analysis, and reflexive approach in the process of analysis (Kassie 2017; Asnake *et al.*, 2019; Gardner *et al.*, 2019). The application of thematic content analysis technique in this study to analyze the qualitative data involved the following steps: Step one: Reading and Re-reading the recorded qualitative data to be familiar with the content; Step two: Organizing the qualitative data by questions; Step three: Coding the data into exhaustive, mutually exclusive, and specified categories or themes; Step four: Reviewing and revising the coding system; Step five: Looking for patterns across categories or themes; and. Step six: Summarizing findings, and recognizing limitations of the data.

Based on prior knowledge of the study area, data collected from the local communities in the watershed, characteristics of Landsat images, ancillary data like Google Earth and field observation, seven land use/land cover classes (Table 3.2) were used for image classification and land use/land cover change analysis. Arc GIS 10.1 software and ERDAS IMAGINE 10 software (Huang *et al.*, 2007; Monkkonen, 2008; Gondo & Zibabgwe, 2010) were employed for the intended image classification, land use/land cover change detection and mapping. While ERDAS IMAGINE 10 software was employed to classify images and detect change over time, ArcGIS10.1 software was employed for geospatial analysis of the classified images and developing maps of land-use/land cover change.

Table3. 2 Description of land use/land cover categories

LULCC	Description
Forest	Include areas covered with dense trees including <i>Eucalyptus</i> , coniferous trees, and riverine trees.
Cultivated land	Include areas used for agriculture with scattered rural settlements.
urban Built-up area	Include areas occupied by urban residential houses, buildings and industrial uses.
Bush/shrub land	Include land with shrubs, bushes and scattered small trees mixed with grasses.
Bare land	Include areas with no or very little vegetation characterized by shallow and rocky surface.
Grassland	Include area predominately covered with grasses, forbs, and grassy areas.
Water	Include areas covered by lake water in the catchment permanently.

The analysis of images involved the key steps of pre-processing; post-processing, overlaying and change detection and creation of maps of land use/ land cover change from Landsat TM imagery for the period, 1979-2017.

The Pre-processing step involved geo-referencing the landsat images, radiometric correction, layer stacking, resolution merge, mosaicing; image enhancement, and adding vector information from administrative boundary of the study area.

The post-processing step involved image classification which was undertaken using hybrid classification methods involving both unsupervised and supervised techniques among different classification algorithms. To this end, maximum likelihood was used for supervised classification by taking ground control points for seven major land use land cover classes. These land use/land cover (LULC) types were identified with the help of visual interpretation elements and the different reflection characteristics of the feature in the satellite images of 1979, 1984, 2009 and 2017. In other words, the supervised classification involved selecting pixels that represents land cover classes that were recognized by the researcher. Accuracy assessment was also undertaken in the post-processing step with the purpose of verifying to what extent the produced classification is compatible with reality on the ground as recommended by Congalton (1991). Accordingly, the underpinning principle for all the

output maps to have the minimum accuracy assessment of 85% was used as the standard (Anderson *et al.*, 1976).

The overlaying and change detection step involved: interpretation of change in land use and land cover change in various years and analysis of its implication for environmental and management issues like flooding risk in Ambo town and its watershed. In other words, post-classification method was employed for the change detection. This technique helps to generate change matrix where different transfers from one land use/ land cover types to another can be visually observed. Accordingly, change metrics for detecting land use and land cover change were constructed between 1979 and 1984, between 1984 and 2009, between 2009 and 2017, and between 1979 and 2017 through pixel-to-pixel comparisons. The classified data were then taken in to ArcGIS 9.1 environment to calculate area for each land use/ land cover type and produce the land use/land cover maps of the area. These land cover maps were compared pixel by pixel with the final results showing both change-no-change information as well as ‘from to’ land cover change information. The land use and land cover change detection (percentage change) was made using the following formula (Fura, 2013; Gashaw *et al.* 2017a, b; Miheretu and Yimer 2017):

$$\Delta = \frac{(A2 - A1)}{A1} \times 100 \dots\dots\dots 2$$

Where: Δ = land use and land cover change (%), A1 = amount of land use/ land cover type in year 1, A2 = amount of land use and land cover type in year 2.

The rate of change in land use and land cover (hectares/ year) between two study periods was determined using the following formula (Gashaw *et al.* 2017a, b; Miheretu and Yimer 2017):

$$\text{Rate of Change} = \frac{A2 - A1}{Z} \dots\dots\dots 3$$

Where, A1=amount of land use and land cover type in year 1, A2=amount of land use and land cover type in year 2, Z is the time interval between A1 and A2 in years.

The final step was creation of maps of land use/land cover change. Accordingly, the analysis of images ended with the creation of maps of land-use and land cover change from Landsat TM imagery for the period, 1979-2017.

3.6.4. Methods of Data Analysis for Urban Flooding Hazard and Risk Analysis

3.6.4.1. Flooding Hazard Factors

The flooding hazard factors were determined by literature review, personal observation, and key informant interview with experts and local residents. The flooding hazard factors were determined by literature review, personal observation, and discussion with experts and local residents. As far as the key informants (experts and local residents) are concerned, 15 experts and 15 local elders were interviewed to decide the important factors causing flooding hazard. Accordingly, Land use/land cover, elevation, slope, drainage density, soil, and rainfall were considered as important flooding hazard factors in Ambo town's watershed.

1. Land Use/Land Cover Factor: Many scholars in the field of flooding risk management attest that land use/land cover change is one of the major contributor of flooding as urban expansion increases, impervious cover increases and forest cover decreases in urban areas contributing to increase in run-off (Tucci, 2007; Jha *et al.*, 2012; Fura, 2013; Mngutyo & Ogwuche, 2013; Migosi, 2014). For instance, land use is asserted to be closely related to the urban development process of rapid urbanization that takes place in most developing countries (Li *et al.*, 2013; Ouma & Tateishi, 2014; Gigovi'c *et al.*, 2017; Rimba *et al.*, 2017). In other words, the ways in which land has to be allocated to a variety of functions such as roads, utilities, housing industrial estates, shopping centers, offices, schools, hospitals and other elements of the physical organization of a city is affirmed to have far-reaching socio-economic, cultural, political, technical and ecological implications (Parkinson, 2003; Few *et al.*, 2004; Claes *et al.*, 2012; Santato *et al.*, 2013; Zhiyu *et al.*, 2013).

Poorly planned and managed urbanization are claimed to contribute to the growing flood hazard due to unsuitable land use change (Tucci, 2007; Kamal-Chaoui & Robert, 2009; McGranahan *et al.*, 2009; Adedeji *et al.*, 2012). In other words, as cities and towns swell and grow outwards to accommodate population increase, large-scale urban expansion often occurs in the form of unplanned development in floodplains, in coastal and inland areas alike, as well as in other flood-prone areas (Tucci, 2007; Brown, 2011; Dang *et al.*, 2011; Jha *et al.*, 2012). According to Jha *et al.* (2012), the accelerating urbanization and urban development could also increase significantly the risk of flooding independent of climate change. The impact of future urban growth on flood risk is influenced by the policies and choices of urban

dwellers as they may or may not occupy areas at risk of flooding, or adopt suitable urban planning and design (Pottier *et al.*, 2005; Tucci, 2007; McGranahan *et al.*, 2009; Jha *et al.*, 2012). In other words, better planned and managed urban development are claimed to mitigate the expected growth in future flood risk (Alemu, 2007; Khailani & Perera, 2013; Mngutyo & Ogwuche, 2013; Ouma & Tateishi, 2014; Getahun & Gebre, 2015).

The land use land cover classes of the study area were prepared from the analysis of images involving the key steps of pre-processing; post-processing, overlaying and change detection and creation of maps of land use/ land cover change from Landsat TM imagery for 2015 by categorizing the land use/land cover types into five general classes and converted to raster layer. The existing land-use classes of the area were reclassified into five groups in order of their capacity to increase or decrease the rate of flooding. Accordingly, water body was ranked with the value of 5 as it is very highly susceptible to flooding hazard. Built-up area land use/land cover type was assigned the value of 4 as it is highly susceptible. Cultivated land was assigned the value of 3 as it is moderately susceptible. Grassland land use/land cover type was assigned the value of 2 as it has low susceptibility. Forest land use/land cover type was assigned the value of 1 as it has very low susceptibility.

2. Elevation Factor: Elevation has a key role in controlling the movement of the overflow direction and in the depth of the water level (Gigović *et al.*, 2017).

For elevation factor, the elevation raster map was prepared using the digital elevation model (DEM) and slope generation tools in ArcGIS software. The elevation raster layer was further reclassified into five sub groups using standard classification schemes namely Equal Interval. This classification scheme divides the range of attribute values into five classes specifying the number of intervals and Arc Map helped in determining where the breaks should be and new values were re-assigned in order of flood hazard rating. In this classification process, the lowest elevation category is ranked as 5 as it has very high susceptibility to flooding hazard and the highest elevation category is ranked as 1 as it has very low susceptibility.

3. Slope Factor: The slope is the ratio of steepness or the degree of inclination of a feature relative to the horizontal plane (Rimba *et al.*, 2017). Slope is claimed to be an important indicator of surface zones, which are highly prone to flooding. Slope is also asserted to be a major factor in determining the rate and duration of water flow. On the flatter surface, water is moving more slowly, collects longer and accumulates so these areas are riskier with respect

to the occurrence of floods in relation to the steeper surfaces (Gigović *et al.*, 2017; Rimba *et al.*, 2017).

For slope factor, the slope raster map was prepared using the digital elevation model (DEM) and slope generation tools in ArcGIS software. The slope raster layer was further reclassified into five sub groups using standard classification Equal Interval scheme. In this classification process, the lowest slope category is ranked as 5 as it has very high susceptibility to flooding hazard while the highest slope category is ranked as 1 as it has very low susceptibility to flooding hazard.

4. Drainage Density Factor: Scholars assert that drainage density (DD) a fundamental concept in hydrologic analysis is defined as the ratio of the length of drainage per basin area. Drainage density is attested to be controlled by permeability, erodability of surface materials, vegetation, slope and time. Scholars affirm that flooding in Africa has been attributed to inadequate drainage causing overland flow and poor waste collection which can block drainage and water channels causing overland and river (fluvial) flooding (Few *et al.*, 2004; Tucci, 2007; Rimba *et al.*, 2017). Drainage density is claimed to be an inverse function of infiltration. Greater drainage density indicates high runoff for basin area along with erodible geologic materials, and less prone to flood. Thus, the rating for drainage density is claimed to decrease with the increase in drainage density (Chibssa, 2007; Wondim, 2016). Drainage density map is claimed to be derived from the drainage map by overlaying drainage map on watershed map and finding out the ratio of total length of streams in the watershed to total area of watershed (Chibssa, 2007; Wondim, 2016; Ouma & Tateishi, 2014).

The drainage density of the watershed is calculated as (Ouma & Tateishi, 2014):

$$D = L / A \dots\dots\dots 4$$

, where, *D* = drainage density of watershed; *L* = total length of drainage channel in watershed (km); *A* = total area of watershed (km²).

For drainage density factor, DEM was used to extract the drainage network from which the drainage density of the streams was calculated. Using the Spatial Analyst extension in ArcGIS environment, line density module was used to compute drainage density of the watershed. Line density module calculates a magnitude per unit area from polyline features that fall within a radius around each cell. The density layer is further reclassified into five sub

group using Equal Interval scheme. In this classification, the highest drainage density category is as 1 as it has very low susceptibility to flooding hazard and the lowest drainage density category is ranked as 5 as it has very high susceptibility.

5. Soil Factor: Scholars attest that soil characteristics in a watershed such as soil layer thickness, permeability, infiltration rate and the degree of moisture in the soil before the rain event have a direct effect on the rainfall-runoff process (Zhiyu *et al.*, 2013; Rimba *et al.*, 2017). The structure and infiltration capacity of soils are claimed to have an important impact on the efficiency of the soil to act as a sponge and soak up water. Moreover, different types of soils are identified to have different capacities. The chance of flood hazard is affirmed to increase with decrease in soil infiltration capacity, which causes increase in surface runoff. Scholars affirm that when water is supplied at a rate that exceeds the soil's infiltration capacity, it moves down slope as runoff on sloping land, and can lead to flooding (Ouma & Tateishi, 2014).

For soil factor, the soil factor of the study area was derived from the FAO standard classification of Ethiopian soil (Table 3.3). The characteristics of each soil group are analyzed based on hydrologic soil grouping system. To this end, the soil group of the study area was grouped into five general classes and converted to raster format. Moreover, the soil raster layer group was reclassified into five groups and new values were reassigned in order of their flood hazard rating. Soil type that has very high capacity to generate very high flood rate is ranked to 5 and the one with very low capacity in generating flood rate is ranked to 1. Accordingly, Pellic and Chromic Vertisols were ranked to the value of 5 as they have very high susceptibility to flooding hazard. Leptosols were ranked to the value of 4 as they have high susceptibility. Orthic and Chromic Luvisols were ranked to the value of 3 as they have moderate susceptibility. Eutric Nitosols were ranked to the value of 2 as they have low susceptibility. Eutric Cambisols were ranked to the value of 1 as they have very low susceptibility to flooding hazard.

Table3. 3 Description of Soil Types in Ambo town and Its Watershed

Sr.No.	Soil Type	Description
1.	Pellic and chromic vertisols	Vertisols are characterized as heavy clay soils in flat areas, having a pronounced dry season during which they shrink and have deep cracks in a polygonal pattern. During the wet season the clay swells and causes pressure in the sub-soil. Vertisols are prone to water erosion due to their slow infiltration (Mesfin, 1998; Chekol, 2014; Assefa, 2015).
2.	Orthic and Chromic luvisols	Luvisols are soils characterized with an argillic B horizon and a base saturation of 50 per cent or more. Those with a strong brown or red B horizon are chromic Luvisols. In soils with a heavy texture B horizon, permeability might be low, and drainage and good root distribution can be hindered (Bezuayehu <i>et al.</i> , 2002; Assefa, 2015).
3.	Eutric Cambisols	Cambisols are soils characterized with medium textured and have good structural stability, high porosity, and good water holding capacity and good internal drainage (Chekol, 2014; Assefa, 2015).
4.	Eutric Nitisols	Nitisols are characterized by deep, porous solum, well drained and easy to plough. Moreover, good texture and high organic matter characterize the Nitisols. They are also well-drained with a high water holding capacity, and have a homogenous and well developed structure (Bezuayehu <i>et al.</i> , 2002; Assen & Tegene, 2008; Assefa, 2015).
5.	Leptosols	Leptosols are characterized as soils limited in depth by continuous hard rock or highly calcareous material or a continuous cemented layer within 25 cm from the soil surface (Assen & Tegene, 2008). Leptosols occur on steep slope of upper footslope, backslopes and summits where erosion is high.

6. Rainfall Factor: Many scholars in the field of flooding risk management attest that flooding risk is the most widespread climate change-related disaster risk in the world, and historically floods have been the most prevalent cause of death from natural disasters (Zhiyu *et al.*, 2013; Jha *et al.*, 2012; Berggren *et al.*, 2013; Santato *et al.*, 2013). Changes in the

global climate and individual climatic variables are attested to affect floods in various ways, together with soil moisture and snow storage. Generally, a warmer atmosphere is claimed to hold more water vapour, which may increase heavy precipitation and therefore floods (Hall *et al.*, 2014; Ouma & Tateishi, 2014). Scholars affirm that more extreme rainfall means more likelihood of floods, particularly flash floods (Few *et al.*, 2004; Guo *et al.*, 2014). Moreover, flooding is one of the most widespread of climatic hazards and poses multiple risks to human health (Andjelkovic, 2001; Few *et al.*, 2004; Dang *et al.*, 2011).

It is attested that climate change is the other large-scale global trend perceived to have a significant impact on flood risk (Andjelkovic, 2001; Few *et al.*, 2004; Hall *et al.*, 2014). The alterations in meteorological patterns which are associated with a warmer climate are claimed to be potentially drivers of increased flooding, with its associated direct and indirect impacts. Observed and projected patterns of climate change are affirmed to have an amplifying effect on existing flood risk. For example, changing local rainfall patterns may lead to more frequent and higher level of floods from rivers and more intense flash flooding (Andjelkovic, 2001; Few *et al.*, 2004; Balaban, 2009; Jha *et al.*, 2012; Berggren *et al.*, 2013). On longer time scales, climate change might play a more significant role and both short-term and long-term prospects are encouraged to be considered in managing flood risk (Hunt & Watkiss, 2011; Linnekamp *et al.*, 2011; Jha *et al.*, 2012; Berggren *et al.*, 2013; Hall *et al.*, 2014).

For rainfall factor, point daily annual maximum rainfall data for 32 years (1984-2015) collected at ten stations (Ambo Plant Protection Research Center, Ginchi, Asgori, Busa, Gedo, Jeldu, Tikur Enchini, Tulu Bolo, WelenKomi, and Woliso) within and around the watershed were received from the Ethiopian Metrology agency (Figure 3.6). As the data received were daily annual maximum rainfall at each station, mean of 32 years (1984-2015) for each station were calculated and then interpolated to Inverse Distance Weight (IDW) in ArcGIS environment. Then it was converted to raster layer to create a continuous raster rainfall data within and around the watershed. This was finally reclassified into five classes using Equal Interval. In this classification, the highest rainfall category was ranked as 5 since it has very high contribution for flooding hazard. On the other hand, the lowest rainfall category is ranked as 1 as it has very low contribution for flooding hazard.

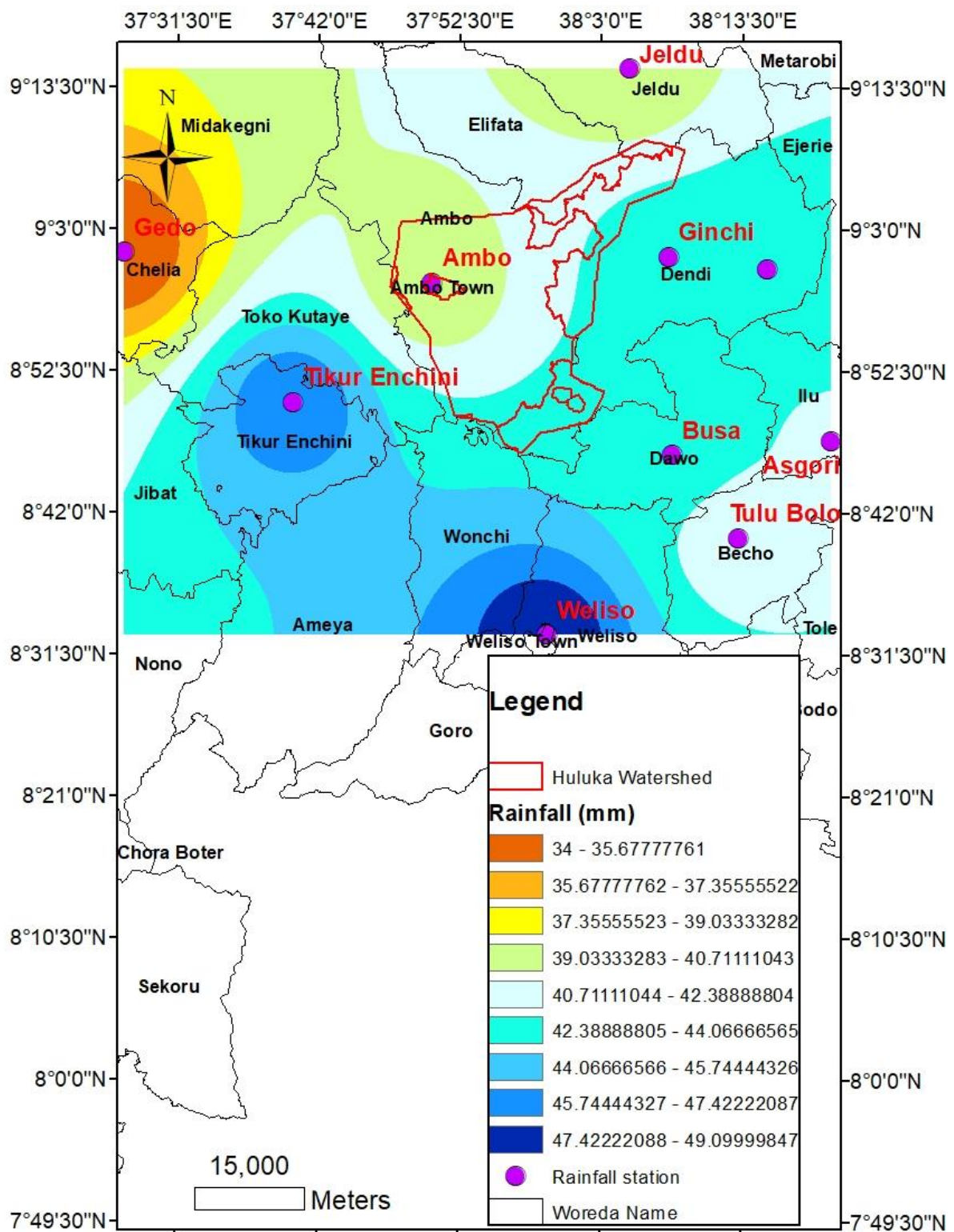


Figure3. 6 Rainfall Stations in and Around Huluka Watershed

3.6.4.2. Flooding Risk Factors

Flood risk of Huluka watershed and Ambo town was analyzed based on the general risk equation (Shook, 1997; Legesse & Gashaw, 2008):

$$\text{Risk} = \text{Hazard} \times \text{Vulnerability} \times \text{Exposure}$$

To analyze flooding risk in Ambo town and its watershed, flooding hazard layer, population density, and land use/land cover type were considered as three important factors. Population density and land use/land cover type were the two elements at risk and vulnerability was assumed to be one. These three factors were considered to be equally important in the weighted overlay process.

1. Population Density Factor: Gross population density calculation method is used to calculate the number of person per square kilometers in the watershed. To this end, the human population estimation for the year 2017 at each village in the watershed was considered. Then population shape file was converted to raster layer using Conversion Tools/Feature to Raster. Then, the data layer was reclassified into five sub-factors which are classified using equal interval scheme and new values were re-assigned in order of increasing number of population that is more susceptible to flood hazard. The population density was reclassified as dense population is more vulnerable to flood risk. Accordingly, the highest population density category is ranked as 5 as it is very highly susceptible to flooding risk. On the other hand, the lowest population density category was ranked as 1 as its susceptibility to flooding risk is very low.

2. Land Use Type Factor: The existing land-use classes of the area (water body, built-up, cultivated land, grass land, and forest) were reclassified into five groups in order of their susceptibility to flooding risk. The land use types of the sub-basin were reclassified into a common scale in order of sensitivity for the flood risk analysis. Accordingly, water body was ranked with the value of 5 as it is very highly susceptible to flooding risk. Built-up area land use/land cover type was ranked with the value of 4 as it is highly susceptible. Cultivated land was ranked with the value of 3 as it is moderately susceptible. Grassland land use/land cover type was ranked with the value of 2 as it has low susceptibility. Forest land use/land cover type was assigned the value of 1 as it has very low susceptibility.

3. Flooding hazard layer: Flooding hazard layer was considered as one of the flooding risk contributing factor in Ambo town’s watershed. Very low, low, moderate, high, and very high flooding hazard classes were reclassified based on their susceptibility to flooding risk. Figure 3.5 summarizes the work flow for flooding hazard and risk analysis in Huluka watershed.

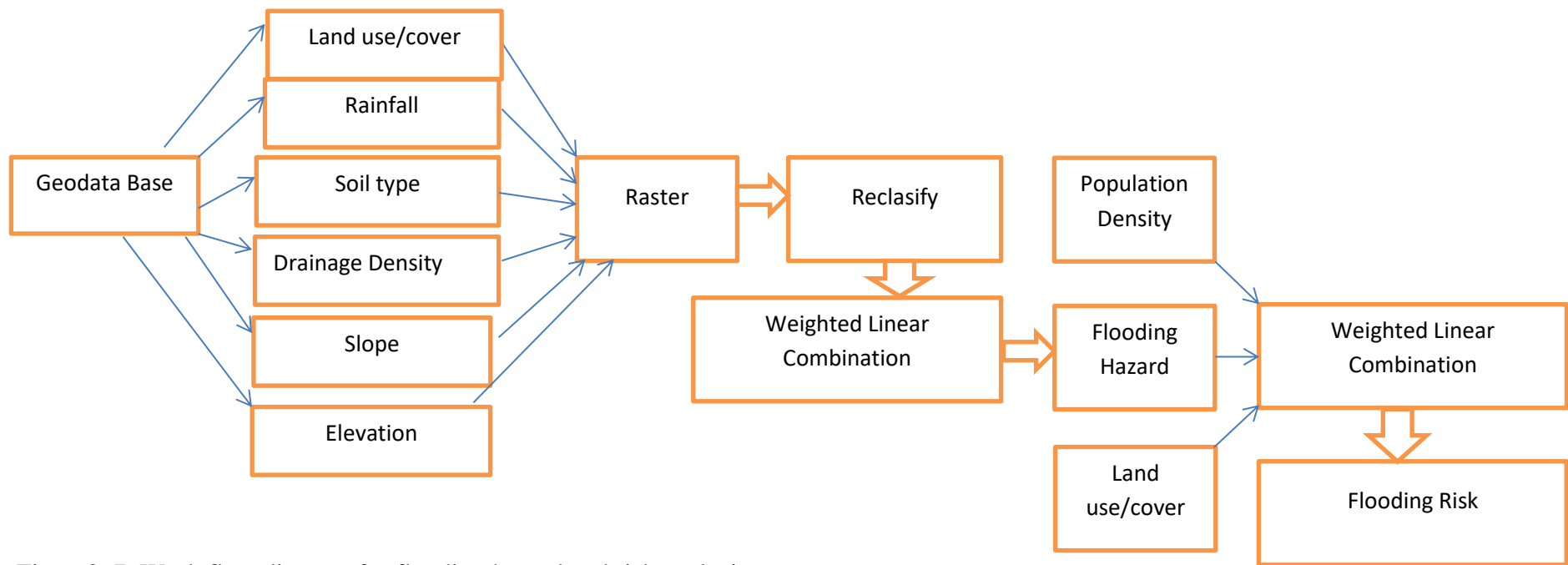


Figure3. 7 Work flow diagram for flooding hazard and risk analysis

(Source: Researcher's elaboration, 2021).

3.6.4.3. Integration of Analytical Hierarchy Process (AHP) into Geographic Information Systems (GIS)

This study employed the Geographic Information Systems (GIS)-based multicriteria analysis approach (Wang *et al.*, 2011; Zou *et al.*, 2013; Gigović *et al.*, 2017; Rimba *et al.*, 2017) to analyze flood hazard and risk in Ambo town and its watershed. GIS is affirmed to provide more and better information about decision making situations as it allows the decision maker to identify and list a predefined set of criteria with the overlay process. Multi-criteria decision analysis within GIS is used to develop and evaluate alternative plans that facilitates compromise among interested parties (Chibssa, 2007; Chen *et al.*, 2011; Gyekye, 2011; Adedeji *et al.*, 2012; Mmom & Ayakpo, 2014; Ouma & Tateishi, 2014; Sepehri *et al.*, 2015; Boudou *et al.*, 2016). GIS is affirmed to be very much helpful in flood analyses as it helps generate a visualization of flooding and creates potential to further analyze these events to estimate probable damage due to floods. More importantly it assists in enabling the comparisons across spatial units; comparison across different themes by category of hazards and disasters; and integrating qualitative assessment and spatial database (Levy, 2005; Meyer *et al.*, 2009; Youssef *et al.*, 2011; Bathrellos *et al.*, 2012; Stefanidis & Stathis, 2013; Ouma & Tateishi, 2014).

It is asserted that flood risk evaluation is an intrinsically complex multidimensional process including both quantitative and qualitative factors which may be uncertain (Yang *et al.*, 2013). Analytic hierarchy process established by Saaty is attested to be a method to solve multiple criteria decision problems by setting their priorities. Analytical hierarchy process (AHP) was adopted for multicriteria decisions in urban flooding hazard and risk analysis (Yahaya *et al.*, 2010; Chowdary *et al.*, 2013; Li *et al.*, 2013; Guo *et al.*, 2014; Rimba *et al.*, 2017). Saaty (1977) affirm that multiple pairwise comparisons are based on a standardized comparison scale of nine levels in AHP. The nine points are claimed to be chosen as psychologists are asserted to conclude that, nine objects are the most that an individual can simultaneously compare and consistently rank (Table 3.4). Pairwise judgements are claimed to be made based on the best information available and the decision maker's knowledge and experience (Chen *et al.*, 2011; Dang *et al.*, 2011; Youssef *et al.*, 2011; Bathrellos *et al.*, 2012; Ouma & Tateishi, 2014; Gigović *et al.*, 2017).

Table3. 4 Nine-point Pair wise comparison scale

Intensity of Importance	Definition	Explanation
1	Equal importance	Two elements are believed to contribute equally
3	Moderate importance	Experience and judgment are believed to slightly favor one parameter over another
5	Strong importance	Experience and judgment are believed to strongly favor one parameter over another
7	Very strong importance	One parameter is believed to be favored very strongly and is considered superior to another; its dominance is believed to be demonstrated in practice
9	Extreme importance	The evidence favoring one parameter as superior to another believed to be of the highest possible order of affirmation

Note: 2,4,6,8 can be used to express intermediate values, 1.1, 1.2, etc. for parameters that are very close in importance.

Source: (Saaty 1977).

It is affirmed that the process of AHP can be summarized in four steps: constructing the decision hierarchy; determining the relative importance of attributes and sub-attributes; evaluating each alternative and calculating its overall weight with regard to each attribute, and checking the consistency of the subjective evaluations (Bathrellos *et al.*, 2012; Yang *et al.*, 2013; Ouma & Tateishi, 2014).

To construct the decision hierarchy, $C = \{C_j | j = 1, 2, \dots, n\}$ is claimed to be the set of criteria. The result of the pairwise comparison on n criteria is claimed to be summarized in an $(n \times n)$ evaluation matrix A in which every element a_{ij} ($i, j = 1, 2, \dots, n$) is the quotient of weights of the criteria, as given in Equation (4) (Ouma & Tateishi, 2014):

$$A = \begin{bmatrix} a_{11} & a_{12} & \cdot & a_{1n} \\ a_{21} & a_{22} & \cdot & a_{2n} \\ \cdot & \cdot & \cdot & \cdot \\ a_{n1} & a_{n2} & \cdot & a_{nn} \end{bmatrix}, a_{ii} = 1, a_{ji} = 1/a_{ij}, a_{ij} \neq 0 \dots\dots\dots 6$$

The right eigen value (w) corresponding to the maximum eigen value (λ_{max}) is claimed to be calculated to normalize and find the relative weight (Aw) of the matrix by following equation (5) (Ouma & Tateishi, 2014):

$$A_w = \lambda_{max} w \dots\dots\dots 7$$

It is affirmed that it is highly recommended that the pairwise comparisons in AHP are completely consistent and in this case the matrix A has rank 1 and $\lambda_{max} = n$. In this case, weights can be obtained by normalizing any of the rows or columns of the matrix A). The quality of the output of the AHP is claimed to be strictly related to the consistency of the pairwise comparison judgments. The consistency is normally asserted to be defined by the relation between the entries of A: $a_{ij} \times a_{jk} = a_{ik}$. The consistency index (CI) is given by Equation (6) (Ouma & Tateishi, 2014):

$$CI = (\lambda_{max} - n)/(n - 1) \dots\dots\dots 8$$

Where λ_{max} represents the sum of the products between the sum of each column of the comparison matrix and the relative weights and n represents the size of the matrix.

The final calculation is the consistency ratio (CR) which is the ratio of the CI and random index (RI) as expressed in equation (7):

$$CR = CI/RI \dots\dots\dots 9$$

Where CI is claimed to represent the consistency index, RI is the random index representing the consistency of a randomly generated pairwise comparison matrix. It is attested to be derived as average random consistency index, computed by Saaty (1980). CR represent consistency ratio.

The values of RI are tabulated in table 3.6 and RI value for six parameters is 1.24 (Saaty, 1980). The maximum threshold of CI is affirmed to be ≤ 0.1 and $CR \leq 10\%$. The usage of CR unperpins the rational decision of the user about the consistency of the evaluation.

Table3. 5 Random index (RI) for Consistency ratios (CR) Calculation.

N	1	2	3	4	5	6	7	8	9	10
Random Index(RI)	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

Source: (Saaty, 1980).

Table3. 6 Ranking of flood hazard contributing factors in Huluka watershed

Flood Hazard Factors	Land Cover (LC)	Slope (S)	Soil Type (ST)	Rainfall (RF)	Drainage Density(DD)	Elevation (E)
Land Cover	1	3	3	5	7	8
Slope	0.33	1	3	3	5	6
Soil Type	0.33	0.33	1	3	3	5
Rainfall	0.2	0.33	0.33	1	3	5
Drainage Density	0.14	0.2	0.33	0.33	1	3
Elevation	0.13	0.16	0.2	0.2	0.33	1
Total	2.13	5.02	7.86	12.53	19.33	28

λ_{max} is claimed to represent the sum of the products between the sum of each column of the Comparison matrix and the relative weights.

Source: (Based on Experts' and local residents' interview, 2019).

The normalized pair-wise comparison matrix for this evaluation was derived by making equal to 1 the sum of the entries on each column. Finally, the objective weight of each factor was built by averaging the entries on each row (Table 3.7). The basic advantage claimed is that the AHP limits the cognitive demand on the decision maker and provides an approach for checking the consistency of the comparisons. It is asserted that the consistency ratio (CR) is used in order to check inconsistency and limit the possibility of random selection during the construction of the comparison matrix (Bathrellos *et al.*, 2012; Ouma & Tateishi, 2014).

Table 3. 7 Weighted Comparison table

Flood Hazard Factors	Land Cover (LC)	Slope (S)	Soil Type (ST)	Rainfall (RF)	Drainage Density(DD)	Elevation (E)	Priority Vector X	Percent
Land Cover	0.5	0.6	0.38	0.39	0.36	0.29	0.42	42%
Slope	0.1	0.2	0.38	0.24	0.26	0.21	0.23	23%
Soil Type	0.1	0.07	0.13	0.24	0.16	0.18	0.15	15%
Rainfall	0.1	0.07	0.042	0.08	0.16	0.18	0.1	10%
Drainage Density	0.1	0.04	0.042	0.03	0.05	0.11	0.06	6%
Elevation	0.1	0.03	0.03	0.02	0.02	0.04	0.04	4%
Total	1	1	1	1	1	1	1	100%

The natural values were normalized by adding the column values and dividing the value of each cell by the total of column values.

Source: (Weighted Comparison Based on Experts' and local residents' interview, 2019)

λ_{max} for Flood contributing factors in the watershed=

$$2.13 \times 0.42 + 5 \times 0.23 + 7.9 \times 0.15 + 12.5 \times 0.1 + 19 \times 0.06 + 28 \times 0.04 = 6.4$$

$$CR = CI/RI; CI = \lambda_{max} - n / n - 1$$

RI = Random consistency index and RI=1.24 for six factors (Table 3.6).

N = Number of criteria=6

λ_{max} is claimed to represent the sum of the products between the sum of each column of the comparison matrix and the relative weights. CR for the flood contributing factors in Ambo town's watershed is 0.06 which is less than the standard 0.1. Hence, the pair-wise matrix ranking is accepted as the evaluation is sufficiently consistent.

To calculate the weight and ranking in each factor, the pairwise comparison matrix and factor map were employed. Accordingly, the weight value provided the prioritized factor expressed as a percentage value between 0 and 100%. Using a linear weighted combination, the sum of weight was expressed as 100%. A summary of targeted factors, their weights and rankings are listed in Table 3.9. The information provided in the table was applied to generate the flooding hazard map in Ambo town's watershed. The ranking of each reclassified factor was based on the literature review, expert interview and local residents' interview. The range of ranking was 1 to 5; the highest influencing factor was rank 5 and the lowest influencing factor was 1. The order of normalized weight was land cover (42%), slope (23%), soil type (15%), rainfall (10%), drainage density (6%), and elevation (4%). Looking at the weight of

each factor, one can see that land cover has the highest weight. It implies that land cover has more contribution to flooding than other factors in Ambo town's watershed.

Table3. 8 Weighted flooding hazard ranking

Parameters	Relative Weight	Reclassified Parameter	Ranking	Hazard
Slope (Degree)	23%	26.04-32.55	1	Very low
		19.53-26.04	2	Low
		13.02-19.53	3	Moderate
		6.51-13.02	4	High
		0-6.51	5	Very high
Elevation (Meters)	4%	2969-3253	1	Very low
		2685-2969	2	Low
		2402-2685	3	Moderate
		2118-2402	4	High
		1834-2118	5	Very high
Rainfall (mm)	10%	39-39.89	1	Very low
		39.89-40.78	2	Low
		40.78-41.67	3	Moderate
		41.67-42.56	4	High
		42.56-43.45	5	Very high
Drainage Density (km/Km ²)	6%	11.04-13.8	1	Very low
		8.28-11.04	2	Low
		5.52-8.28	3	Moderate
		2.76-5.52	4	High
		0-2.76	5	Very high
Soil Type	15%	Eutric Cambisols	1	Very low
		Eutric Nitisols	2	Low
		Orthic and Chromic Luvisols	3	Moderate
		Leptosols	4	High
		Pellic and Chromic Vertisols	5	Very High
Land use/Land Cover	42%	Forest	1	Very low
		Grassland	2	Low
		Cultivated land	3	Moderate
		Built-up area	4	High
		Water Body	5	Very high

Source: (Based on Experts' and local residents' interview, 2019 and literature review, 2019)

Once the weight in each factor was determined, the multi-criteria analysis was performed to produce a flooding hazard map by using the GIS approach. In other words, weighted linear combination (WLC) method was employed in the process of criteria map aggregation. The underpinning reason for employing WLC is that low scores in one criterion are compensated by high scores in another one in the process of aggregating the criteria flooding hazard maps. In other words, the weighted linear combination (WLC) method multiplies each fuzzy standardized criteria map with criteria weights, obtaining different variations from the AHP method, and then sums the results (Bathrellos *et al.*, 2012; Gigović *et al.*, 2017). Accordingly, flooding hazard map for the watershed was computed as shown in equation (10):

$$\text{Flooding hazard Index} = 0.42 \times \text{land use/land cover} + 0.23 \times \text{slope} + 0.15 \times \text{soil type} + 0.1 \times \text{rainfall} + 0.06 \times \text{drainage density} + 0.04 \times \text{elevation}$$

.....10

The result was the flooding hazard area in the watershed. It was categorized into five hazard classes: very low, low, moderate, high, and very high.

To compute the flooding risk map for Ambo town’s watershed, a weight linear combination was applied as shown in equation (11):

$$\text{Flooding risk Index} = 0.3333 \times \text{flooding hazard} + 0.3333 \times \text{population density (person per square kilometers)} + 0.3333 \times \text{land use/land cover}$$

.....11

Flood risk analysis and mapping for the watershed was done using the flooding hazard layer and the two elements at risk (population and land use/land cover) (Wondim, 2016). These three factors were considered to be equally important in the weighted linear combination (WLC) process. A summary of targeted factors, their weights and rankings are listed in Table 3.9. The information provided in the table was applied to generate the flooding risk map in the watershed. The result was the flooding risk area in the watershed. It was categorized into five risk classes: very low, low, moderate, high, and very high.

Table3. 9 Weighted flooding risk ranking

Parameters	Relative Weight	Reclassified Parameter	Ranking	Hazard
Flooding hazard Classes	33.33%	Very low	1	Very low
		Low	2	Low
		Moderate	3	Moderate
		High	4	High
		Very high	5	Very high
Population Density(Person/Sq.km)	33.33%	0-58	1	Very low
		58-161	2	Low
		161-209	3	Moderate
		209-1846	4	High
		1846-6596	5	Very high
Land use/Land Cover	33.33%	Forest	1	Very low
		Grassland	2	Low
		Cultivated land	3	Moderate
		Built-up area	4	High
		Water Body	5	Very high

3.6.5. Methods of Data Analysis for Establishing Intensity-Duration-Frequency Relationship

Data analysis involved the conversion of maximum daily rainfall data to hourly rainfall data, discussion of the probability distributions, and development of the IDF relationships. The rainfall data for Huluka watershed was based on seven rainfall stations in and around the watershed. They consist of daily rainfall values from 1984 to 2015. The data was processed in order to obtain the maximum rainfall series. The extreme annual rainfall series for seven important rainfall stations are shown in tables 1 to 7. The Indian Meteorological Department (IMD) formula used to convert extreme annual daily rainfall series to shorter duration series (0.5, 1, 2, 3, 6, 12, and 24h series) is given as (Rashid *et al.*, 2012):

$$P_t = P_{24} \left(\frac{t}{24} \right)^{1/3} \dots\dots\dots 12$$

Where **P_t** is the rainfall of **t** hour's duration in mm, **P₂₄** is the daily rainfall value in mm and **t** is the shorter duration in hours (0.5, 1, 2, 3, 6, 12, and 24).

Gumbel's Distribution

This distribution utilizes the Fisher-Tippet extreme value function, which relates magnitude linearly with the logarithm of the reciprocal of the exceedance probability given as (Al-Wagdany, 2020):

$$K_T = \frac{\sqrt{6}}{\pi} \left\{ 0.5772 + \ln \left[\ln \left(\frac{T}{T-1} \right) \right] \right\} \dots\dots\dots 13$$

$$P_T = P_{ave} + K_T S \dots\dots\dots 14$$

$$P_{ave} = \frac{1}{n} \sum_{i=1}^n P_i \dots\dots\dots 15$$

$$S = \left[\frac{1}{n-1} \sum_{i=1}^n (P_i - P_{ave})^2 \right]^{1/2} \dots\dots\dots 16$$

Where **P_T** is the probable rainfall at return period **T**, **P_{ave}** is the mean of the annual maximum rainfall series, **S** is the standard deviation of annual maximum rainfall series, **K_T** is the frequency factor at return period **T**, **P_i** is the annual maximum rainfall series, **T** is the return period and **n** is the number of years of record. The rainfall intensity, **I_T** in mm/hr for the return period **T** is given by (Al-Wagdany, 2020):

$$I_T = \frac{P_T}{T_d} \dots\dots\dots 17$$

Where **T_d** is the duration in hours.

3.6.6. Methods of Data Analysis for Proposing Integrated Urban Flooding Risk Management

The final output of the study was the proposed integrated urban flooding risk management strategy for the watershed and the town. To address this objective a mix of qualitative

methods and quantitative methods of data analysis were employed. While primary data collected through focus group discussion and key informant interview were analyzed through thematic content analysis, quantitative data collected through interview schedule/household survey questionnaire were analyzed through simple descriptive statistics. Moreover, geospatial data were analyzed through spatial analysis function of Arc-GIS. More importantly, the results of all the other objectives were coordinated and integrated to propose effective flood risk management strategy for the study watershed and other small watersheds. Figure 3.6 summarizes the work flow of the study. Furthermore, international and local flood risk management experiences were reviewed and synthesized for the same purpose.

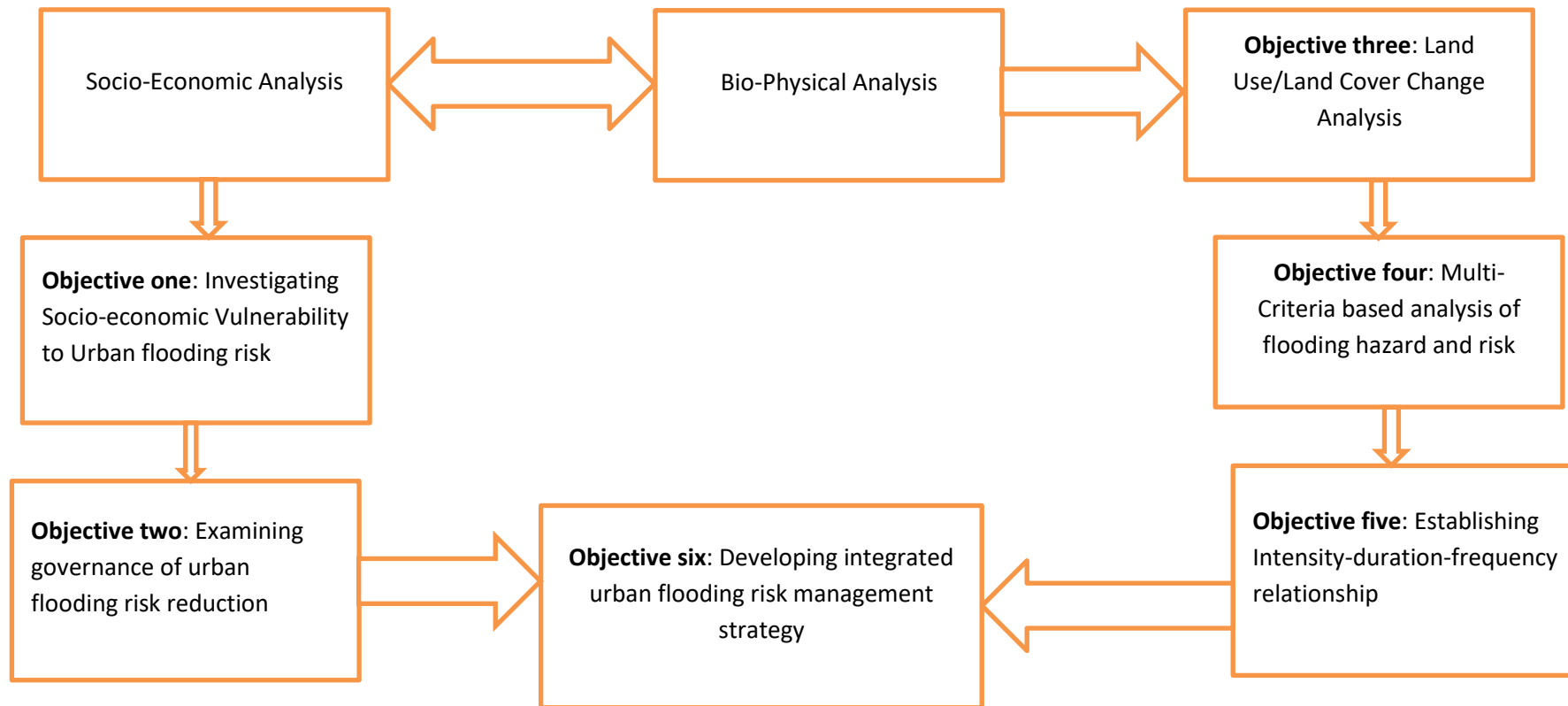


Figure3. 8 Work Flow Diagram of the Study

(Source: Researcher's Elaboration, 2021).

3.7. Ethical Consideration

The author did consider all relevant ethical principles in the research process to maintain the quality of the research work and respect the human rights of the participants of different primary data collection methods.

CHAPTER FOUR: SOCIO-ECONOMIC VULNERABILITY TO URBAN FLOODING RISK IN AMBO TOWN

This chapter presents analysis and discussion on causes of urban flooding risk, effects of urban flooding risk, socio-economic vulnerability of urban flooding risk, and local adaptation strategies of urban flooding risk in Ambo town (Specific objective three).

4.1. Causes of urban flooding disaster risk in Ambo town

Respondents were asked to identify the common type/types of urban flooding in Ambo town. About 68% (n=294) of the respondents identified fluvial, pluvial, and flash flooding as the three common types of urban flooding in Ambo town. 21.8% (n=95), 5.5% (n=24), and 5.1% (n=22) of the respondents identified pluvial flooding, flash flooding, and fluvial flooding respectively as the common type of urban flooding in Ambo town. The aforementioned analysis reveals that fluvial, pluvial, and flash flooding are the three common types of urban flooding perceived by urban households in Ambo town (Table 4.1).

Table4. 1 Perceived types of urban flooding in Ambo town

Sr.No	Type of Urban Flooding	Count	Percentage
1	River/Fluvial Flooding	22	5.1
2	Pluvial/Overland Flooding	95	21.8
3	Flash Flooding	24	5.5
4	Fluvial, Pluvial, and Flash Flooding	294	67.6
5	Total	435	100

Source: Survey, 2015

Respondents were further asked to identify the causes of urban flooding in Ambo town. 49.2% (n=214) of the respondents opined that increased intensity in rainfall during rainy season, inadequate land use and channelization of natural water ways, inflow from the rivers/streams during high stages into urban drainage system, soil erosion generating material that clogs drainage system and inlets, inadequate street cleaning practice that clogs street inlets, and continuing unplanned urban expansion are causes of urban flooding in Ambo town. Only 4.1% (n=18) of the respondents opined that increased intensity of rainfall, continuing unplanned urban expansion, and inadequate channelization of natural water ways are the causes of urban flooding in Ambo town. Only 3.9% (n=17) of the respondents opined that increased intensity in rainfall during rainy season as independent cause of urban flooding in Ambo town. The above analysis reveals that urban flooding in Ambo town is perceived by

more proportion of respondents in Ambo town to be caused by the aforementioned multiple factors (Table 4.2; Figure 4.1). Personal observation, key informant interview, and focus group discussions administered also reveal that urban flooding is caused by multiple factors and it should not be associated with any single factor.

Table4. 2 Perceived Causes of Urban Flooding in Ambo Town

Sr. No	Cause	Count	Percentage
1	Increased Intensity in Rainfall During Rainy Season	17	3.9
2	Inadequate land use and channelization of natural water ways	83	19.1
3	Inflow from the rivers/streams during high stages into urban drainage system	23	5.3
4	soil erosion generating material that clogs drainage system and inlets	32	7.4
5	Inadequate street cleaning practice that clogs street inlets	25	5.7
6	continuing unplanned urban expansion	23	5.3
7	Increased intensity of rainfall, continuing unplanned urban expansion, and inadequate channelization of natural water ways	18	4.1
8	All*	214	49.2
9	Total	435	100

All:* Increased intensity in rainfall during rainy season, inadequate land use and channelization of natural water ways, inflow from the rivers/streams during high stages into urban drainage system, soil erosion generating material that clogs drainage system and inlets, inadequate street cleaning practice that clogs street inlets, and continuing unplanned urban expansion.



A: Huluka River in August



B: Debis River in August



C: Awaro River in August



D: Boji River in August



E: Taltale River in August



F: Kerise River in August

Figure4. 1 Rivers in Ambo town causing fluvial and flash flooding
(Source: Researcher's personal observation, August, 2015).

4.2. Effects of urban flooding disaster risk in Ambo town

Respondents were asked to identify the negative effects of urban flooding in Ambo town. 50% (n=217) of the respondents opined that loss of human life, flooding of streets, intersections and transportation systems, flooding of streets and transportation systems, damage to public and personal properties, exacerbated health risks in the home and local environment, disrupted infrastructure and access to services like water supply, cleanup demand, adverse effects upon the aesthetics, disturbance of wildlife habitat, and disrupted business activities are the negative effects of urban flooding in Ambo town. Only 0.2% (n=1) of the respondents opined that disturbance of wildlife habitat is the negative effect of urban flooding in Ambo town. This analysis reveals that half of the respondents in Ambo town perceived that urban flooding has multiple negative effects on their livelihoods (Table 4.3). Personal observation, key informant interview, and focus group discussions administered also reveal that urban flooding has multiple negative effects on the livelihoods of urban households in Ambo town (Figure 4.2).

Respondents were further asked to identify the positive effects of urban flooding in Ambo town. 79% (n=343) of the respondents opined that urban flooding has positive effects like Cleaning the town, facilitating sand mining as one livelihood option, facilitating mud-based wall making during rainy season, and promoting flood-based farming as one livelihood option. Only 1.1% (n=5) of the respondents opined that promoting flood-based farming as one livelihood option is the only positive effect of urban flooding in Ambo town. This analysis reveals that majority of the respondents in Ambo town perceived that urban flooding has some positive effects on the livelihoods of urban households in Ambo town (Table 4.4). Personal observation, key informant interview, and focus group discussions administered also reveal that urban flooding has some positive effects on the livelihoods of urban households in Ambo town.

Table4. 3 Perceived negative effects of urban flooding disaster risk in Ambo town

Sr. No	Negative effects	Count	Percentage
1	Loss of human life	5	1.1
2	Flooding of streets, intersections and transportation systems	31	7.1
3	Flooding of streets and transportation systems	24	5.5
4	Damage to public and personal properties	77	17.7
5	Exacerbating health risks in the home and local environment	43	9.9
6	Disrupting infrastructure and access to services like water supply	32	7.4
7	Cleanup demand	1	0.2
8	Disturbance of wildlife habitat	1	0.2
9	Flooding of housing, damage to properties, health risks, and disrupting infrastructures	2	0.5
10	All*	217	49.9
11	Total	435	100

All: Loss of human life, flooding of streets, intersections and transportation systems, flooding of streets and transportation systems, damage to public and personal properties, exacerbating health risks in the home and local environment, disrupting infrastructure and access to services like water supply, cleanup demand, adverse effects upon the aesthetics, disturbance of wildlife habitat, and disrupting business activities.*



Figure4. 2 Some of the negative effects of urban flooding in Ambo town

(Source: Researcher's personal observation, August, 2015).

Table4. 4 Perceived Positive effects of urban flooding

Sr.No	Positive effects of urban flooding	Count	Percentage
1	Cleaning the town	48	11.0
2	Facilitates sand mining	17	3.9
3	Facilitates mud-based wall making	22	5.1
4	Promote flood based urban farming	5	1.1
5	Cleaning the town, facilitates sand mining, facilitates mud-based wall making, and promotes flood-based farming	343	78.9
6	Total	435	100

4.3. Socio-economic vulnerability of urban flooding disaster risk in Ambo town

Respondents were asked to identify much vulnerable groups to urban flooding disaster risk in Ambo town. 77.2% (n=336) of the respondents opined that much vulnerable groups to urban flooding disaster risk in Ambo town include: old persons, children, women, and persons with different abilities. Only 0.2% (n=1) of the respondents opined that only persons with different abilities are much vulnerable group to urban flooding disaster risk in Ambo town (Table 4.5). This analysis reveal that majority of the respondents in Ambo town perceived that the above mentioned social groups are much vulnerable to urban flooding disaster risk in Ambo town.

Respondents were further asked to identify underlying causes of socio-economic vulnerability to urban flooding disaster risk in Ambo town. 73.1% (n=318) of the respondents opined that residing in flood prone area, poverty, lack of alternative livelihoods, and lack of proper drainage channels are the underlying causes of socio-economic vulnerability to urban flooding disaster risk in Ambo town. Only 0.5% (n=2) of the respondents opined that only lack of proper drainage channels is the underlying cause of socio-economic vulnerability (Table 4.6). This analysis reveals that majority of the respondents in Ambo town attribute socio-economic vulnerability to urban flooding disaster risk to the aforementioned multiple factors.

Table4. 5 Much vulnerable Groups to urban flooding disaster risk

Sr.No	Vulnerable groups	Count	Percentage
1	Old persons	12	2.8
2	Children	18	4.1
3	Women	6	4.1
4	women and children	62	14.3
5	Persons with different abilities	1	.2
6	Old persons, children, women, and persons with different abilities	336	77.2
7	Total	435	100

Table4. 6 Underlying causes of vulnerability to urban flooding disaster risk

Sr.No	Vulnerable groups	Count	Percentage
1	Residing in a flood prone area	26	6.0
2	Poverty	58	13.3
3	Lack of alternative livelihoods	31	7.1
4	Lack of proper drainage channels	2	.5
5	Residing in flood prone area, poverty, lack of alternative livelihoods, and lack of proper drainage channels	318	73.1
7	Total	435	100

Respondents were also asked to rate sensitivity of different urban sectors to urban flooding disaster risk in Ambo town. 96.1%, 96.1%, 94.5%, 94.5%, and 94.5% of the respondents rated water supply system, sanitary facilities, health facilities, road facilities, and private and public infrastructures respectively as very highly sensitive to urban flooding disaster risk in Ambo town. Water supply system and Private and public infrastructures (mean=4.91) were identified as the most sensitive urban sectors to urban flooding disaster risk in Ambo town.

Sanitary facilities (mean=4.90) were identified as the second most sensitive urban sector to urban flooding disaster risk in Ambo town. Health facilities and road facilities (mean=4.89) were identified as the third most sensitive urban sectors to urban flooding disaster risk in Ambo town. A grand mean of 4.4 also reveal that all the identified urban sectors are highly sensitive to urban flooding disaster risk in Ambo town (Table 4.7).

In relation to the very high sensitivity of water supply sector to urban flooding disaster risk in Ambo town, respondents were further asked about the circumstances of water used for domestic consumption in Ambo town during urban flooding (rainy season). 92.4% (n=402) opined that water used for domestic consumption in Ambo town has a disturbed state during urban flooding. Only 3% (n=13) of the respondents opined that the water has clear state during the same period. 96.3% (n=419) of the respondents opined that water used for domestic consumption in Ambo town has bad muddy taste during urban flooding. Only 0.5% (n=2) of the respondents opined that the water has bad salty taste during the same period. 92.4% (n=402) of the respondents opined that water used for domestic consumption in Ambo town has bad smell during flooding. Only 7.6% (n=33) of the respondents opined that the water has no bad smell during the same period. 82.5% (n=359) of the respondents opined that they never boil water used for domestic consumption in Ambo town during urban flooding. Only 17.5% (n=76) of the respondents opined that they boil the water during the same period (Table 4.8).

In relation to high sensitivity of different urban sectors to urban flooding disaster risk in Ambo town, respondents were further asked about circumstances of households' solid waste and waste water during urban flooding in Ambo town. 69.9% (n=304) of the respondent opined that they use dust bins and open spaces as the most common solid waste disposal mechanisms in Ambo town. Only 2.1% (n=9) of the respondents opined that they dispose solid waste into the river. 85.5% (n=372) of the respondents opined that no specific sector or organization is charge of collecting households' solid waste in Ambo town. Only 2.1% (n=9) of the respondents opined that community-based organizations are in charge of collecting households' solid waste in Ambo town. Only 4.6% (n=20) of the respondents opined that Ambo town's municipality is in charge of collecting households' solid waste in Ambo town. 93.8% (n=408) of the respondents opined that they dispose their used water/ waste water to open spaces outside their yard. Only 2.8% (n=12) of the respondents opined that they dispose

their waste water/used water into pits in their yard. Only 3.4% (n=15) of the respondents dispose their waste water into drainage channels outside their yard (Table 4.9).

The aforementioned analyses reveal that there is no good household's solid waste and waste water management practices in Ambo town. Moreover, there is no solid waste and waste water management strategy in the town and this exacerbates sensitivity of different urban sectors to urban flooding disaster risk and resulting vulnerability of different social groups in the town. The personal observation, key informant interview, and focus group discussions administered also complement the aforementioned analysis.

Table4. 7 Households' perceived rate of sensitivity of different sectors to urban flooding disaster risk in Ambo town

Sr No	Sectors affected	Perceived rate of sensitivity (%)				Very high	Mean	Relative sensitivity (%)	Rank
		Very low	Low	Mod.	High				
1	Water supply system	0.7	0.7	1.8	0.7	96.1	4.91	15.72	1
2	Sanitary facilities	1.1	0.9	0.7	1.1	96.1	4.90	15.70	2
3	Energy facilities	0.9	0.2	78.6	2.1	18.2	3.36	10.75	5
4	Health facilities	0.7	0.5	2.8	1.6	94.5	4.89	15.60	3
5	Road facilities	0.9	0.2	2.3	2.1	94.5	4.89	15.60	3
6	Education facilities	0.5	0.5	79.3	1.1	18.6	3.37	10.79	4
7	Private and public infrastructures	0.2	0.2	2.3	2.8	94.5	4.91	15.72	1
10	Sum of Mean						31.23	100	
11	Grand Mean						4.4		

Table4. 8 Perceived circumstances of water used for domestic consumption during urban flooding

Variables	Frequency (n=435)	Percentage (%)
The State of water used		
Clear	13	3.0
Turbid	402	92.4
With suspended matter	20	4.6
Taste of water used		
Good soft	14	3.2
Bad Salty	2	0.5
Bad muddy taste	419	96.3
Bad Smell of water used		
Yes	402	92.4
No	33	7.6
Boiling of water used		
Yes	76	17.5
No	359	82.5

Source: Survey, 2015

Table4. 9 Perceived circumstances of households' solid waste and waste water during urban flooding in Ambo town

Variables	Frequency (n=435)	Percentage (%)
solid waste disposal mechanism		
Dust bins	14	3.2
Into the river	9	2.1
Open spaces	91	20.9
Land fills	17	3.9
Dust bins and open spaces	304	69.9
Persons or organizations in charge of collecting households' solid waste		
Town's municipality	20	4.6
Private waste collectors	34	7.8
community based organizations	9	2.1
No one is in charge	372	85.5
Households' disposal mechanism for used water		
Disposed to open spaces outside our yard	408	93.8
Disposed to drainage channel outside our yard	15	3.4
Disposed to pit in our yard	12	2.8

Source: Survey, 2015

Cross-tabulation was employed further to investigate the relationship between member of family contracting disease associated with the after-effect of urban flooding and characteristics of respondents. Accordingly, the relationship between the aforementioned variable and different characteristics of respondents were presented in the following tables.

Table4. 10 Relationship between total annual household income and contracting disease

Total Annual Household Income by Category	Member of family contracting disease associated with the after-effect of urban flooding				Total	
	Yes		No		Count	Percent
	Count	Percent	Count	Percent	Count	Percent
< 5000 Ethiopian Birr	13	30.2	30	69.8	43	100
5001-10000	9	11.8	67	88.2	76	100
10001-30000	42	40	63	60	105	100
30001-50000	2	2.2	87	97.8	89	100
50001-100000	8	8	92	92	100	100
> 100000 Ethiopian Birr	1	4.6	21	95.5	22	100
Total	75	17.2	360	82.8	435	100

$\chi^2=67.25$; $df=5$; $P=.000$

A chi-square test was employed to investigate a relationship between member of family contracting disease associated with the after-effect of urban flooding and total annual household income of respondents. 82.8% (n=360) of the respondents responded to no answer while only 17.2 % (n=75) responded to yes answer. A chi-square test ($\chi^2=67.25$; $df=5$; $P<0.05$) indicated that there is a statistically significant difference among different income groups in contracting disease associated with the after-effect of urban flooding (Table 4.10). This imply that strategic interventions are required to improve income of households to enable them adapt to urban flooding risk in the study area.

Table4. 11 Relationship between age of respondents and contracting disease

Age Category of Respondent	Member of family contracting disease associated with the after-effect of urban flooding				Total	
	Yes		No		Count	Percent
	Count	Percent	Count	Percent		
18-30 Years of Age	6	12	44	88	50	100
31-50 Years of Age	31	13.5	199	86.5	230	100
>50 Years of Ag	38	24.5	117	75.5	155	100
Total	75	17.2	360	82.8	435	100

$\chi^2=9$; $df=2$; $P=.01$

A chi-square test was employed to investigate a relationship between member of family contracting disease associated with the after-effect of urban flooding and age of respondents. 82.8% (n=360) of the respondents responded to no answer while only 17.2 % (n=75) responded to yes answer. A chi-square test $\chi^2=9$; $df=2$; $P<0.05$) indicated that there is a statistically significant difference among different age groups in contracting disease associated with the after-effect of urban flooding (Table 4.11). This implies that strategic interventions are required in protecting more vulnerable age groups at the time of urban flooding risk.

Table4. 12 Relationship between family size of respondents and contracting disease

Family Size by Category	Member of family contracting disease associated with the after-effect of urban flooding				Total	
	Yes		No		Count	Percent
	Count	Percent	Count	Percent		
< 3	5	9.3	49	90.7	54	100
3-7	54	15.8	288	84.2	342	100
8-10	14	37.8	23	62.2	37	100
> 10	2	100	0	0	2	100
Total	75	17.2	360	82.8	435	100

$\chi^2=23.52$; $df=3$; $P=.000$

A chi-square test was employed to investigate a relationship between member of family contracting disease associated with the after-effect of urban flooding and family size of respondents. 82.8% (n=360) of the respondents responded to no answer while only 17.2 % (n=75) responded to yes answer. A chi-square test ($\chi^2=23.52$; $df=3$; $P<0.05$) indicated that there is a statistically significant difference among different family size categories in contracting disease associated with the after-effect of urban flooding (Table 4.12). This implies that strategic interventions are required in protecting vulnerable families at the time of urban flooding risk.

Table4. 13 Relationship between education level of respondents and contracting disease

Level of education by category	Member of family contracting disease associated with the after-effect of urban flooding				Total	
	Yes		No		Count	Percent
	Count	Percent	Count	Percent	Count	Percent
No education	11	42.3	15	57.8	26	100
Non-formal education	25	40.3	37	59.7	62	100
Primary education	16	23.2	53	76.8	69	100
Secondary education	11	22.9	37	77.1	48	100
College education	1	3.4	29	96.7	30	100
Bachelor degree education	9	5.6	153	94.4	162	100
Masters	2	5.5	34	94.4	36	100
PhDs	0	0	2	100	2	100
Total	75	17.2	360	82.8	435	100

$\chi^2=60.82$; $df=7$; $P=.000$

A chi-square test was employed to investigate a relationship between education level of respondents and contracting disease associated with the after-effect of urban flooding. 82.8% (n=360) of the respondents responded to no answer while only 17.2 % (n=75) responded to yes answer. A chi-square test ($\chi^2=60.82$; $df=7$; $P<0.05$) indicated that there is a statistically significant difference among different education level categories of respondents in contracting disease associated with the after-effect of urban flooding (Table 4.13). This implies that strategic interventions are required in improving education level of respondents.

Table4. 14 Relationship between ownership details of residential houses of respondents and contracting disease

Ownership Details of Residential House	Member of family contracting disease associated with the after-effect of urban flooding				Total	
	Yes		No		Count	Percent
	Count	Percent	Count	Percent		
Owner	69	22.3	241	77.7	310	100
Private rented	5	6.3	75	93.8	80	100
Government rented	1	2.3	44	97.8	45	100
Total	75	17.2	360	82.8	435	100

$\chi^2=19.36$; $df=2$; $P=.000$

A chi-square test was employed to investigate a relationship between ownership details of residential homes of respondents and contracting disease associated with the after-effect of urban flooding. 82.8% (n=360) of the respondents responded to no answer while only 17.2 % (n=75) responded to yes answer. A chi-square test ($\chi^2=19.36$; $df=2$; $P<0.05$) indicated that there is a statistically significant difference among different residential home groups in contracting disease associated with the after-effect of urban flooding (Table 4.14). This implies that strategic interventions are required in protecting residential homes from urban flooding risk.

Table4. 15 Relationship between employment status of respondents and contracting disease

Employment status of respondent	Member of family contracting disease associated with the after-effect of urban flooding				Total	
	Yes		No		Count	Percent
	Count	Percent	Count	Percent		
Employed	12	4.7	213	83.5	255	100
Self-employed	11	13.8	69	86.3	80	100
Dependent	0	0	13	100	13	100
Retired officer	1	16.7	5	83.4	6	100
Farmer	51	54.3	43	45.7	94	100
Labor work	0	0	17	100	17	100
Total	75	17.2	360	82.8	435	100

$\chi^2=119.55$; $df=5$; $P=.000$

A chi-square test was employed to investigate a relationship between employment status of respondents and contracting disease associated with the after-effect of urban flooding. 82.8% (n=360) of the respondents responded to no answer while only 17.2 % (n=75) responded to yes answer. A chi-square test ($\chi^2=119.55$; $df=5$; $P<0.05$) indicated that there is a statistically significant difference among different employment status categories in contracting disease associated with the after-effect of urban flooding (Table 4.15). This implies that strategic interventions are required in improving employment status of respondents in the study area.

Table4. 16 Relationship between nature of floor of residential home and contracting disease

Nature of Floor of Residential Home	Member of family contracting disease associated with the after-effect of urban flooding				Total	
	Yes		No		Count	Percent
	Count	Percent	Count	Percent		
Concrete	12	4.7	245	95.3	257	100
Earthen	63	35.4	115	64.6	178	100
Total	75	17.2	360	82.8	435	100

$\chi^2=69.57$; $df=1$; $P=.000$

A chi-square test was employed to investigate a relationship between nature of floor of residential home and contracting disease associated with the after-effect of urban flooding. 82.8% (n=360) of the respondents responded to no answer while only 17.2 % (n=75) responded to yes answer. A chi-square test ($\chi^2=69.57$; $df=1$; $P<0.05$) indicated that there is a statistically significant difference between residential homes with concrete and earthen floor in contracting disease associated with the after-effect of urban flooding (Table 4.16). This implies that strategic interventions are required in improving floor of residential homes in the study area.

Given the importance of credit in adaptive capacity of households in adapting to urban flooding risk, relationship between respondents’ access to credit and characteristics of respondents was further investigated. Accordingly, relationship between access to credit and education level, annual income of respondents, employment status, building materials used for walls, and nature of floor of residential home.

Table4. 17 Relationship between education level and access to credit

Category of education level	Respondents' access to credit				Total	
	Yes		No		Count	Percent
	Count	Percent	Count	Percent	Count	Percent
No education	0	0	26	100	26	100
Non-formal education	1	1.6	61	98.4	62	100
Primary education	0	0	69	69	69	100
Secondary education	1	2.1	47	97.9	48	100
College education	3	10	27	90	30	100
Bachelor degree education	16	9.9	146	90.1	162	100
Masters	7	19.4	29	80.6	36	100
PhDs	0	0	2	100	2	100
Total	28	6.4	407	93.6	435	100

$\chi^2=24.51$; $df=7$; $P=.001$

A chi-square test was employed to investigate a relationship between education level of respondents and their access to credit. 93.6% (n=407) of the respondents responded to no answer while only 6.4 % (n=28) responded to yes answer. A chi-square test ($\chi^2=24.51$; $df=7$; $P<0.05$) indicated that there is a statistically significant difference among different education level categories of respondents in their access to credit in the study area (Table 4.17).

Table4. 18 Relationship between total annual income and access to credit

Total annual income of respondents	Respondents' access to credit				Total	
	Yes		No		Count	Percent
	Count	Percent	Count	Percent	Count	Percent
< 5000 Ethiopian Birr	0	0	43	100	43	100
5001-10000	0	0	76	100	76	100
10001-30000	2	1.9	103	98.1	105	100
30001-50000	6	6.7	83	93.3	89	100
50001-100000	18	18	82	82	100	100
> 100000 Ethiopian Birr	2	9.1	20	90.9	22	100
Total	28	6.4	407	93.6	435	100

$X^2=34.24$; $df=5$; $P=0.000$

A chi-square test was employed to investigate a relationship between total annual household income of respondents and their access to credit. 93.6% (n=407) of the respondents responded to no answer while only 6.4 % (n=28) responded to yes answer. A chi-square test (34.24; df=5; P<0.05) indicated that there is a statistically significant difference among different income categories of respondents in their access to credit in the study area (Table 4.18).

Table4. 19 Relationship between employment status of respondents and access to credit

Employment status of respondent	Respondents' access to credit				Total	
	Yes		No		Count	Percent
	Count	Percent	Count	Percent		
Employed	26	11.6	199	88.4	225	100
Self-employed	1	1.3	79	98.8	80	100
Dependent	0	0	13	100	13	100
Retired officer	0	0	6	100	6	100
Farmer	1	1.1	93	98.9	94	100
Labor worker	0	0	17	100	17	100
Total	28	6.4	407	93.6	435	100

$X^2=20.35$; $df=5$; $P=.001$

A chi-square test was employed to investigate a relationship between total annual household income of respondents and their access to credit. 93.6% (n=407) of the respondents responded to no answer while only 6.4 % (n=28) responded to yes answer. A chi-square test ($X^2=20.35$; $df=5$; $P<0.05$) indicated that there is a statistically significant difference among different employment status categories in their access to credit in the study area (Table 4.19).

Table4. 20 Relationship between building materials for wall and access to credit

Building materials used for walls	Respondents' Access to Credit				Total	
	Yes		No		Count	Percent
	Count	Percent	Count	Percent		
Stones	2	40	3	60	5	100
Bricks	5	41.7	7	58.4	12	100
Wood and Mud	21	5	397	95	418	100
	28	6.4	407	93.6	435	100

$X^2=35.47$; $df=2$; $P=.000$

A chi-square test was employed to investigate a relationship between building materials used for the wall by respondents and access to credit. 93.6% (n=407) of the respondents

responded to no answer while only 6.4 % (n=28) responded to yes answer. A chi-square test ($X^2=35.47$; $df=2$; $P<0.05$) indicated that there is a statistically significant difference among respondents who used different types of building materials in their access to credit in the study area (Table 4.20).

Table 4. 21 Relationship between nature of floor of residential home and access to credit

Nature of Floor of Residential Home	Respondents' access to credit				Total	
	Yes		No		Count	Percent
	Count	Percent	Count	Percent	Count	Percent
Concrete	25	9.7	232	90.3	257	100
Earthen	3	1.69	175	98.3	178	100
Total	28	6.4	407	93.6	435	100

$X^2=11.29$; $df=1$; $P=.001$

A chi-square test was employed to investigate a relationship between nature of floor of residential home and respondents' access to credit. 93.6% (n=407) of the respondents responded to no answer while only 6.4 % (n=28) responded to yes answer. A chi-square test ($X^2=11.29$; $df=1$; $P<0.05$) indicated that there is a statistically significant difference among respondents who used different types of building materials in their access to credit in the study area (Table 4.21).

4.4. Adaptive Capacity of Urban Local Communities and Ambo Town Administration

This section analyzes the factors affecting adaptive capacities of local communities and adaptive capacity of Ambo town administration. To this end, twelve focus group discussions (six male groups and six female groups) were administered with members of urban local communities' development associations in six urban villages with the help of a group discussion checklist.

4.4.1. Adaptive Capacity of Local Communities

Participants were asked to discuss on measures to reduce the vulnerability of the most vulnerable groups, influencing factors for the implementation of these measures, and the capacity of the local communities.

They identified developing adaptive capacity of urban local communities, disseminating information on successful adaptations, improving access to credit and insurance, preventing maladaptation through regulation, enforcing environmental regulations, assessing adaptation needs (including technological needs) through stakeholder engagement, improving access to five capitals, developing alternative livelihood strategies for the urban poor, and relocating vulnerable people as measures that would reduce vulnerability of the groups.

They identified political will and commitment, good governance, awareness of urban flooding disaster risk, willingness of people to move, and availability and affordability of housing in less exposed areas as factors that determine whether the aforementioned measures are taken. They also come to the consensus that these factors can be assessed in order to measure the capacity of the system population to implement these measures.

4.4.2. Adaptive capacity of Ambo Town Administration

Focus group discussions and key informant interview methods were employed to assess the determinants for adaptive capacity of Ambo town to manage urban flooding disaster risk. To this end, participants of focus group discussions and key informants were asked to discuss on five major factors (asset base, institutions and entitlements, flexible forward-looking decision-making and governance, innovation, and knowledge and information) which determine the adaptive capacity at local level (Ambo town).

1. Asset Base

Participants of focus group discussion were asked to discuss on the availability of key assets in Ambo town administration/ municipality that allow the system to respond to evolving circumstances of urban flooding disaster risk. After detail discussion on the issue under investigation, the participants came to the consensus that there are no adequate assets in the town administration/municipality that allow it to respond to evolving circumstances of urban flooding disaster risk. For instance, poor data base and data management was mentioned as

indicator for limited human and physical assets in Ambo town administration/municipality in relation to urban flooding disaster risk management. The key informants from urban planning sector of the town also complement the aforementioned finding. In other words, shortage of assets is one of the constraints for Ambo town to respond to evolving circumstances of urban flooding disaster risk.

2. Institutions and Entitlements

Participants of focus group discussion were also asked to discuss on existence of an appropriate and evolving institutional environment in Ambo town that allows fair access and entitlement to key assets and capitals. After detail discussion on the issue under investigation, the participants came to the consensus that the existing institutional environment in Ambo town does not allow fair access and entitlement to key assets and capitals. Limited participation of community in local projects planning and implementation was mentioned as indicator for lack of an appropriate and evolving institutional environment that allows fair access and entitlement to key assets and capitals in Ambo town administration. Moreover, some industries were claimed to be established in residential areas which are threats to human health. Hence, absence of an appropriate and evolving institutional environment that allows fair access and entitlement to key assets and capitals in Ambo town administration is one of the key constraints for adaptive capacity of Ambo town to respond to urban flooding disaster risk.

3. Flexible Forward-Looking Decision-Making and Governance

Participants of focus group discussion were also asked to discuss on the capacity of current urban flooding disaster risk governance system in Ambo town in relation to anticipating, incorporating, and responding to changes with regard to its governance structures and future planning. After detail discussion on the issue under investigation, the participants came to the consensus that the current governance of urban flooding disaster risk is very poor. Very Poor sanitation and lack of proper sewerage system in the town was mentioned as indicator of governance failure in Ambo town in relation to urban flooding disaster risk. However, participants appreciated current establishment of better urban drainage channels in the inner parts of the town. The key informants from the urban planning sector of the town claimed that the town has better plan to establish proper drainage channels in all urban villages of the town in the years to come.

4. Knowledge and Information

Participants of focus group discussion were also asked to discuss on the capacity of Ambo town administration to have the ability to collect, analyze, and disseminate knowledge and

information in support of urban flooding disaster risk management activities. After detail discussion on the issue under investigation, the participants came to the consensus that Ambo town administration has no capacity to be able to collect, analyze, and disseminate knowledge and information in support of urban flooding disaster risk management activities. Absence of urban disaster management sector in the town administration was mentioned as indicator for the limited capacity of Ambo town administration with regard to the ability to collect, analyze, and disseminate knowledge and information in support of urban flooding disaster risk management activities. The key informants from the urban planning sector of the town claimed that the town has better plan to establish knowledge and information management system which may foster sustainable urban development in the years to come.

5. Innovation

Participants of focus group discussion were also asked to discuss on the capacity of Ambo town administration to create an enabling environment to foster innovation, experimentation, and the ability to explore niche solutions in order to take advantage of new opportunities in urban flooding disaster risk. After detail discussion on the issue under investigation, the participants came to the consensus that Ambo town administration has no capacity to create an enabling environment to foster innovation, experimentation, and the ability to explore niche solutions in order to take advantage of new opportunities in urban flooding disaster risk. Poor management and misuse of urban green areas and spaces were mentioned as one indicator for lack of such capacities in Ambo town administration. The key informants from the urban planning sector of the town claimed that the town has better plan to create an enabling environment to foster innovation and experimentation to result in sustainable management of urban disaster risk in relation to the new sustainable development goals for urban areas.

4.5. Local adaptation strategies of urban flooding disaster risk in Ambo town

Respondents were generally asked about how they cope with the challenges of urban flooding disaster risk in Ambo town. 82.5% (n=359) of the respondents opined that they cope with the challenge of urban flooding disaster risk with the help of existing social capital in urban communities (Table 4.22). Respondents were further asked about the elements of social capital that helped them to cope with the challenges of urban flooding disaster risk. 77.7% (n=338) of the respondents opined that they rely on informal contact and participation in community group as the two vital elements of social capital that helps them cope with the

challenges of urban flooding disaster risk in Ambo town. Only 1.4% (n=6) of respondents opined that applying for monetary assistance to government is the element of social capital that helped them to cope with the challenge of urban flooding disaster risk (Table 4.23).

Respondents were further asked about specific preventive measures at household level to adapt to urban flooding in Ambo town. 73.1% (n=318) opined that they practice preventive investment into yard, preventive investment into house, and preventive cleaning of drainage channel as preventive measures for urban flooding disaster risk in Ambo town. Only 0.2% (n=1) of the respondents opined that they practice preventive investment into yard and preventive cleaning of drainage channel as preventive measures at household level (Table 4.24). Respondents were further asked about specific measures practiced at household level during urban flooding to adapt to urban flooding in Ambo town. 75.4% (n=328) of respondents opined that they practice helping others, piling up furniture, making traditional drainage lines and migrating to safer places as adaptation measures during urban flooding in Ambo town. Only 0.9% (n=4) and 0.9% (n=4) of the respondents opined that migrating to safer places and making traditional drainage lines are adaptation measures during urban flooding in Ambo town (Table 4.25). Respondents were further asked about specific measures practiced at household level after urban flooding to adapt to urban flooding in Ambo town. 69.9% (n=304) opined that they practice Cleaning and repairing homes and cleaning drainage system afterward as adaptation measures after urban flooding in Ambo town. Only 3.2% (n=14) of the respondents opined that they practice no adaptation measures after flooding in Ambo town (Table 4.26). The personal observation, key informant interview, and focus group discussions administered also complement the aforementioned analysis of coping strategies and adaptation measures for urban flooding disaster risk at household level.

Table4. 22 Urban households' coping strategies for urban flooding

Sr.No	Household's coping strategy with urban flooding	Count	Percentage
1	Migrate to safer places	8	1.8
2	Selling of properties to get income	13	3.0
3	Drop out of school to earn income	2	0.5
4	social capital	359	82.5
5	Flood relief from government/agencies	2	0.5
6	Migrate to safer places and social capital	9	2.1
7	No coping strategy	2	0.5
8	Migrate to safer place, selling of properties, and social capital	31	7.1
9	Early warning system	8	1.8
10	Making traditional drainage lines	1	0.2
11	Total	435	100.0

Table4. 23 Element of social capital which helped your household adapt to flooding in Ambo town

Sr.No	Element of social capital	Count	Percentage
1	Informal contact	23	5.3
2	Participation in community group	68	15.6
3	Apply for monetary assistance to government	6	1.4
4	Informal contact and participation in community group	338	77.7
5	Total	435	100.0

Table4. 24 Households' preventive measures to adapt to urban flooding in Ambo town

Sr.No	Households' preventive measures practiced	Count	Percentage
1	Preventive investment into yard	17	3.9
2	Preventive investment into house	21	4.8
3	Preventive cleaning of drainage channel	63	14.5
4	Preventive investment into yard and preventive cleaning of drainage channel	1	0.2
5	Preventive investment into yard, preventive investment into house, and preventive cleaning of drainage channel	318	73.1
6	No prevention measure	15	3.4
7	Total	435	100.0

Table4. 25 Households' adaptation measures practiced during urban flooding in Ambo town

Sr.No	Adaptation measures practiced during flooding	Count	Percentage
1	Helping others	75	17.2
2	Piling up furniture	16	3.7
3	No adaptation measure	8	1.8
4	Migrate to safer places	4	0.9
5	Making traditional drainage lines	4	0.9
6	Helping others, piling up furniture, making traditional drainage lines and migrate to safer places	328	75.4
7	Total	435	100.0

Table4. 26 Households’ adaptation measures practiced after flooding in Ambo town

Sr.No	Adaptation measures practiced after flooding	Count	Percentage
1	Cleaning and repairing homes	36	8.3
2	Cleaning drainage system afterward	81	18.6
3	Cleaning and repairing homes and cleaning drainage system afterward	304	69.9
4	No adaptation measure	14	3.2
5	Total	435	100.0

4.6. Urban Households’ Perceived Climatic Hazards and Adaptation strategies in Ambo Town

4.6.1. Perceived Climatic Hazards in Ambo Town

Participants of the focus group discussion were asked to discuss on climatic hazards in Ambo town. They reported urban flooding disaster risk (Figure 4.3), water stress/water shortage, urban heat island effect/increased urban heat, wind storms, and dust storms as the five critical climate change related disaster risks in Ambo town (Table 4.27).

Table4. 27 Community-based pair-wise ranking chart for climate change related disaster risks in Ambo town

	UF	Water Stress	Wind storms	UHIE	Dust Storms	Score	Rank
Urban Flooding		UF	UF	UF	UF	4	1
Water Stress			WS	WS	WS	3	2
Wind storms				UHIE	WST	1	4
Urban Heat Island Effect					UHIE	2	3
Dust Storms						0	5

UF=Urban Flooding, WS=water stress, WST=Wind Storm, UHIE = Urban Heat Island Effect, DS=Dust storms

Source: Focus Group Discussion, 2013.

The local criteria used in the ranking process were: duration of occurrence, current negative effect of the disaster risk, future negative effect of the disaster risk, severity of the disaster risk, and possibility of planned adaptation to the negative effects of climate change related disaster risk. They also indicated in which months of the year these disaster risks occur in Ambo town (Table 4.28).

Table4. 28 Community-based appraisal of seasonal occurrence of climate change related disaster risks in Ambo town

Climate Hazards	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
Urban Flooding												
Water Stress												
Urban Heat Island Effect												
Wind Storms												
Dust Storms												

Source: Focus Group Discussion, 2013.



Figure4. 3 Some of the negative socio-economic effects of urban flooding risk in Ambo town (Source: Field Observation, July, 2015).

4.6.2. Urban Households strategies to Adapt with Climatic Hazards in Ambo Town

Key informants from Ambo town were asked to explain their personal experience with climate change related disaster risks and their adaptation strategies. Harvesting rainwater during rainy season and fetching water from Huluka River during dry season were reported as adaptation strategies of urban households to adapt to water stress/water shortage. Planting trees around home, growing grasses around home, making traditional urban flooding passage around their home, maintaining and cleaning existing drainage channels with sense of ownership, cleaning their environment, taking appropriate care for their families during flooding season, and paying tax timely to the city administration, putting sand bags in front of their homes, covering ground with plastic sheets at market places, using rubber boots, rain coats, and umbrella during flooding season were reported as adaptation strategies for urban flooding by urban households in Ambo town (Figure 4.4). Using umbrella during hot season, wearing light cloths and shoes during hot season, undertaking livelihood activities under shading of trees, and consuming much cold drinking water were reported as adaptation strategies by urban households in Ambo town to adapt to urban heat island effect/increased urban heat.



Figure4. 4 Some of the autonomous adaptation strategies to urban flooding disaster risk in Ambo town

(Source: Field Observation, July 2015).

4.7. Discussion

Finding of the study reveals that there are three types of flooding identified in Ambo town. With regard to types of flooding in urban environment, scholars identified four different types

of flooding (Few *et al.*, 2004; Douglas & Alam, 2006): localized flooding due to inadequate drainage; flooding from small streams; flooding from major rivers; and coastal flooding from the sea. Localized flooding is claimed to occur many times a year in many informal settlements, because there are few drains (or those that exist are blocked), most of the ground is highly compacted and pathways between dwellings become streams after heavy rain (Few *et al.*, 2004).

Finding of the study reveals that urban flooding disaster risk in Ambo town is attributable to multiple factors. This complies with the assertion of other scholars in urban flooding disaster risk management who assert that urban floods typically stem from a complex combination of causes (Santato *et al.*, 2013). The urban environment is asserted to be subject to the same natural forces as the natural environment and the presence of urban settlements exacerbates the problem. In other words, urban areas are affirmed to be flooded by rivers, coastal floods, pluvial and groundwater floods and artificial system failures (Jha *et al.*, 2012; Fadairo, 2013).

It is affirmed that the two main causes or drivers of flood events are extreme precipitation and increased vulnerability to natural disasters underpinned by growing urban population, environmental degradation and a lack of planning, land management and preparedness (Li *et al.*, 2009; Smith, 2009; WMO, 2012; IPCC, 2007; Cordaid & IIRR, 2011; Santato *et al.*, 2013).

Urban floods are also asserted to be caused by the effects of deficient or improper land use planning (Li *et al.*, 2009; Smith, 2009; Claes *et al.*, 2012; Santato *et al.*, 2013). For instance, many urban areas are attested to face the challenge of increased urbanization with rising populations and high demands for land (Tucci, 2007; Kamal-Chaoui & Robert, 2009; McGranahan *et al.*, 2009). Population growth and settlement pattern related to urbanization is also claimed to be an important factor for urban flooding (Few *et al.*, 2004; Owuor, 2006; Santato *et al.*, 2013). Governance failure is also identified as one of the causes of urban flooding in developing countries (Andjelkovic, 2001).

The finding of the study reveals that urban flooding disaster risk has multiple negative effects on the livelihoods of people and different urban infrastructures. With regard to the negative effects of urban flooding disaster risk, many scholars of urban flooding disaster risk attest that urban flooding poses a serious challenge to development and the lives of people, particularly the residents of the rapidly expanding towns and cities in developing countries (Few *et al.*, 2004; Smith, 2009; Jha *et al.*, 2012).

It is asserted that all types of floods can cause sustained damage to livelihoods, either through the immediate damage and loss of life or through the damage caused by prolonged inundation (Few *et al.*, 2004; Noji, 2005; Smith, 2009; Cordaid & IIRR, 2011; Cosgrave, 2014). Moreover, flooding is affirmed to cause widespread disruption to transportation, power and communication systems, as well as structural damage to buildings and infrastructure (Andjelkovic, 2001; Kolsky & Butler, 2002; Parkinson, 2003; Few *et al.*, 2004; Cordaid & IIRR, 2011).

The finding of the study reveals that poor social groups are more vulnerable to urban flooding disaster risk and there is difference in sensitivity among different urban sectors to urban flooding disaster risk in Ambo town. With regard to vulnerability of the poor social groups to urban flooding disaster risk, scholars of urban flooding disaster risk management affirm that due to the high intensities of rainfall during the rainy seasons, the lack of drainage infrastructure and the failure to maintain existing systems, the impacts of flooding are widespread in the tropical countries and it is the poor who are most susceptible and most vulnerable (Few *et al.*, 2004; Siegrist & Gutscher, 2006; Fadairo, 2013). In other words, the environmental health impacts of flooding are claimed to be compounded in poor communities. The livelihoods of the poor are asserted to be more vulnerable to the risks associated with flooding and are more susceptible to disruption (Few *et al.*, 2004; Sohail *et al.*, 2005). Moreover, the location of poor neighborhoods and the inferior construction materials used to build homes for the poor are asserted to contribute to their greater vulnerability (Parkinson, 2003; Few *et al.*, 2004; Sohail *et al.*, 2005).

The finding of the study reveals that urban households and urban communities in Ambo town adapt to the challenges of urban flooding disaster risk with the help of local adaptation measures. With regard to autonomous local adaptation measures to overcome challenges of urban flooding disaster risk, it is affirmed that urban households and urban communities adapt to urban flooding autonomously (Owuor, 2006; Cordaid & IIRR, 2011). Moreover, they are asserted to have important knowledge and skills which are relevant to be mainstreamed into planned adaptation to urban flooding risk. Smith (2009) asserts that demonstrating cultural sensitivity, and providing responses that demonstrate awareness of social and cultural beliefs and practices is vital in flood risk management. Moreover, scholars affirm that priority should be given to vulnerable groups, in terms of both responses to flooding and disaster risk reduction activities as they are the ones mostly vulnerable and they

have better knowledge and experience both about the urban flooding risk and possible adaptation strategies (Smith, 2009; Owuor, 2006; Cordaid & IIRR, 2011).

Urban land use planning is asserted to play vital role in urban flooding risk management (Zheng & Qi, 2011; Ezemonye & Emeribe, 2014; Früh-Müller *et al.*, 2014; Linnerooth-Bayer *et al.*, 2014; Idris & Dharmasiri, 2015). According to Mngutyo & Ogwuche (2013), Urban land use planning is attested to be concerned with the design and organization of urban space to guide and ensure the orderly development of settlements and communities. In other words, urban land use planning is claimed to become more vital as the society becomes more urbanized, ranging from producing blue print to more strategic approach of structure and local planning (Atedhor *et al.*, 2011; UN-Habitat, 2011; Mngutyo & Ogwuche, 2013; Murtaza *et al.*, 2015; Umezuruike, 2015).

Adaptation planning for water sector is attested to be a planning process of developing institutional and political capacities to ensure adequate water supply and water quality in the face of intensifying risks from climate and climate-related impacts (Nikitina *et al.*, 2010; Sowers *et al.*, 2011; Herrfahrtd-Pähle *et al.*, 2013). Urban adaptation strategies and discourses are encouraged to deal more strongly with processes and the knowledge base on how to improve adaptive capacities and adaptive planning, rather than focusing solely on a list of options to adjust physical structures and the built environment (Björklund *et al.*, 2009; Hardoy & Pandiella, 2009; Birkmann *et al.*, 2010; van Buuren *et al.*, 2014). It is also affirmed that proper management of water demand, improved water use efficiency, and conservation of natural resources are vital for adapting the water sector to climate-induced disasters (Mata & Budhooram, 2007; Luthe *et al.*, 2012; Porthin *et al.*, 2013).

Compared to rural areas, cities are asserted to have higher air and surface temperatures due to the urban heat-island effect: the tendency of cities to retain heat more than their surrounding rural areas (Yow, 2007; UN-Habitat, 2011). By increasing temperatures, urban heat-island effects are asserted to aggravate the heat-related negative implications of climate change and impose costly energy demands on urban systems as they attempt to adapt to higher temperatures. The degree of these effects are claimed not to be uniform across cities. The physical layout of a city, its population size and density, and structural features of the built environment are affirmed to influence the strength of the urban heat-island effect (Yow, 2007; UN-Habitat, 2011; Umezuruike, 2015). It is affirmed that incorporating vegetation in

developed areas, reducing energy consumption, and installing green roofs or rooftop gardens are the best adaptation strategies for urban heat island effect (Yu & Hien, 2006; Zomer *et al.*, 2008; Chen *et al.*, 2013; Demuzere *et al.*, 2014; Laves *et al.*, 2014).

Both wind storm and dust storm may be adapted to properly through the practice of ecosystem-based adaptation both in Ambo town and Huluka watershed. An Ecosystem is affirmed to be the dynamic complex of plant, animal and micro-organism communities and the nonliving environment interacting as a functional unit. It is claimed to assume that people are an integral part of ecosystems (Millennium Ecosystem Assessment, 2005). Ecosystem-based Adaptation (EbA) is encouraged to give vital concern for mainstreaming the use of biodiversity and ecosystem services into climate change adaptation strategy (Niemelä *et al.*, 2010; Oteros-Rozas *et al.*, 2014; EEA, 2015). It is asserted to include the sustainable management, conservation and restoration of ecosystems to provide services that help people adapt to both current climate variability, and climate change (Millennium Ecosystem Assessment, 2005; EEA, 2015). Ecosystem-based Adaptation is attested to reduce vulnerability to both climate and non-climate risks and provides multiple economic, social, environmental and cultural benefits, including: disaster risk reduction, livelihood sustenance and food security, biodiversity conservation, carbon sequestration, and sustainable water management (Colls, *et al.*, 2009; Ngigi, 2009; Ludi, 2009; Vignola *et al.*, 2009; Lantz *et al.*, 2013; Wu *et al.*, 2013).

Mainstreaming adaptation to climate change related disaster risks into urban land use planning and management is asserted to reduce the devastating consequences of unanticipated climate-related disaster risks, including costs that constitute significant drains on resources, thereby stifling the achievement of set goals (Wilson, 2006; Kok *et al.*, 2008; Wilson & Piper, 2008; Yaro *et al.*, 2010; Hurlimann & March, 2012). It is also claimed to ensure that development programs and policies are not at odds with climate risks both now and in the future (Lindley *et al.*, 2007; Huxtable & Yen, 2009; Chinvanno, 2011; Li, 2012).

It is affirmed that there is a growing need for policy-makers, particularly in the ministries related to development such as in finance or planning, to better understand how climate change adaptation can be addressed in national and sub-national/regional planning processes, and through fiscal and investment decisions. For example, when making decisions on long-lived infrastructure, it may be more cost-effective to take adaptation needs into account earlier rather than later (Lebel *et al.*, 2012; Faleiro *et al.*, 2013; Ayers *et al.*, 2014).

Mainstreaming adaptation into urban land use planning and management is asserted to be an effective way to respond to climate change in urban areas and the expected benefits for sustainable urban development in Ambo town include: avoided policy conflicts; reduced risks and vulnerability; greater efficiency compared with managing adaptation separately; leveraging the much larger financial flows in sectors affected by climate risks than the amounts available for financing adaptation separately, and easier to start with existing policies and practices, rather than creating new ones (Huxtable & Yen, 2009; Chinvanno, 2011; Lebel *et al.*, 2012).

CHAPTER FIVE: GOVERNANCE OF URBAN FLOODING RISK REDUCTION IN AMBO TOWN

The aim of this chapter is to examine governance of urban flooding risk reduction and explore its barriers in Ambo town.

5.1. Urban Households' Perceived Governance of Urban Flooding Disaster Risk Reduction in Ambo Town

The current governance of urban flooding disaster risk reduction in Ambo town was evaluated. A grand mean of 1.93 (maximum=5; minimum=1) indicates the overall poor performance of the current governance of urban flooding disaster risk reduction in Ambo town. The results for all the nine variables considered are presented hereunder.

1. Accountability: Respondents were asked to rate the current governance of urban flooding disaster risk reduction in Ambo town from accountability perspective. 47.6 % of the respondents rated the practice of accountability in governing urban flooding disaster risk reduction in Ambo town as very poor. A mean of 1.94 also indicates absence of good governance in current governance of urban flooding disaster risk reduction in Ambo town from the perspective of accountability.

2. Legality: Respondents were asked to rate the current governance of urban flooding disaster risk reduction in Ambo town from legality perspective. 46.2 % of the respondents rated the practice of legality in governing urban flooding disaster risk reduction in Ambo town as very poor. A mean of 1.95 also indicates absence of good governance in current governance of urban flooding disaster risk reduction in Ambo town from the perspective of legality.

3. Impartiality: Respondents were asked to rate the current governance of urban flooding disaster risk reduction in Ambo town from impartiality perspective. 45.3 % of the respondents rated the practice of impartiality in governing urban flooding disaster risk reduction in Ambo town as very poor. A mean of 2.01 also indicates absence of good governance in current governance of urban flooding disaster risk in Ambo town from the perspective of impartiality.

4. Transparency: Respondents were asked to rate the current governance of urban flooding disaster risk in Ambo town from impartiality perspective. 47.1 % of the respondents rated the practice of transparency in governing urban flooding disaster risk reduction in Ambo town as very poor. A mean of 1.91 also indicates absence of good governance in current management of urban flooding disaster risk reduction in Ambo town from the perspective of transparency.

5. Participation: Respondents were asked to rate the current governance of urban flooding disaster risk reduction in Ambo town from participation perspective. 45.7 % of the respondents rated the practice of participation in governing urban flooding disaster risk management in Ambo town as very poor. A mean of 1.94 also indicates absence of good governance in current governance of urban flooding disaster risk in Ambo town from the perspective of participation.

6. Coordination: Respondents were asked to rate the current governance of urban flooding disaster risk reduction in Ambo town from coordination perspective. 45.7 % of the respondents rated the practice of coordination in governing urban flooding disaster risk reduction in Ambo town as very poor. A mean of 1.92 also indicates absence of good governance in current management of urban flooding disaster risk in Ambo town from the perspective of coordination.

7. Effectiveness: Respondents were asked to rate the current governance of urban flooding disaster risk reduction in Ambo town from effectiveness perspective. 48.5 % of the respondents rated the practice of effectiveness in governing urban flooding disaster risk reduction in Ambo town as very poor. A mean of 1.87 also indicates absence of good governance in current governance of urban flooding disaster risk reduction in Ambo town from the perspective of effectiveness.

8. Education/Awareness: Respondents were asked to rate the current governance of urban flooding disaster risk in Ambo town from education/awareness creation perspective. 48.5 % of the respondents rated the practice of education/ awareness creation in governing urban flooding disaster risk management in Ambo town as very poor. A mean of 1.88 also indicates absence of good governance in current governance of urban flooding disaster risk reduction in Ambo town from the perspective of education/awareness creation.

9. Subsidiarity: Respondents were asked to rate the current governance of urban flooding disaster risk reduction in Ambo town from impartiality perspective. 46.9 % of the

respondents rated the practice of subsidiarity in governing urban flooding disaster risk management in Ambo town as very poor. A mean of 1.92 also indicates absence of good governance in current governance of urban flooding disaster risk reduction in Ambo town from the perspective of subsidiarity.

Table5. 1 Urban households' Perceived rate of current governance of urban flooding disaster risk reduction in Ambo town

Sr No	Variable of good governance	Rate of current governance (%)					Mean	Relative performance (%)	Rank
		Very poor	Poor	Fair	Good	Very good			
1	Accountability	47.6	17.9	29.9	2.5	2.1	1.94	11.2	3
2	Legality	46.2	18.9	30.1	3.0	1.8	1.95	11.3	2
3	Impartiality	45.3	17.7	30.1	4.1	2.8	2.01	11.6	1
4	Transparency	47.1	20.2	28.7	2.5	1.4	1.91	11.0	5
5	Participation	45.7	21.6	27.8	3.0	1.8	1.94	11.2	3
6	Coordination	45.7	21.8	28.5	2.3	1.6	1.92	11.1	4
7	Effectiveness	48.3	21.1	26.9	2.3	1.4	1.87	10.7	7
8	Education	48.5	20.5	27.1	2.5	1.4	1.88	10.8	6
9	Subsidiarity	46.9	20.5	28.3	2.8	1.6	1.92	11.1	4
10	Sum of Mean						17.34	100	
11	Grand Mean						1.93		

Source: Survey, 2015

Respondents were also asked to identify structural urban flooding disaster risk management measures currently being undertaken by Ambo town municipality. Majority of the respondents (n= 427; 98.2 %) opined that the municipality of Ambo town is currently undertaking drainage channel modification; drainage lines construction, maintenance and cleaning; and road coverage with cobble stone, gravel, and red ashes as structural urban flooding management related activities. Respondents were also asked to identify non-structural urban flooding disaster risk management measures currently being practiced by the municipality of Ambo town. Majority of the respondents (n=433; 99.5%) opined that the municipality of Ambo town is currently undertaking land use planning, capacity building, enactment of rules and regulations, and flood risk preparedness as non-structural urban flooding disaster risk management related activities (see table 5.2).

Table5. 2 Current structural and non-structural urban flooding disaster risk management measures practiced by Ambo town municipality

Structural Measures	Frequency (n=435)	Percentage (%)
Drainage system construction, maintenance, and cleaning	1	0.2
Flood wall construction	1	0.2
River bank elevation	1	0.2
Channel modification	5	1.1
Channel modification; drainage system construction, maintenance and cleaning; and road coverage with coble stone, gravel, and red ashes	427	98.2
Non-structural Measures		
Enactment of rules and regulations	1	0.2
Flood risk preparedness	1	0.2
Land use planning, Capacity building, enactment of rules and regulations, and flood risk preparedness	433	99.5

Source: Survey, 2015.

Respondents were also asked to rate the effectiveness of structural and non-structural urban flooding disaster risk management measures currently practiced by Ambo town municipality. Drainage channel modification; drainage system construction, maintenance and cleaning; and road coverage with coble stone, gravel, and red ashes were all rated with very poor performance by more proportion of the respondents (48.3%). Even though there was no difference in relative performance among the three categories of structural urban flooding disaster risk management measures practiced by the municipality of Ambo town, a grand mean of 1.4 indicates very poor performance of effectiveness (see table 5.3).

Table 5.3 Perceived rate of effectiveness for current structural measures of urban flooding disaster risk management measures practiced by Ambo town municipality

Structural Measures	Rate of effectiveness (%)				Mean	Relative performance (%)	
	Very Poor	poor	Fair	Good			
Channel modification	48.3	20.9	26.9	2.5	1.4	1.88	44.8
Drainage system construction, maintenance and cleaning	48.3	20.9	26.9	2.5	1.4	1.88	44.8
Road coverage with cobble stone, gravel, and red ashes	48.3	20.9	26.9	2.5	1.4	1.88	44.8
Sum of Mean						4.2	100
Grand Mean						1.4	

Source: Survey, 2015.

49%, 48.7%, 48.5%, and 48.5% of the respondents rated flood risk preparedness, land use planning, enactment of rules and regulations, and capacity building respectively with very low performance of effectiveness. A grand mean of 1.5 indicates the overall very poor performance of effectiveness of non-structural urban flooding management measures practiced by the municipality of Ambo town (see table 5.4).

Table5. 4 Perceived rate of effectiveness for current non-structural measures of urban flooding disaster risk management measures practiced by Ambo town municipality

Non-Structural Measures	Rate of effectiveness (%)				Mean	Relative performance (%)	
	Very Poor	poor	Fair	Good			
Land use planning	48.7	20.9	26.4	2.3	1.6	1.87	32.2
Capacity building	48.5	20.9	26.7	2.5	1.4	1.87	32.2
Enactment of rules and regulations	48.5	20.9	26.9	2.3	1.4	1.87	32.2
Flood risk preparedness	49.0	20.7	26.9	2.1	1.4	1.86	32.1
Sum of Mean						5.8	100
Grand Mean						1.5	

A spearman’s correlation was employed to test the association between perceived effectiveness of current governance of urban flooding risk reduction and perceived effectiveness of current structural and non-structural measures of urban flooding risk management in Ambo town. To decide on the level of the strength of correlation, the assumption of Somwkh and Lewin (2005) was followed: when correlation coefficient (r) is below 0.33 it indicates weak association; when correlation coefficient (r) is between 0.34 and 0.66 it indicates moderate association; and when the correlation coefficient (r) is between 0.67 and 0.99 it indicates a strong association.

A strong positive associations ($r=0.99$; $p=0.000$; $p<0.01$) were confirmed between urban households’ perception on drainage system construction, drainage channel modification, and (road upgrading with cobblestone, gravel, and redashes) as structural urban flooding risk management measures and their perception on the effectiveness of the current governance of urban flooding risk reduction.

A strong positive association ($r=0.98$; $p=0.000$; $p<0.01$) was confirmed between urban households' perception on land use planning as non-structural urban flooding risk management measure and their perception on the effectiveness of the current governance of urban flooding risk reduction. A strong positive association ($r=0.98$; $p=0.000$; $p<0.01$) was confirmed between urban households' perception on capacity building as non-structural urban flooding risk management measure and their perception on the effectiveness of the current governance of urban flooding risk reduction. A strong positive association ($r=0.98$; $p=0.000$; $p<0.01$) was confirmed between urban households' perception on enactment of rules and regulations as non-structural urban flooding risk management measure and their perception on the effectiveness of the current governance of urban flooding risk reduction. A strong positive association ($r=0.97$; $p=0.000$; $p<0.01$) was confirmed between urban households' perception on flood risk preparedness as non-structural urban flooding risk management measure and their perception on the effectiveness of the current governance of urban flooding risk reduction. The above results imply that respondents' perceptions on structural and non-structural measures of urban flooding risk management measures had strong positive associations with their perception on the effectiveness of current governance of urban flooding risk reduction in Ambo town. In other words, good governance matters for effective urban flooding risk management (integration of structural and non-structural management measures) in Ambo town.

5.2. Barriers for Governance of Urban Flooding Disaster Risk Reduction in Ambo Town

Participants of the focus group discussion were asked to discuss on the external and internal barriers to the governance of urban flooding disaster risk reduction in Ambo town and mechanisms to remove capacity constraints from key barriers to governance of urban flooding disaster risk reduction. They identified economic policies that affect the price of inputs and outputs, lack of new land available for relocation, and limitations placed on local authorities by central government as external barriers for governance of urban flooding disaster risk reduction.

Participants identified unwillingness of people to move away from hazard-prone areas due to the nature of their livelihoods, the high prices of properties, and a lack of awareness of the risk of hazards anticipated as internal barriers to governance of urban flooding disaster risk. As far as capacity constraints for urban flooding risk reduction in Ambo town are concerned, findings reveal that the town has serious technical capacity constraint. For instance, the existing urban planners in the town have no adequate knowledge and skills on geospatial and remote sensing techniques which are vital for mapping city level multihazards. Another important capacity constraint identified was institutional capacity constraint. For instance, Ambo town has no disaster risk reduction sector in its municipal structure. This was claimed to contribute for lack of focus and attention for existing natural disasters like flood disaster risk in the town. Another important capacity constraint is related to political commitment and willingness. Eventhough management of natural disasters like flooding disaster risk require high political commitment, the existing political system has given more focus to many other pressing issues and natural disaster risk reduction was claimed to be forgotten and only reactive responses are practiced whenever disaster risks occur.

Participants identified awareness creation on impacts of urban flooding disaster risk, the provision of loans or grants, awareness-raising (education), supporting alternative livelihoods that do not require proximity to hazard-prone areas, and developing adaptive capacity of local communities as mechanisms to remove capacity constraints from key barriers to governance of urban flooding disaster risk reduction.

5.3. Discussion

The findings of the study reveal that the current performance of governance of urban flooding risk reduction in Ambo town is very poor. It is asserted that governance failure is one of the contributors for urban flooding disaster risk as cities and towns in developing countries have many priority development issues than urban flooding (e.g. Santato *et al.*, 2013; Jones *et al.*, 2014).

Urban areas are affirmed to always present some risk of flooding when rainfall occurs (Few *et al.*, 2004; Tucci, 2007; Jha *et al.*, 2012; Santato *et al.*, 2013). Buildings, roads, infrastructure and other paved areas are asserted to prevent rainfall from infiltrating into the soil – and so produce more runoff (Allan, 2004; Wheater & Evans, 2009). Heavy and/or prolonged rainfall is claimed to produce very large volumes of surface water in any city,

which can easily overwhelm drainage systems (Andjelkovic, 2001; Jha *et al.*, 2012; Santato *et al.*, 2013; Hao *et al.*, 2015). It is attested that well-governed cities can easily manage urban flooding related problems as good provision for storm and surface drainage is easily built into the urban fabric, with complementary measures to protect against flooding – for instance the use of parks and other areas of open space to accommodate floodwaters safely from unusually serious storms. But in poorly governed cities, this does not happen – and it is common for buildings or infrastructure to be constructed that actually obstructs natural drainage channels as asserted by scholars (Andjelkovic, 2001; Vasquez, 2004; Jha *et al.*, 2012).

Governance for sustainable development is affirmed to involve participation, rule of law; transparency, responsiveness, consensus orientation, equity, effectiveness and efficiency, accountability, and strategic vision as important criteria (Sohail *et al.*, 2005; Ness, 2007; Bulkeley, 2010). Empowerment and mutual ownership of the flood problem by relevant bodies and individuals are claimed to lead to positive actions to reduce risk (Parkinson, 2002; Jha *et al.*, 2012). Moreover, effective engagement with the people at risk at all stages is asserted as a key success factor. Furthermore, engagement is affirmed to increase compliance, generate increased capacity and reduce conflict. This is encouraged to be combined with strong, decisive leadership and commitment from national and local governments (Parkinson, 2002; Kamal-Chaoui & Robert, 2009; Bulkeley, 2010; Mpofu, 2011; Jha *et al.*, 2012).

Good urban governance is claimed to have vibrant role in the multi-stakeholder coordination and communication process for mainstreaming integrated urban flooding risk management into spatial planning and land use management of cities and towns of least developed countries (Buyana *et al.*, 2014). For instance, applying climate science and ecosystem management and restoration in disaster risk reduction activities to an urban area is asserted to be possible with a proper mindset, inclusive and transformative partnerships with key stakeholders from different tiers of governance, political leadership, and the effective use of science (Arcilla & Lagdameo, 2015).

Good communication and co-operation between different agencies (national and international) when responding to floods are asserted to be important so that responses are well coordinated, and information and resources can be shared during and after the emergency (Cordaid & IIRR, 2011). Furthermore, effective integration of emergency preparedness planning and implementation of the plan when responding to an emergency is

affirmed to be crucial for sustainable urban flooding risk management (Parkinson, 2002; Smith, 2009).

The finding of the study also reveals that governance of urban flooding disaster risk reduction has external and internal barriers. In relation to barriers for governance of urban flooding disaster risk reduction, scholars in the field of urban flooding disaster risk reduction claims that urban governance and decision-making often fall short of what is needed to adequately respond to the challenge of flooding (Kamal-Chaoui & Robert, 2009). Moreover, enforcement of standards and regulations is affirmed to be often incomplete or even absent (Andjelkovic, 2001; Few *et al.*, 2004). In other words, regulatory frameworks often demand unrealistic minimum standards while at the same time there is lack of adequate mechanisms for the enforcement of regulations. Funding is often limited too (Andjelkovic, 2001; Few *et al.*, 2004; Kamal-Chaoui & Robert, 2009; Jha *et al.*, 2012).

It is affirmed that a critical governance issue is that most urban growth in low- and middle-income nations is happening without “good local governance” and so without the provisions needed to reduce risks (Bulkeley, 2010). Poor adaptive capacity of a city and its dwellers is also claimed as one of the governance issues of urban flooding disaster risk reduction. In other words, there is lack of adaptive capacity and the very large backlogs in provision for infrastructure and services in most urban centres in low- and middle-income nations (Sohail *et al.*, 2005; Ness, 2007; Cordaid & IIRR, 2011). For instance, most city and municipal governments in least developed countries are asserted to have almost no investment capacity at all. However, improved competence, capacity and accountability within city and municipal governments almost by definition are affirmed to increase adaptation capacity and increase the possibilities of it being “pro-poor” (Cordaid & IIRR, 2011).

Urban governance is claimed to be largely unprepared for the scale of change to come and the need to adopt more sustainable practices. To change this undesirable condition, strengthening urban governance, recognizing the importance of local leadership, utilizing local networks, involving local communities and leveraging local resources are encouraged to promote sustainable urban development and manage urban disasters like urban flooding in developing countries (Sohail *et al.*, 2005; Ness, 2007).

CHAPTER SIX: DYNAMICS OF LAND USE/LAND COVER CHANGE AND ENVIRONMENTAL IMPLICATIONS IN HULUKA WATERSHED

The aim of this chapter is presenting the analysis of land use and land cover dynamics, their drivers and environmental implications in Huluka Watershed.

6.1. Composition of Land Use and Land Cover in Huluka Watershed

Forest, cultivated land, urban built-up, bush/shrub land, bare land, grassland, and water body were identified as the seven types of land use and land cover in the watershed. Forest land use and land cover in the watershed is characterized by areas covered with dense trees including Eucalyptus and Coniferous trees, and riverine trees. Bush/shrub land use and land cover is characterized by land with shrubs and bushes, and scattered small trees mixed with grasses. Grassland land use and land cover is characterized by land predominately covered with grasses, forbs, and grassy areas used for communal grazing. Cultivated land use and land cover is characterized by areas used for rain-fed crop production and scattered rural settlements. Areas occupied by urban residential houses, buildings, and industrial uses. Urban Built-up land use and land cover is characterized by areas occupied by urban residential houses, buildings, and industrial uses. Water land use and land cover is characterized by areas covered by lake water in the watershed permanently. Bare land is characterized by areas with no or very little vegetation cover and characterized by shallow and rocky surface along the flooding area of the local stream valleys, over gentle and steep mountain slopes.

6.2. Dynamics of Land Use and Land Cover Changes in Huluka Watershed

The overall classification accuracy for the output maps was 92.28%, 92.67%, 93.27%, and 90.19% for the years 1979, 1984, 2009, and 2017 respectively. The overall kappa coefficient for the study period was 0.89, 0.90, 0.91, and 0.80 for the years 1979, 1984, 2009, and 2017 respectively (Table 6.1).

Table 6. 1 Accuracy assessment of the Land Use/Land Cover classification for the Study Period

Accuracy	1979	1984	2009	2017
Overall classification accuracy (%)	92.28	92.67	93.27	90.19
Overall Kappa coefficient	0.89	0.90	0.91	0.80

The spatio-temporal dynamics of land use and land cover changes in the watershed for forest land, cultivated land, urban built-up area, bush/shrub land, bare land, grassland, and waterbody between 1979 and 2017 are presented hereunder.

1. Forest land

Forest land was represented by areas covered with dense trees, which include both Eucalyptus and coniferous trees, and riverine trees. Forest land covered 10550.52 ha (13%) in 1979, 8925.75 ha (10.9%) in 1984, 4232.253 ha (5.2%) in 2009 and 4298.85 ha (5.3) % in 2017. It decreased by 15.4% (324.95ha/year) between 1979 and 1984 and 52.6% (187.74ha/year) between 1984 and 2009. However, it increased by 1.6% (8.33 ha/year) between 2009 and 2017. It decreased by 59.3% (164.52 ha/year) between 1979 and 2017. The decrease of forest land in the watershed was attributable to its transformation to other land use and land cover types. It was largely transformed to cultivated land (4641.69 ha) and grassland (2221.13 ha) between 1979 and 2017 (Table 6.2 6.3, 6.4, and 6.5; Figures 6.1 and 6.2).

2. Cultivated land

Cultivated land was represented by areas used for rain-fed crop production and scattered rural settlements usually associated with cultivated lands. Cultivated land covered 25005.24 ha (30.8%) in 1979, 28639.27 ha (35.3%) in 1984, 43833.98 ha (54%) in 2009 and 51329.96 ha (63.2) % in 2017. It increased by 14.5 % (726.81 ha/year) between 1979 and 1984, 53.1% (607.79 ha/year) between 1984 and 2009, 17.1% (937.00 ha/year) between 2009 and 2017, and 105.3% (692.76 ha/year) between 1979 and 2017. The increase of cultivated land in the watershed was attributable to the transformation of other land use and land cover types into

cultivated land. A large proportion of grassland (17552.41 ha), shrub/bush land (11085.04 ha), and forest land (4641.69 ha) was transformed into cultivated land between 1979 and 2017 (Table 6.2 6.3, 6.4, and 6.5; Figures 6.1 and 6.2).

3. Urban built-up area

Urban built-up area was represented by areas occupied by urban residential houses, buildings, and industrial uses. Urban built-up area covered 175.32 ha (0.2%) in 1979, 349.74 ha (0.4%) in 1984, 425.79 ha (0.5%) in 2009 and 790.74 ha (1%) in 2017. It increased by 99.5 % (34.88 ha/year) between 1979 and 1984, 21.7 % (3.04 ha/year) between 1984 and 2009, 85.7% (45.62 ha/year) between 2009 2017, and 351 % (16.20 ha/year) between 1979 and 2017. The increase of urban built-up areas in the watershed was attributable to the transformation of other land use and land cover types into urban built-up areas. A large proportion of grassland (274.77 ha), cultivated land (177.57 ha), shrub/bush land (118.53 ha), and forest land (91.98 ha) was transformed into urban built-up area between 1979 and 2017 (Table 6.2 6.3, 6.4, and 6.5; Figures 6.1 and 6.2).

4. Bush/Shrub land

Bush/shrub land was represented by land covered by shrubs and bushes and sometimes with scattered small trees mixed with grasses. Bush/Shrub land covered 17746.11ha (21.8%) in 1979, 12767.1ha (15.7%) in 1984, 7907.733 ha (9.7%) in 2009 and 5635.09ha (6.9%) in 2017. It decreased by 28.1% (995.80 ha/year) between 1979 and 1984, 38.1% (194.38 ha/year) between 1984 and 2009, 28.7% (284.08 ha/year) between 2009 and 2017, and 68.2% (318.71 ha/year) between 1979 and 2017. The decrease of bush/shrub land in the watershed was attributable to its transformation to other land use and land cover types. Its large proportion was transformed into cultivated land (11085.04 ha) and grassland (4268.89 ha) between 1979 and 2017 (Table 6.2 6.3, 6.4, and 6.5; Figures 6.1 and 6.2).

5. Bare land

Bare land was represented by areas with no or very little vegetation cover and characterized by shallow, and rocky surface along the flooding area of the local stream valleys, over gentle and steep mountain slopes. Bare land covered 362.16 ha (0.4%) in 1979, 368.2 ha (0.5%) in 1984, 431.46 ha (0.5%) in 2009 and 513.97 ha (0.6%) in 2017. It increased by 1.7 (1.21 ha/year) % between 1979 and 1984, 17.2 % (2.53 ha/year) between 1984 and 2009, 19.1% (10.31 ha/year) between 2009 2017, and 41.9 % (4.00 ha/year) between 1979 and 2017. The

increase of bare land cover in the watershed was attributable to the transformation of other land use and land cover types into bare land. A large proportion of cultivated land (246.69 ha), grassland (115.20 ha), and shrub/bush land (111.15 ha) was transformed into bare land between 1979 and 2017 (Table 6.2 6.3, 6.4, and 6.5; Figures 6.1 and 6.2).

6. Waterbody

Waterbody was represented by areas covered by lake water in the catchment permanently. Waterbody covered 789.48 ha (1%) in 1979, 811.98 ha (1%) in 1984, 748.44 ha (0.9%) in 2009 and 749.07 ha (0.9%) in 2017. It increased by 2.9 % (4.5 ha/year) between 1979 and 1984. However, it decreased by 7.8% (2.54 ha/year) between 1984 and 2009. It increased by 0.1% (0.08 ha/year) between 2009 and 2017. It decreased by 5.1 % (1.06 ha/year) between 1979 and 2017. The decrease of the waterbody in the watershed was attributable to its transformation to other land use and land cover types. Its large proportion was transformed into grassland (48.6 ha) and cultivated land (4.5 ha) between 1979 and 2017 (Table 6.2 6.3, 6.4, and 6.5; Figures 6.1 and 6.2).

7. Grassland

Grassland was represented by land predominately covered with grasses, forbs, grassy areas used for communal grazing. Grassland covered 26607.96 ha (32.8%) in 1979, 29374.75 ha (36.2%) in 1984, 23657.14 ha (29.1%) in 2009 and 17919.11ha (22%) in 2017. It increased by 10.4%(553.36 ha/year) between 1979 and 1984. It decreased by 19.5% (228.70 ha/year) between 1984 and 2009, 24.3% (717.25 ha/year) between 2009 and 2017, and 32.7% (228.65 ha/year) between 1979 and 2017. The decrease of grassland in the watershed was attributable to its transformation to other land use and land cover types. It was largely transformed into cultivated land between 1979 and 2017(Table 6.2 6.3, 6.4, and 6.5; Figures 6.1 and 6.2).

Table6. 2 Proportion of Land Use/Land Cover Change in Huluka/Ambo Town's Watershed (1979-2017)

No	Land use/cover	Area of land use/ cover Class							
		1979		1984		2009		2017	
		Ha	%	Ha	%	Ha	%	Ha	%
1	Forest	10550.52	13	8925.75	10.9	4232.253	5.2	4298.85	5.3
2	cultivated land	25005.24	30.8	28639.27	35.3	43833.98	54	51329.96	63.2
3	Urban built-up area	175.32	0.2	349.74	0.4	425.79	0.5	790.74	1
4	Bush and shrub land	17746.11	21.8	12767.1	15.7	7907.733	9.7	5635.09	6.9
5	Bare land	362.16	0.4	368.2	0.5	431.46	0.5	513.97	0.6
6	Water	789.48	1	811.98	1	748.44	0.9	749.07	0.9
7	Grassland	26607.96	32.8	29374.75	36.2	23657.14	29.1	17919.11	22
8	Total	81236.79	100	81236.79	100	81236.79	100	81236.79	100

Table6. 3 Changes of land use and land cover in Huluka Watershed (Percentage)

No	Land use/cover class	Change of land use and land cover (%)			
		1979-1984	1984-2009	2009-20017	1979-2017
1	Forest	-15.4	-52.6	1.6	-59.3
2	cultivated land	14.5	53.1	17.1	105.3
3	Urban built-up area	99.5	21.7	85.7	351
4	Bush and shrub land	-28.1	-38.1	-28.7	-68.2
5	Bare land	1.7	17.2	19.1	41.9
6	Water	2.9	-7.8	0.1	-5.1
7	Grassland	10.4	-19.5	-24.3	-32.7

Table6. 4 Rate of Changes of land use and land cover in Huluka Watershed (ha/year)

No	Land use/cover class	Rate of Change of land use and land cover (Hectares/year)			
		1979-1984	1984-2009	2009-20017	1979-2017
1	Forest	-324.95	-187.74	8.33	-164.52
2	cultivated land	726.81	607.79	937.00	692.76
3	Urban built-up area	34.88	3.04	45.62	16.20
4	Bush and shrub land	-995.80	-194.38	-284.08	-318.71
5	Bare land	1.21	2.53	10.31	4.00
6	Water	4.5	-2.54	0.08	-1.06
7	Grassland	553.36	-228.70	-717.25	-228.65

Table6. 5 Matrix for land use and land cover changes for 1979 to 2017 in Hectares (ha)

From 1979	To 2017							
	Forest	Cultivated	Built-up	Bush/shrub	Bare	Water	Grass	Total
Forest	2355.048	4641.698	91.98	1207.098	30.6	2.97	2221.126	10550.52
Cultivated	389.592	17788.73	177.57	1245.042	246.69	4.14	5153.472	25005.24
Built-up	20.52	0	127.89	4.86	0.45	0	21.6	175.32
Bush/shrab	782.388	11085.04	118.53	1377.676	111.15	2.43	4268.898	17746.11
Bare land	2.43	257.58	0	17.37	9.88	0	74.9	362.16
water	0	4.5	0	0.36	0	736.02	48.6	789.48
Grass	748.872	17552.41	274.77	1782.684	115.2	3.51	6130.512	26607.96
Total	4298.85	51329.96	790.74	5635.09	513.97	749.07	17919.11	81236.79

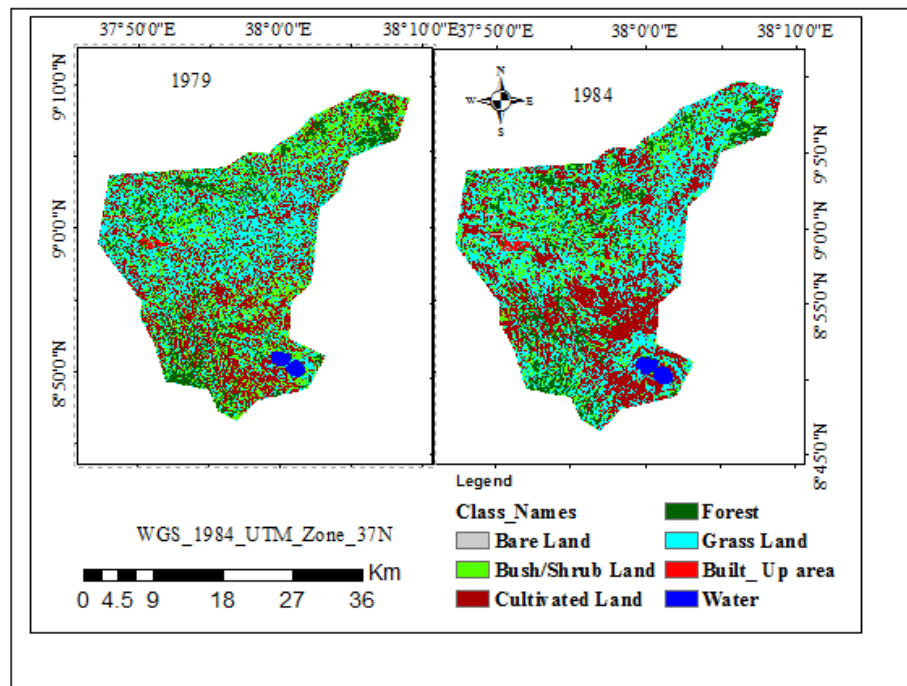


Figure6. 1 Land use and land cover Maps of Huluka Watershed for 1979 and 1984.

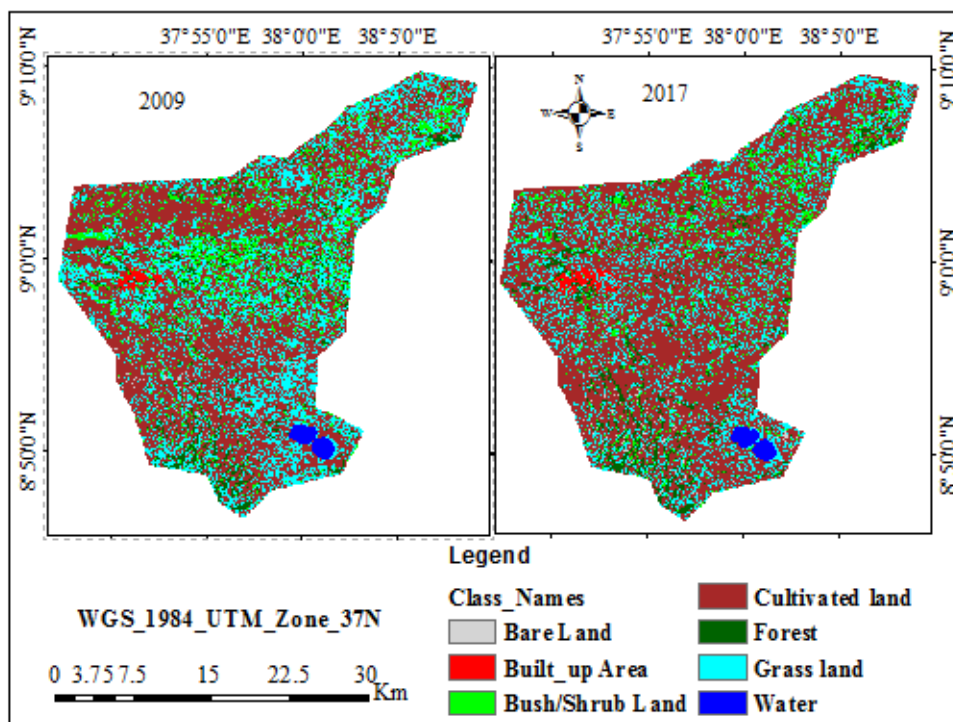


Figure6. 2 Land use and land cover Maps of Huluka Watershed for 2009 and 2017

6.3. Drivers and Local Effects of Land use and Land Cover Changes in Huluka

Watershed

6.3.1. Drivers of Land Use and Land Cover Changes in Huluka Watershed

The major themes of the thematic content analysis of qualitative data were drivers of land use and land cover changes and the relationship between the drivers and land use and land cover changes in the Huluka watershed. The summary of findings from focus group discussions indicates that the local communities in the watershed felt that the land use and land cover changes in their watershed are visible and underpinned by infrastructural and agricultural expansions, increased demand for wood, local environmental and biophysical drivers, rapid human population growth, economic drivers, technological drivers, policy and institutional drivers, and local socio-cultural drivers. The entire key informants also felt that the aforementioned drivers underpin land use and land cover changes in their watershed. The perceived causal relationship between land use and land cover changes and the drivers are summarized hereunder.

1. Infrastructural and Agricultural Expansion

All the focus groups confirmed that unplanned expansion of infrastructure and agriculture are among the major drivers of land use and land cover changes in the Huluka watershed. This finding was further confirmed by the entire key informants who felt that many of the infrastructural and agricultural expansions are not planned and land use and land cover changes in the watershed are underpinned by unplanned expansions. Many of the key informants emphasized that they appreciate the planned expansion of relevant infrastructures like roads, electrification, and telecommunication. However, they suggested that appropriate environmental impact assessment must precede any infrastructural expansion in their watershed. It was also possible to observe the unplanned infrastructural and agricultural expansions in the watershed through participant observation.

2. Increased Demand for Wood

All the focus groups affirmed that there is currently an increased demand for wood (fuelwood and wood for construction) in the Huluka watershed. The women focus groups emphasized that the challenge of fuelwood is visible in their environment as they do not find easily trees in their environment despite their increased demand for it. This affirmation was further supported by the assertion of the entire key informants who felt that trees in the watershed are at big risk as humans need them for fuelwood and construction purposes without thinking to plant or replace them for future sustainable use. Key informants from the down-stream of

Huluka watershed where Ambo town is situated further attest that there is increased demand for wood for construction purposes in the watershed especially in the urbanized part of the watershed. It was also possible to observe the increased demand for fuelwood and wood for construction through participant observation.

3. Local Environmental and Biophysical Drivers

All the focus groups attested that vulnerable soil quality, hilly topography, and lands without forest, bushes/shrubs, and grass cover are the local environmental drivers exacerbating the land use and land cover changes in the Huluka watershed. They affirmed also that flooding is one of the contributing local bio-physical drivers for land use and land cover changes. The entire key informants also agreed with the aforementioned attestation as they felt that these local environmental and bio-physical factors contribute much to land use and land cover changes in the watershed. The key informants from the urbanized part of the watershed emphasized that vulnerable soil types in their locality and hilly topography contribute to land use and land cover changes in the watershed. They also felt that flooding exacerbate the aforementioned undesirable environmental situation. It was also possible to observe some local environmental, and biophysical drivers through participant observation (Figure 6).

4. Rapid Growth of Human Population

All the focus groups asserted that the rapidly growing human population in the watershed is one of the major drivers of land use and land cover changes in the Huluka watershed. The entire key informants agreed with the above assertion as they further emphasized that the rapidly growing human population in the watershed demands much resources from the natural environment which threatens the natural environment resulting in the degradation of natural resources. The key informants from the urbanized part of the watershed felt that the demand for shelter and food certainly hasten the transformation of land use and land cover to urban built-up areas and cultivated land. This threatens forest land, grassland, and bush/shrub land as they attested. It was also possible to observe the detrimental effect of human unplanned settlement in the watershed exacerbating the land use and land cover changes (Figure 6.3).

5. Economic Drivers

All the focus groups confirmed that market growth and commercialization, urban expansion, and price increase are among the major economic drivers contributing to land use and land cover changes in the watershed. The entire key informants agreed with the above confirmation as they further emphasized that the economic needs of different stakeholders in

the watershed significantly drive the land use and land cover changes in the watershed. It was also possible to observe some economic drivers through participant observation.

6. Technological Drivers

All the focus groups affirmed that agro technical change and agricultural production factors are among the major technological drivers contributing to land use and land cover changes in the watershed. The entire key informants agreed with the above affirmation as they further emphasized that land use and land cover changes in the watershed are much affected by access to technologies by different stakeholders in the watershed. It was also possible to observe some technological drivers through participant observation.

7. Policy and Institutional Drivers

All the focus groups confirmed that formal land policy, property rights, and the absence of relevant institutions are among the major drivers of land use and land cover changes in the Huluka watershed. The entire key informants agreed with the above confirmation. For instance, key informants from the urbanized part of the watershed felt that urban development policy and land use policy contribute much to land use and land cover changes that threaten their livelihoods. Most of the key informants felt that the absence of strong and stringent environmental protection policies and strategies underpins the degradation of natural resources in the Huluka watershed. They also felt that the property rights issue affects their attitude towards the conservation of natural resources. It was also possible to observe some of the policy and institutional drivers through participant observation.

8. Local Socio-Cultural Drivers

All the focus groups asserted that religious institutions, public attitudes, and beliefs, and individual and household behavior are among the socio-cultural drivers contributing to land use and land cover changes in the Huluka watershed. The entire key informants agreed with the above confirmation. For instance, many key informants felt that forest land cover is more conserved in religious institutions as they promote living in peace with nature. They also affirm that the conservation or degradation of natural resources in the watershed is determined by public attitudes and beliefs, and individual and household behavior. It was also possible to observe some of the socio-cultural drivers through participant observation.



Figure6. 3 Partial view of drivers of land use and land cover changes in Huluka watershed: A)vulnerable local soil, B)Vulnerable hilly topography, C)Water erosion induced gully, D)Flooded urban environment, E)Human settlement around the lake, and F)Disturbed lake water

(Source: Ogato et al., 2021).

6.3.2. Local Effects of Land Use and Land Cover Changes in Huluka Watershed

The major themes of the thematic content analysis of qualitative data were local negative effects of land use and land cover changes on farmers’ livelihoods, the reciprocal cause-effect relationship between flooding risk and land use and land cover changes, strengths, and

weaknesses of the current community-based soil and water conservation measures practiced, and effective adaptation measures to land use and land cover changes. A summary of the findings for the aforementioned themes is presented hereunder.

1. Local Negative Effects of Land Use and Land Cover Changes on Farmers' Livelihoods

All the focus groups attest that land use and land cover changes in the Huluka watershed have negative local effects on their livelihoods. Accordingly, they identified increased flooding risk, increased soil erosion, increased sedimentation into water resources like lakes and rivers, decrease in soil fertility, loss of biodiversity, loss of springs, decrease in annual rainfall and increase in heat during the dry season. The entire key informants also felt that the negative local effects of land use and land cover changes on their livelihoods are current realities and affirmed that many of the environmental disasters in the watershed are highly attributable to the land use and land cover changes. It was also possible to observe some of the negative local effects.

2. Reciprocal Cause-effect Relationship between Flooding Risk and Land Use and Land Cover Changes

All the focus groups affirmed that flooding risk in their watershed is highly linked to land use and land cover changes as the transformation of land use and land cover from forest land, grassland, and bush/shrub land to cultivated land, and urban built-up areas exacerbate flooding risk caused by other factors. They also asserted that flooding risk in the watershed also exacerbated land use and land cover changes as it hastens the transformation of productive land use and land cover into degraded land use and land covers. The entire key informants also felt that a reciprocal cause-effect relationship exists between land use and land cover change and flooding risk. They attest that land areas without forest, grass, bush/shrub, and water are much vulnerable to flooding risk. They also confirmed that flooding risk in their watershed is highly underpinned by the changes in land use and land cover in the watershed. Hence, the existence of the reciprocal cause-effect relationship between flooding risk and change in land use and land cover was attested by the focus groups and the key informants. It was also possible to observe the negative effects of flooding risk on different land use and land cover types.

3. Strengths and Weaknesses of The Current Community-based Soil and Water Conservation Measures

All the focus groups affirmed that the current community-based soil and water conservation measures practiced in the watershed have contributed to increased soil fertility, healing of degraded land areas, conservation of soil and water resources, local adaptation to the flooding risk, improvement in yield from crop production, and improvement in social capital among local farmers, and between farmers and agricultural development professionals. However, they identified weaknesses that require careful attention in future interventions for sustainable watershed management. Accordingly, they identified poorly supervised and managed soil and water conservation measures in some places, lack of planting appropriate tree species on the established soil and water conservation structures, lack of considering rehabilitation of degraded lands in the soil and water conservation measures practiced, negative downstream impacts of some practiced measures, interference of livestock in the established structures, and lack of mainstreaming non-structural measures. The entire key informants also felt that the aforementioned strengths and weaknesses properly characterize the current community-based soil and water conservation measures practiced in the Huluka watershed. It was also possible to observe some of the strengths and weaknesses.

4. Effective Adaptation Measures to Land Use and Land Cover Changes

All the focus groups suggested compost preparation and use, the practice of crop rotation, effective planning to rehabilitate degraded lands through structural and non-structural soil and water conservation measures, strengthening the ongoing community-based soil and water conservation practices, institutionalizing appropriate environmental impact assessment into any local development projects, planting appropriate tree species and management on established soil and conservation structures, and establishing an appropriate institutional framework for forest and other natural resources' management as effective adaptation measures to land use and land cover changes. The entire key informants also felt that the aforementioned suggestions by local communities for sustainable watershed development are vital.

6.4. Discussion

The increase in urban built-up area land use and land cover by 351% at an average rate of 16.20 ha/year over 38 years (1979-2017) was confirmed in the Huluka watershed. This is similar to the previous study by Oluwayemisi *et al.* (2020) who confirmed the drastic increase in built-up area coverage over 20 years (1999-2019). Abebe *et al.* (2019) assert that rapid population growth and economic development underpin expansions of built-up areas in Ethiopia. Gashaw *et al.* (2017) reported increased coverage of built-up areas over 30 years (1985-2015) with similar predicted trends for 2030 and 2045.

The increase in urban built-up areas has grave implications for promoting sustainable development in the Huluka watershed and beyond. Scholars in the field assert that land use is closely related to the urban development process of rapid urbanization that takes place in most developing countries (Miheretu & Yimer 2017; Abebe *et al.* 2019). In other words, how land has to be allocated to a variety of functions such as roads, utilities, housing industrial estates, shopping centers, offices, schools, hospitals and other elements of the physical organization of a city are attested to have far-reaching socio-economic, cultural, political, technical and ecological implications (Andjelkovic 2001; Parkinson 2003; Tucci 2007; Claes *et al.* 2012; Santato *et al.* 2013).

The continued high rate of urbanization, in general, is affirmed to lead to problems such as urban poverty, a lack of urban services, especially to the urban poor, poor provision of urban services, considerable strain on existing urban infrastructural facilities, street children, urban unemployment, urban transportation problems, displaced persons, urban crime, a proliferation of slums and squatter settlements, and urban environmental degradation (Balzerek *et al.* 2003; Ujoh *et al.* 2010; Hao *et al.* 2015; Abebe *et al.* 2019). These urban challenges were also confirmed to affect the urban development process in the Huluka watershed where Ambo town is situated. As the aforementioned challenges are underpinned by unplanned urban expansion, only sustainable land use planning and management and sustainable urban development are feasible solutions (Gashu & Gebre-Egziabher, 2018). In other words, protecting land from the urban expansion is affirmed to be imperative for countries whose economic viability and environmental sustainability are increasingly threatened by growing population pressures on a limited natural resource base, the agricultural expansion of marginal lands, deforestation to meet growing demands for food,

energy, and construction, and climate change (Brown 2011; FDRE-MUDHC 2014; Miheretu & Yimer 2017; Worku *et al.* 2017; Abera *et al.* 2020).

The increase in cultivated land use and land cover by 105.3% at an average rate of 692.76 over 38 years (1979- 2017) was confirmed in the Huluka watershed. This is similar to a previous study by Abera *et al.* (2020) who reported that cultivated land use and land cover increased at an average rate of 1515.7 ha/year between 2000 and 2018. Wubie *et al.* (2016) reported a consistent expansion of cultivated land use and land cover over the four decades analyzed (1957–2005). Hassen & Assen (2017) reported the expansion of cultivated land by about 57.68% (91.5 ha/year). Miheretu & Yimer (2017) reported an increase in cultivated land by 7.13% over 50 years (1964-2014). Woldesenbet *et.al.* (2020) reported an increase in area coverage for the cultivated land-use system over 30 years. Deribew & Dalacho (2019) reported an increase in cultivated land cover by 36.70% over 60 years (1957-2017). Gashaw *et al.* (2017) reported increased coverage of cultivated land cover over 30 years (1985-2015) with similar predicted trends for 2030 and 2045.

The increase in cultivated land use and land cover has grave environmental implications for the Huluka watershed and beyond. For instance, the increase in cultivated land was at the expense of forest land, grassland, and bush/shrub land use and land cover and this affects the livelihoods of the human population and other members of the ecosystem in the watershed. In other words, elements of the ecosystem in the watershed are much vulnerable to disaster risks like flooding and soil erosion. Scholars of sustainable development recommend integrated watershed management to address diverse water-related issues in the watershed. In other words, sustainable land management (SLM) is attested to have a vital contribution. The main objective of SLM is affirmed to be integrating people's coexistence with nature over the long-term, so that the provisioning, regulating, cultural, and supporting services of ecosystems are ensured (Ali *et al.* 2011; Liniger *et al.* 2011; FDRE-MUDHC 2014).

The increase in bare land use and land cover by 41.9% at an average rate of 4.00 ha/year over 38 years (1979- 2017) was confirmed in the Huluka watershed. This is similar to the previous study by Hassen & Assen (2017) who reported an exceptional expansion of bare land by 11.37 ha/year underpinned by the presence of unsustainable land management practices. Contrary to our finding, the decrease in bare land use and land cover by 46.8% at an average rate of 27 ha/year (2000-2018) was confirmed by a previous study conducted in Ethiopia by

Abera and his colleagues. They identified the expansion of built-up areas at the expense of bare land as the underpinning reason (Abera *et al.* 2020).

The decrease in the forest land use and land cover by 59.3% at an average rate of 164.52 ha/year over 38 years (1979- 2017) was confirmed in the Huluka watershed. This is similar to some previous studies in Ethiopia which confirmed the decrease in forest land use and land cover. For instance, Negassa *et al.* (2020) confirmed a reduction in dense and open forest cover in the Komto forest priority area of East Wollega Zone, Ethiopia. A reduction in forest land use and land cover by 59.9% at an average rate of 745.2 ha/year was also confirmed by the current similar study conducted in the Chewaka district of Ethiopia (Abera *et al.* 2020). Woldesenbet *et.al.* (2020) also confirmed a decrease in area coverage for forest land-use systems over 30 years. Oluwayemisi *et al.* (2020) also confirmed a drastic decrease in forest land coverage over 20 years (1999-2019). Deribew & Dalacho (2019) also reported a decrease in forest land cover by 39.79% over 60 years (1957-2017). Gashaw *et al.* (2017) reported decreased coverage of forest land use and land cover over 30 years (1985-2015) with similar predicted trends for 2030 and 2045.

The reduction in forest land use and land cover has serious implications for exacerbating environmental problems in the watershed and beyond. For instance, deforestation and logging are regularly affirmed for exacerbating the disastrous effects of floods generated by extreme rainfall (Gebresamuel *et al.* 2015). In other words, deforestation tends to generate higher flows, net erosion, and nutrient losses. To avert this undesired human impact on the natural environment, afforestation is recommended as it tends to reduce groundwater recharge and net water availability. In other words, trees are attested to have the capacity to intercept part of the precipitation and, owing to their deeper root systems, transpire more water than grasses during the drier periods (Birkinshaw *et al.* 2010; Santato *et al.* 2013).

The urban areas, which are growing rapidly, are attested to need forests to improve the human well-being of the urban population by creating green spaces. Besides this, forests are asserted to provide multiple ecosystem services for people living in rural areas (Dessie & Tadesse 2013; Gashu & Gebre-Egziabher 2018). Furthermore, the importance of forests for sustainable development is increasingly being recognized, not only as a source of wood and timber, but also for carbon sequestration, as a source of renewable energy, for cultural and spiritual values, and recreation, among others (Muller and Reinstorf 2011; Dessie & Tadesse 2013; Abera *et al.* 2020). Abera *et al.* (2020) attest that developing a proper land-use plan and

limiting population growth through family planning are of paramount importance to conserve and protect forest land use and land cover. Hence, conservation and wise use of forest land resources in the Huluka watershed is of paramount importance to promote sustainable watershed development.

The decrease in shrub/bush land use and land cover by 68.2% at an average rate of 318.71 ha/year over 38 years (1979- 2017) was confirmed in the Huluka watershed. This is similar to the finding of Gashaw *et al.* (2017) who reported decreased coverage of shrub/bush land use and land cover over 30 years (1985-2015) with similar predicted trends for 2030 and 2045. The decrease in shrub/bush land use and land cover implies that land without shrub/bush cover is vulnerable to soil erosion, flooding, and climate change. Moreover, the livelihoods of local communities are affected since feed shortage and fuelwood shortage are exacerbated in the watershed and beyond.

The decrease in grassland use and land cover by 32.7% at an average rate of 228.65 ha/year over 38 years (1979- 2017) was confirmed in the Huluka watershed. This is similar to the study by Woldesenbet *et al.* (2020) who reported a decrease in area coverage for grassland use systems over 30 years. Oluwayemisi *et al.* (2020) reported a drastic decrease in grassland coverage over 20 years (1999-2019). Gashaw *et al.* (2017) reported decreased coverage of grassland use and land cover over 30 years (1985-2015) with similar predicted trends for 2030 and 2045. The decrease in grassland use and land cover has grave environmental implications for the Huluka watershed and beyond. For instance, the reduction in grassland use and cover implies a shortage of grazing land and feed shortage for livestock affecting the mixed crop-livestock farming system in the watershed and beyond. Reduction in grassland use and land cover also mean increased risk of land to flooding and soil erosion.

The decrease in waterbody by 5.1 % at an average rate of 1.06 ha/year over 38 years (1979- 2017) was confirmed in the Huluka watershed. This is similar to a previous study conducted by Oluwayemisi *et al.* (2020) who confirmed a drastic decrease in water body coverage over 20 years (1999-2019).

The decrease in water body has serious environmental implications for the watershed and beyond, as ecosystem services from the water body (Dendi lake) are detrimentally affected by human-induced and natural factors. Some of the ecosystem services provided by lake include Habitat for aquatic birds, other animals and plants; fish and shellfish production; biodiversity;

food production; water storage, including mitigating the effects of floods, and droughts; groundwater recharge; shoreline stabilization, and storm protection; water purification; nutrient cycling; sediment retention and export; recreation and tourism; climate change mitigation; timber production; education and research; and aesthetic, and cultural value (Ozesmi and Baur 2002; Abunie 2003; Galbraith *et al.* 2005; Millennium Ecosystem Assessment 2005; Wetlands International 2010). Hence, sustainable wetland conservation and restoration policies and strategies should be integrated into sustainable local development and poverty alleviation policies and strategies as environmentally sound economic development underpin sustainable development that creates livelihood options and employment opportunities for current as well as future generations (Ogato 2013b; Yohannes *et al.*, 2020).

The finding of the study indicates that infrastructural and agricultural expansions, increased demand for wood, local environmental and bio-physical drivers, the rapid growth of human population, economic drivers, technological drivers, policy and institutional drivers, and local socio-cultural drivers were the perceived drivers of land use and land cover changes in Huluka watershed. While technological drivers, local environmental and bio-physical drivers, and socio-cultural drivers were not well confirmed by previous studies in Ethiopia, drivers like rapid growth of human population, increased demand for wood, policy, and institutional drivers were well confirmed as discussed hereunder.

It is affirmed that the main drivers of land use and land cover changes are the combination of biophysical processes, demographic dynamics, urbanization, and successive government policies (Jember 2014; Gashaw *et al.* 2017; Karki *et al.* 2018; Deribew & Dalacho 2019; Yesuph & Dagneu 2019). An increase in the human population is confirmed to be the major driver for land use and land cover changes in Ethiopia (Kindu *et al.* 2013; Gashaw *et al.* 2017; Abebe *et al.* 2019; Hassan *et al.* 2016; Wubie *et al.* 2016; Miheretu & Yimer 2017; Worku *et al.* 2017; Abera *et al.* 2020). For instance, Worku *et al.* (2017) and Wubie *et al.* (2016) assert that Population growth increases demands of more cultivated land, fuelwood, charcoal, and infrastructural development. Abera *et al.* (2020) assert that rapid population growth and high population density induce increased demand for resources and exacerbate the rate of resource depletion in the area. Local environmental and biophysical drivers are affirmed to underpin land use and land cover changes in Ethiopia (Kindu *et al.* 2013; Gashaw *et al.* 2017; Yesuph & Dagneu 2019). For Gashaw *et al.* (2017), the reduction of land

productivity underpinning the intension of the people for getting new fertile cultivable lands is one of the biophysical drivers.

Policy and institutional drivers are also attested to contribute to land use and land cover changes in Ethiopia (Kindu *et al.* 2013; Hassen & Assen 2017; Zewdie *et al.* 2017; Gashu & Gebre-Egziabher 2018, Yesuph & Dagneu 2019; Abera *et al.* 2020). For instance, Gashu & Gebre-Egziabher (2018) assert that policy and institutional drivers underpin the dynamics of land use and land cover changes in Ethiopia. Economic drivers are also affirmed to contribute to land use and land cover changes in Ethiopia (Kindu *et al.* 2013; Minale 2013; Gebresamuel *et al.* 2015; Hassan *et al.* 2016; Hassen & Assen 2017; Yesuph & Dagneu 2019; Abera *et al.* 2020). For instance, Hassan *et al.* (2016) identified economic development, climate change, population growth, rapid urbanization, and deforestation as drivers of land use and land cover changes.

The finding of the study indicates that increased flooding risk, increased soil erosion, increased sedimentation into water resources(lake and rivers), decrease in soil fertility, loss of biodiversity, loss of springs, decrease in annual rainfall, and increase in heat during the dry season were the perceived local negative effects of land use and land cover changes in Huluka watershed. While there are limited empirical pieces of evidence linking annual rainfall and environmental heat to changes in land use and land cover in Ethiopia, other local effects were well documented as discussed hereunder.

Increased flooding risk was one of the perceived negative local effects of land use and land cover changes in the Huluka watershed. This perception is similar to the attestations by previous studies in Ethiopia which attested that flooding risk in Ethiopia is underpinned by land use and land cover changes. For instance, scholars in the field affirm that the hydrology of a watershed is much affected by land use and land cover changes resulting in flooding risk (Assen 2011; Gebresamuel *et al.* 2015; Gashaw *et al.* 2017; Yesuph & Dagneu 2019). Scholars also assert that urban built-up area is characterized by urban runoff which is defined as streamflow or the sum of surface runoff and subsurface runoff from an urban area (Zhiyu *et al.* 2013; Gashu & Gebre-Egziabher 2018). Increased soil erosion was one of the perceived negative local effects of land use and land cover changes in the Huluka watershed. This perception is similar to the confirmations by previous studies in Ethiopia which confirmed that soil erosion is the result of land use and land cover transformation. For instance, scholars

in the field attest that cultivated land use and land cover, and bare land use and land cover are vulnerable to soil erosion (Assen 2011; Wubie *et al.* 2016; Miheretu & Yimer 2017; Tellen & Yerima 2018; Yesuph & Dagneu 2019; Girma & Gebre 2020).

Increased sedimentation into water resources was one of the perceived negative local effects of land use and land cover changes in the Huluka watershed. This perception is similar to the assertions of scholars in the field who assert that land use and land cover changes underpin water pollution and threaten the lives of globally important species dependent on wetlands like lakes and rivers (Esa *et al.* 2018; Karki *et al.* 2018). The decrease in soil fertility was one of the perceived negative local effects of land use and land cover changes in the Huluka watershed. This perception is similar to the assertion of scholars who assert that decline in soil fertility is underpinned by the transformation of land use and land cover (Wubie *et al.* 2016; Bekele *et al.* 2018; Karki *et al.* 2018).

The negative local effects of land use and land cover changes have critical implications for sustainable watershed management in the study area. It is attested that appropriate strategic measures should be practiced to reduce the negative local effects of land use and land cover changes (Gashaw *et al.* 2017; Hassen & Assen 2017; Hishe *et al.* 2017; Kassie 2017; Mekuriaw 2017; Worku *et al.* 2017; Zewdie *et al.* 2017; Gella 2018). Many of them strongly affirm that it is vital to institutionalize sustainable biological and physical soil conservation measures to mitigate land degradation and improve the livelihood of the local community in the watershed (Amdihun *et al.* 2014; Wolancho 2015; Wolka *et al.* 2015; Yimer *et al.* 2015; Tadesse *et al.* 2017; Deribew & Dalacho 2019; Kidane *et al.* 2019). Others assert that integrated water resources planning and management is vital as one of the elements of natural resources management (Laekemariam *et al.* 2016; Qayum *et al.* 2016; Seyoum 2016; Teshome 2016; Miheretu & Yimer 2017; Meshesha & Khare 2019). Others affirm that payments for ecological services are vital for the sustainable management of natural resources (Tolessa *et al.* 2017; Bogale 2020; Hasan *et al.* 2020).

CHAPTER SEVEN: ANALYSIS OF FLOODING HAZARD AND RISK IN HULUKA WATERSHED AND AMBO TOWN

The aim of this chapter is to analyze flooding hazard and risk in Huluka watershed and Ambo town.

7.1. Flood Hazard Analysis and Mapping in Huluka Watershed

7.1.1. Contributing Factors for Flood Hazard

Land use and land cover was considered as one of the flood hazard contributing factor in Ambo town's watershed. Forest, grass land, cultivated land, built-up area, and water body were rated as very low, low, moderate, high, and very high flooding hazard land use and land cover respectively (Figure 7.1).

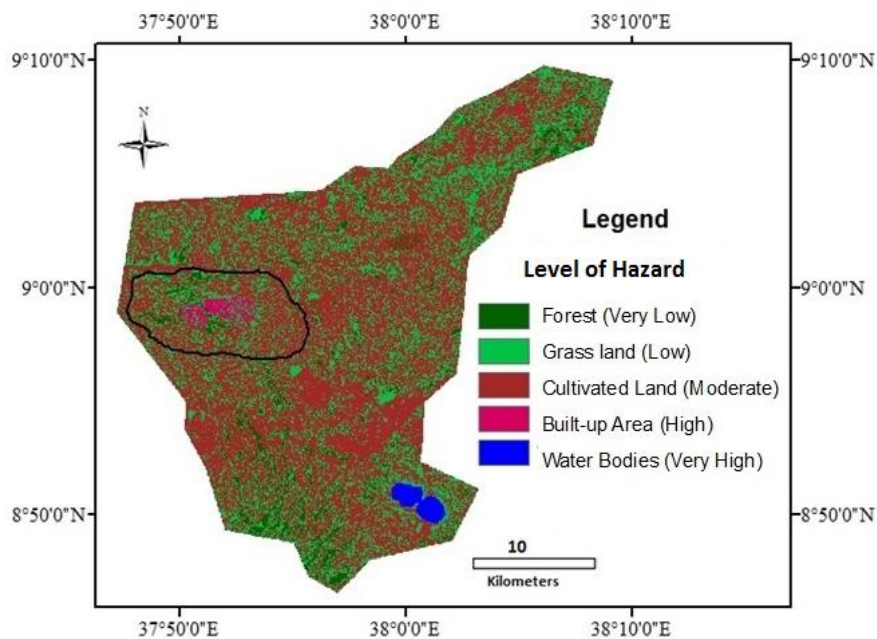


Figure 7.1 Land Use factor map for flood hazard in Ambo town's watershed (weighted)

Elevation was considered as one of the flooding hazard contributing factor in Ambo town's watershed. The highest elevation of the watershed is 3253 meter while the lowest elevation is 1834m. The lowest elevation category (1834m-2118m) was rated as very high flooding hazard elevation category while the highest elevation category (2969m-3253m) was rated as very low flooding hazard elevation category (Figure 7.2).

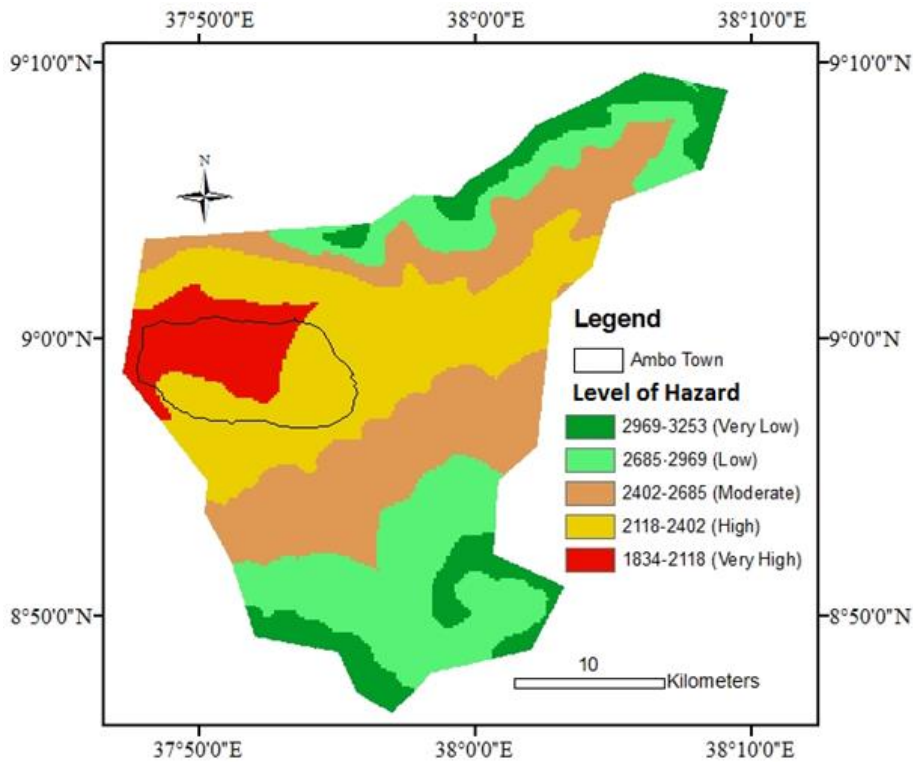


Figure 7. 2 Elevation factor map for flood hazard in Ambo town's watershed (weighted)

Slope was considered as one of the flood hazard contributing factor in Ambo town's watershed. The highest slope of the watershed is 32 degree while the lowest slope is 0 degree. The lowest slope category (0-6.51 degree) was rated as very high flooding hazard slope category while the highest slope category (26.04-32.55 degree) was rated as very low flooding hazard slope category (Figure 7.3).

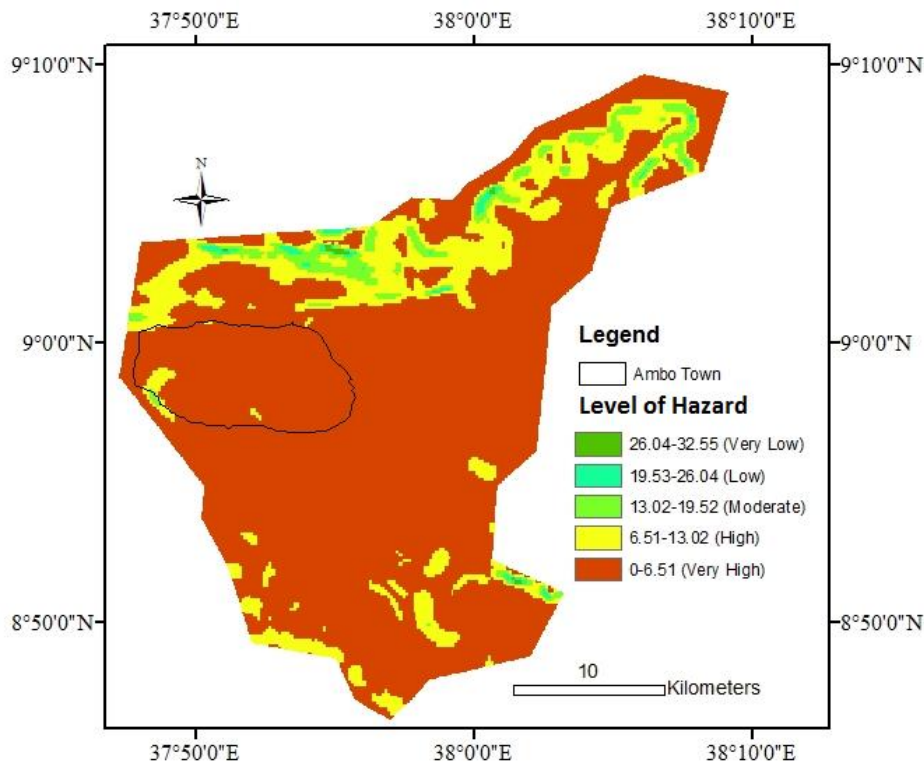


Figure7. 3 Slope factor map for flood hazard in Ambo town’s watershed (weighted)

Drainage density was considered as one of the flood hazard contributing factor in Ambo town’s watershed. The highest drainage density the watershed is 13.8 km/Km^2 while the lowest drainage density is 0 km/Km^2 . The lowest drainage density category ($0\text{-}2.76 \text{ km/Km}^2$) was rated as very high flooding hazard drainage density category while the highest drainage density category ($11.04\text{-}13.8 \text{ km/Km}^2$) was rated as very low flooding hazard category (Figure7.4).

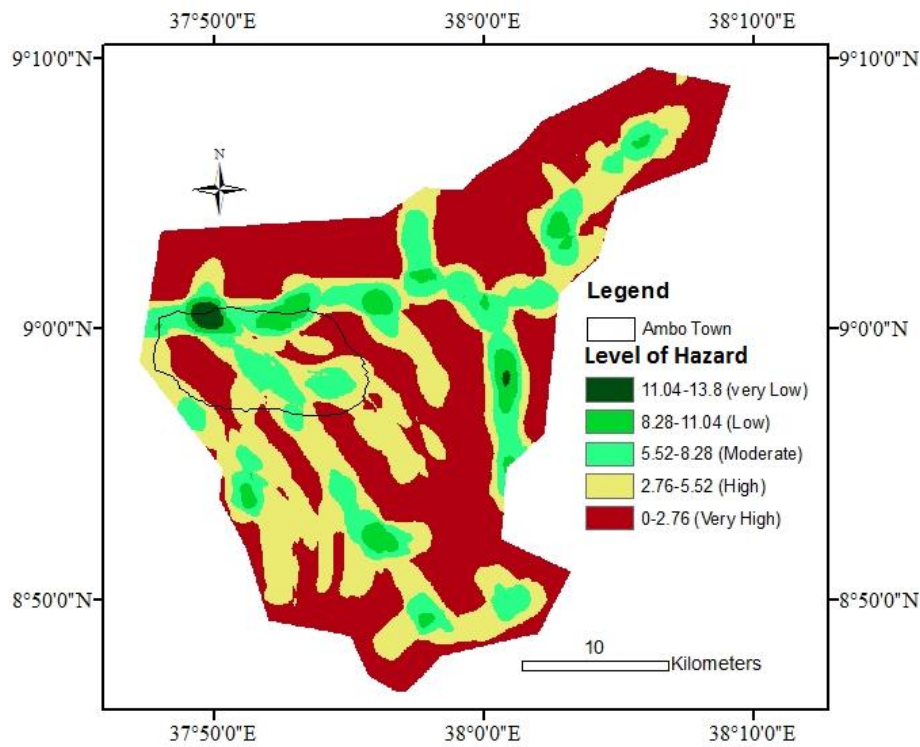


Figure7. 4 Drainage density factor map for flood hazard in Ambo town's watershed (km/Km²) (weighted)

Soil type was considered as one of the flooding hazard contributing factors in Ambo town's watershed. Eutric Cambisols, Eutric Nitosols, Orthic and Chromic Luvisols, Leptosols, and Pellic and Chromic Vertisols were rated as very low, low, moderate, high, and very high flooding hazard soil type respectively (Figure 7.5).

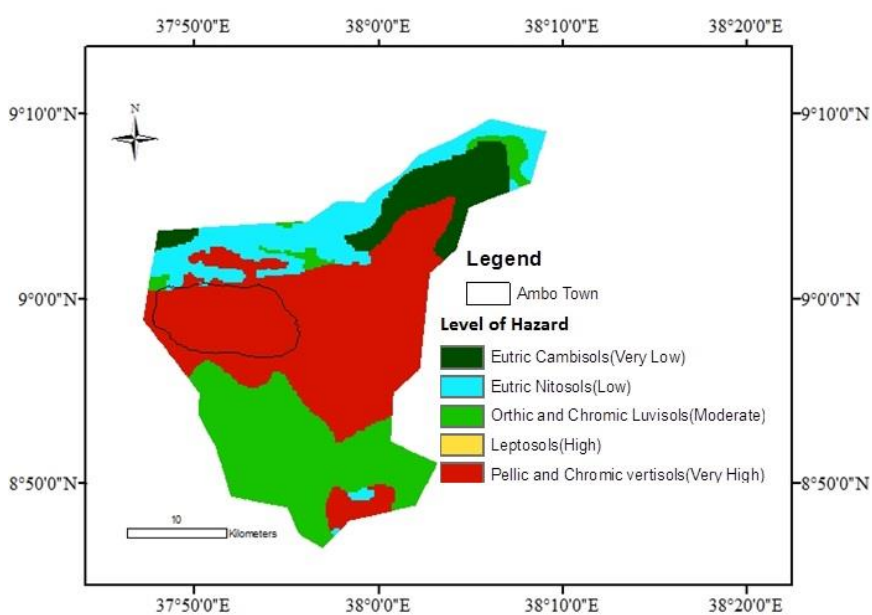


Figure7. 5 Soil type factor map for flood hazard in Ambo town's watershed (Weighted)

Rainfall was considered as one of the flood hazard contributing factor in Huluka Watershed. The highest average daily maximum annual rainfall of the watershed over 32 years (1984-2015) was 43.45 while the lowest was 39 mm. The lowest category (39-39.89mm) was rated as very low flooding hazard category while the highest rainfall category (42.56mm-43.45mm) was rated as very high flooding hazard rainfall category (Figure 7.6).

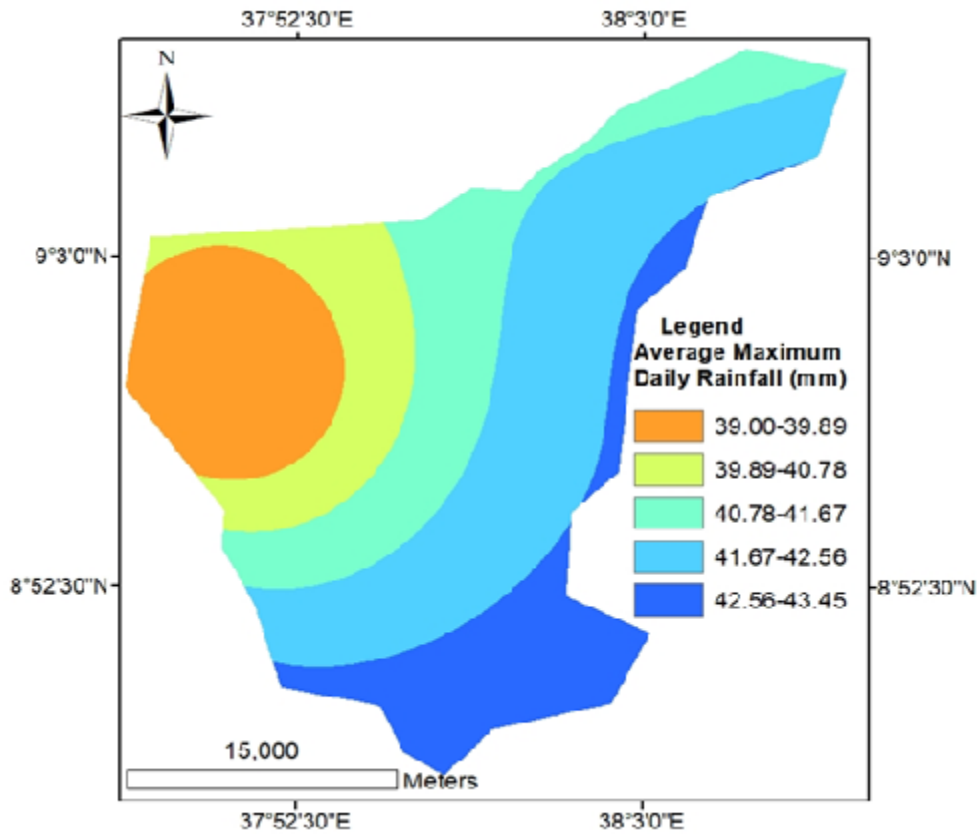


Figure 7.6 Rainfall factor map for flood hazard in Huluka watershed (Weighted)

7.1.2. Flood hazard mapping in Huluka watershed

The result of the flooding hazard in the watershed reveals that 63.04% (509176346m²) of the watershed is moderate flooding hazard area (Figure 7.7 and Table 7.1). The result confirmed that about 52.9% (44866800m²) of Ambo town is moderate flooding hazard area (Figure 7.8 and Table 7.2).

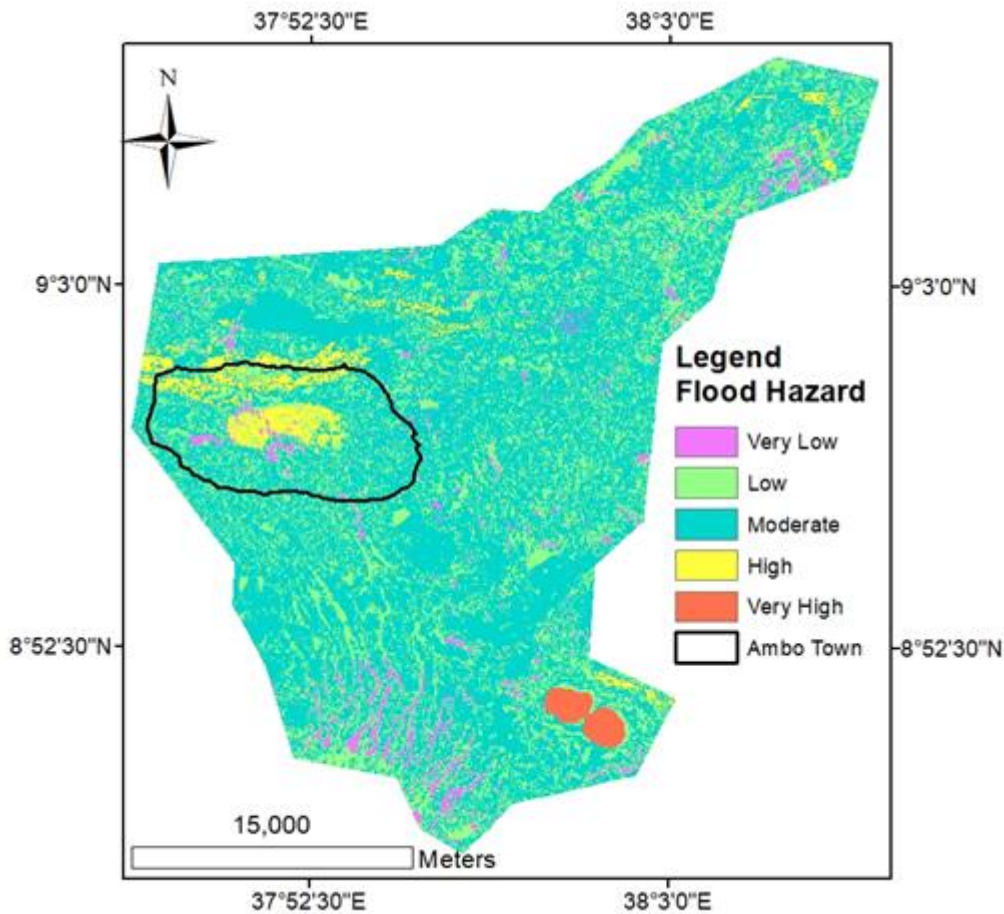


Figure 7.7 Flooding hazard Map of Huluka watershed

Table 7.1 Flooding hazard area in Huluka watershed

Flooding hazard value	Area (m ²)	Percent
Very Low	28420112	3.52
Low	234399104	29.04
Moderate	509176346	63.04
High	27806372	3.44
Very High	7474666.7	0.95
Total	807276600	100

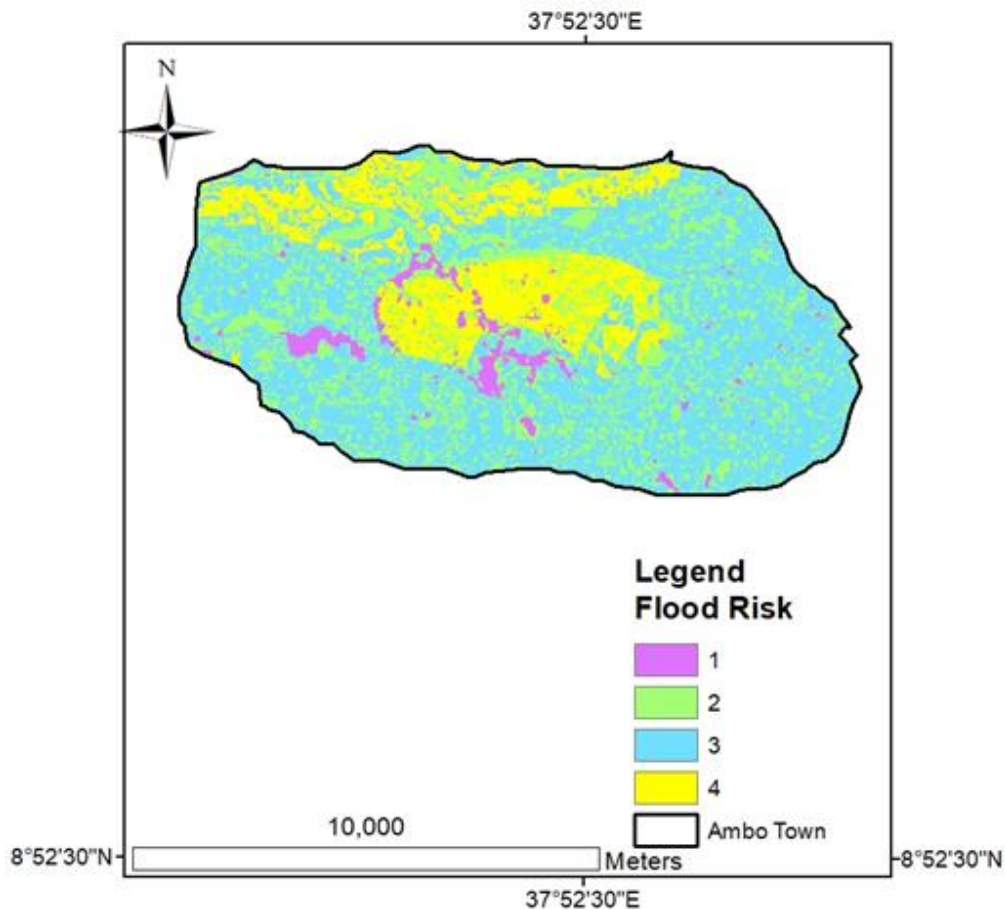


Figure7. 8 Flood Hazard Map for Ambo town

Table7. 2 Flooding hazard Area in Ambo town

Flooding hazard value	Area (m ²)	Percent
Very Low	3015000	3.55
Low	22635900	26.68
Moderate	44866800	52.88
High	29348100	16.89
Very High	-	-
Total	84846600	100

7.2. Flood Risk Analysis and Mapping in Huluka Watershed

7.2.1. Contributing Factors for Flood Risk

Human population density was considered as one of the flooding risk contributing factor in Ambo town’s watershed. The highest human population density of the watershed is 6596

persons/Km² while the lowest human population density is 0 persons/Km². The lowest human population density category (0-58 persons/Km²) was rated as very low flooding risk human population density category while the highest human population density category (1846-6596 persons /Km²) was rated as very high flooding risk category (Figure 7.9).

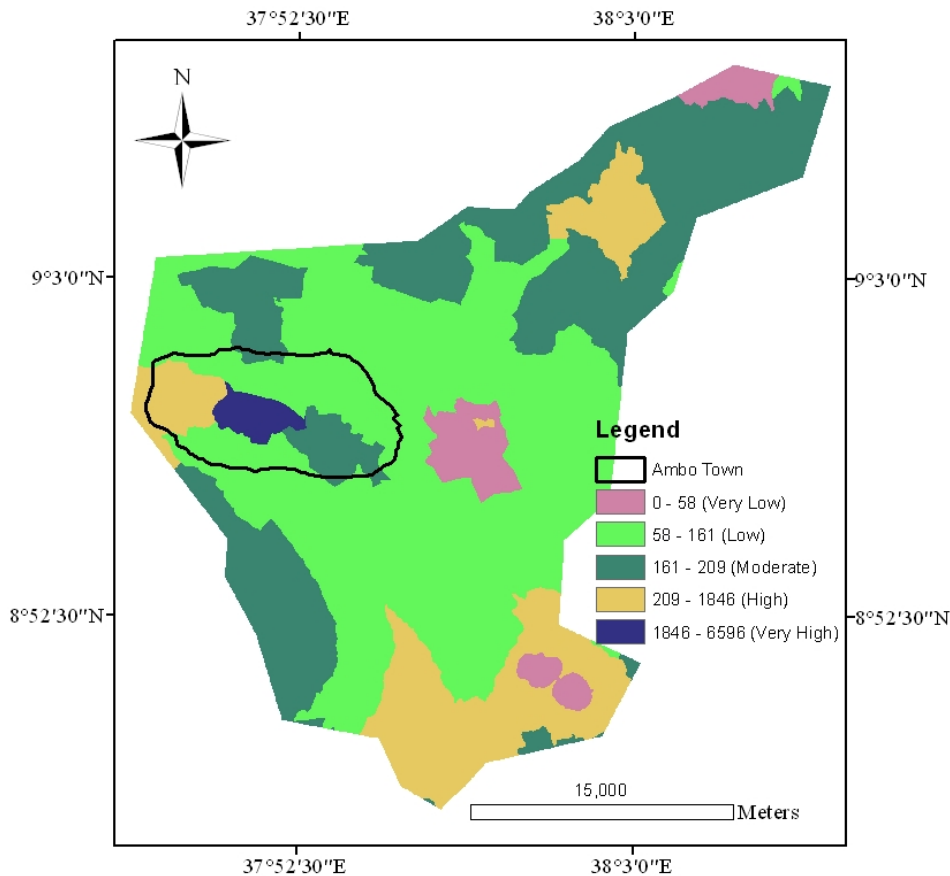


Figure7. 9 Human population density factor for flooding risk in Ambo Town’s watershed (Weighted)

Land use and land cover was considered as one of the flooding risk contributing factor in Ambo town’s watershed. Forest, grass land, cultivated land, built-up area, and water body were rated as very low, low, moderate, high, and very high flooding risk land use and land cover respectively (Figure 7.10). Flooding hazard layer was considered as one of the flooding risk contributing factor in Ambo town’s watershed. Very low, low, moderate, high, and very high flooding hazard area was rated as very low, low, moderate, high, and very high flooding risk area respectively (Figure 7.11).

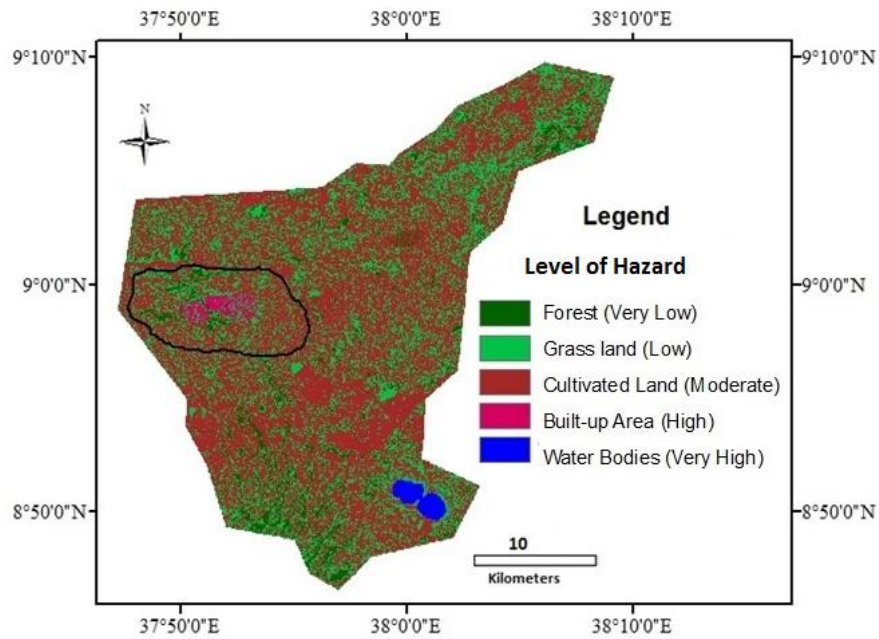


Figure7. 10 Land use factor map for flooding risk in Ambo town's watershed (weighted)

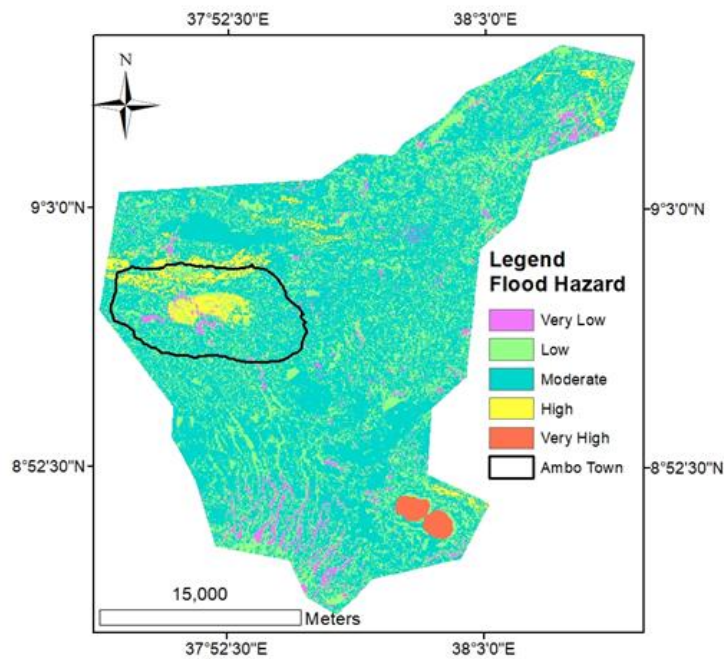


Figure7. 11 Flooding hazard factor for flooding risk in Ambo Town's watershed (weighted)

7.2.2. Flood risk mapping in Huluka Watershed

The result of the flooding risk in the watershed reveals that 20.2% (162972211m²) of the watershed is moderate flooding risk area (Figure 7.12 and Table 7.3). Moreover, 21% of Ambo town is high and very high flooding risk area (Figure 7.13 and Table 7.4).

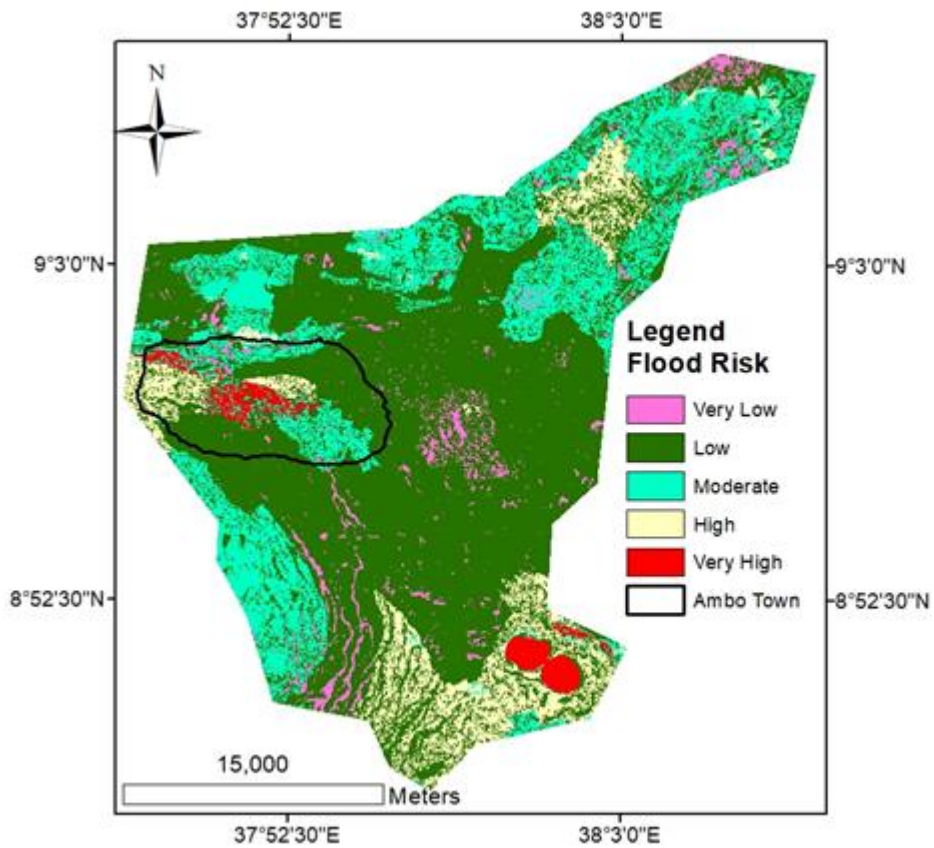


Figure7. 12 Flood risk Map for Huluka Watershed

Table7. 3 Flooding Risk Area in Huluka watershed

Flooding Risk Value	Area (M²)	Percent
Very Low	35834484	4.44
Low	515662010	63.88
Moderate	162972211	20.19
High	75399103	9.34
Very High	17408792	2.16
Total	807276600	100

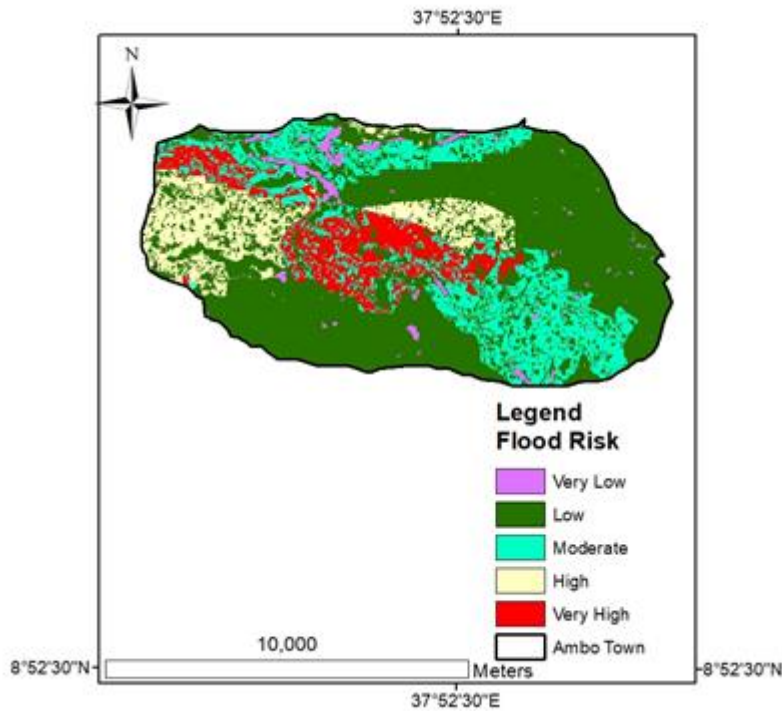


Figure7. 13 Flood Risk map for Ambo town

Table7. 4 Flooding Risk Area in Ambo town

Flooding Risk Value	Area (M ²)	Percent
Very Low	1957625	2.31
Low	47766040	56.30
Moderate	17446710	20.56
High	9051876	10.67
Very High	8624349	10.16
Total	84846600	100

7.3. Verification and Observation of Flood Risk in Huluka Watershed

Verification and observation of flood risk was made during 2017 rainy season (June, July, August, and September) in Huluka watershed to compare the final flood risk mapping with the current real field condition in the watershed. To this end, 259 GPS reading ground truth data of flood affected areas across different land use and land cover types were registered and converted to shape file. These point shape files were superimposed with the flood risk map and the flood risk map was verified with the actual field situations (Figure 7.14).

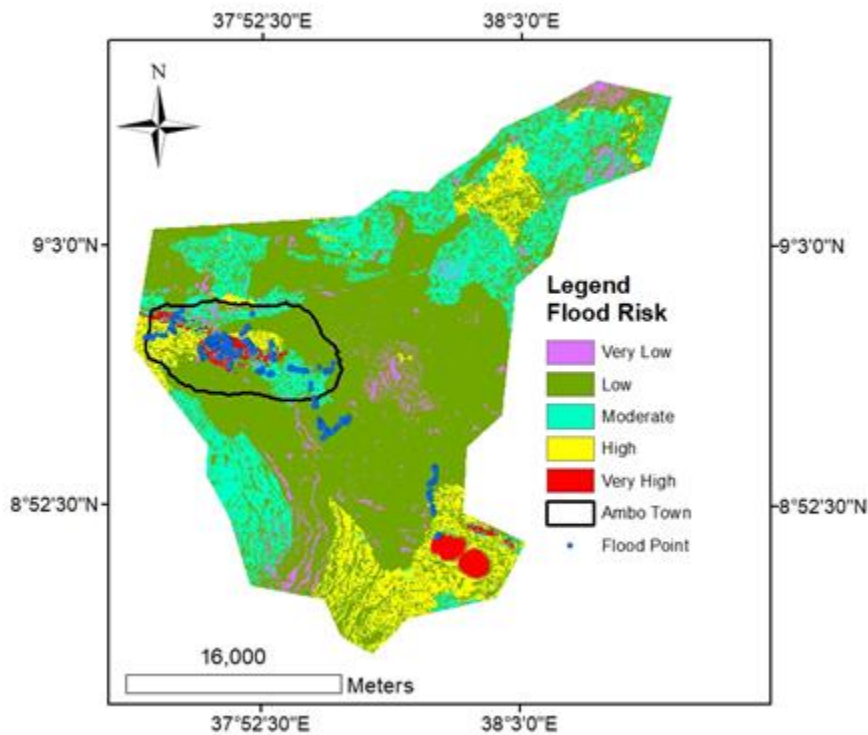


Figure7. 14 Distribution of ground truth points of flood risk areas in Ambo town's watershed

7.4. Discussion

Flood disasters are asserted to be among the most frequent and devastating types of disasters over the world. Scholars affirm that it is necessary to analyze flood risk to ensure healthy and sustainable economic development, and flood risk assessment has become worldwide one of the hot issues in the field of natural science and technology (Yahaya *et al.*, 2010; Zou *et al.*, 2013). It is asserted that comprehensive flood risk assessment is a synthetic evaluation and consists of many factors, including the hazard of disaster-inducing factors and disaster-breeding environment, as well as the vulnerability of hazards-bearing bodies (Zerger & Smith, 2003; Sayers *et al.*, 2013; Zou *et al.*, 2013; Guo *et al.*, 2014). For instance, assessing areas vulnerable to flooding disasters is one of the parameters in creating a flood-risk map for disaster mitigation and urban planning (Wang *et al.*, 2011; Ouma & Tateishi, 2014; Islam *et al.*, 2016; Gigovi'c *et al.*, 2017 ;Rimba *et al.*, 2017).

This study considered land use/land cover, elevation, slope, drainage density, soil, and rainfall as important flooding hazard factors in Ambo town's watershed. It is attested that

land use/land cover change is one of the major contributor of flooding hazard as urban expansion increases, impervious cover increases and forest cover decreases in urban areas contributing to increase in run-off (Tucci, 2007; Jha *et al.*, 2012; Mngutyo & Ogwuche, 2013; Migosi, 2014). For scholars like Gigović *et al.* (2017) elevation has a key role in controlling the movement of the overflow direction and in the depth of the water level. Slope is a major factor in determining the rate and duration of water flow as flatter surface areas are riskier with respect to the occurrence of floods in relation to the steeper surfaces (Gigović *et al.*, 2017; Rimba *et al.*, 2017).

Drainage density is one of the important flooding hazard factors and it is an inverse function of infiltration (Chibssa, 2007; Ouma & Tateishi, 2014; Wondim, 2016). Soil characteristics in a watershed such as soil layer thickness, permeability, infiltration rate and the degree of moisture in the soil before the rain event are claimed to have a direct effect on the rainfall-runoff process (Zhiyu *et al.*, 2013; Ouma & Tateishi, 2014; Rimba *et al.*, 2017). Observed and projected patterns of climate change are attested to have an amplifying effect on existing flood risk. For example, changing local rainfall patterns may lead to more frequent and higher level of floods from rivers and more intense flash flooding (Andjelkovic, 2001; Few *et al.*, 2004; Jha *et al.*, 2012; Berggren *et al.*, 2013; Hall *et al.*, 2014).

This study considered flooding hazard layer, population density, and land use/land cover type as the three important factors for flooding risk mapping and these three factors were considered to be equally important in the weighted overlay process (Chibssa, 2007; Wondim, 2016). Scholars of sustainable urban flooding risk management assert that flooding risk is contributed to by two components, flood hazard and flood vulnerability. The flood hazard component is claimed to represent physical processes, whereas flood vulnerability is claimed to represent susceptibility to damage or loss, the risk of human lives, property or human activities (Dang *et al.*, 2011). The flood risk maps thus developed are claimed to be useful to policy-makers and responsible authorities, as well as to local residents in finding suitable measures for reducing flood risk in the study area (Zerger & Smith, 2003; Dang *et al.*, 2011; Sayers *et al.*, 2013).

Urbanization is claimed to be implicated in and compound flood risk (Few *et al.*, 2004; Jha *et al.*, 2012; Santato *et al.*, 2013). Few *et al.* (2004) attests that human vulnerability to floods is affected by drivers of change like population growth and settlement pattern. In other words,

as cities become larger and larger, and as populations become more and more urbanized, urban environmental effects are affirmed to increase (Andjelkovic, 2001; Few *et al.*, 2004; Santato *et al.*, 2013).

Population growth is asserted to be one of the contributors for urban flooding risk as human population in cities and towns in developing countries is rapidly growing and there is settlement of watersheds and valley bottoms greatly altering drainage patterns and destabilizing slopes and resulting in increasing the risks of flooding and landslides (Dewan *et al.*, 2007; Diagne, 2007; Jha *et al.*, 2012; Wilby & Keenan, 2012; Santato *et al.*, 2013). Dewan *et al.* (2007) contend that increasing population pressure may force many people to enter the vacant land of cities and towns of least developed countries by filling up of natural channels and floodplains which may result in increased flood risk. In other words, when population growth is faster than the rate at which the municipal authorities or the private sector can provide housing and basic infrastructure, risks can build up quickly. Moreover, settlement of watersheds and valley bottoms are claimed to greatly alter drainage patterns and destabilize slopes, increasing the risks of flooding and landslides (Diagne, 2007; Dewan *et al.*, 2007; Few *et al.*, 2004; Santato *et al.*, 2013).

According to Jha *et al.* (2012), the accelerating urbanization and urban development could also increase significantly the risk of flooding independent of climate change. The impact of future urban growth on flood risk is claimed to be influenced by the policies and choices of urban dwellers as they may or may not occupy areas at risk of flooding, or adopt suitable urban planning and design (Few *et al.*, 2004; Pottier *et al.*, 2005; Tucci, 2007; McGranahan *et al.*, 2009; Jha *et al.*, 2012). In other words, better planned and managed urban development is asserted to mitigate the expected growth in future flood risk (Tucci, 2007; Jha *et al.*, 2012; Mngutyo & Ogwuche, 2013).

CHAPTER EIGHT: INTENSITY-DURATION-FREQUENCY (IDF) RELATIONSHIP IN AMBO TOWN AND ITS WATERSHED

8.1. Extreme Shorter Duration rainfall Series for Seven Stations

Table8. 1 Extreme shorter duration rainfall series for Ambo Agricultural Research Center Station (1984-2015)

S.No	Years	30Min	60Min	120Min	180Min	360Min	720Min	1440Min
1	1984	7.2	10.4	13.8	15.2	20.7	27.6	34.5
2	1985	4.9	7.1	9.4	10.3	14.1	18.8	23.5
3	1986	6.2	8.9	11.8	13	17.7	23.6	29.5
4	1987	8.4	12	16	17.6	24	32	40
5	1988	17	24.3	32.4	35.6	48.6	64.8	81
6	1989	7.6	10.8	14.4	15.8	21.6	28.8	36
7	1990	14	20	26.7	29.4	40.1	53.4	66.8
8	1991	9.5	13.6	18.1	19.9	27.2	36.2	45.3
9	1992	7.5	10.7	14.3	15.8	21.5	28.6	35.8
10	1993	8	11.5	15.3	16.8	22.9	30.6	38.2
11	1994	10.8	15.4	20.5	22.6	30.8	41	51.3
12	1995	6.9	10	13.2	14.5	19.8	26.4	33
13	1996	7.9	11.3	15.1	16.6	22.6	30.2	37.7
14	1997	6.8	9.8	13	14.3	19.5	26	32.5
15	1998	9.3	13.4	17.8	19.6	26.7	35.6	44.5
16	1999	6.1	8.7	11.6	12.7	17.3	23.1	28.9
17	2000	6.8	9.8	13	14.3	19.5	26	32.5
18	2001	6.4	9.2	12.2	13.4	18.3	24.4	30.5
19	2002	3.8	5.5	7.3	8.1	11	14.6	18.3
20	2003	12	17	22.8	25.1	34.3	45.7	57.1
21	2004	5.9	8.4	11.2	12.3	16.8	22.4	28
22	2005	3.9	5.6	7.4	8.1	11.1	14.8	18.5
23	2006	10.3	14.7	19.6	21.6	29.4	39.2	49
24	2007	9.4	13.4	17.8	19.6	26.8	35.7	44.6
25	2008	7.5	10.7	14.2	15.6	21.3	28.4	35.5
26	2009	7.6	10.8	14.4	15.8	21.6	28.8	36
27	2010	8.2	11.7	15.6	17.2	23.4	31.2	39
28	2011	8.5	12	16.2	17.8	24.3	32.4	40.5
29	2012	10.2	14.6	19.4	21.4	29.2	38.9	48.6
30	2013	9.6	13.7	18.2	20	27.3	36.4	45.5
31	2014	8.7	12.5	16.6	18.3	25	29.1	41.6
32	2015	4.9	6.9	9.2	10.2	14	18.5	23.1
	Mean	8.3	11.9	15.6	17.1	23.4	31	39
	SD	2.7	3.9	5.2	5.7	7.8	10.4	13

Source: Excel Computation based on The Indian Meteorological Department (IMD) formula

Table8. 2 Extreme shorter duration rainfall series for Asgori Station (1984-2015)

S.No	Years	30Min	60Min	120Min	180Min	360Min	720Min	1440Min
1	1984	8.1	11.5	15.4	16.9	23	30.7	38.4
2	1985	9.9	20.1	18.9	20.8	28.3	37.8	47.2
3	1986	14.1	20.1	26.8	29.4	40.1	53.5	66.9
4	1987	8	11.5	15.3	16.8	22.9	30.6	38.2
5	1988	7.6	10.9	14.6	16	21.8	29.1	36.4
6	1989	7.4	10.6	14.1	15.5	21.2	28.2	35.3
7	1990	9.1	13	17.3	19	25.9	34.6	43.2
8	1991	10.2	14.6	19.4	21.3	29.1	38.8	48.5
9	1992	9.5	13.6	18.1	19.9	27.1	36.2	45.2
10	1993	9.9	14.2	18.9	20.8	28.4	37.8	47.3
11	1994	11.2	16.1	21.4	23.5	32.1	42.8	53.5
12	1995	6	8.6	11.4	12.5	17.1	22.8	28.5
13	1996	6.4	9.1	12.1	13.3	18.2	24.2	30.3
14	1997	9.7	13.9	18.5	20.4	27.8	37	46.3
15	1998	10.4	14.8	19.7	21.7	29.6	39.4	49.3
16	1999	11.7	16.7	22.3	24.6	33.5	44.6	55.8
17	2000	6.6	9.5	12.6	13.9	18.9	25.2	31.5
18	2001	6.7	9.5	12.7	14	19.1	25.4	31.8
19	2002	7.9	11.3	15	16.5	22.5	30	37.5
20	2003	8.2	11.7	15.6	17.2	23.4	31.2	39
21	2004	8.7	12.4	16.5	18.2	24.8	33	41.3
22	2005	8.4	12.1	16.1	17.7	24.1	32.2	40.2
23	2006	10	14.3	19	20.9	28.6	38.1	47.6
24	2007	8.6	12.3	16.4	18	24.5	32.7	40.9
25	2008	6.8	9.8	13	14.3	19.6	26.1	32.6
26	2009	8.2	11.6	15.5	17.1	23.3	31	38.8
27	2010	8.3	11.9	15.8	17.4	23.7	31.6	39.5
28	2011	7	10	13.4	14.7	20	26.7	33.4
29	2012	8.9	12.8	17	18.7	25.6	34.1	42.6
30	2013	8.8	12.6	16.8	18.5	25.2	33.6	42
31	2014	12.6	18	24	26.5	36.1	48.1	60.1
32	2015	8.1	11.5	15.4	16.9	23	30.7	38.4
	Mean	8.8	12.8	16.8	18.5	25.3	33.7	42.1
	STDev	1.8	2.9	3.5	3.8	5.2	7	9

Source: Excel Computation based on The Indian Meteorological Department (IMD) formula

Table8. 3 Extreme shorter duration rainfall series for Busa Station (1984-2015)

S.No	Years	30Min	60Min	120Min	180Min	360Min	720Min	1440Min
1	1984	6.7	9.5	12.7	13.9	19	25.4	31.7
2	1985	7.5	10.7	14.2	15.6	21.3	28.4	35.5
3	1986	8.5	12.2	16.3	17.9	24.4	32.6	40.7
4	1987	5.4	7.7	10.2	11.2	15.3	20.4	25.5
5	1988	8.9	12.7	16.9	18.6	25.3	33.8	42.2
6	1989	6.2	8.9	11.9	13.1	17.8	23.8	29.7
7	1990	15.1	21.5	28.7	31.6	43.1	57.4	71.8
8	1991	13.8	19.7	26.2	28.9	39.4	52.5	65.6
9	1992	10.7	15.3	20.4	22.5	30.6	40.8	51.1
10	1993	10.8	15.4	20.6	22.6	30.8	41.1	51.4
11	1994	11.7	16.7	22.2	24.5	33.4	44.5	55.6
12	1995	5.8	8.3	11.1	12.2	16.7	22.2	27.8
13	1996	10.7	15.3	20.4	22.4	30.6	40.8	51
14	1997	9.4	13.4	17.9	19.7	26.9	35.8	44.8
15	1998	9.8	14	18.6	20.5	28	37.3	46.6
16	1999	11.8	16.9	22.5	24.7	33.7	45	56.2
17	2000	12	17.1	22.8	25.1	34.2	45.6	57
18	2001	12.1	17.3	23.1	25.4	34.6	46.2	57.7
19	2002	9.24	13.2	17.6	19.4	26.4	35.2	44
20	2003	9.24	13.2	17.6	19.4	26.4	35.2	44
21	2004	6.9	9.9	13.2	14.5	19.8	26.4	33
22	2005	8.7	12.5	16.6	18.3	24.9	33.2	41.5
23	2006	11.2	15.9	21.2	23.4	31.9	42.5	53.1
24	2007	10	14.3	19.1	21	28.7	38.2	47.8
25	2008	9	12.9	17.2	18.9	25.7	34.3	42.9
26	2009	7.8	11.2	14.9	16.4	22.4	29.8	37.3
27	2010	7.4	10.6	14.2	15.6	21.2	28.3	35.4
28	2011	7.9	11.3	15	16.5	22.5	30	37.5
29	2012	9.4	13.4	17.8	19.6	26.8	35.7	44.6
30	2013	7.2	10.3	13.8	15.1	20.6	27.5	34.4
31	2014	5.2	7.4	9.9	10.9	14.9	19.8	24.8
32	2015	8.1	11.5	15.4	16.9	23	30.7	38.4
	Mean	9.2	13.1	17.5	19.3	26.3	35	43.8
	STDev	2.4	3.4	4.5	5	6.8	9	11.3

Source: Excel Computation based on The Indian Meteorological Department (IMD) formula

Table8. 4 Extreme shorter duration rainfall series for Ginchi Station (1984-2015)

S.No	Years	30Min	60Min	120Min	180Min	360Min	720Min	1440Min
1	1984	9.8	13.9	18.6	20.5	27.9	37.2	46.5
2	1985	10	14.2	19	20.9	28.4	37.9	47.4
3	1986	10.5	14.9	19.9	21.9	29.9	39.8	49.8
4	1987	12.8	18.2	24.3	26.8	36.5	48.6	60.8
5	1988	12.6	18	24	26.4	36	48	60
6	1989	15.6	22.3	29.7	32.7	44.6	59.4	74.3
7	1990	7.4	10.5	14	15.4	21	28	35
8	1991	8.6	12.3	16.4	18.1	24.7	32.9	41.1
9	1992	6.3	9	12	13.2	18	24	30
10	1993	11.4	16.4	21.8	24	32.7	43.6	54.5
11	1994	8	11.4	15.2	16.8	22.9	30.5	38.1
12	1995	9.2	13.2	17.6	19.4	26.4	35.2	44
13	1996	7.5	10.7	14.2	15.7	21.4	28.5	35.6
14	1997	11.4	16.3	21.7	23.8	32.5	43.4	54.2
15	1998	7.6	10.8	14.4	15.9	21.7	28.9	36.1
16	1999	14	20	26.6	29.3	40	53.3	66.6
17	2000	6.7	9.6	12.8	14.1	19.2	25.6	32
18	2001	8.4	12	16	17.6	24	32	40
19	2002	10.2	14.6	19.4	21.3	29.1	38.8	48.5
20	2003	6.3	9.1	12.1	13.3	18.1	24.2	30.2
21	2004	9.8	14	18.6	20.5	27.9	37.2	46.5
22	2005	6.8	9.8	13	14.3	19.5	26	32.5
23	2006	8.6	12.3	16.4	18	24.5	32.7	40.9
24	2007	8.2	11.8	15.7	17.2	23.5	31.4	39.2
25	2008	6.2	8.8	11.8	12.9	17.6	23.5	29.4
26	2009	9.1	13	17.3	19.1	26	34.6	43.3
27	2010	6.3	9	12	13.2	18	24	30
28	2011	6.3	9.1	12.1	13.3	18.1	24.2	30.2
29	2012	8.6	12.3	16.4	18	24.6	32.8	41
30	2013	14.8	21.1	28.2	31	42.2	56.3	70.4
31	2014	6.5	9.3	12.4	13.7	18.7	24.9	31.1
32	2015	5.5	7.9	10.5	11.6	15.8	21	26.3
	Mean	9.1	13	17.3	19.1	26	34.6	43.3
	Stdev	2.7	3.8	5.1	5.6	7.6	10.2	12.7

Source: Excel Computation based on The Indian Meteorological Department (IMD) formula

Table8. 5 Extreme shorter duration rainfall series for Jeldu Station (1984-2015)

S.No	Years	30Min	60Min	120Min	180Min	360Min	720Min	1440Min
1	1984	8.4	11.9	15.9	17.5	23.9	31.8	39.8
2	1985	8.3	11.8	15.8	17.3	23.6	31.5	39.4
3	1986	10.2	14.6	19.5	21.4	29.2	39	48.7
4	1987	9.8	14	18.6	20.5	28	37.3	46.6
5	1988	11.6	16.5	22	24.2	33	44	55
6	1989	8.1	11.6	15.5	17	23.2	31	38.7
7	1990	7.7	11.1	14.8	16.2	22.1	29.5	36.9
8	1991	9.7	13.9	18.5	20.4	27.8	37	46.3
9	1992	6.8	9.7	12.9	14.2	19.3	25.8	32.2
10	1993	9.9	14.1	18.8	20.7	28.2	37.6	47
11	1994	10	14.3	19.1	21	28.6	38.2	47.7
12	1995	5.6	8	10.6	11.7	15.9	21.2	26.5
13	1996	9.9	14.2	18.9	20.8	28.4	37.8	47.3
14	1997	9.5	13.5	18	19.8	27	36	45
15	1998	7.7	11.1	14.8	16.2	22.1	29.5	36.9
16	1999	6.7	9.6	12.8	14.1	19.3	25.7	32.1
17	2000	7.1	10.1	13.4	14.8	20.2	26.9	33.6
18	2001	9.7	13.9	18.5	20.4	27.8	37	46.3
19	2002	6.3	9	12	13.2	18	24	30
20	2003	7.4	10.6	14.2	15.6	21.2	28.3	35.4
21	2004	5.5	7.9	10.6	11.6	15.8	21.1	26.4
22	2005	6.4	9.1	12.2	13.4	18.2	24.3	30.4
23	2006	11.1	15.8	21.1	23.2	31.7	42.2	52.8
24	2007	8.2	11.7	15.6	17.2	23.4	31.2	39
25	2008	6.8	9.8	13	14.3	19.5	26	32.5
26	2009	8.3	11.8	15.8	17.3	23.6	31.5	39.4
27	2010	5.9	8.4	11.2	12.3	16.8	22.4	28
28	2011	6.2	8.9	11.8	13	17.7	23.6	29.5
29	2012	9.3	13.2	17.6	19.4	26.5	35.3	44.1
30	2013	7.9	11.3	15	16.5	22.5	30	37.5
31	2014	9.6	13.7	18.2	20.1	27.4	36.5	45.6
32	2015	6.3	8.9	11.9	13.1	17.9	23.8	29.8
	Mean	8.2	11.7	15.6	17.1	23.4	31.2	39
	STDev	1.7	2.4	3.2	3.5	4.8	6.4	8

Source: Excel Computation based on The Indian Meteorological Department (IMD) formula

Table8. 6 Extreme shorter duration rainfall series for Tulu Bolo Station (1984-2015)

S.No	Years	30Min	60Min	120Min	180Min	360Min	720Min	1440Min
1	1984	6.4	9.2	12.2	13.5	18.4	24.5	30.6
2	1985	10	14.3	19	20.9	28.6	38.1	47.6
3	1986	11.8	16.9	22.5	24.8	33.8	45	56.3
4	1987	5.9	8.5	11.3	12.4	16.9	22.6	28.2
5	1988	8.4	12	16	17.6	24	32	40
6	1989	5.9	8.4	11.2	12.3	16.8	22.4	28
7	1990	4.3	6.1	8.1	8.9	12.2	16.2	20.3
8	1991	4.3	6.1	8.2	9	12.2	16.3	20.4
9	1992	18.5	26.5	35.3	38.9	53	70.6	88.3
10	1993	7	9.9	13.2	14.6	19.9	26.5	33.1
11	1994	6.3	9	12	13.2	18	24	30
12	1995	5.9	8.4	11.2	12.3	16.8	22.4	28
13	1996	8.5	12.1	16.2	17.8	24.2	32.3	40.4
14	1997	8.6	12.3	16.4	18.1	24.7	32.9	41.1
15	1998	11	15.7	20.9	23.1	31.4	41.9	52.4
16	1999	9.7	13.8	18.4	20.2	27.6	36.8	46
17	2000	10.1	14.4	19.2	21.12	28.8	38.4	48
18	2001	6.1	8.7	11.6	12.8	17.4	23.2	29
19	2002	8.7	12.4	16.6	18.2	24.8	33.1	41.4
20	2003	15.8	22.6	30.1	33.1	45.2	60.2	75.3
21	2004	7.5	10.7	14.2	15.6	21.3	28.4	35.5
22	2005	10.3	14.7	19.6	21.6	29.4	39.2	49
23	2006	9.3	13.3	17.7	19.5	26.6	35.4	44.3
24	2007	6.3	9	12	13.2	18	24	30
25	2008	7.4	10.5	14	15.4	21	28	35
26	2009	6.6	9.5	12.6	13.9	18.9	25.2	31.5
27	2010	6.3	9	12	13.2	18	24	30
28	2011	13.2	18.8	25.1	27.6	37.7	50.2	62.8
29	2012	13.7	19.5	26	28.6	39	52	65
30	2013	7.4	10.5	14	15.4	21	28	35
31	2014	6.3	9	12	13.2	18	24	30
32	2015	6.8	9.7	12.9	14.2	19.3	25.8	32.2
	Mean	8.6	12.2	16.3	17.9	24.5	32.6	40.8
	STDev	3.2	4.6	6.2	6.8	9.3	12.4	15.5

Source: Excel Computation based on The Indian Meteorological Department (IMD) formula

Table8. 7 Extreme shorter duration rainfall series for Woliso Station (1984-2015)

S.No	Years	30Min	60Min	120Min	180Min	360Min	720Min	1440Min
1	1984	9.3	13.4	17.8	19.6	26.7	35.6	44.5
2	1985	9.7	13.9	18.6	20.4	27.8	37.1	46.4
3	1986	8.1	11.6	15.5	17.1	23.3	31	38.8
4	1987	9.7	13.9	18.5	20.4	27.8	37	46.3
5	1988	12	17.2	22.9	25.2	34.3	45.8	57.2
6	1989	9.8	14	18.7	20.6	28.1	37.4	46.8
7	1990	10.2	14.5	19.4	21.3	29	38.7	48.4
8	1991	6.6	9.4	12.5	13.8	18.8	25	31.3
9	1992	8.2	11.7	15.6	17.1	23.3	23.3	38.9
10	1993	7.7	11	14.6	16.1	22	29.3	36.6
11	1994	13.1	18.7	24.9	27.4	37.4	49.8	62.3
12	1995	9.9	14.1	18.8	20.7	28.2	37.6	47
13	1996	14.3	20.5	27.3	30.1	41	54.6	68.3
14	1997	8.9	12.8	17	18.7	25.5	34	42.5
15	1998	8.7	12.5	16.6	18.3	24.9	33.2	41.5
16	1999	11.3	16.1	21.5	23.6	32.2	43	53.7
17	2000	13.3	19	25.4	28	38	50.7	63.4
18	2001	12.4	17.7	23.6	26	35.4	47.2	59
19	2002	10.9	15.6	20.8	22.9	31.2	41.6	52
20	2003	15.9	22.7	30.2	33.2	45.3	60.4	75.5
21	2004	10.3	14.8	19.7	21.6	29.5	39.4	49.2
22	2005	9.9	14.1	18.8	20.7	28.2	37.6	47
23	2006	11.4	16.3	21.8	23.9	32.6	43.5	54.4
24	2007	9.7	13.8	18.4	20.2	27.6	36.8	46
25	2008	13.5	19.3	25.8	28.3	38.6	51.5	64.4
26	2009	7.8	11.1	14.8	16.3	22.2	29.6	37
27	2010	9.7	13.8	18.4	20.2	27.6	36.8	46
28	2011	7.3	10.4	13.9	15.3	20.8	27.8	34.7
29	2012	5.9	8.4	11.2	12.3	16.7	22.3	27.9
30	2013	9.9	14.1	18.8	20.7	28.2	37.6	47
31	2014	12.8	18.3	24.4	26.8	36.5	48.7	60.9
32	2015	11.9	17	22.6	24.9	33.9	45.2	56.5
	Mean	10.3	14.7	19.7	21.6	29.5	39	49.1
	STDev	2.3	3.3	4.4	4.8	6.6	9.1	11

Source: Excel Computation based on The Indian Meteorological Department (IMD) formula

8.2. Probable Rainfall for Different Durations and Return Periods Using Gumbel's Distribution

Table 8. 8 Probable rainfall for different durations and return periods using Gumbel's distribution (Ambo)

30Minutes(Duration)				60Minutes(Duration)				120Minutes			
P_{ave}		8.3		P_{ave}		11.9		P_{ave}		15.6	
S		2.7		S		3.9		S		5.2	
Tr(Year)	K	$P_T(mm)$	$I_T(mm/h)$	Tr(Year)	K	$P_T(mm)$	$I_T(mm/h)$	Tr(Year)	K	$P_T(mm)$	$I_T(mm/h)$
2	- 0.164	7.86	15.7	2	- 0.164	11.3	11.3	2	- 0.164	14.8	7.4
5	0.719	10.2	20.4	5	0.719	14.7	14.7	5	0.719	19.3	9.7
10	1.305	11.8	23.6	10	1.305	17	17	10	1.305	22.4	11.2
25	2.044	13.8	27.6	25	2.044	20	20	25	2.044	26.2	13.1
50	2.592	15.3	30.6	50	2.592	22	22	50	2.592	29.1	14.6
100	3.137	16.8	33.6	100	3.137	24.1	24.1	100	3.137	31.9	16
180Minutes				360 Minutes				720 Minutes			
P_{ave}		17.1		P_{ave}		23.4		P_{ave}		31	
S		5.7		S		7.8		S		10.4	
Tr(Year)	K	$P_T(mm)$	$I_T(mm/h)$	Tr(Year)	K	$P_T(mm)$	$I_T(mm/h)$	Tr(Year)	K	$P_T(mm)$	$I_T(mm/h)$
2	- 0.164	16.2	5.4	2	- 0.164	22.1	3.7	2	- 0.164	29.3	2.4
5	0.719	21.2	7.1	5	0.719	29	4.8	5	0.719	38.5	3.2
10	1.305	24.5	8.1	10	1.305	33.6	5.6	10	1.305	44.6	3.7
25	2.044	28.8	9.6	25	2.044	39.3	6.6	25	2.044	52.3	4.4
50	2.592	31.9	10.6	50	2.592	43.6	7.3	50	2.592	58	4.8
100	3.137	35	11.7	100	3.137	47.9	8	100	3.137	63.6	5.3
1440Minutes											
P_{ave}		39									
S		13									
Tr(Year)	K	$P_T(mm)$	$I_T(mm/h)$								
2	- 0.164	36.9	1.5								
5	0.719	48.3	2								
10	1.305	56	2.4								
25	2.044	65.6	2.7								
50	2.592	73	3								
100	3.137	79.9	3.3								

Table8. 9 Probable rainfall for different durations and return periods using Gumbel's distribution (Asgori)

30Minutes(Duration)				60Minutes(Duration)				120Minutes						
P_{ave}				8.8	P_{ave}				12.8	P_{ave}				16.8
S				1.8	S				2.9	S				3.5
Tr(Year)	K	P _T (mm)	I _T mm/h	Tr(Year)	K	P _T (mm)	I _T mm/h	Tr(Year)	K	P _T (mm)	I _T mm/h			
2	- 0.164	8.5	17	2	- 0.164	12.3	12.3	2	- 0.164	16.3	8.2			
5	0.719	10.1	20.2	5	0.719	14.9	14.9	5	0.719	19.3	9.7			
10	1.305	11.1	22.2	10	1.305	16.6	16.6	10	1.305	21.4	10.7			
25	2.044	12.5	25	25	2.044	18.7	18.7	25	2.044	24	12			
50	2.592	13.5	27	50	2.592	20.3	20.3	50	2.592	25.9	13			
100	3.137	14.4	28.8	100	3.137	21.9	21.9	100	3.137	28	14			
180Minutes				360 Minutes				720 Minutes						
P_{ave}				18.5	P_{ave}				25.3	P_{ave}				33.7
S				3.8	S				5.2	S				7
Tr(Year)	K	P _T (mm)	I _T mm/h	Tr(Year)	K	P _T (mm)	I _T mm/h	Tr(Year)	K	P _T (mm)	I _T mm/h			
2	- 0.164	17.9	6	2	- 0.164	24.4	4.1	2	- 0.164	32.6	2.7			
5	0.719	21.2	7.1	5	0.719	29	4.8	5	0.719	38.7	3.2			
10	1.305	23.5	7.8	10	1.305	32.1	5.4	10	1.305	42.8	3.6			
25	2.044	26.3	8.8	25	2.044	35.9	6	25	2.044	48	4			
50	2.592	28.3	9.4	50	2.592	38.8	6.5	50	2.592	51.8	4.3			
100	3.137	30.4	10.1	100	3.137	41.6	6.9	100	3.137	55.7	4.6			
1440Minutes														
P_{ave}				42.1										
S				9										
Tr(Year)	K	P _T (mm)	I _T mm/h											
2	- 0.164	40.6	1.7											
5	0.719	48.6	2											
10	1.305	53.8	2.2											
25	2.044	60.5	2.5											
50	2.592	65.4	2.7											
100	3.137	70.3	2.9											

Table8. 10 Probable rainfall for different durations and return periods using Gumbel's distribution (Busa)

30Minutes(Duration)				60Minutes(Duration)				120Minutes			
P_{ave}		9.2		P_{ave}		13.1		P_{ave}		17.5	
S		2.4		S		3.4		S		4.5	
Tr(Year)	K	P_T(mm)	I_Tmm/h	Tr(Year)	K	P_T(mm)	I_Tmm/h	Tr(Year)	K	P_T(mm)	I_Tmm/h
2	- 0.164	8.8	17.6	2	- 0.164	12.5	12.5	2	- 0.164	16.8	8.4
5	0.719	10.9	21.8	5	0.719	15.5	15.5	5	0.719	20.7	10.4
10	1.305	12.3	24.6	10	1.305	17.5	17.5	10	1.305	23.4	11.7
25	2.044	14.1	28.2	25	2.044	20	20	25	2.044	26.7	13.4
50	2.592	15.4	30.8	50	2.592	21.9	21.9	50	2.592	29.2	14.6
100	3.137	16.7	33.4	100	3.137	23.8	23.8	100	3.137	31.6	15.8
180Minutes				360 Minutes				720 Minutes			
P_{ave}		19.3		P_{ave}		26.3		P_{ave}		35	
S		5		S		6.8		S		9	
Tr(Year)	K	P_T(mm)	I_Tmm/h	Tr(Year)	K	P_T(mm)	I_Tmm/h	Tr(Year)	K	P_T(mm)	I_Tmm/h
2	- 0.164	18.5	6.2	2	- 0.164	25.2	4.2	2	- 0.164	33.5	2.8
5	0.719	22.9	7.6	5	0.719	31.2	5.2	5	0.719	41.5	3.5
10	1.305	25.8	8.6	10	1.305	35.2	5.9	10	1.305	46.7	3.9
25	2.044	29.5	9.8	25	2.044	40.2	6.7	25	2.044	53.4	4.5
50	2.592	32.3	10.8	50	2.592	43.9	7.3	50	2.592	58.3	4.9
100	3.137	35	11.7	100	3.137	47.6	7.9	100	3.137	63.2	5.3
1440Minutes											
P_{ave}		43.8									
S		11.3									
Tr(Year)	K	P_T(mm)	I_Tmm/h								
2	- 0.164	41.9	1.7								
5	0.719	51.9	2.2								
10	1.305	58.5	2.4								
25	2.044	66.9	2.8								
50	2.592	73.1	3								
100	3.137	79.2	3.3								

Table8. 11 Probable rainfall for different durations and return periods using Gumbel's distribution (Ginchi)

30Minutes(Duration)				60Minutes(Duration)				120Minutes			
P_{ave}		9.1		P_{ave}		13		P_{ave}		17.3	
S		2.7		S		3.8		S		5.1	
Tr(Year)	K	P _T (mm)	I _T mm/h	Tr(Year)	K	P _T (mm)	I _T mm/h	Tr(Year)	K	P _T (mm)	I _T mm/h
2	- 0.164	8.7	17.4	2	- 0.164	12.4	12.4	2	- 0.164	16.5	8.3
5	0.719	11	22	5	0.719	15.7	15.7	5	0.719	21	10.5
10	1.305	12.6	25.2	10	1.305	18	18	10	1.305	24	12
25	2.044	14.6	29.2	25	2.044	20.8	20.8	25	2.044	27.7	13.9
50	2.592	16.1	32.2	50	2.592	22.8	22.8	50	2.592	30.5	15.3
100	3.137	17.6	35.2	100	3.137	24.9	24.9	100	3.137	33.3	16.7
180Minutes				360 Minutes				720 Minutes			
P_{ave}		19.1		P_{ave}		26		P_{ave}		34.6	
S		5.6		S		7.6		S		10.2	
Tr(Year)	K	P _T (mm)	I _T mm/h	Tr(Year)	K	P _T (mm)	I _T mm/h	Tr(Year)	K	P _T (mm)	I _T mm/h
2	- 0.164	18.2	6.1	2	- 0.164	24.8	4.1	2	- 0.164	32.9	2.7
5	0.719	23.1	7.7	5	0.719	31.5	5.3	5	0.719	41.9	3.5
10	1.305	26.4	8.8	10	1.305	35.9	6	10	1.305	47.9	4
25	2.044	30.5	10.2	25	2.044	41.5	6.9	25	2.044	55.4	4.6
50	2.592	33.6	11.2	50	2.592	45.7	7.6	50	2.592	61	5.1
100	3.137	36.7	12.2	100	3.137	49.8	8.3	100	3.137	66.6	5.6
1440Minutes											
P_{ave}		43.3									
S		12.7									
Tr(Year)	K	P _T (mm)	I _T mm/h								
2	- 0.164	41.2	1.7								
5	0.719	52.4	2.2								
10	1.305	60	2.5								
25	2.044	69.3	2.9								
50	2.592	76.2	3.2								
100	3.137	83.1	3.5								

Table8. 12 Probable rainfall for different durations and return periods using Gumbel's distribution (Jeldu)

30Minutes(Duration)				60Minutes(Duration)				120Minutes						
P_{ave}				8.2	P_{ave}				11.7	P_{ave}				15.6
S				1.7	S				2.4	S				3.2
Tr(Year)	K	P _T (mm)	I _T mm/h	Tr(Year)	K	P _T (mm)	I _T mm/h	Tr(Year)	K	P _T (mm)	I _T mm/h			
2	- 0.164	7.9	15.8	2	- 0.164	11.3	11.3	2	- 0.164	15.1	7.6			
5	0.719	9.4	18.8	5	0.719	13.4	13.4	5	0.719	17.9	9			
10	1.305	10.4	20.8	10	1.305	14.8	14.8	10	1.305	19.8	9.9			
25	2.044	11.7	23.4	25	2.044	16.6	16.6	25	2.044	22.1	11.05			
50	2.592	12.6	25.2	50	2.592	17.9	17.9	50	2.592	23.9	12			
100	3.137	13.5	27	100	3.137	19.2	19.2	100	3.137	25.6	13			
180Minutes				360 Minutes				720 Minutes						
P_{ave}				17.1	P_{ave}				23.4	P_{ave}				31.2
S				3.5	S				4.8	S				6.4
Tr(Year)	K	P _T (mm)	I _T mm/h	Tr(Year)	K	P _T (mm)	I _T mm/h	Tr(Year)	K	P _T (mm)	I _T mm/h			
2	- 0.164	16.5	5.5	2	- 0.164	22.6	3.8	2	- 0.164	30.2	2.5			
5	0.719	19.6	6.5	5	0.719	26.9	4.5	5	0.719	35.8	3			
10	1.305	21.7	7.2	10	1.305	29.7	5	10	1.305	39.6	3.3			
25	2.044	24.3	8.1	25	2.044	33.2	5.5	25	2.044	44.3	3.7			
50	2.592	26.2	8.7	50	2.592	35.8	6	50	2.592	47.8	4			
100	3.137	28.1	9.4	100	3.137	38.5	6.4	100	3.137	51.3	4.3			
1440Minutes														
P_{ave}				39	P_{ave}					P_{ave}				
S				8	S					S				
Tr(Year)	K	P _T (mm)	I _T mm/h											
2	- 0.164	37.7	1.6											
5	0.719	44.8	1.9											
10	1.305	49.4	2.1											
25	2.044	55.3	2.3											
50	2.592	59.7	2.5											
100	3.137	64.1	2.7											

Table8. 13 Probable rainfall for different durations and return periods using Gumbel's distribution (Tulu Bolo)

30Minutes(Duration)				60Minutes(Duration)				120Minutes			
P_{ave}		8.6		P_{ave}		12.2		P_{ave}		16.3	
S		3.2		S		4.6		S		6.2	
Tr(Year)	K	P _T (mm)	I _T mm/h	Tr(Year)	K	P _T (mm)	I _T mm/h	Tr(Year)	K	P _T (mm)	I _T mm/h
2	- 0.164	8.1	16.2	2	- 0.164	11.4	11.4	2	- 0.164	15.3	7.7
5	0.719	10.9	21.8	5	0.719	15.5	15.5	5	0.719	20.8	10.4
10	1.305	12.8	25.6	10	1.305	18.2	18.2	10	1.305	24.4	12.2
25	2.044	15.1	30.2	25	2.044	21.6	21.6	25	2.044	29	14.5
50	2.592	16.9	33.8	50	2.592	24.1	24.1	50	2.592	32.4	16.2
100	3.137	18.6	37.2	100	3.137	26.6	26.6	100	3.137	35.7	18.8
180Minutes				360 Minutes				720 Minutes			
P_{ave}		17.9		P_{ave}		24.5		P_{ave}		32.6	
S		6.8		S		9.3		S		12.4	
Tr(Year)	K	P _T (mm)	I _T mm/h	Tr(Year)	K	P _T (mm)	I _T mm/h	Tr(Year)	K	P _T (mm)	I _T mm/h
2	- 0.164	16.8	5.6	2	- 0.164	23	3.8	2	- 0.164	30.6	2.6
5	0.719	22.8	7.6	5	0.719	31.2	5.2	5	0.719	41.5	3.5
10	1.305	26.8	8.9	10	1.305	36.6	6.1	10	1.305	48.8	4.1
25	2.044	31.8	10.6	25	2.044	43.5	7.3	25	2.044	57.9	4.8
50	2.592	35.5	11.8	50	2.592	48.6	8.1	50	2.592	64.7	5.4
100	3.137	39.2	13.1	100	3.137	53.7	9	100	3.137	71.5	6
1440Minutes											
P_{ave}		40.8									
S		15.5									
Tr(Year)	K	P _T (mm)	I _T mm/h								
2	- 0.164	38.3	1.6								
5	0.719	51.9	2.2								
10	1.305	61	2.5								
25	2.044	72.5	3								
50	2.592	81	3.4								
100	3.137	89.4	3.8								

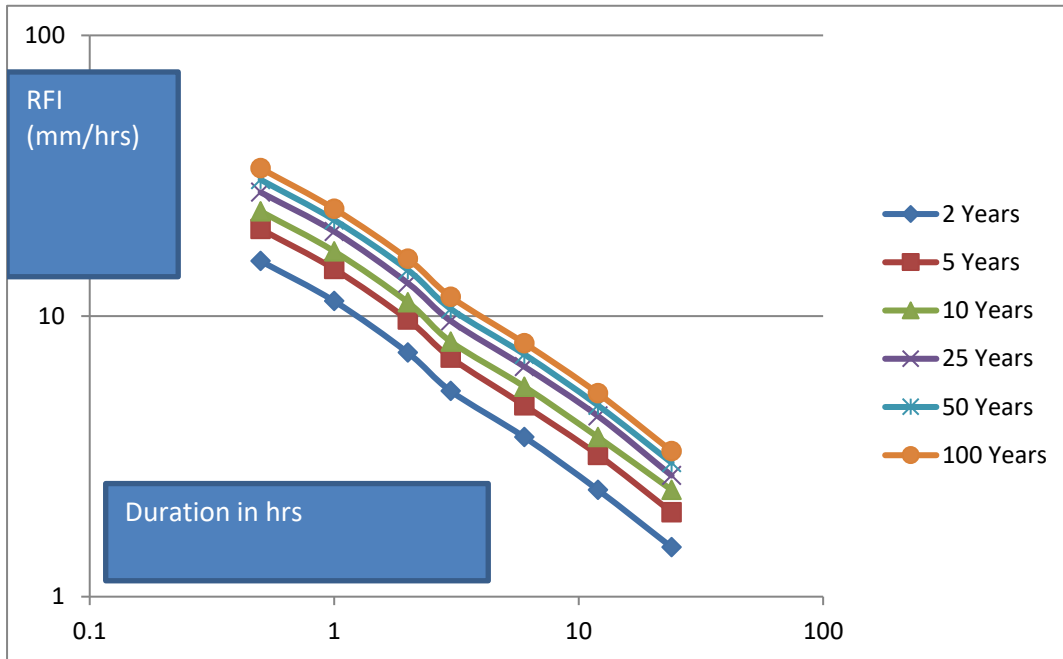
Table8. 14 Probable rainfall for different durations and return periods using Gumbel's distribution (Woliso)

30Minutes(Duration)				60Minutes(Duration)				120Minutes			
P _{ave}			10.3	P _{ave}			14.7	P _{ave}			19.7
S			2.3	S			3.3	S			4.4
Tr(Year)	K	P _T (mm)	I _T mm/h	Tr(Year)	K	P _T (mm)	I _T mm/h	Tr(Year)	K	P _T (mm)	I _T mm/h
2	- 0.164	9.9	19.8	2	- 0.164	14.2	14.2	2	- 0.164	19	9.5
5	0.719	12	24	5	0.719	17.1	17.1	5	0.719	22.9	11.45
10	1.305	13.3	26.6	10	1.305	19	19	10	1.305	25.4	12.7
25	2.044	15	30	25	2.044	21.4	21.4	25	2.044	28.7	14.4
50	2.592	16.3	32.6	50	2.592	23.3	23.3	50	2.592	31.1	15.6
100	3.137	17.5	35	100	3.137	25.1	25.1	100	3.137	33.5	16.8
180Minutes				360 Minutes				720 Minutes			
P _{ave}			21.6	P _{ave}			29.5	P _{ave}			39
S			4.8	S			6.6	S			9.1
Tr(Year)	K	P _T (mm)	I _T mm/h	Tr(Year)	K	P _T (mm)	I _T mm/h	Tr(Year)	K	P _T (mm)	I _T mm/h
2	- 0.164	20.8	6.9	2	- 0.164	28.4	4.7	2	- 0.164	37.5	3.1
5	0.719	25.1	8.4	5	0.719	34.2	5.7	5	0.719	45.5	3.8
10	1.305	27.9	9.3	10	1.305	38.1	6.4	10	1.305	50.9	4.2
25	2.044	31.4	10.5	25	2.044	43	7.2	25	2.044	57.6	4.8
50	2.592	34	11.3	50	2.592	46.6	7.8	50	2.592	62.6	5.2
100	3.137	36.7	12.2	100	3.137	50.2	8.4	100	3.137	67.5	5.6
1440Minutes											
P _{ave}			49.1								
S			11								
Tr(Year)	K	P _T (mm)	I _T mm/h								
2	- 0.164	47.3	2								
5	0.719	57	2.4								
10	1.305	63.5	2.6								
25	2.044	71.6	3								
50	2.592	77.6	3.2								
100	3.137	83.6	3.5								

Table8. 15 Probable rainfall for different durations and return periods using Gumbel's distribution (Huluka Watershed_Mean of All Stations)

30 Minutes		60Minutes(Duration)		120Minutes		180Minutes		360 Minutes	
Tr(Year)	I_Tmm/h	Tr(Year)	I_Tmm/h	Tr(Year)	I_Tmm/h	Tr(Year)	I_Tmm/h	Tr(Year)	I_Tmm/h
2	17.1	2	12.2	2	8.2	2	6	2	4.1
5	21.3	5	15.3	5	10.2	5	7.4	5	5.1
10	24.1	10	17.3	10	11.5	10	8.4	10	5.8
25	27.7	25	19.9	25	13.2	25	9.7	25	6.6
50	30.3	50	21.8	50	14.5	50	10.5	50	7.2
100	32.9	100	23.7	100	15.9	100	11.5	100	7.8
720 Minutes		1440Minutes							
Tr(Year)	I_Tmm/h	Tr(Year)	I_Tmm/h						
2	2.7	2	1.7						
5	3.4	5	2.1						
10	3.8	10	2.4						
25	4.4	25	2.7						
50	4.8	50	3						
100	5.2	100	3.3						

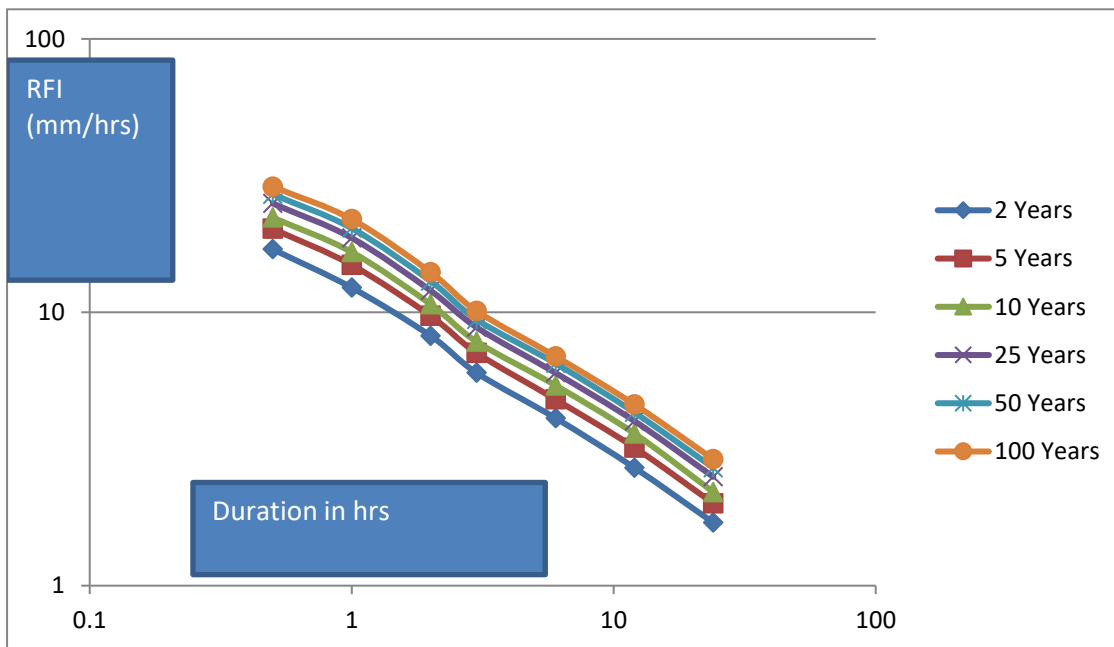
8.3. Intensity-Duration- Frequency Relationship of Seven Stations and Huluka Watershed



Remark: RFI=Rainfall intensities

Figure8. 1 Ambo Plant Protection Research Center Station IDF Curve

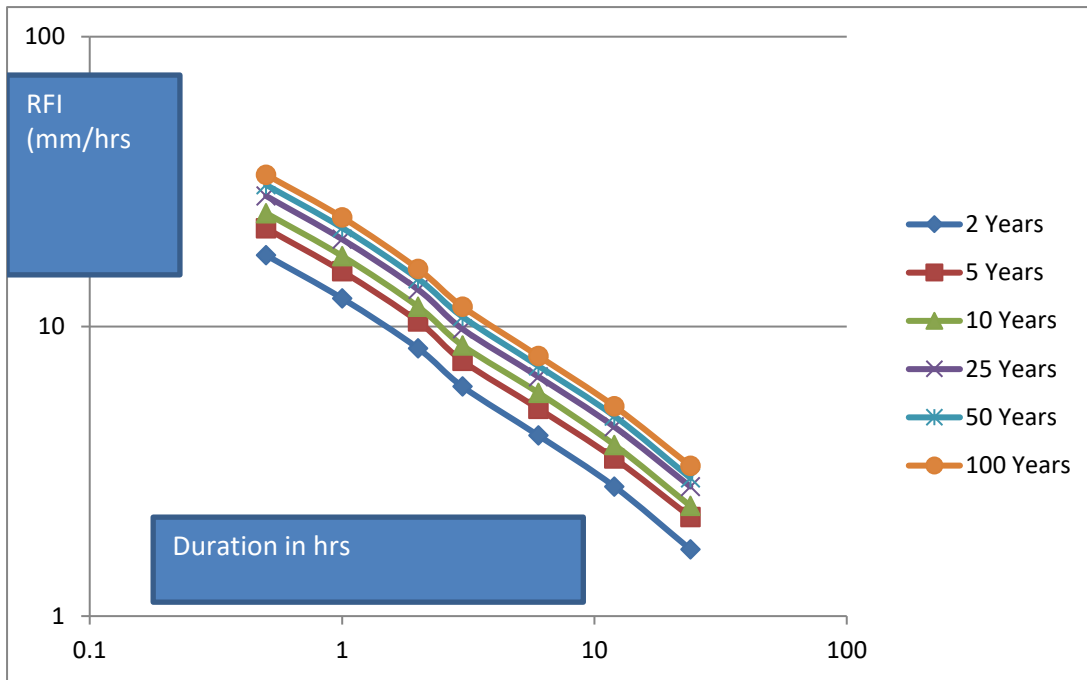
(Source: Researcher's computation)



Remark: RFI=Rainfall intensities

Figure8. 2 Asgori Station IDF Curve

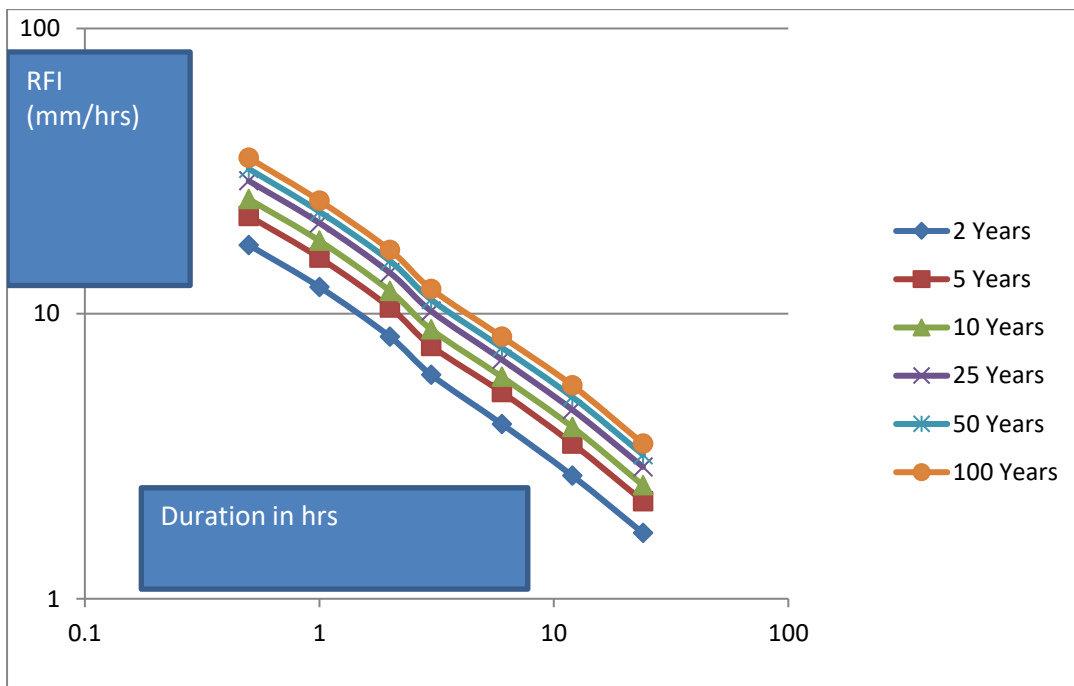
(Source: Researcher's computation)



Remark: RFI=Rainfall intensities

Figure8. 3 Busa Station IDF Curve

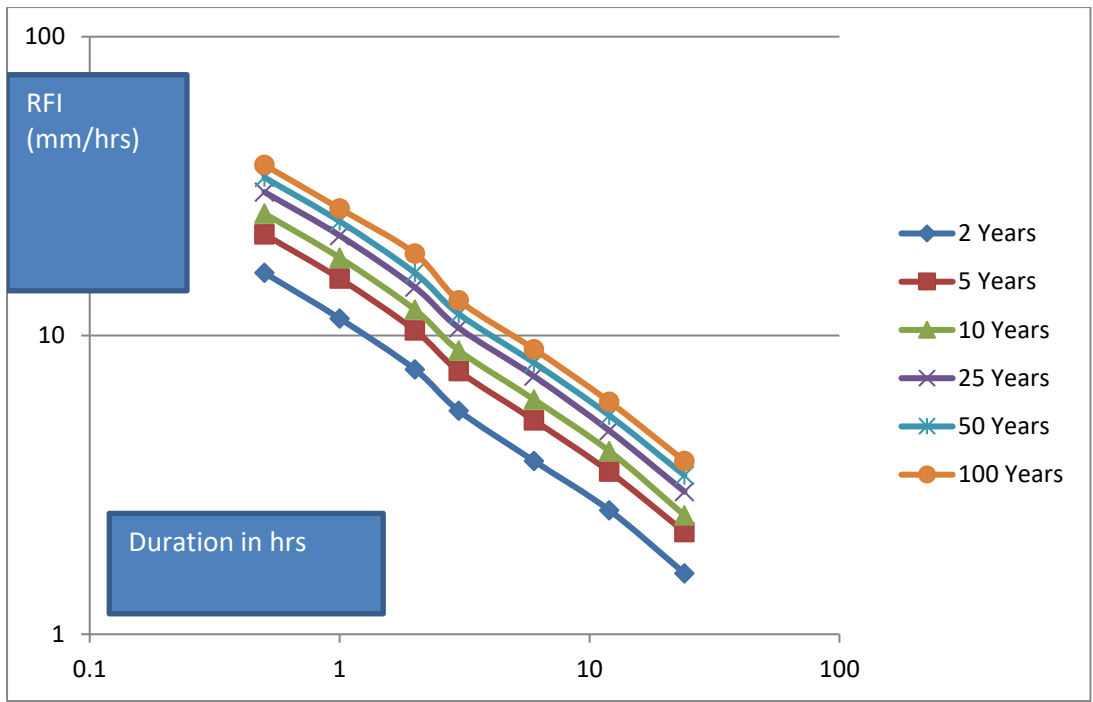
(Source: Researcher's computation)



Remark: RFI=Rainfall intensities

Figure8. 4 Ginchi Station IDF Curve

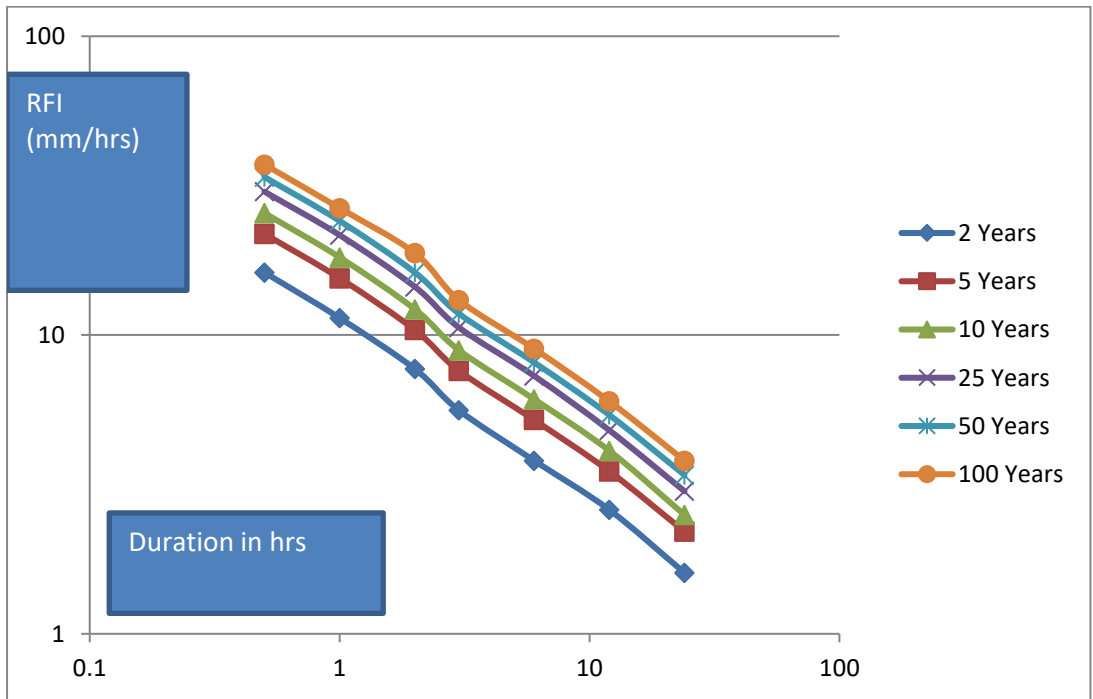
(Source: Researcher's computation)



Remark: RFI=Rainfall intensities

Figure8. 5 Jeldu Station IDF Curve

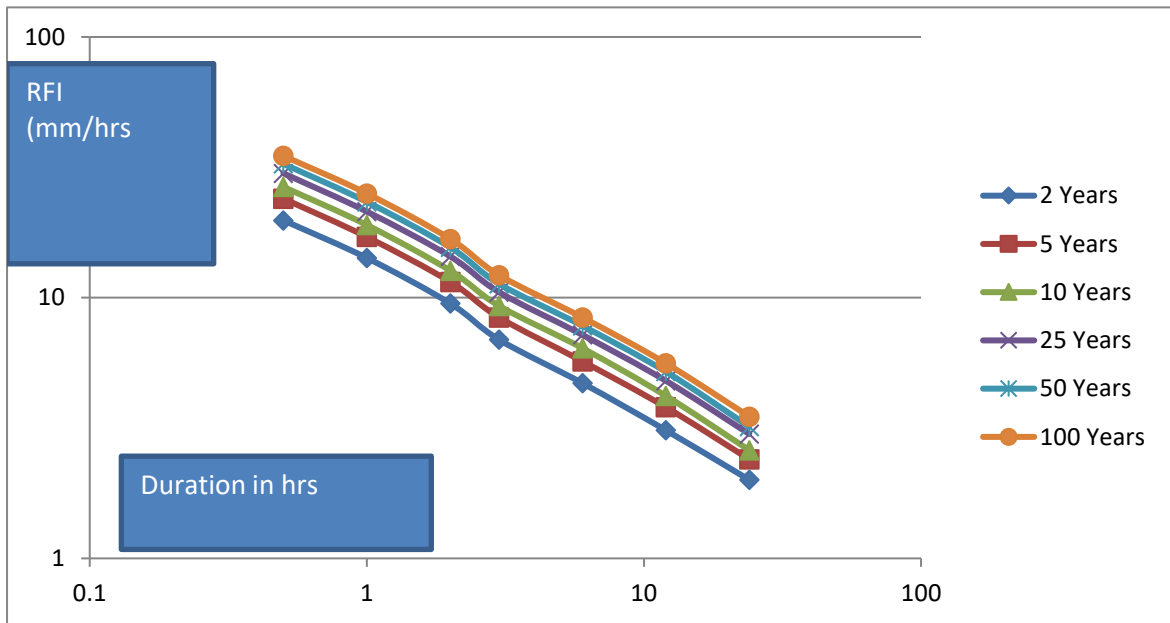
(Source: Researcher's computation)



Remark: RFI=Rainfall intensities

Figure8. 6 Tulu Bolo Station IDF Curve

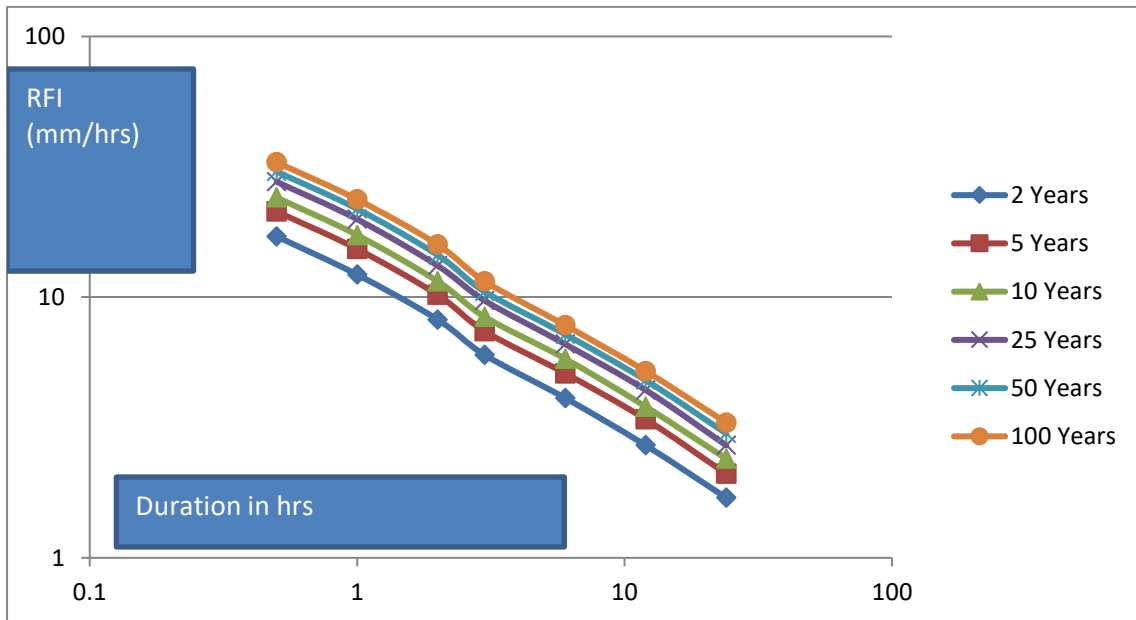
(Source: Researcher's computation)



Remark: RFI=Rainfall intensities

Figure8. 7 Woliso Station IDF Curve

(Source: Researcher's computation)



Remark: RFI=Rainfall intensities

Figure8. 8 Huluka watershed IDF Curve

(Source: Researcher's computation)

Table8. 16 IDF Formula and R² for Seven Stations and Huluka Watershed

Station/Watershed	Return Periods	IDF Formula	R ²
Ambo Plant Protection Research Center Station	2 Years	$Y = -0.4405x + 9.8234$	0.5304
	5 Years	$Y = -0.5713x + 12.801$	0.5315
	10 Years	$Y = -0.6563x + 14.776$	0.5262
	25 Years	$Y = -0.7738x + 17.361$	0.5331
	50 Years	$Y = -0.8566x + 19.207$	0.5326
	100 Years	$Y = -0.9394x + 21.08$	0.5327
Asgori Station	2 Years	$Y = -0.4774x + 10.736$	0.5371
	5 Years	$Y = -0.5711x + 12.8$	0.5355
	10 Years	$Y = -0.6304x + 14.153$	0.5385
	25 Years	$Y = -0.7091x + 15.913$	0.5359
	50 Years	$Y = -0.767x + 17.2$	0.5349
	100 Years	$Y = -0.8227x + 18.443$	0.5367
Busa Station	2 Years	$Y = -0.4921x + 11.038$	0.5365
	5 Years	$Y = -0.6049x + 13.648$	0.5306
	10 Years	$Y = -0.6865x + 15.413$	0.5342
	25 Years	$Y = -0.783x + 17.625$	0.5304
	50 Years	$Y = -0.8589x + 19.279$	0.5331
	100 Years	$Y = -0.9299x + 20.9$	0.5312
Ginchi Station	2 Years	$Y = -0.4867x + 10.901$	0.5334
	5 Years	$Y = -0.6129x + 13.804$	0.5333
	10 Years	$Y = -0.7025x + 15.796$	0.5321
	25 Years	$Y = -0.8134x + 18.278$	0.5312
	50 Years	$Y = -0.8939x + 20.108$	0.5297
	100 Years	$Y = -0.9758x + 21.961$	0.5287

Table 8.16. IDF Formula and R² for Seven Stations and Huluka Watershed (Continued...)

Station/Watershed	Return Periods	IDF Formula	R ²
Jeldu Station	2 Years	$Y=-0.4403x+9.9218$	0.5324
	5 Years	$Y=-0.5221x+11.775$	0.5301
	10 Years	$Y=-0.5771x+13.013$	0.5297
	25 Years	$Y=-0.6505x+14.607$	0.5293
	50 Years	$Y=-0.7002x+15.752$	0.53
	100 Years	$Y=-0.7518x+16.923$	0.5322
Tulu Bolo Station	2 Years	$Y=-0.4484x+10.093$	0.5285
	5 Years	$Y=-0.6049x+13.648$	0.5306
	10 Years	$Y=-0.7134x+16.028$	0.5329
	25 Years	$Y=-0.8441x+18.991$	0.5358
	50 Years	$Y=-0.9407x+21.203$	0.5325
	100 Years	$Y=-1.0456x+23.602$	0.5426
Woliso Station	2 Years	$Y=-0.5525x+12.428$	0.5312
	5 Years	$Y=-0.6688x+15.048$	0.5325
	10 Years	$Y=-0.7439x+16.697$	0.5352
	25 Years	$Y=-0.8362x+18.836$	0.5339
	50 Years	$Y=-0.9102x+20.449$	0.5332
	100 Years	$Y=-0.9769x+21.997$	0.5334
Huluka Watershed	2 Years	$Y=-0.4775x+10.737$	0.5346
	5 Years	$Y=-0.5956x+13.384$	0.5336
	10 Years	$Y=-0.6732x+15.136$	0.533
	25 Years	$Y=-0.776x+17.405$	0.5346
	50 Years	$Y=-0.8472x+19.027$	0.5319
	100 Years	$Y=-0.9214x+20.713$	0.5337

The IDF curves developed indicate that rainfall intensities increase with increase in return periods for all the seven stations and the Huluka watershed. Moreover, high rainfall intensities were confirmed to be related to short durations while low rainfall intensities related to long durations for the same return periods.

8.4. Discussion

Barrie & Scott (2021) assert that one of the most significant tools used for planning, designing and operating of water resources development infrastructures is the rainfall IDF relationship. Gebremedhin (2017) affirms that IDF curve and IDF parameters for the return periods of 2, 5, 10, 25, 50 and 100 years for all durations are good to use for water resource designing, soil and water conservation practices, etc. According to Wambua (2019) and Akpan & Okoro (2013), IDF curves are used in management of hydraulic structures within a river basin. David & Nwaogazie (2020) assert that the Rainfall Intensity-Duration-Frequency (IDF) relationship is one of the most commonly used tools for the design of hydraulic and water resources engineering control structures. Palaka *et al.* (2016) affirm that IDF Curves and empirical equations are useful for planning and designing of any water resource management projects. For Barrie & Scott (2021), rainfall intensity for a particular frequency and duration is one of the most important parameter for the hydrologic design of dam, reservoirs, storm sewers, culverts and many other hydraulic structures. Liew *et al.* (2014) affirm that development of IDF curves is crucial for undertaking short-term measures and long-term management and adaptations in water related sectors. IDF curves are asserted to be used in aiding the engineers design urban drainage works (Okonkwo & Mbajiorgu, 2010; Elsebaie, 2012; Rasel & Hossain, 2015).

The IDF formulae are affirmed to be the empirical equations representing a relationship among maximum rainfall intensity (as dependent variable) and rainfall duration and frequency as independent variables (David & Nwaogazie, 2020). Intensity-Duration-Frequency curve is affirmed to be useful in predicting the average rainfall intensity of a storm event to the duration of storm for a given return period. Normally, Rainfall Intensity in mm/hr is asserted to be plotted on the y-axis and duration in hours is on the x-axis (Palaka *et al.*, 2016). Generally, the high-intensity portion of a storm is affirmed to have a shorter duration than the low-intensity portion (Okonkwo & Mbajiorgu, 2010). This affirmation was found to be true in the IDF relationship of the seven stations and Huluka watershed.

CHAPTER NINE: INTEGRATED URBAN FLOODING RISK MANAGEMENT STRATEGY FOR AMBO TOWN AND ITS WATERSHED

9.1. The Need for Mainstreaming Integrated Urban Flooding Risk into Spatial Planning and Land Use Management in Ambo Town

Respondents were asked to rate the extent of importance of proper land use planning and management for urban flooding risk management. 95.4% (n=415) of the respondents rated the extent as very high while only 0.7% (n=3) rated the extent as very low (Table 9.1). Respondents were further asked to choose from the options given on the possible positive effect of land use planning on urban flooding disaster risk in Ambo town. 84.4% (n=367) of the respondents opined that Planning may lead to reduced flooding and planning may result in reduced flooding risks in their area. Only 1.4% (n=6) of the respondents opined that Planning may result in improved stormwater drainage facilities (Table 9.2).

Table9. 1 Extent of importance of proper land use planning and management for urban flooding risk management in Ambo town

Sr.No	Extent of importance of proper land use planning and management	Count	Percentage
1	Low	3	0.7
2	Moderate	6	1.4
3	High	11	2.5
4	Very high	415	95.4
5	Total	435	100.0

Table9. 2 Possible positive effect of land use planning on urban flooding disaster risk in Ambo town

Sr.No	Possible positive effect of land use planning	Count	Percentage
1	Planning may lead to reduced flooding/surface run-off	30	6.9
2	Planning may result in improved stormwater drainage facilities	6	1.4
3	Planning may result in reduced informal settlements	7	1.6
4	Planning may result in reduced urban flooding risks	17	3.9
5	Planned areas may ease stormwater drainage system maintenance	8	1.8
6	Planning may lead to reduced flooding and planning may result in reduced flooding risks	367	84.4
7	Total	435	100.0

Respondents were further asked to choose from the options given on possible positive effect of proper implementation of land use planning policies and regulations for urban flooding risk management in their area. 85.5% (n=372) of the respondents opined that informal settlement may be reduced, unplanned development may be avoided, ignorance of building bylaws and regulations may be reduced, and planning policies and regulations may be adhered to due to proper implementation of land use planning policies and regulations (Table 9.3) .

Respondents were also asked to choose from the options given on the possible positive effect of stakeholders' participation for sustainable urban flooding risk management in their area. 88.5% (n=385) of the respondents opined that solid waste may be properly disposed, sense of ownership may be developed or increased, maintenance of drains may be enhanced, awareness may be created on warning signs of flooding, and flooding risks may be reduced due to stakeholders' participation in urban flooding risk management (Table 9.4).

Table9. 3 Possible positive effect of proper implementation of land use planning policies and regulations for urban flooding risk management in Ambo town

Sr.No	Possible positive effect of proper implementation of land use planning policies and regulations	Count	Percentage
1	Informal settlement may be reduced	19	4.4
2	Unplanned development may be avoided	16	3.7
3	Ignorance of building bylaws and regulations may be reduced	9	2.1
4	Planning policies and regulations may be adhered to	7	1.6
5	Informal settlement may be reduced and unplanned development may be avoided	12	2.8
6	All*	372	85.5
7	Total	435	100.0

All: Informal settlement may be reduced, unplanned development may be avoided, ignorance of building bylaws and regulations may be reduced, and Planning policies and regulations may be adhered to.*

Respondents were further asked to choose from the options given on the possible positive effect of stakeholders' awareness campaign for sustainable urban flooding risk management in their area. 87.6% (n=381) of the respondents opined that solid waste may be properly disposed, encroachment on storm water drains may be reduced, drainage infrastructure may be protected due to sense of ownership, public may be sensitized on flooding risks, and community may be made aware of warning signs of flooding due to stakeholders' awareness campaign on urban flooding risk management (Table 9.5).

Respondents were also asked to choose from the options given on the type of floodplain development proposed for Ambo town. 95.2% (n=414) of the respondents opined that floodplain in Ambo town should be developed by preventing development from constricting floodway and allowing the flood fringes to obtain housing, commercial, and other purposes as long as the encroachment results in only insignificant increase in the water surface elevation. Only 1.4% (n=6) of the respondents opined that floodplain in Ambo town should be developed by restricting the use of the floodplain and leaving it in its original unoccupied

state (Table 9.6). It was also possible to observe the current urban development pattern of floodplains in Ambo town (Figure 9.1).



Figure9. 1 Floodplain at Village 02, Ambo town

(Source: Personal Observation, 2015).

Respondents were further asked to choose from the options given on development and land use technique for urban flooding disaster risk management. 80.7% (n=351) of the respondents opined that permanent evacuation, open space programmes, zoning ordinances for limiting types of land use, regional planning, subdivision regulation, building codes of practice, housing codes of practice, sanitary and other utility codes of practice, redevelopment policies such as proper design of utilities, source pollution control, flood proofing, and public acquisition are important development and land use techniques for urban flooding risk management in Ambo town (Table 9.7).

Table9. 4 Possible positive effect of stakeholders’ participation for sustainable urban flooding risk management in Ambo town

Sr.No	Possible positive effect of stakeholders participation	Count	Percentage
1	Solid waste may be properly disposed	10	2.3
2	Sense of ownership may be developed or increased	16	3.7
3	Maintenance of drains may be enhanced	6	1.4
4	Awareness may be created on warning signs of flooding	1	0.2
5	Flooding risks may be reduced	17	3.9
6	All*	385	88.5
7	Total	435	100.0

All: Solid waste may be properly disposed, sense of ownership may be developed or increased, maintenance of drains may be enhanced, awareness may be created on warning signs of flooding, and flooding risks may be reduced.*

Table9. 5 Possible positive effect of stakeholders' awareness campaign for sustainable urban flooding risk management in Ambo town

Sr.No	Possible positive effect of stakeholders' awareness campaign	Count	Percentage
1	Solid waste may be properly disposed	10	2.3
2	Encroachment on stormwater drains may be reduced	4	0.9
3	Drainage infrastructure may be protected due to sense of ownership	22	5.1
4	public may be sensitized on flooding risks	3	0.7
5	Community may be made aware of warning signs of flooding	8	1.8
	Drainage infrastructure may be protected, public may be sensitized on flooding risk, and community may be made aware of warning signs	7	1.6
6	All*	381	87.6
7	Total	435	100.0

All: solid waste may be properly disposed, encroachment on storm water drains may be reduced, drainage infrastructure may be protected due to sense of ownership, public may be sensitized on flooding risks, and community may be made aware of warning signs of flooding.*

Table9. 6 Type of floodplain development proposed for Ambo town

Sr.No	Type of floodplain development proposed for Ambo town	Count	Percentage
1	Preventing development from constricting floodway and allowing the flood fringes to be preserved for agricultural and recreational purpose.	15	3.4
2	Preventing development from constricting floodway and allowing the flood fringes to obtain housing, commercial, and other purposes as long as the encroachment results in only insignificant increase in the water surface elevation.	414	95.2
3	Restricting the use of the floodplain and leaving it in its original unoccupied state	6	1.4
5	Total	435	100.0

Table9. 7 Development and land use techniques for urban flooding disaster risk management proposed for Ambo town

Sr.No	Proposed development and land use techniques	Count	Percentage
1	Permanent evacuation	7	1.6
2	Open space programmes	6	1.4
3	Zoning ordinances for limiting types of land use	35	8.0
4	Regional planning	9	2.1
5	Subdivision regulation	7	1.6
6	Building codes of practice	4	0.9
7	Housing codes of practice	1	0.2
8	Sanitary and other utility codes of practice	6	1.4
9	Redevelopment policies such as proper design of utilities	9	2.1
10	All*	351	80.7
7	Total	435	100.0

All: Permanent evacuation, open space programmes, zoning ordinances for limiting types of land use, regional planning, subdivision regulation, building codes of practice, housing codes of practice, sanitary and other utility codes of practice, redevelopment policies such as proper design of utilities, source pollution control, flood proofing, and public acquisition.*

Respondents were also asked to choose from the options given on suitable and sustainable urban flooding disaster risk management measure in the context of Ambo town. 87.8% (n=382) of the respondents opined that reducing degradation, and constructing and managing appropriate drainage system are suitable and sustainable urban flooding disaster risk management measures for Ambo town (Table 9.8).

Respondents were further asked to rate the extent of need for urban flooding disaster risk management strategy at household, community, and town level in Ambo town. Majority of the respondents (91.7%) rated the extent of need for urban flooding disaster risk management strategy at household level as very high. Majority of the respondents (93.8%) rated the extent of need for urban flooding disaster risk management strategy at community level as very

high. Majority of the respondents (92.2%) rated the extent of need for urban flooding disaster risk management strategy at town level as very high (Table 9.9).

Table9. 8 Suitable and sustainable urban flooding disaster risk management option in the context of Ambo town

Sr.No	Suitable and sustainable urban flooding disaster risk management option	Count	Percentage
1	Build dams to collect water	7	1.6
2	Reduce degradation	19	4.4
3	Construct and manage appropriate drainage system	27	6.2
4	Reduce degradation, and construct and manage appropriate drainage system	382	87.8
5	Total	435	100.0

Table9. 9 Extent of the need for urban flooding disaster risk management strategy at different administrative levels of Ambo town

Sr No	Administrative Level	Rate of need for adaptation strategy (%)					Mean
		Very low	Low	Mod.	High	Very high	
1	Urban households	-	0.7	3.4	4.1	91.7	4.87
2	Urban communities	-	0.7	2.3	3.2	93.8	4.90
3	Ambo town	-	0.7	3.0	4.1	92.2	4.88

9.2. Discussion

Spatial planning is affirmed to be an important mechanism in coping with flood risk due to climate change (Schmidt-Thomé, 2006; Tingsanchali, 2012; Dewan, 2013; Khailani & Perera, 2013). It is asserted that that effective flood risk management requires geo-spatial data representing accurate representations of the flood area, post flood and flood plain reference marks. Sources of this data include geological survey maps, satellite imagery and

the local community. Such data when collected are processed and analyzed, and then incorporated into a variety of community plans which are comprehensive documents that cover land-use, transportation, zoning, subdivisions, capital improvements, parks, health, welfare and safety (Andjelkovic, 2001; Richardson & Otero, 2012; Jabareen, 2013; Mngutyo & Ogwuche, 2013).

It is asserted that a holistic approach to flood risk management should be adopted, rather than a narrow techno-centric approach (Mitchell, 2005; Akinmoladun & Adejumo, 2011). It is also affirmed that such a holistic approach should incorporate the views and perceptions of stakeholders, rather than merely the views of technical experts. A holistic approach to flood risk assessment is asserted to integrate physical, economic, social, and cultural vulnerabilities, along with perceived risk (Prabhakar *et al.*, 2009; Vojinovic *et al.*, 2016).

It is affirmed that recent paradigms of urban flooding risk management call for a participatory process in which the different stakeholders are involved early in the urban flooding risk assessment procedure and urban good governance has vital role in the process (Merz *et al.*, 2010; Mpofu, 2011; Jha *et al.*, 2012; Santato *et al.*, 2013). Moreover, the implementation of flood map and flood risk management plans are asserted to require multi-stakeholder cooperation and communication is affirmed to be necessary to raise awareness and reinforce preparedness (Corfee-Morlot *et al.*, 2009; Mpofu, 2011; Jha *et al.*, 2012; Santato *et al.*, 2013).

9.3. Integrated Urban Flooding Risk Management Strategy for Ambo Town and Huluka Watershed

The hub of the study was proposing an integrated urban flooding risk management strategy for Ambo town and Huluka watershed. Accordingly, strategic measures recommended to be implemented at watershed, town, community, and building levels based on the findings of the study and best practices in different parts of the world are presented in the following sections.

9.3.1 Integrated Urban Flooding Risk Management Strategy at Watershed Level

The following strategic measures are worth considering in the integrated flooding risk management strategy at watershed level:

- Integrated water resource management (IWRM) should be practiced at watershed level since it is a process which promotes the co-coordinated development and management of water, land and related resources in order to maximize the resultant

economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems (Mitchell, 2005; Kidd & Shaw, 2007; Barua, 2008);

- Land use planning for cities and communities, neighborhoods and allotments has to be seen as an integrated process and holistic approach of the ecosystem in urban and rural development. The holistic approach of the city as an ecosystem needs to be assessed at different scales from regional to city, urban and rural area to district, allotment and building level (Djordjevic *et al.*, 2011; Claes *et al.*, 2012; Steinberg & Lindfield, 2012; Santato *et al.*, 2013; Kernaghan & da Silva, 2014);
- Flooding hazard map and flooding risk map developed for the watershed should be utilized by stakeholders to plan and implement participatory flooding risk management at watershed level as the watershed was confirmed to suffer from very high and high flooding hazard and risk. The implementation of flood map and flood risk management plans requires multi-stakeholder cooperation and communication is necessary to raise awareness and reinforce preparedness (Corfee-Morlot *et al.*, 2009; Mpofu, 2011; Jha *et al.*, 2012; Santato *et al.*, 2013). The flood map is designed to increase awareness among the public, local authorities and other organizations of the likelihood of flooding, and to encourage people living and working in areas prone to flooding to take appropriate action (Parkinson, 2002; Santato *et al.*, 2013);
- As controlling land use solely with the purpose of minimizing flood losses would be inefficient and simply create other problems which might be worse, appropriate spatial planning and land use management should be practiced at watershed level with the concept of multi-functional land use that would result in a combination of flood prevention measures with agri-environment practices, territorial planning policies and nature development strategies, including river restoration (Barua, 2008; Balaban, 2009; Claes *et al.*, 2012; Santato *et al.*, 2013; Sayers *et al.*, 2013);
- It is vital to mainstream prospective disaster risk management into sustainable development planning. This means development programs and projects are expected to carefully consider their relationship to minimize or exacerbate vulnerability and hazard (Pelling *et al.*, 2004; Claes *et al.*, 2012; Sayers *et al.*, 2013); and
- It is recommended that ecological networks must be strengthened as good climate change adaptation strategy because of their flexibility, ability to cope with processes on different spatial scales, and their effectiveness in the implementation in the planning processes (Vos *et al.*, 2010).

9.3.2. Integrated Urban Flooding Risk Management Strategy at Town Level

The following strategic measures are worth considering in the integrated urban flooding flooding risk management strategy at town level:

- Good urban governance has vibrant role in the multi-stakeholder coordination and communication process for integrated urban flooding risk management at town level (Satterthwaite *et al.*, 2007; Steinberg & Lindfield, 2012; Buyana *et al.*, 2014). For instance, applying climate science and ecosystem management and restoration in disaster risk reduction activities to an urban area is possible. But it needs: a proper mindset; inclusive and transformative partnerships with key stakeholders from different tiers of governance; political leadership; and the effective use of science (Hurst *et al.*, 2012; Lehmann, 2012; Wright, 2012; Arcilla & Lagdameo, 2015);
- Flooding hazard map and flooding risk map developed for Ambo town should be utilized by stakeholders of the town to plan and impliment participatory flooding risk management in Ambo town as the town was confirmed to suffer from very high and high flooding hazard and risk;
- Replacement of impermeable surfaces by sustainable Drainage Systems (SUDS) such as permeable pavement, gravel or grass should be planned for and practiced at town level to enable water soak away as the purpose is to understand and manage flood pathways and protecting areas at risk (Cordaid & IIRR, 2011; Claes *et al.*, 2012; Santato *et al.*, 2013).
- Reducing degradation, and constructing and managing appropriate drainage system underpinned by intensity-duration-frequency (IDF) curve should be practiced as suitable and sustainable urban flooding disaster risk management option;
- Integrating consideration of changing climate and urban disaster risks management into the wide array of decisions made by local governments, from operating municipal services to capital spending, enforcement and inspection activities, collection of taxes, and administration of disaster response programs is of paramount importance at town level (Balaban, 2009; Richardson & Otero, 2012). Where possible, adaptations to flooding should also harmonize with natural processes to deliver other benefits including habitat creation, river restoration and lower carbon emissions. These can be implemented in a progressive way in response to changing information on future flood risks (Parkinson, 2003; Tucci, 2007; Balaban, 2009; Jha *et al.*, 2012; Wilby & Keenan, 2012).
- It is of paramount importance to integrate prospective disaster risk management into sustainable development planning. To this end, development programs and projects are

encouraged to consider their potential to minimize or exacerbate vulnerability and hazard (Pelling *et al.*, 2004; Claes *et al.*, 2012; Sayers *et al.*, 2013).

- Urban green spaces are asserted to have an important role to play within flood risk management (FRM). They are affirmed to provide soft surfaces which will absorb water (as opposed to hard standing such as car parks which water runs off). It is also vital to develop schemes with landscaped green banks with purpose of flooding and slowing the flow of the water. Typically, rivers were affirmed to be restored to a more 'natural' state and as a consequence provided attractive public green spaces (Twigger-Ross, 2005; Sayers *et al.*, 2013); and
- Nonstructural best management practices (BMPs) (town planning controls, strategic planning and institutional controls, pollution prevention procedures, education and participation programmes, and regulatory controls should complement the structural flooding risk management measures to make the flooding risk management strategy effective and sustainable (Taylor & Wong, 2002).

9.3.3. Integrated Urban Flooding Risk Management Strategy at Community Level

The following strategic measures are worth considering in the flooding risk management strategy at community level:

- The flood management measures in pre, during and post-disaster phase should be well planned and integrated with one phase to another;
- It is expected that policy makers and planners may introduce latest and contemporary community based flood management strategies for sustainable and fruitful flood management along with the existing strategies by incorporating local knowledge to manage flood disaster for proper development of the community or the town (Merz *et al.*, 2010; Paul & Hossain, 2013);
- Training must be given to local communities on integrated urban flooding risk management; and
- Credit should be provided to urban households to improve their adaptive capacity.

9.3.4. Integrated Urban Flooding Risk Management Strategy at Building Level

The following strategic measures are worth considering in the integrated flooding risk management strategy at building level:

- As the aim at building scale is to minimize the exposure to flooding whilst incorporating structural solutions which help to reduce the vulnerability, new

developments need to be carefully assessed to ensure that they are built to cope with flood risks as they change over time and that risks in adjacent areas are not exacerbated (Cordaid & IIRR, 2011; Claes *et al.*, 2012; Santato *et al.*, 2013); and

- Permanent evacuation, open space programmes, zoning ordinances for limiting types of land use, regional planning, subdivision regulation, building codes of practice, housing codes of practice, sanitary and other utility codes of practice, redevelopment policies such as proper design of utilities, source pollution control, flood proofing, and public acquisition should be practiced as appropriate land use planning and management techniques for urban flooding disaster risk management at building scale.

CHAPTER TEN: CONCLUSIONS

The conclusions of the study based on the research questions relating to the specific objectives were:

- Economic policies that affect the price of inputs and outputs, lack of new land available for relocation, and limitations placed on local authorities by central government were identified as external barriers for governance of urban flooding disaster risk reduction in Ambo town;
- Unwillingness of people to move away from hazard-prone areas due to the nature of their livelihoods, the high prices of properties, and a lack of awareness of the risk of hazards anticipated were identified as internal barriers to governance of urban flooding disaster risk reduction in Ambo town.
- Technical capacity constraint, institutional capacity constraint, and insufficient political will and commitment to address flooding risk reduction were identified as capacity constraints in relation to governance of flooding risk reduction.
- A grand mean of 1.93 (maximum=5; minimum=1) indicates the overall poor performance of the current governance of urban flooding disaster risk reduction in Ambo town;
- 49.2% (n=214) of the respondents opined that increased intensity in rainfall during rainy season, inadequate land use and channelization of natural water ways, inflow from the rivers/streams during high stages into urban drainage system, soil erosion generating material that clogs drainage system and inlets, inadequate street cleaning practice that clogs street inlets, and continuing unplanned urban expansion are causes of urban flooding in Ambo town;
- 50% (n=217) of the respondents opined that loss of human life, flooding of streets, intersections and transportation systems, flooding of streets and transportation systems, damage to public and personal properties, exacerbated health risks in the home and local environment, disrupted infrastructure and access to services like water supply, cleanup demand, adverse effects upon the aesthetics, disturbance of wildlife habitat, and disrupted business activities are the negative effects of urban flooding in Ambo town; 77.2% (n=336) of the respondents opined that much vulnerable groups to urban flooding disaster risk in Ambo town include: old persons, children, women, and persons with different abilities;
- 73.1% (n=318) of the respondents opined that residing in flood prone area, poverty, lack of alternative livelihoods, and lack of proper drainage channels are the

underlying causes of socio-economic vulnerability to urban flooding disaster risk in Ambo town;

- 82.5% (n=359) of the respondents opined that they cope with the challenge of urban flooding disaster risk with the help of existing social capital in urban communities;
- 77.7% (n=338) of the respondents opined that they rely on informal contact and participation in community group as the two vital elements of social capital that helps them cope with the challenges of urban flooding disaster risk in Ambo town;
- 73.1% (n=318) opined that they practice preventive investment into yard, preventive investment into house, and preventive cleaning of drainage channel as preventive measures for urban flooding disaster risk in Ambo town;
- 75.4% (n=328) of respondents opined that they practice helping others, piling up furniture, making traditional drainage lines and migrating to safer places as adaptation measures during urban flooding in Ambo town;
- 69.9% (n=304) opined that they practice Cleaning and repairing homes and cleaning drainage system afterward as adaptation measures after urban flooding in Ambo town;
- Developing adaptive capacity of urban local communities, disseminating information on successful adaptations, improving access to credit and insurance, preventing maladaptation through regulation, enforcing environmental regulations, assessing adaptation needs (including technological needs) through stakeholder engagement, improving access to five capitals, developing alternative livelihood strategies for the urban poor, and relocating vulnerable people as measures that would reduce vulnerability of the local communities;
- Asset base, institutions and entitlements, flexible forward-looking decision-making and governance, innovation, and knowledge and information were identified as the five major factors influencing the adaptive capacity of Ambo town administration in relation to governance of urban flooding risk reduction;
- Forest area, cultivated land area, urban built-up area, bush/shrub land area, bare land area, grassland area, and water area were identified as the seven land use/land cover types in Huluka watershed;
- The overall decline of bush and shrub land, forest, grassland, and water land use/land cover type by 68.2%, 59.3%, 32.7%, and 5.1% respectively between 1979 and 2017 is bad news for the watershed as the potential of the watershed to contribute in

mitigating flooding disaster risk decline with the decline of these land use/land cover types;

- The overall increase of urban built-up area, cultivated land, and bare land use/land cover type by 351%, 105%, and 41.9% respectively between the year 1979 and 2017 implies the increase in flooding disaster risk in the watershed as such land use/land cover types exacerbate flooding or the run-off conditions in the watershed;
- Infrastructural expansion, agricultural expansion, increased demand for fuel wood and wood for construction, local environmental factors (examples: soil quality, topography, and land use/land cover), local biophysical drivers (examples: flooding and land use/land cover change), and local social events were confirmed to be perceived proximate causes of land use/land cover change in the watershed.
- Demographic factors (examples: natural increase and migration of human population into the watershed), economic factors (examples: market growth and commercialization, urban expansion, and price increase), technological factors (examples: agro technical change, and agricultural production factors), policy and institutional factors (examples: formal policy and property right), and cultural factors (examples: public attitudes and beliefs and individual and household behavior) were confirmed to be perceived underlying causes of land use/land cover change in the watershed;
- Increased flooding risk, increased soil erosion, increased sedimentation into the lake and rivers, decrease in soil fertility resulting from flooding risk, and change in climatic parameters (decrease in annual rainfall and increase in heat during dry season) were identified as the perceived major negative effects of land use/land cover change in the watershed.
- Land use/ land cover type, elevation, slope, drainage density, soil type, and rainfall were identified as the six important factors for flooding risk mapping;
- Human population density, land use/land cover type, and flooding hazard layer were considered as three important factors in flooding risk mapping;
- 63.04% of the watershed is moderate flooding hazard area while 52.9% of Ambo town is moderate flooding hazard area;
- 20.2% of Huluka watershed is moderate flooding risk area while 21% of Ambo town is high and very high flooding risk area.

- The IDF curves developed indicate that rainfall intensities increase with increase in return periods for all the seven stations and the Huluka watershed; and
- High rainfall intensities were confirmed to be related to short durations while low rainfall intensities related to long durations for the same return periods.

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ANNEX ONE: PUBLICATIONS FROM THE PHD DISSERTATION

1. Ogato,G.S., Abebe,K., Bantider,A., and Geneletti.D. (2017).Towards Mainstreaming Climate Change Adaptation into Urban Land Use Planning and Management: The Case of Ambo Town, Ethiopia. In: Filho,W.L., Kalangu,J., Musiyiwa, K., Munishi,P., Simane,B., and Menas Wuta, M.(eds). Climate Change Adaptation in an African Context: fostering resilience and capacity to adapt. Berlin: Springer (See Anexed_next pages). Available at: <https://www.springer.com/gp/book/9783319495194>
2. Ogato,G.S., Bantider,A., Abebe,K., and Geneletti.D. (2020).Geographic information system (GIS)-Based multicriteria analysis of flooding hazard and risk in Ambo Town and its watershed, West shoa zone, oromia regional State, Ethiopia. Journal of Hydrology: Regional Studies, 27,1-18 (See Anexed_next pages). Available at:www.sciencedirect.com/science/article/pii/S2214581819300801
3. Ogato,G.S., Bantider,A., and Geneletti.D. 2021. Dynamics of land use and land cover changes in Huluka watershed of Oromia Regional State, Ethiopia. Environmental Systems Research,10,10,1-20. Available: <https://environmentalsystemsresearch.springeropen.com/articles/10.1186/s40068-021-00218->

Climate Change Management

Walter Leal Filho
Belay Simane
Jokasha Kalangu
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Kumbirai Musiyiwa *Editors*

Climate Change Adaptation in Africa

Fostering Resilience and Capacity to
Adapt

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Towards Mainstreaming Climate Change Adaptation into Urban Land Use Planning and Management: The Case of Ambo Town, Ethiopia

Gemechu Shale Ogato, Ketema Abebe, Amare Bantider
and Davide Geneletti

1 Introduction

Adaptation to climate change and mainstreaming adaptation to climate change into urban land use planning and management underpin this paper as the two major concepts in climate change adaptation research. Adaptation to climate change may refer to “the process through which focus is given on building adaptive capacity of the most vulnerable people, reducing exposure or sensitivity to climate impacts, and ensuring that development initiatives don’t inadvertently increase vulnerability” (Adger et al. 2002; Brooks et al. 2004; Füssel 2007; Huxtable and Yen 2009; UNPEI 2011). Mainstreaming climate change adaptation in this paper may refer to “the process of integrating considerations of climate change adaptation into

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policy-making, budgeting, implementation and monitoring processes at urban land use planning and management level" (Lebel et al. 2012; Oates et al. 2011; UNPEI 2011).

Cities and towns in Least Developed Countries (LDCs) like Ethiopia are vulnerable to climate change and climate extremes in part because they concentrate many activities, people and wealth in limited areas (Sanderson 2000; Hallegatte et al. 2011). More importantly, urban poor can be very vulnerable to climate shocks, whether direct or indirect (Ziervogel et al. 2008; Watson 2009; Parikh et al. 2014; Stein and Moser 2014). However, traditional urban planning in cities and towns of least developed countries (LDCs) including those of Ethiopia has served to exclude the poor (Sanchez-Rodriguez 2009; Watson 2009; Nielsen and Reenberg 2010).

Adaptation to climate change and climate variability in cities demands a better understanding of the poor's adaptive capacity and of their autonomous coping strategies (Gill et al. 2007; Kazmierczak and Carter 2010; Lwasa 2010; UN-Habitat 2011; Chappin and van der Lei 2014; Taylor and Peter 2014). This is because the urban poor are affected by the 'double vulnerability' of climate change and poverty, which means that they are disproportionately affected in terms of both their exposure to climate related risks and the limited resources at their disposal to respond to such risks (Sanderson 2000; Van Aalst et al. 2008; Bartlett et al. 2012; Jabeen et al. 2012; Birkmann et al. 2010). Finding ways of integrating development interventions with the emergent climate adaptation responses is necessary in order not to duplicate efforts (Ziervogel et al. 2008; Hurlimann and March 2012; Loret and Ioannilli 2012; Jabareen 2013). Moreover, it is important to contextualize a response to climate change within the existing socio-political urban context (Bartlett et al. 2012; Jabeen et al. 2012; Fünfgeld 2012; Parikh et al. 2014). Adem and Bewket (2011) affirm that addressing current and future climate vulnerabilities in development planning and programming should be an immediate priority for Ethiopia as development-as-usual without consideration of climate risks and opportunities, will lead to maladaptive practices weakening national resilience to climate change.

According to UN-HABITAT (2006), high level of solid waste; water and air pollution; lack of adequate water and sanitation; and lack of legal access to land are some of the urban challenges for Ethiopian cities and towns. Sanderson (2000) contends that much urban legislation in LDCs including Ethiopia results in increased vulnerability of the poor. For instance, the prevention of permanent services to illegal settlements can increase ill-health, while the withholding of tenure inhibits consolidation of buildings, resulting in poorly-built shelters that easily collapse, catch fire or harbour disease (Sanderson 2000; Parikh et al. 2014; Stein and Moser 2014). Moreover, income inequality; poverty; growing job and residential informality; and high urbanization rates characterize cities and towns of Least Developed Countries (LDCs) including those of Ethiopia (Watson 2009; Sowers et al. 2011). Despite the aforementioned major urban challenges in those cities and towns, the capacity of local government is claimed to be weak and cities and towns have been shaped by national economic development policies and

rampant market forces (Sanderson 2000; Ziervogel et al. 2008; Belinda and Kong 2012; Posey 2009; Watson 2009; McCarney 2012). Furthermore, their urban planning system is characterized by frequent corruption and clientelism. As a result, the ability to manage growth and deliver services equitably is lacking (Van Aalst et al. 2008; Watson 2009; Measham et al. 2011; Fünfgeld 2012).

Previous studies confirmed that urban areas play a key role in social and economic development as well as in change at global, regional, national, and local scales. Despite their key importance, far less attention has been given to the question on how to adapt cities and urban governance and planning systems to address climate change adaptation (Denton 2002; Birkmann et al. 2010; Measham et al. 2011; Dede et al. 2012; Jabareen 2013; Uittenbroek et al. 2013; Mashila 2014; Reid and Huq 2014; Vasileiadou et al. 2014; van den Brink et al. 2014; EEA 2015; Kelman et al. 2015; Yang et al. 2015). More importantly, studies on local socio-economic vulnerability to climate change and the quest of mainstreaming climate change adaptation into urban land use planning and management in Ethiopia are scant (Adem and Bewket 2011; Adem and Guta 2011; Ogato 2013b).

Mainstreaming adaptation to climate change into urban land use planning and management is currently being promoted as effective adaptation approach in cities and towns of least developed countries (LDCs) (Biesbroek 2009; Baloye et al. 2010; Hurlimann and March 2012; de Bruin et al. 2014; Kareem and Lwasa 2014; Mashila 2014; Reid et al. 2015; Sussans et al. 2015) and this necessitates careful understanding of vulnerabilities and adaptive capacities of vulnerable communities in small towns of Ethiopia like Ambo. Ambo town was taken as a case study town in this study in order to properly understand perceived climate change related disaster risks and local climate change adaptation strategies in Ambo town and its watershed. In a nutshell, this study intends to forward feasible recommendations for mainstreaming climate change adaptation into urban land use planning and management in Ambo town.

2 Research Methodology

This section deals with description of the study area, sampling procedures and methods, methods employed for data collection and methods employed for data analysis.

2.1 Study Area

The geographical location of Ambo town is approximately between 8°56'30"N–8°59'30"N latitude and between 37°47'30"E–37°55'15"E longitude. It is located in the Western Shoa Zone of the Oromiya region (See Fig. 1). Relatively Ambo town is located 114 km far away West of Addis Ababa, 60 km North West of Weliso town

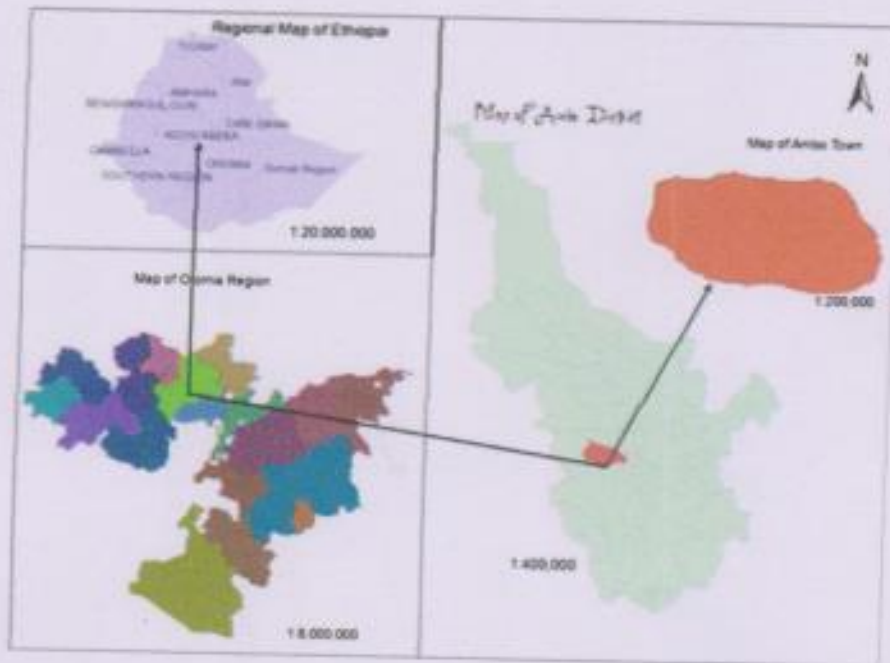


Fig. 1 Geographic location map of Ambo Town

and 12 km East of Guder town (UN-HABITAT 2008; Shanmugham and Tekele 2011; Ambo Town Administration Office 2013).

Most of the existing built up areas of the town is with gentle slope and undulating topography while some hilly slope and mountains are also seen in some parts of the town. Along the course of rivers and streams, steep slope and gullies are also observed. The town's altitude ranges from 1924 m above sea level (m.a.s) to 2384 m above sea level (m.a.s) (see Fig. 2). The slope classification of Ambo is largely dominated by terrain with flat to undulating and steep slopes. Slopes with 21–60% cover small area in the town whereas slopes with 2–20% cover the majority areas of the town (Ambo Town Administration Office 2013; Ogato 2013b).

The town is drained by Perennial and seasonal rivers and streams. The town is found within the Abay drainage basin, and it is particularly drained by major rivers (Huluka, Dehis and Taltale); minor seasonal rivers (Aleltu, Awaro, Boji, Dobi, Kerise, Chafe Jara, Jalina, Maja, solbe, Jabdu and Sankale); and a number of intermittent or seasonal streams within the catchment area. The rivers and streams drain to the major Huluka river in the surrounding area of Ambo and Huluka river drains Westward to Guder river and finally Guder river drains to Abay drainage basin. The discharges of the streams are relatively small or absent during dry seasons, whereas the volume of these rivers/streams drastically increases during wet

1931, and a master plan since 1983 (UN-HABITAT 2008). It is governed through the Oromiya region municipal establishment proclamation no. 65/95 and has two tiers of administration. The highest level is the municipal council, which is responsible for service delivery, administering funds and management of the city (UN-HABITAT 2008; Ambo Town Administration Office 2013).

2.2 Sampling Techniques and Procedures

The study employed both purposive and simple random sampling techniques. First, Ambo town was selected by employing purposive sampling technique as the main purpose of the study is to assess the need for mainstreaming climate change adaptation into urban land use planning and management in Ambo town. To identify climate change related hazards in Ambo town, participants for focus group discussions and key informant interview were also purposively selected. Secondly, to assess perceived changes in climatic parameters (rainfall, temperature, and wind), Huluka watershed (where Ambo town is located) was stratified on the basis of altitude: upstream (2735–3328 m.a.s), midstream (2384–2735 m.a.s), and downstream (1924–2384 m.a.s). The sample size determination formula employed to determine sample size for households from Houlka Watershed was (Yemane 1967):

$$n = N/1 + N(e)^2$$

where

n = designates the sample size the study uses;

N = designates total number of households;

e = designates maximum variability or margin of error 5%;

1 = designates the probability of the event occurring.

Entering data of the study area into the aforementioned formula,

$$n = 3488/1 + 3488(0.05)^2 = 349$$

After determining the sample size for the study area, the sample for each altitude (stream) was distributed proportional to the size of the total households in each stream. Finally, 100 households from each stream were randomly selected based on the purpose of the study and resource limitation (see Table 1).

2.3 Methods of Data Collection

Both secondary and primary data sources were used as sources of data. The secondary sources were reports of urban development sectors in Ambo town, national

Table 1 Household sample design for households' survey questionnaire in Huluka Watershed

Sr. No.	Altitude	Target population (households)	Sample households	Actual sample
1	Upstream (2735–3328 m.a.s)	476	48	100 ^a
2	Midstream (2384–2735 m.a.s)	1594	159	100 ^a
3	Downstream (1924–2384 m.a.s)	1418	142	100 ^a
Total		3488	349	300

^aDecided based on the purpose of the study and limitation of financial resources

and regional climate change adaptation policies and strategies, and robust published materials (books, journal articles, reports of national and international organizations, and internet sources) on the issues under investigation. The primary sources were urban planners of Ambo town, urban households in Ambo town, and households in Huluka Watershed. The methods employed to collect primary data are presented hereunder.

2.3.1 Semi-structured Questionnaire

A semi-structured questionnaire was designed, pre-tested and administered through interview schedule for 300 households in Huluka Watershed where Ambo town is located to understand households' perceptions on trends of change in climatic parameters (rainfall, temperature and wind intensity) in Huluka watershed.

2.3.2 Personal Observation

Personal observation was also employed to visually observe and document indicators of urban vulnerabilities to climate change and environmental problems in Ambo town and Huluka watershed. The personal observation was guided by a semi-structured checklist and knowledgeable local person in each study village in the watershed.

2.3.3 Focus Group Discussion

Focus group discussion was also employed to collect data from members of urban local communities' development associations. Accordingly, a total of six focus

group discussions (60 participants) were administered in three urban villages of Ambo town. Participants of the focus group discussion were members of the urban local communities' development associations who lived in Ambo town for more than 20 years and knowledgeable about negative impacts of climate change and climate variability. Each focus group discussion participated 10 persons and the discussion in each group took about 60 min. Each focus group discussion was started and closed with blessings of local elders as per the norm of Oromo culture in each urban village of Ambo town.

2.3.4 Key Informant Interview

Key informant interview was also employed to collect primary qualitative data. Accordingly, in-depth interview was made with 12 key informants from three urban villages (Village 1, village 2, and village 3 of Ambo town) and 15 key informants from pre-urban and rural villages (Awaro Kora, Sankile Farisi, Uko Korke, Kure Gatira, and Dendi Mumicha) in Huluka Watershed on their personal experiences with climate change and their adaptation measures in Ambo town and Huluka Watershed. The key informants were men and women who lived in Ambo town and Huluka watershed for more than 20 years and older than or equal to 50 years of age at the time of interview.

2.4 Methods of Data Analysis

Both qualitative and quantitative methods of data analysis were employed to analyze the collected data. The qualitative data captured through focus group discussion, personal observation, and key informant interview were analyzed in the form of narrations and descriptions. Simple descriptive statistics like mean, standard deviation, frequencies and percentages were employed to analyze data collected through household survey questionnaire and quantitative secondary data. SPSS software (SPSS-Version 20) was used to help the quantitative analysis of the study.

3 Results

3.1 Demographic and Socio-economic Profile of Respondents

96.3% (n = 289) of the respondents were males while 3.7% (n = 11) were females. 43.7% (n = 131) of the respondents were above 50 years of age. 94.7% (n = 284)

Table 2 Demographic and socio-economic profile of respondents

Variables	Frequency (n = 300)	Percentage (%)
<i>Sex of respondent</i>		
Male	289	96.3
Female	11	3.7
<i>Age of respondent</i>		
18-30	55	18.3
31-50	114	38.0
>50	131	43.7
<i>Marital status</i>		
Single	8	2.7
Married	284	94.7
Divorced	3	1.0
Widow	3	1.0
Widower	2	0.7
<i>Educational level</i>		
No education	43	14.3
Non-formal	70	23.3
Primary	150	50.0
Secondary	35	11.7
College	2	0.7
<i>Agricultural land size</i>		
Landless	77	25.7
0.25-1 ha	129	43.0
1.1-4 ha	89	29.7
4.1-10 ha	5	1.7
<i>Main source of livelihood</i>		
Agriculture	288	96
Off-farm activities	1	0.3
Employed	1	0.3
Labourer	2	0.7
Stone mining	8	2.7

of the respondents were with married marital status. 50% of the respondents were with primary education level. 43% of the respondents were within the agricultural land size category of 0.25-1 ha. 96% of the respondents pursue agriculture as the main source of livelihoods at the time of the interview (see Table 2).

3.2 *Perceptions, Negative Effects of Change in Climatic Parameters on Livelihoods and Adaptation Strategies of Households in Huluka Watershed*

3.2.1 *Perceptions of Households in Huluka Watershed on Change in Climatic Parameters*

Respondents were asked how they perceive changes in climatic parameters in their area. 99.3, 99.0, and 97.7% of the respondents perceived decreasing trend in annual rainfall, rainfall during rainy period, and rainfall during dry period respectively in their area. On the other hand, 98% of the respondents perceived increasing trend of rainfall intensity during rainy period in their area. 99.3 and 97.7% of the respondents perceived increasing trend in temperature of hot period and cold period respectively in their area. Similarly, 97% of the respondents perceived increasing trend of heat intensity during hot period in their area. 65.3 and 58.7% of the respondents perceived increasing trend of wind intensity during dry period and rainy period respectively in their area (see Table 3).

3.3 *Negative Effects of Change in Climatic Parameters on Livelihoods of Households in Huluka Watershed*

Key informants were asked to identify negative effects of change in climatic parameters on their livelihoods. Accordingly, the following negative economic, environmental, and social effects of change in climatic parameters were identified as analyzed hereunder.

Table 3 Perception of households in Huluka Watershed on change in climatic parameters

Climatic parameter	Attribute	Increase		No change		Decrease	
		Freq.	%	Freq.	%	Freq.	%
Rainfall	Annual	1	0.3	1	0.3	298	99.3
	Rainy period	1	0.3	2	0.7	297	99.0
	Dry period	-	-	7	2.3	293	97.7
	Rain intensity	294	98.0	2	0.7	4	1.3
Temperature	Hot period	298	99.3	1	0.3	1	0.3
	Cold period	293	97.7	3	1.0	4	1.3
	Heat intensity	291	97.0	7	2.3	2	0.7
Wind intensity	Dry period	196	65.3	87	29.0	17	5.7
	Rainy period	176	58.7	95	31.7	29	9.7

Similar answers were received across the three streams of the watershed (upstream, midstream, and downstream) on the negative economic effects. The negative economic effects reported were: Low crop yield associated with variability and change in climatic parameters, high cost of labour at the time of pick harvesting or planting, disease infestation resulting from shortage/excess of rainfall, stunted growth and eventual die back of trees and annual crops during prolong dry-season, destruction of trees and crops due to wind throw and flooding, and reducing production of crops to one cycle due to delay in rainfall.

No similar answers were received across the three streams of the watershed (upstream, midstream, and downstream) on the negative social effects. The negative social effects reported were: outbreak of diseases like malaria and water related diseases. These diseases were reported to exist in downstream of Huluka watershed where Ambo town is situated. For instance, the key informants from downstream of Huluka watershed reported prevalence of malaria in their residential area linked to change in climatic parameters (temperature and rainfall). On the other hand, key informants from upstream and midstream of Huluka watershed did not report any outbreak of diseases associated with change in climatic parameters in their area.

Similar answers were received across the three streams of the watershed (upstream, midstream, and downstream) on the negative environmental effects. The negative environmental effects reported were: Flooding in rainy season, too much heat in dry season, outbreak of pests associated with change and variability in climatic parameters, and loss of biodiversity resulting from rapid expansion of agricultural activities to forest areas in Huluka watershed.

3.4 Adaptation Strategies of Households in Huluka Watershed and Challenges for Adaptation to Change in Climatic Parameters

Key informants were asked to identify their adaptation strategies to negative effects of change in climatic parameters in their residential areas. Similar answers were received across the three streams of the watershed (upstream, midstream, and downstream). The following adaptation strategies were reported: Planting different crops, planting of short duration varieties, adjustment in planting period, and Prayer.

Key informants were also asked to identify challenges for adaptation to change in climatic parameters in their area. Similar answers were received across the three streams of the watershed (upstream, midstream, and downstream). The following challenges were reported: Lack of information on weather forecast, inadequate supply of improved varieties, limited access to water for irrigation, inadequate information on modern adaptation techniques, lack of financial capital, and lack of modern equipment.

3.5 *Climate Change Related Disaster Risks and Urban Households Adaptation Strategies in Ambo Town*

3.5.1 *Climate Change Related Disaster Risks in Ambo Town*

Participants of the focus group discussion were asked to discuss on climate change related disaster risks in Ambo town. They reported urban flooding disaster risk (see Fig. 3), water stress/water shortage, urban heat island effect/increased urban heat, wind storms, and dust storms as the five critical climate change related disaster risks in Ambo town (See Table 4).

The local criteria used in the ranking process were: duration of occurrence, current negative effect of the disaster risk, future negative effect of the disaster risk, severity of the disaster risk, and possibility of planned adaptation to the negative effects of climate change related disaster risk. They also indicated in which months of the year these disaster risks occur in Ambo town (see Table 5).



Fig. 3 Some of the negative effects of urban flooding disaster risk in Ambo town. Source Field Observation, July, 2015

Table 4 Community-based pair-wise ranking chart for climate change related disaster risks in Ambo town

	UF	Water Stress	Wind storms	UHIE	Dust Storms	Score	Rank
Urban Flooding		UF	UF	UF	UF	4	1
Water Stress			WS	WS	WS	3	2
Wind storms				UHIE	WST	1	4
Urban Heat Island Effect					UHIE	2	3
Dust Storms						0	5

UF urban flooding, WS water stress, WST wind storm, UHIE urban heat island effect, DS dust storms

Table 5 Community-based appraisal of seasonal occurrence of climate change related disaster risks in Ambo town

Climate Hazards	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
Urban Flooding												
Water Stress												
Urban Heat Island Effect												
Wind Storms												
Dust Storms												

3.6 Urban Households Strategies to Adapt with Climate Change Related Disaster Risks in Ambo Town

Key informants from Ambo town were asked to explain their personal experience with climate change related disaster risks and their adaptation strategies. Harvesting rainwater during rainy season and fetching water from Huluka River during dry season were reported as adaptation strategies of urban households to adapt to water stress/water shortage. Planting trees around home, growing grasses in their home, making traditional urban flooding passage around their home, maintaining and cleaning existing drainage channels with sense of ownership, cleaning their environment, taking appropriate care for their families during flooding season, and paying tax timely to the city administration, putting sand bags in front of their



Fig. 4 Some of the autonomous adaptation strategies to urban flooding disaster risk in Ambo town. Source Field Observation, July 2015

homes, covering ground with plastic sheets at market places, using rubber boots, rain coats, and umbrella during flooding season were reported as adaptation strategies for urban flooding by urban households in Ambo town (see Fig. 4). Using umbrella during hot season, wearing light cloths and shoes during hot season, undertaking livelihood activities under shading of trees, and consuming much cold drinking water were reported as adaptation strategies by urban households in Ambo town to adapt to urban heat island effect/increased urban heat.

4 Discussions

4.1 Climate Change Related Urban Disaster Risks

The climate change related disaster risks identified in Ambo town were: urban flooding, water stress/water shortage, urban heat island effect/increased urban heat, wind storm, and dust storms. Climate change related disaster risks, their impacts and adaptation strategies are discussed hereunder.

4.2 Urban Flooding Disaster Risk, Impacts, and Adaptation Strategies

The first priority climate change related disaster risk in Ambo town was urban flooding. Majority of the respondents from Huluka watershed where Ambo town is

situated also reported that there is increasing trend in rainfall intensity during rainy period (July, August, and September) which is one of the major contributors of urban flooding (Parkinson 2003; Few 2003; Few et al. 2004; Tucci 2007; Douglas et al. 2008; Satterthwaite 2011; Jha et al. 2012; Kebede and Nicholls 2012; Wilby and Keenan 2012; Hambati and Gaston 2015; Messling et al. 2015; Yang et al. 2015).

Scholars of sustainable urban flooding risk management assert that urban land use planning plays vital role in urban flooding risk management (Zheng and Qi 2011; de Moel et al. 2014; Ezemonye and Emeribe 2014; Früh-Müller et al. 2014; Linnerooth-Bayer et al. 2014; Guerrin 2015; Idris and Dharmasiri 2015; Mashila 2014; EEA 2015). According to Mngutyo and Ogwuche (2013). Urban land use planning is concerned with the design and organization of urban space to guide and ensure the orderly development of settlements and communities. In other words, urban land use planning has become more vital as the society becomes more urbanized, ranging from producing blue print to more strategic approach of structure and local planning (Atedhor et al. 2011; UN-Habitat 2011; Wilby and Keenan 2012; Mngutyo and Ogwuche 2013; Murtaza et al. 2015; Umezuruike 2015).

4.3 Water Stress/Water Shortage, Impacts, and Adaptation Strategies

The second priority climate change related disaster risk reported by local communities in Ambo town was water stress/water shortage. Urban areas where there is a failure to address the impacts of climate change on water resources will leave their inhabitants vulnerable to a range of immediate acute and slow-onset disasters (Muller 2007; Fünfgeld 2010; Su et al. 2012; Wapwera et al. 2015). In other words, climate change has the potential to significantly alter river flow regimes in a river catchment which may seriously affect urban water supply (Hall and Murphy 2010).

Adaptation planning for water sector is a planning process of developing institutional and political capacities to ensure adequate water supply and water quality in the face of intensifying risks from climate and climate-related impacts (Nikitina et al. 2010; Sowers et al. 2011; Herrfahrdt-Pähle 2013). Urban adaptation strategies and discourses need to deal more strongly with processes and the knowledge base on how to improve adaptive capacities and adaptive planning, rather than focusing solely on a list of options to adjust physical structures and the built environment (Björklund et al. 2009; Hardoy and Pandiella 2009; Birkmann et al. 2010; van Buuren et al. 2014). Managing water demand, improving the efficiency of water use, and promoting conservation will be key ingredients in responding to climate-induced impacts on the water sector (Mata and Budhooram 2007; ECE 2009; Luthe et al. 2012; Porthin et al. 2013; Padgham et al. 2015; Sietz and Van Dijk 2015).

4.4 Urban Heat Island Effect/Increased Urban Heat, Impacts, and Adaptation Strategies

The third priority climate change related disaster risk identified in Ambo town was urban heat island effect (UHIE). January, February, March, April, and May were reported as the months when the urban heat island effect in Ambo town is grave.

While physical climate changes can impact upon both rural and urban areas, urban settlements generate unique local conditions that interact with heat events. Compared to rural areas, cities tend to have higher air and surface temperatures due to the urban heat-island effect: the tendency of cities to retain heat more than their surrounding rural areas (Yow 2007; UN-Habitat 2011). By increasing temperatures, urban heat-island effects can aggravate the heat-related negative implications of climate change and impose costly energy demands on urban systems as they attempt to adapt to higher temperatures. The degree of these effects is not uniform across cities. The physical layout of a city, its population size and density, and structural features of the built environment all influence the strength of the urban heat-island effect (Yow 2007; UN-Habitat 2011; Djibril et al. 2012; Umezuruike 2015). Scholars of climate change adaptation studies recommends incorporating vegetation in developed areas, reducing energy consumption, and installing green roofs or rooftop gardens as some of the best adaptation strategies for urban heat island effect (McKendry 2003; Yow and Carbone 2006; Yu and Hien 2006; Zomer et al. 2008; Chen et al. 2013; Demuzere et al. 2014; Laves et al. 2014; MacDonald et al. 2014; Murgida et al. 2014).

4.5 Wind Storms, Dust Storms, Impacts, and Adaptation Strategies

The fourth priority climate change related disaster risk identified in Ambo town was wind storm. The fifth priority climate change related disaster risk in Ambo town was dust storm. Majority of the respondents from Huluka watershed where Ambo town is situated also reported that there is increasing trend in wind intensity both in dry period and rainy period. January, February, March, April, and May were reported as the months when the wind storm and dust storm in Ambo town is severe.

Both wind storm and dust storm may be adapted to properly through the practice of ecosystem-based adaptation both in Ambo town and Huluka watershed. An Ecosystem is the dynamic complex of plant, animal and micro-organism communities and the nonliving environment interacting as a functional unit. It assumes that people are an integral part of ecosystems (Millennium Ecosystem Assessment

2005). Ecosystem-based Adaptation (EbA) integrates the use of biodiversity and ecosystem services into an overall strategy to help people adapt to the adverse impacts of climate change (Niemi et al. 2010; Oteros-Rozas et al. 2014; EEA 2015). It includes the sustainable management, conservation and restoration of ecosystems to provide services that help people adapt to both current climate variability, and climate change (Millennium Ecosystem Assessment 2005; EEA 2015). Ecosystem-based Adaptation reduces vulnerability to both climate and non-climate risks and provides multiple economic, social, environmental and cultural benefits, including: disaster risk reduction, livelihood sustenance and food security, biodiversity conservation, carbon sequestration, and sustainable water management (Colls et al. 2009; Ngigi 2009; Ludi 2009; Vignola et al. 2009; Niemi et al. 2010; Lantz et al. 2013; Wu et al. 2013; EEA 2015).

4.6 The Need to Mainstream Adaptation to Climate Change into Urban Land Use Planning and Management in Ambo Town

Mainstreaming adaptation to climate change related disaster risks into urban land use planning and management reduces the devastating consequences of unanticipated climate-related disaster risks, including costs that constitute significant drains on resources, thereby stifling the achievement of set goals (Klein et al. 2003; Wilson 2006; Kok et al. 2008; Wilson and Piper 2008; Yaro et al. 2010; Hurlimann and March 2012). It can also ensure that development programs and policies are not at odds with climate risks both now and in the future (Lindley et al. 2007; Huxtable and Yen 2009; Chinvano 2011; Li 2012). There is a growing need for policy-makers, particularly in the ministries related to development such as in finance or planning, to better understand how climate change adaptation can be addressed in national and sub-national/regional planning processes, and through fiscal and investment decisions. For example, when making decisions on long-lived infrastructure, it may be more cost-effective to take adaptation needs into account earlier rather than later (Lebel et al. 2012; Faleiro et al. 2013; Ayers et al. 2014).

Mainstreaming adaptation into urban land use planning and management has been promoted as an effective way to respond to climate change in urban areas and the expected benefits for sustainable urban development in Ambo town include: avoided policy conflicts; reduced risks and vulnerability; greater efficiency compared with managing adaptation separately; leveraging the much larger financial flows in sectors affected by climate risks than the amounts available for financing adaptation separately, and easier to start with existing policies and practices, rather than creating new ones (Klein et al. 2003; Huxtable and Yen 2009; Chinvano 2011; Oates et al. 2011; UNPEI 2011; Lebel et al. 2012).

5 Conclusion and Recommendations

Majority of the respondents in Huluka Watershed perceived decreasing trends of annual rainfall, wet period rainfall, and dry period rainfall. On the other hand, Majority of the respondents in Huluka watershed perceived increasing trends of rain intensity in wet period, hot period temperature, cold period temperature, heat intensity, and wind intensity in their area. Negative economic, social, and environmental effects of change in climatic parameters on livelihoods of households in Huluka Watershed and local adaptation strategies were also assessed. Climate change related disaster risks in Ambo town. Urban flooding disaster risk, water stress/water shortage, urban heat island effect/increased urban heat, wind storms, and dust storms were identified as the five critical climate change related disaster risks in Ambo town. Furthermore, autonomous adaptation strategies of urban communities to climate change related disaster risks were assessed.

In conclusion, there are convincing reasons to mainstream climate change adaptation into urban land use planning and management in Ambo town. Further investigation and characterization of each climate change related disaster risk in Ambo town with the help of geographic information system (GIS) and remote sensing techniques are of paramount importance in the mainstreaming process of climate change adaptation into urban land use planning and management. While it is commendable to appreciate the good start of urban greening and beautification by Ambo town administration and its municipality, the town administration has to take strategic actions to adapt Ambo town and its watershed to the negative impacts of climate change and climate variability.

The following strategic measures are forwarded to mainstream climate change adaptation into urban land use planning and management in Ambo town in the years to come:

- Awareness of urban local communities and other stakeholders on the benefits of mainstreaming climate change adaptation into urban land use planning and management should be created and increased for achieving sustainable development in Ambo town and Huluka Watershed;
- Community participation should be mainstreamed in the vulnerability assessment and adaptation planning to motivate them for active participation and benefit sharing from the urban development process;
- Vulnerable sectors, most vulnerable groups, and adaptive capacity of local communities should be assessed to mainstream climate change into different urban development activities in the town and in the watershed;
- Training and education opportunities on mainstreaming climate change adaptation into urban land use planning and management should be provided for urban land use planners to improve planning, implementation, monitoring and evaluation activities of mainstreaming;
- Stakeholders should be well informed about their roles and responsibilities in vulnerability assessment and adaptation process;

- Urban investment permits should include mainstreaming adaptation to climate change into urban development activities as key criteria;
- Mainstreaming climate change adaptation into urban land use planning should reduce the negative social, economic and environmental impacts of urban development and enable the most vulnerable groups like women, children, physically handicapped groups, and elderly adapt to climate change related disaster risks;
- Rural-Urban linkage in managing watersheds in rural villages should be strengthened to adapt Ambo town and neighboring rural villages to negative impacts of climate change and climate variability;
- Ambo town administration should properly monitor and evaluate climate adaptation projects in its development sector to check whether they meet their climate adaptation objectives, and what other benefits or adverse impacts they may have on the environment.
- The local urban government in Ambo town should be able to provide the available social services efficiently and effectively and mobilize urban local communities' resources to enable Ambo town and its watershed adapt to negative effects of climate change and climatic variability; and
- The adaptation measures should include participatory planting of indigenous and eco-friendly exotic trees and management both in urban and rural villages in Huluka Watershed.

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Declaration of Conflict of Interest

The authors fully declare that they have no conflict of interest in publishing the manuscript.

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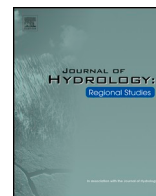
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Geographic information system (GIS)-Based multicriteria analysis of flooding hazard and risk in Ambo Town and its watershed, West shoa zone, oromia regional State, Ethiopia



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ABSTRACT

The purpose of the study was to analyze flooding hazard and risk from Geographic Information Systems (GIS)-based multicriteria perspective in Ambo town and its watershed and proposes strategic measures for sustainable flooding disaster risk management in urban watershed. Land use/land cover, elevation, slope, drainage density, soil, and rainfall were considered as important flooding hazard factors. Analysis of flooding risk was undertaken for Ambo town's watershed using flooding hazard layer and the two elements at risk, namely human population and land use. Weighted linear combination (WLC) method was used in the process of criteria map aggregation for both flooding hazard and flooding risk. The result of the flooding hazard in the watershed reveals that more proportion of the watershed is high and very high flooding hazard area (60.58%). Moreover, more proportion of the town is high and very high flooding hazard area (66.87%). The result of the flooding risk in the watershed reveals that more proportion of the watershed is high and very high flooding risk area (41.76%). Moreover, half of the town is high and very high flooding risk area (50.09%). An integrated basin wide approach to flood management should be practiced as it is essential to address multiple water related issues at watershed level. Moreover, environmental education should be emphasized to build civic responsibility among the citizens.

1. Introduction

Scholars of sustainable disaster risk management assert that spatial planning plays a significant role in integrated disaster risk management, particularly through its potential contribution to long term disaster mitigation (Basawaraja et al., 2011; Steinberg and Lindfield, 2012; Wapwera and Egbu, 2013; Watson and Agbola, 2013; UNDP, 2015). In other words, effective risk-based planning aims to minimize damages to people and assets before a disaster strikes, but its performance in disaster mitigation requires a high level of technical and political cooperation and coordination, and equally a commitment from other societal stakeholders as partners in sustainable development (Onyenechere, 2010; Sutanta, 2012; Watson and Agbola, 2013).

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Spatial planning is increasingly being considered as an important mechanism in coping with flood risk (Schmidt-Thomé, 2006; A. Dewan, 2013; A.M. Dewan, 2013; Khailani and Perera, 2013). One of the reasons for this is that engineering approaches are increasingly expensive and cannot provide complete certainty of protection against flooding risk. In other words, planning is considered as the regulation of physical implementation as well as the process of policy-making that guides spatial development. This process is claimed to mainly involve the interaction and collaboration between actors (both public and private) (Kazmierczak and Cavan, 2011; Lu, 2014). However, spatial Planning is absent in most developing countries due to the stronghold by the traditional master planning approach to achieve controlled urban development and its management (Watson, 2009; Wapwera and Egbu, 2013).

It is vital to appreciate the role of geographic information system (GIS) and remote sensing technologies in planning for flooding disaster risks in urban watersheds. For instance, geospatial technology provides the best potential to analyze and provide results required for prompt and effective decision-making on floods (Dewan and Yamaguchi, 2009; Manfreda et al., 2011; Suriya and Mudgal, 2011; Albano et al., 2014; Samela et al., 2016, 2017b).

Given that flood hazard is spatial phenomenon, the application of GIS and Remote Sensing techniques are essential to the flood hazard/risk management process. For instance, Geographical Information Systems (GIS) with their ability to handle spatial data are an appropriate tool for processing spatial data on flood risk (Alfasi et al., 2012; Uddin et al., 2013; Samela et al., 2018). Moreover, flood hazard and risk maps are effective tools for reducing flood damage (Zerger and Smith, 2003; Marchi et al., 2010; Sayers et al., 2013; Wondim, 2016). Hazard zoning is also appreciated by scholars of disaster risk management in urban watersheds as it provide a detailed overview of the hazard situation and a basis for spatial planning processes (Balaban, 2009; Adedeji et al., 2012; Sutanta, 2012; Santato et al., 2013). Despite the aforementioned benefits of spatial planning for sustainable disaster risk management in urban watersheds in developing countries, lack of proper spatial planning and land use management coupled with poor adaptive capacity of governments to ensure good urban governance exacerbate the cases of urban flooding disaster risk.

Multi-criteria analysis methods are claimed as decision support tools for dealing with complex decision constellations where technological, economical, ecological, and social aspects have to be covered. These methods have been repeatedly combined with geographical information systems (GIS) and are therefore suitable to optimize the landuse planning (Levy, 2005; Wang et al., 2011; Bathrellos et al., 2012; Chowdary et al., 2013; Li et al., 2013; Yang et al., 2013; Guo et al., 2014). Spatial multi-criteria decision assessment/analysis (MCA) or multi-criteria evaluation (MCE) has received renewed interest because of the following: (1) it allows improved decision making; (2) it supports developing and evaluating alternative plans; and (3) it is predominantly appropriate for spatial decision making, as the data that the decision makers rely on are mostly related to space (Kubal et al. (2009); Chen et al., 2011; A. Dewan, 2013; A.M. Dewan, 2013; Zhiyu et al., 2013; Rahmati et al., 2016). The GIS-multi-criteria decision analysis (MCDA) approach is claimed to use the capabilities of GIS in the management of geospatial data and the flexibility MCDA to combine factual information (e.g., land use, slope, drainage system, etc.) with value-based information (e.g., expert opinion, standards, surveys, etc.) (Yahaya et al., 2010; Wang et al., 2011; Stefanidis and Stathis (2013); Zou et al., 2013; Gigovi'c et al., 2017; Rimba et al., 2017; Seejata et al., 2018).

Ethiopia is located in northeast Africa between 3° and 18° North latitude and 33° and 48° East longitude. Elevations range between 100 m below and 4600 m. above sea level. It has a land area of about 1,100,000 sq. km (Achamyeleh, 2003). The rainy season in Ethiopia is concentrated in the three months between June and September when about 80% of the rains are received. Torrential down pours are common in most parts of the country. As the topography of the country is rather rugged with distinctly defined water-courses, large scale flooding is rare and limited to the lowland areas where major rivers cross to neighboring countries. However, intense rainfall in the highlands could cause flooding of settlements close to any stretch of river course (Achamyeleh, 2003; Chibssa, 2007; Alemu, 2011; Dessie and Tadesse, 2013; Alemu, 2015; Getahun and Gebre, 2015).

Previous studies undertaken on the environmental problems of Ambo town and its watershed identified: low infiltration of rain Water, storm water occurrence, inundation of low gradient areas, incidence of sheet and gully erosion, inefficient and uncoordinated utilization of potential site and resources; sanitation problem associated with lack of waste collection system and disposal site for both solid and liquid waste, mixed waste disposal in open spaces and rivers, water stress, urban heat island effects, wind storms, dust storms, flash flood, growing water and air pollution, and unplanned expansion and deforestation as critical environmental challenges for urban development in Ambo town and its watershed (Ambo Town Administration Office, 2013; Ogato, 2013a). Moreover, UN-HABITAT (2008) affirms that the environment of Ambo town and its watershed has been in a constant decline characterized with most of the solid waste not properly collected, lack of environmental regulations and sanitation, absence of sewerage system in place, and lack of sanitary dumping site.

UN-HABITA (2008) further contends that the municipality of Ambo town is not in a position to address the aforementioned problems due to resource and capacity limitations. Furthermore, Ogato (2013a) and Ogato et al. (2017) assert that Ambo town and its dwellers are vulnerable to the negative impacts of climate change related hazards and mainstreaming climate change adaptation into urban planning is vital. This paper focuses on analyzing flooding hazard and risk from Geographic Information Systems (GIS)-based multicriteria perspective in Ambo town and its watershed and proposes strategic measures for sustainable flooding disaster risk management in urban watershed.

2. Research methodology

2.1. Description of the study area

Huluka watershed is located in West Shoa Zone, Oromia Regional State, Ethiopia. Geographically, it is located between 8°49'26" to 8°55'22"N lat. and 37°49'50" to 38°8'08"E long (Fig. 1). The total land area of the watershed is about 81,237 ha and composed of

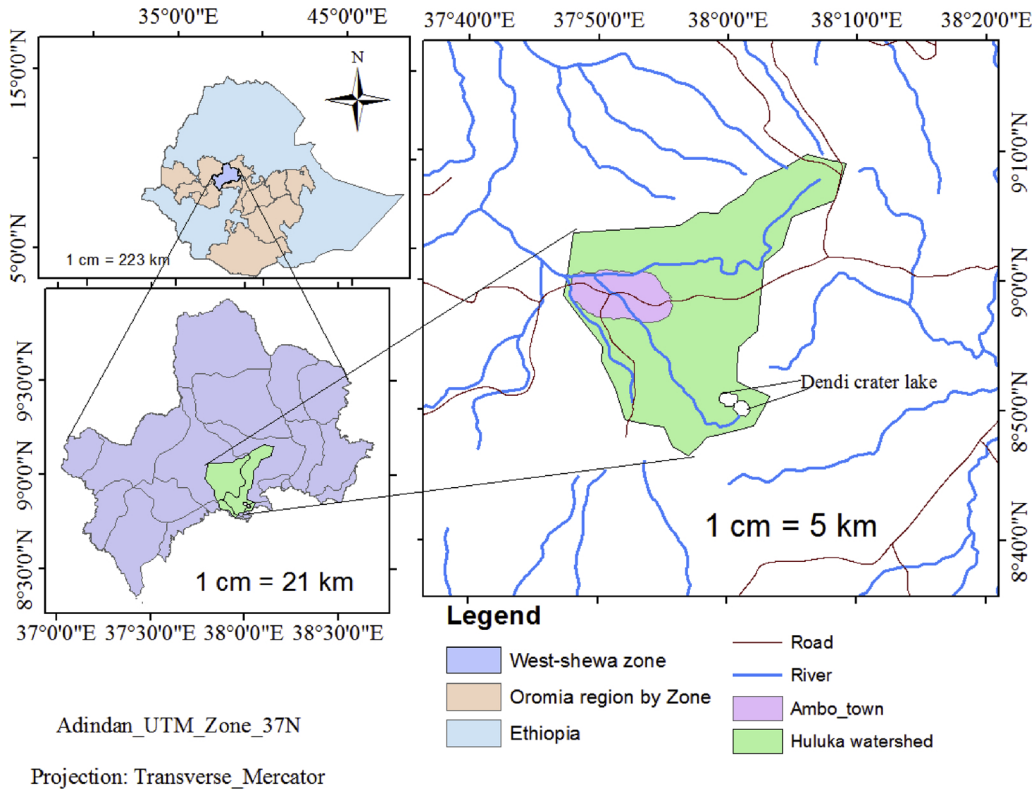


Fig. 1. Geographical location map of Huluka watershed.

villages mainly from Ambo, Dawo, Dendi, Elfeta, Jeldu, Toke Kutaye and Wonchi districts and Ambo town. The total human population of the watershed is about 303,416 in the year 2017.

Seven land use/land cover types were identified in the watershed in the year 2017. The identified land use/land cover types in the watershed were: forest area, cultivated land area, urban built-up area, bush/shrub land area, bare land area, grassland area, and water area (Fig. 2).

Forest land covered 4232.253 ha (5.2%) in 2009 and 4298.85 ha (5.3%) in 2017. It increased by 1.6% between 2009 and 2017. Cultivated land covered 43,833.98 ha (54%) in 2009 and 51329.96 ha (63.2%) in 2017. It increased by 17.1% between 2009 and 2017. The increase of cultivated land in the watershed was attributable to the transformation of other land use/land cover types into cultivated land use/land cover type. Urban built-up area covered 425.79 ha (0.5%) in 2009 and 790.74 ha (1%) in 2017. It increased by 85.7% between 2009 and 2017. Bush/Shrub land covered 7907.733 ha (9.7%) in 2009 and 5635.09 ha (6.9%) in 2017. It decreased by 28.7% between 2009 and 2017. Bare land covered 431.46 ha (0.5%) in 2009 and 513.97 ha (0.6%) in 2017. It increased by 19.1% between 2009 and 2017. Water body covered 748.44 ha (0.9%) in 2009 and 749.07 ha (0.9%) in 2017. It increased by 0.1% between 2009 and 2017. Grassland covered 23657.14 ha (29.1%) in 2009 and 17919.11 ha (22%) in 2017. It decreased by 24.3% between 2009 and 2017 (Ogato, 2019).

The highest elevation in the watershed is 3253 m above sea level while the lowest elevation of the watershed is 1834 m above sea level. The slope of the watershed ranges between 0% and 32.5%. The seven soil types dominating the watershed include: Chromic Luvisols, Chromic Vertisols, Eutric Cambisols, Eutric Nitisols, Leptosols, Orthic Luvisols, and Pellic Vertisols (Ogato, 2019). The watershed is drained by perennial major rivers (Huluka, Debis and Taltale); minor seasonal rivers (Aleltu, Awaro, Boji, Dobi, Kerise, Chafe Jara, Jalina, Maja, Solbe, Jabdu and Sankale); and a number of intermittent or seasonal streams within the watershed (Ogato et al., 2017). The rainfall of the area is bimodal, with unpredictable short rains from March to April and the main season ranging over June to September. The highest mean total annual rainfall of the watershed over 32 years (1984–2015) was 1181 mm while the lowest was 1036 mm. The lowest and highest annual average temperature are 13 and 27 °C, respectively (Atnafe et al., 2015).

Ambo town in the watershed represents the urban feature of the watershed. The human population of Ambo town has been growing rapidly over the past few years. According to CSA (2017), the population of the town was 76,544 with the growth rate of 2.5%. The poor quality of housing and inability of the administration to increase supply could be taken as key indicators that a wide reform is necessary for Ambo town. Ambo is one of the oldest towns in Ethiopia (Established in 1889). It is among a few privileged towns of its time to have its own municipal administration since 1931, and a master plan since 1983 (United Nations Human Settlements Programme (UN-HABITAT), 2008; Ogato et al., 2017).

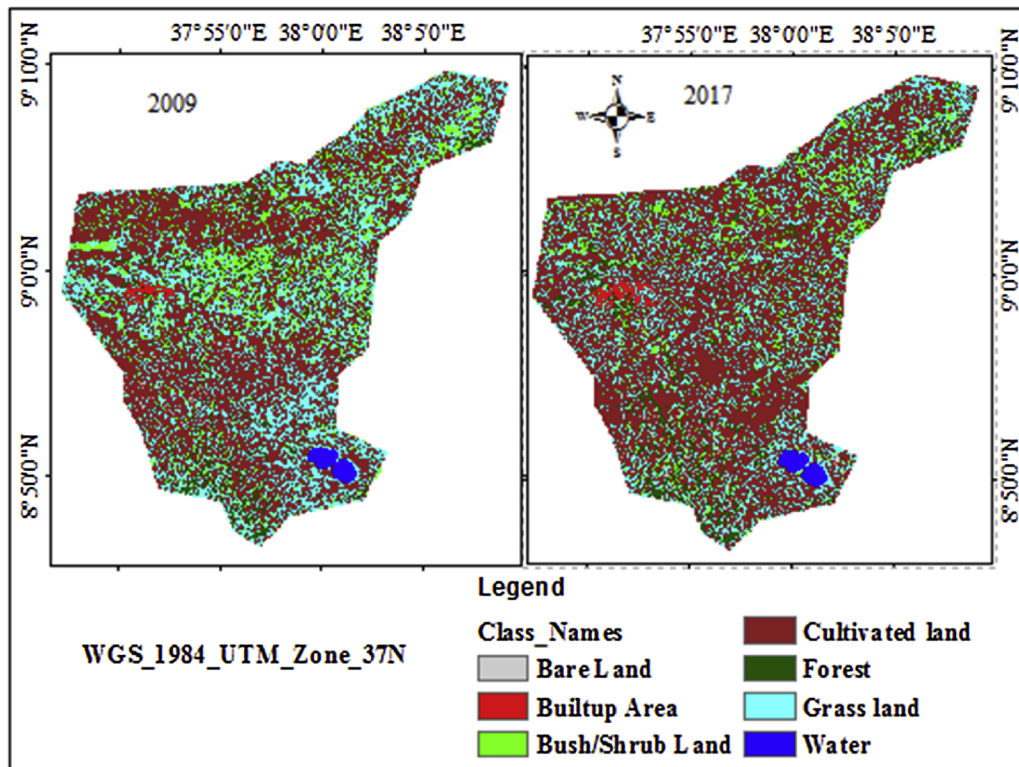


Fig. 2. Map of Land Use/Land Cover for the Watershed (2009 and 2017).

2.2. Methods of data collection

Landsat images of 2015; digital map on shape file with the scale of 1:50,000 from Ethiopian Mapping Authority; rainfall data (1984–2015) for the study watershed from the Ethiopian Meteorology Agency, Digital Elevation Model (DEM) of the watershed; soil types of Ethiopia; human population, and flood points in the watershed were the type of data used for the study. The sources of data included: Central Statistical Authority (CSA) of Ethiopia, Ethiopian Mapping Agency (EMA), Ethiopian Meteorology Agency, Landsat website of www.glovis.USGS.gov, urban and rural communities in Huluka watershed, urban planners of Ambo town, and land use planners and managers in the watershed. To collect relevant data to analyze flooding hazard and risk in the watershed, online Satellite Imagery (Monkkonen, 2008; Gondo and Zibabgwe, 2010); field observation; and document review were employed.

2.3. Methods of data analysis

2.3.1. Flooding hazard factors

The flooding hazard factors were determined by literature review, personal observation, and discussion with experts and local residents. As far as the key informants (experts and local residents) are concerned, 15 experts and 15 local elders were interviewed to decide the important factors causing flooding hazard. Accordingly, Land use/land cover, elevation, slope, drainage density, soil, and rainfall were considered as important flooding hazard factors in Ambo town's watershed.

1. Land Use/Land Cover Factor

Many scholars in the field of flooding risk management attest that land use/land cover change is one of the major contributor of flooding as urban expansion increases, impervious cover increases and forest cover decreases in urban areas contributing to increase in run-off (Tucci, 2007; Jha et al., 2012; Fura, 2013; Mngutyo and Ogwuche, 2013; Hall et al., 2014).

The existing land-use classes of the area were further reclassified into five groups in order of their capacity to increase or decrease the rate of flooding from very highly susceptible to very low susceptible. Accordingly, water body was ranked with the value of 5 as it is very highly susceptible to flooding hazard. Built-up area land use/land cover type was assigned the value of 4 as it is highly susceptible to flooding hazard. Cultivated land use/land cover type was assigned the value of 3 as it is moderately susceptible to flooding hazard. Grassland land use/land cover type was assigned the value of 2 as it is low susceptible to flooding hazard. Forest land use/land cover type was assigned the value of 1 as it is very low susceptible to flooding hazard.

2. Elevation Factor

Elevation has a key role in controlling the movement of the overflow direction and in the depth of the water level (Gigović et al., 2017).

For elevation factor, the elevation raster map was prepared using the digital elevation model (DEM) and slope generation tools in ArcGIS software. The elevation raster layer was further reclassified into five sub groups using standard classification schemes namely Equal Interval. This classification scheme divides the range of attribute values into equal-sized sub ranges, specifying the number of intervals while Arc Map determines where the breaks should be and new values re-assigned in order of flood hazard rating. In this classification process, the lowest elevation category is ranked to the value of 5 as it has very high susceptibility to flooding hazard while the highest elevation category is ranked to the value of 1 as it has very low susceptibility.

3. Slope Factor

The slope is the ratio of steepness or the degree of inclination of a feature relative to the horizontal plane (Rimba et al., 2017). Slope is an important indicator of surface zones, which are highly prone to flooding. Slope is a major factor in determining the rate and duration of water flow. On the flatter surface, water is moving more slowly, collects longer and accumulates so these areas are riskier with respect to the occurrence of floods in relation to the steeper surfaces (Gigovi 'c et al., 2017; Rimba et al., 2017).

For slope factor, the slope raster map was prepared using the digital elevation model (DEM) and slope generation tools in ArcGIS software. The slope raster layer was further reclassified into five sub groups using standard classification schemes namely Equal Interval. This classification scheme divides the range of attribute values into equal-sized sub ranges, specifying the number of intervals while Arc Map determines where the breaks should be and new values re-assigned in order of flood hazard rating. In this classification process, the lowest slope category is ranked to the value of 5 as it has very high susceptibility to flooding hazard while the highest slope category is ranked to the value of 1 as it has very low susceptibility.

4. Drainage Density Factor

Drainage density (DD) a fundamental concept in hydrologic analysis is defined as the ratio of the length of drainage per basin area. Drainage density is controlled by permeability, erodability of surface materials, vegetation, slope and time. Flooding in Africa has been attributed to inadequate drainage causing overland flow and poor waste collection which can block drainage and water channels causing overland and river (fluvial) flooding (Few et al., 2004; Tucci, 2007; Rimba et al., 2017). Drainage density is an inverse function of infiltration. Greater drainage density indicates high runoff for basin area along with erodible geologic materials, and less prone to flood. Thus, the rating for drainage density decreases with increasing drainage density (Chibssa, 2007; Wondim, 2016). Drainage density map could be derived from the drainage map. *i.e.*, drainage map is overlaid on watershed map to find out the ratio of total length of streams in the watershed to total area of watershed and is categorized.

The drainage density of the watershed is calculated as (Ouma and Tateishi, 2014):

$$D = L / A$$

, where, D = drainage density of watershed; L = total length of drainage channel in watershed (km); A = total area of watershed (km^2).

For drainage density factor, DEM was used to extract the drainage network from which the drainage density of the streams was calculated. Using the Spatial Analyst extension in ArcGIS environment, line density module was used to compute drainage density of the watershed. Line density module calculates a magnitude per unit area from polyline features that fall within a radius around each cell. The density layer is further reclassified into five sub group using standard classification schemes namely Equal Interval. In this classification, the highest drainage density category is ranked to 1 as it has very low susceptibility to flooding hazard while the lowest drainage density category is ranked to 5 as it has very high susceptibility.

5. Soil Factor

Soil characteristics in a watershed such as soil layer thickness, permeability, infiltration rate and the degree of moisture in the soil before the rain event have a direct effect on the rainfall-runoff process (Zhiyu et al., 2013; Rimba et al., 2017). The structure and infiltration capacity of soils will also have an important impact on the efficiency of the soil to act as a sponge and soak up water. Different types of soils have differing capacities. The chance of flood hazard increases with decrease in soil infiltration capacity, which causes increase in surface runoff. When water is supplied at a rate that exceeds the soil's infiltration capacity, it moves down slope as runoff on sloping land, and can lead to flooding (Ouma and Tateishi, 2014).

For soil factor, the soil factor of the study area was derived from the FAO standard classification of Ethiopian soil (Mesfine, 1998; Food and Agricultural Organization (FAO), 2006; Assen and Tegene, 2008; Chekol, 2014; Assefa, 2015). The characteristics of each soil group were analyzed based on hydrologic soil grouping system. To this end, the soil group of the study area was grouped into five general classes and converted to raster format. Moreover, the soil raster layer group was reclassified into five groups and new values were reassigned in order of their flood hazard rating. Soil type that has very high capacity to generate very high flood rate is ranked to 5 and the one with very low capacity in generating flood rate is ranked to 1. Accordingly, Pellic and Chromic Vertisols were ranked to the value of 5 as they have very high susceptibility to flooding hazard. Leptosols were ranked to the value of 4 as they have high susceptibility. Orthic and Chromic Luvisols were ranked to the value of 3 as they have moderate susceptibility. Eutric Nitisols were ranked to the value of 2 as they have low susceptibility. Eutric Cambisols were ranked to the value of 1 as they have very low susceptibility to flooding hazard.

6. Rainfall Factor

Many scholars in the field of flooding risk management contend that flooding risk is the most widespread climate change-related disaster risk in the world, and historically floods have been the most prevalent cause of death from natural disasters (Zhiyu et al., 2013; Jha et al., 2012; Santato et al., 2013). Changes in the global climate and individual climatic variables can affect floods in various ways, together with soil moisture and snow storage. Generally, a warmer atmosphere can hold more water vapour, which may increase heavy precipitation and therefore floods (Hall et al., 2014; Ouma and Tateishi, 2014). More extreme rainfall means

more likelihood of floods, particularly flash floods (Few et al., 2004; Guo et al., 2014). Moreover, flooding is one of the most widespread of climatic hazards and poses multiple risks to human health (Few et al., 2004; Dang et al., 2011).

For rainfall factor, point rainfall data for 32 years (1984–2015) collected at ten stations (Ambo Plant Protection Research Center, Ginchi, Asgori, Busa, Gedo, Jeldu, Tikur Enchini, Tulu Bolo, WelenKomi, and Woliso) within and around the watershed were received from the Ethiopian Metrology agency. As the data received were monthly total rainfall, total annual rainfall for each year at each station and mean of 32 years (1984–2015) for each station were calculated and then interpolated to Inverse Distance Weight (IDW) in ArcGIS environment. Then it was converted to raster layer to create a continuous raster rainfall data within and around the watershed. This was finally reclassified into five classes using Equal Interval. In this classification, the highest rainfall category was ranked to the value of 5 as it has very high contribution for flooding hazard. On the other hand, the lowest rainfall category is ranked to the value of 1 as it has very low contribution for flooding hazard.

2.3.2. Flooding risk factors

To analyze flooding risk in Ambo town and its watershed, flooding hazard layer, population density, and land use/land cover type were considered as three important factors. These three factors were considered to be equally important in the weighted overlay process.

1. Population Density Factor

Gross population density calculation method is used to calculate the number of person per square kilometers in the watershed. To this end, the human population estimation for the year 2017 at each village in the watershed was considered. Then population shape file was converted to raster layer using Conversion Tools/Feature to Raster. Then, the data layer was reclassified into five sub-factors which are classified using equal interval method and new values re-assigned in order of increasing number of population that is more susceptible to flood hazard. The population density was reclassified in the assumption that the denser the population, the more vulnerable it will be to flood hazard. Accordingly, the highest population density category is ranked to the value of 5 as it is very highly susceptible to flooding risk. On the other hand, the lowest population density category was ranked to the value of 1 as its susceptibility to flooding risk is very low.

2. Land Use Type Factor

The existing land-use classes of the area (water body, built-up, cultivated land, grass land, and forest) were reclassified into five groups in order of their susceptibility to flooding risk. The land use types of the sub-basin were reclassified into a common scale in order of sensitivity for the flood risk analysis. Accordingly, water body was ranked with the value of 5 as it is very highly susceptible to flooding risk. Built-up area land use/land cover type was ranked with the value of 4 as it is highly susceptible to flooding risk. Cultivated land was ranked with the value of 3 as it is moderately susceptible to flooding risk. Grassland land use/land cover type was ranked with the value of 2 as it is low susceptible to flooding risk. Forest land use/land cover type was assigned the value of 1 as it is very low susceptible to flooding risk.

3. Flooding hazard layer

Flooding hazard layer was considered as one of the flooding risk contributing factor in Ambo town's watershed. Very low, low, moderate, high, and very high flooding hazard classes were reclassified based on their susceptibility to flooding risk. Very high flood hazard layer was ranked with the value of 5 as it has the highest susceptibility to flooding risk. On the other hand, very low flooding hazard layer was ranked with the value of 1 as it has the lowest susceptibility to flooding risk.

2.3.3. Integration of analytical hierarchy process (AHP) into Geographic Information Systems (GIS)

This study employed the Geographic Information Systems (GIS)-based multicriteria analysis approach (Wang et al., 2011; Zou et al., 2013; Gigović et al., 2017; Rimba et al., 2017) to analyze flood hazard and risk in Ambo town and its watershed.

Flood risk evaluation is an intrinsically complex multidimensional process including both quantitative and qualitative factors which may be uncertain (Yang et al., 2013). Analytic hierarchy process established by Saaty is a method to solve multiple criteria decision problems by setting their priorities. Analytical hierarchy process (AHP) was adopted for multicriteria decisions in urban flooding hazard and risk analysis (Yahaya et al., 2010; Chowdary et al., 2013; Li et al., 2013; Guo et al., 2014; Rimba et al., 2017). In AHP, multiple pairwise comparisons are based on a standardized comparison scale of nine levels (Saaty, 1977). The nine points are chosen because psychologists conclude that, nine objects are the most that an individual can simultaneously compare and consistently rank (Table 1). Pairwise judgements are made based on the best information available and the decision maker's knowledge

Table 1

Nine-point Pair wise comparison scale.

Source: (Saaty, 1977).

Intensity of Importance	Definition	Explanation
1	Equal importance	Two elements contribute equally to the objective
3	Moderate importance	Experience and judgment slightly favor one parameter over another
5	Strong importance	Experience and judgment strongly favor one parameter over another
7	Very strong importance	One parameter is favored very strongly and is considered superior to another; its dominance is demonstrated in practice
9	Extreme importance	The evidence favoring one parameter as superior to another is of the highest possible order of affirmation

Note: 2,4,6,8 can be used to express intermediate values, 1.1, 1.2, etc. for parameters that are very close in importance.

and experience (Chen et al., 2011; Dang et al., 2011; Youssef et al., 2011; Bathrellos et al., 2012; Ouma and Tateishi, 2014; Gigović et al., 2017).

The process of AHP can be summarized in four steps: construct the decision hierarchy; determine the relative importance of attributes and sub-attributes; evaluate each alternative and calculate its overall weight with regard to each attribute, and check the consistency of the subjective evaluations (Bathrellos et al., 2012; Yang et al., 2013; Ouma and Tateishi, 2014).

Let $C = \{C_j | j = 1, 2, \dots, n\}$ be the set of criteria. The result of the pairwise comparison on n criteria can be summarized in an (n, n) evaluation matrix A in which every element a_{ij} ($i, j = 1, 2, \dots, n$) is the quotient of weights of the criteria, as given in Eq. (1) (Ouma and Tateishi, 2014):

$$A = \begin{bmatrix} a_{11} & a_{12} & \dots & a_{1n} \\ a_{21} & a_{22} & \dots & a_{2n} \\ \dots & \dots & \dots & \dots \\ a_{n1} & a_{n2} & \dots & a_{nn} \end{bmatrix}, a_{ii} = 1, a_{jj} = 1/a_{jj}, a_{ij} \neq 0 \tag{1}$$

The right eigen value (v) corresponding to the maximum eigen value (λ_{max}) is calculated to normalize and find the relative weight (A_v) of the matrix by following Eq. (2) (Ouma and Tateishi, 2014):

$$A_w = \lambda_{max} w \tag{2}$$

It is highly recommended that the pairwise comparisons in AHP are completely consistent and in this case the matrix A has rank 1 and $\lambda_{max} = n$. In this case, weights can be obtained by normalizing any of the rows or columns of the matrix A . The quality of the output of the AHP is claimed to be strictly related to the consistency of the pairwise comparison judgments. The consistency is normally defined by the relation between the entries of A : $a_{ij} \times a_{jk} = a_{ik}$. The consistency index (CI) is given by Eq. (3) (Ouma and Tateishi, 2014):

$$CI = (\lambda_{max} - n)/(n - 1) \tag{3}$$

Where λ_{max} represents the sum of the products between the sum of each column of the comparison matrix and the relative weights and n represents the size of the matrix.

The final calculation is the consistency ratio (CR) which is the ratio of the CI and random index (RI) as expressed in Eq. (4):

$$CR = CI/RI \tag{4}$$

Where CI represents the consistency index, RI is the random index representing the consistency of a randomly generated pairwise comparison matrix. It is derived as average random consistency index, computed by Saaty (1980). CR represent consistency ratio.

The values of RI are tabulated in Table 2 and RI value for six parameters is 1.24 (Saaty, 1980). The maximum threshold of CI is ≤ 0.1 and $CR \leq 10\%$. The rational value is when the CI and CR have fulfilled the maximum threshold value. The usage of CR lets the user to conclude whether the evaluations are sufficiently consistent Table 3.

The normalized pair-wise comparison matrix is derived by making equal to 1 the sum of the entries on each column. Finally, the objective weight of each factor was built by averaging the entries on each row (Table 4). The basic advantage is that the AHP limits the cognitive demand on the decision maker and provides an approach for checking the consistency of the comparisons. The consistency ratio (CR) is used in order to check inconsistency and limit the possibility of random selection during the construction of the comparison matrix (Bathrellos et al., 2012; Ouma and Tateishi, 2014).

λ_{max} for Flood contributing factors in the watershed = $2.13 \times 0.42 + 5 \times 0.23 + 7.9 \times 0.15 + 12.5 \times 0.1 + 19 \times 0.06 + 28 \times 0.04 = 6.4$

$CR = CI/RI$; $CI = \lambda_{max} - n/n - 1$

$RI =$ Random consistency index and $RI = 1.24$ for six factors (Table 2).

$N =$ Number of criteria = 6

λ_{max} represents the sum of the products between the sum of each column of the comparison matrix and the relative weights. CR for the flood contributing factors in Ambo town’s watershed is 0.06 which is less than the standard 0.1. Hence, the pair-wise matrix ranking is accepted.

To calculate the weight and ranking in each factor, the pair-wise comparison matrix and factor map are employed. The weight value provided the prioritized factor expressed as a percentage value between 0 and 100%. Using a linear weighted combination, the sum of weight was expressed as 100%. A summary of targeted factors, their weights and rankings are listed in Table 5 hereunder. The information provided in the table was applied to generate the flooding hazard map in the study watershed. The ranking of each reclassified factor is based on the literature review, expert interview and local residents’ interview. The range of ranking was 1–5; the highest influence factor was rank 5 and the lowest influence factor was 1. The order of normalized weight was land cover (42%),

Table 2
Random index (RI) used to compute consistency ratios (CR).
Source: (Saaty, 1980).

N	1	2	3	4	5	6	7	8	9	10
Random Index(RI)	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

Table 3

Ranking of flood hazard contributing factors in the watershed.

Source: (Based on Experts' and local residents' interview, 2019).

Flood Hazard Factors	Land Cover (LC)	Slope (S)	Soil Type (ST)	Rainfall (RF)	Drainage Density(DD)	Elevation (E)
Land Cover	1	3	3	5	7	8
Slope	0.33	1	3	3	5	6
Soil Type	0.33	0.33	1	3	3	5
Rainfall	0.2	0.33	0.33	1	3	5
Drainage Density	0.14	0.2	0.33	0.33	1	3
Elevation	0.13	0.16	0.2	0.2	0.33	1
Total	2.13	5.02	7.86	12.53	19.33	28

λ_{\max} represents the sum of the products between the sum of each column of the comparison matrix and the relative weights.

Table 4

Weighted Comparison table.

Source: (Weighted Comparison Based on Experts' and local residents' interview, 2019)

Flood Hazard Factors	Land Cover (LC)	Slope (S)	Soil Type (ST)	Rainfall (RF)	Drainage Density(DD)	Elevation (E)	Priority Vector X	Percent
Land Cover	0.5	0.6	0.38	0.39	0.36	0.29	0.42	42%
Slope	0.1	0.2	0.38	0.24	0.26	0.21	0.23	23%
Soil Type	0.1	0.07	0.13	0.24	0.16	0.18	0.15	15%
Rainfall	0.1	0.07	0.042	0.08	0.16	0.18	0.1	10%
Drainage Density	0.1	0.04	0.042	0.03	0.05	0.11	0.06	6%
Elevation	0.1	0.03	0.03	0.02	0.02	0.04	0.04	4%
Total	1	1	1	1	1	1	1	100 %

The natural values were normalized by adding the column values and dividing the value of each cell by the total of column values.

Table 5

Weighted flooding hazard ranking for the watershed.

Source: (Based on Experts' and local residents' interview, 2019 and literature review, 2019)

Parameters	Relative Weight	Reclassified Parameter	Ranking	Hazard
Slope (Degree)	23%	26.04-32.55	1	Very low
		19.53-26.04	2	Low
		13.02-19.53	3	Moderate
		6.51-13.02	4	High
		0-6.51	5	Very high
Elevation (Meters)	4%	2969-3253	1	Very low
		2685-2969	2	Low
		2402-2685	3	Moderate
		2118-2402	4	High
		1834-2118	5	Very high
Rainfall (mm)	10%	1036-1065	1	Very low
		1065-1094	2	Low
		1094-1123	3	Moderate
		1123-1152	4	High
		1152-1181	5	Very high
Drainage Density (km/Km ²)	6%	11.04-13.8	1	Very low
		8.28-11.04	2	Low
		5.52-8.28	3	Moderate
		2.76-5.52	4	High
		0-2.76	5	Very high
Soil Type	15%	Eutric Cambisols	1	Very low
		Eutric Nitisols	2	Low
		Orthic and Chromic Luvisols	3	Moderate
		Leptosols	4	High
		Pellic and Chromic Vertisols	5	Very High
Land use/Land Cover	42%	Forest	1	Very low
		Grassland	2	Low
		Cultivated land	3	Moderate
		Built-up area	4	High
		Water Body	5	Very high

slope (23%), soil type (15%), rainfall (10%), drainage density (6%), and elevation (4%). Looking at the weight of each factor, one can see that land cover has the highest weight. It implies that land cover has more contribution to flooding than other factors.

Once the weight in each factor was determined, the multi-criteria analysis was performed to produce a flooding hazard map by using the GIS approach. In other words, weighted linear combination (WLC) method is used in the process of criteria map aggregation. The underpinning reason for employing WLC is that low scores in one criterion are compensated by high scores in another one in the process of aggregating the criteria flooding hazard maps. In other words, the weighted linear combination (WLC) method multiplies each fuzzy standardized criteria map with criteria weights, obtaining different variations from the AHP method, and then sums the results (Bathrellos et al., 2012; Gigović et al., 2017). Accordingly, flooding hazard map for the watershed was computed as shown in Eq. (5):

$$\text{Flooding hazard Index} = 0.42 \times \text{landuse/landcover} + 0.23 \times \text{slope} + 0.15 \times \text{soil type} + 0.1 \times \text{rainfall} + 0.06 \times \text{drainage density} + 0.04 \times \text{elevation} \quad (5)$$

The result was the flooding hazard area in the watershed. It was categorized into five hazard classes: very low, low, moderate, high, and very high.

To compute the flooding risk map for the watershed, a weight linear combination was applied as shown in Eq. (6):

$$\text{Flooding risk Index} = 0.3333 \times \text{flooding hazard} + 0.3333 \times \text{population density (person per square kilometers)} + 0.3333 \times \text{land use/land cover} \quad (6)$$

Flood risk analysis and mapping for the watershed was done using the flooding hazard layer and the two elements at risk, namely population and land use/land cover (Wondim, 2016). These three factors were considered to be equally important in the weighted linear combination (WLC) process. A summary of targeted factors, their weights and rankings are listed in Table 6 hereunder. The information provided in the table was applied to generate the flooding risk map in Ambo town's watershed. The result was the flooding risk area in the watershed. It was categorized into five risk classes: very low, low, moderate, high, and very high.

3. Results

3.1. Flood hazard analysis and mapping in Ambo Town's watershed

3.1.1. Contributing factors for flood hazard

Land use and land cover was considered as one of the flood hazard contributing factor in Ambo town's watershed. Forest, grass land, cultivated land, built-up area, and water body were rated as very low, low, moderate, high, and very high flooding hazard land use and land cover respectively. Elevation was considered as one of the flooding hazard contributing factor in Ambo town's watershed. The highest elevation of the watershed is 3253 m while the lowest elevation is 1834 m. The lowest elevation category (1834 m–2118 m) was rated as very high flooding hazard elevation category while the highest elevation category (2969 m–3253 m) was rated as very low flooding hazard elevation category. Slope was considered as one of the flood hazard contributing factor in Ambo town's watershed. The highest slope of the watershed is 32° while the lowest slope is 0°. The lowest slope category (0–6.51 degree) was rated as very high flooding hazard slope category while the highest slope category (26.04–32.55 degree) was rated as very low flooding hazard slope category.

Drainage density was considered as one of the flood hazard contributing factor in Ambo town's watershed. The highest drainage density the watershed is 13.8 km/Km² while the lowest drainage density is 0 km/Km². The lowest drainage density category (0–2.76 km/Km²) was rated as very high flooding hazard drainage density category while the highest drainage density category

Table 6

Weighted flooding risk ranking for the watershed.

Source: Adapted from Wondim, 2016)

Parameters	Relative Weight	Reclassified Parameter	Ranking	Hazard
Flooding hazard Classes	33.33%	Very low	1	Very low
		Low	2	Low
		Moderate	3	Moderate
		High	4	High
		Very high	5	Very high
Population Density(Person/Sq.km)	33.33%	0-58	1	Very low
		58-161	2	Low
		161-209	3	Moderate
		209-1846	4	High
		1846-6596	5	Very high
Land use/Land Cover	33.33%	Forest	1	Very low
		Grassland	2	Low
		Cultivated land	3	Moderate
		Built-up area	4	High
		Water Body	5	Very high

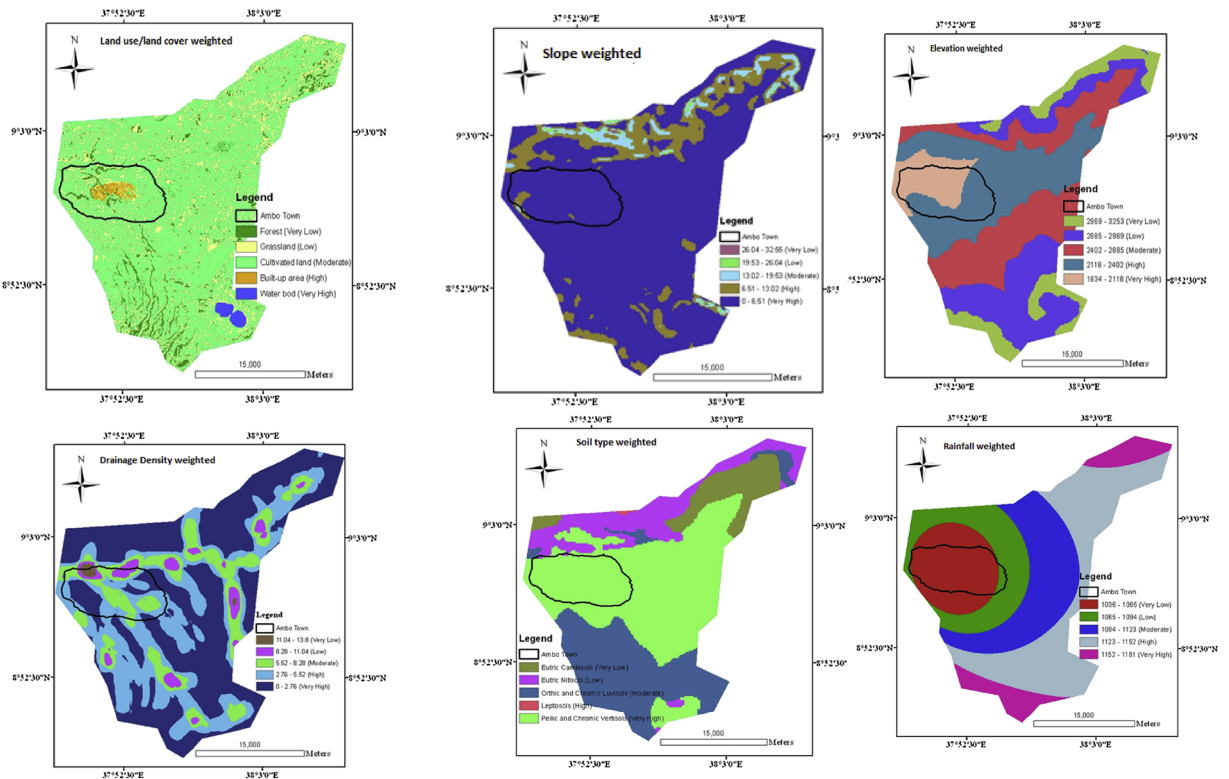


Fig. 3. Land use, slope, elevation, drainage density, soil type, and rainfall as flooding hazard factors.

(11.04–13.8 km²/Km²) was rated as very low flooding hazard category. Soil type was considered as one of the flooding hazard contributing factors in Ambo town's watershed. Eutric Cambisols, Eutric Nitisols, Orthic and Chromic Luvisols, Leptosols, and Pellic and Chromic Vertisols were rated as very low, low, moderate, high, and very high flooding hazard soil type respectively. Rainfall was considered as one of the flood hazard contributing factor in Ambo town's watershed. The highest average annual rainfall of the watershed is 1181 mm while the lowest average rainfall is 1036 mm. The lowest rainfall category (1036 mm–1065 mm) was rated as very low flooding hazard category while the highest rainfall category (1036 mm–1065 mm) was rated as very high flooding hazard rainfall category (Fig. 3).

3.1.2. Flood hazard mapping in the watershed

The result of the flooding hazard in the watershed reveals that 32.24% (260,287,200 m²), 28.34 % (228753900m²), 23.95 % (193336190m²), 11.58 % (93468600m²), and 3.89 % (31430700m²) of the watershed is high, very high, moderate, low, and very low flooding hazard area respectively. This implies that more proportion of the watershed is high and very high flooding hazard area (60.58%). Moreover, 34.59% (29348100m²) and 32.28% (27385200 m²) of Ambo town is high and very high flooding hazard area respectively (Fig. 4). This implies that more proportion of the town is high and very high flooding hazard area (66.87%).

3.2. Flood risk analysis and mapping in Ambo Town's watershed

3.2.1. Contributing factors for flood risk

Human population density was considered as one of the flooding risk contributing factor in Ambo town's watershed. The highest human population density of the watershed is 6596 persons/Km² while the lowest human population density is 0 persons/Km². The lowest human population density category (0–58 persons/Km²) was rated as very low flooding risk human population density category while the highest human population density category (1846–6596 persons /Km²) was rated as very high flooding risk category. Land use and land cover was considered as one of the flooding risk contributing factor in Ambo town's watershed. Forest, grass land, cultivated land, built-up area, and water body were rated as very low, low, moderate, high, and very high flooding risk land use and land cover respectively. Flooding hazard layer was considered as one of the flooding risk contributing factor in Ambo town's watershed. Very low, low, moderate, high, and very high flooding hazard area was rated as very low, low, moderate, high, and very high flooding risk area respectively.

3.2.2. Flood risk mapping in Ambo Town's watershed

The result of the flooding risk in the watershed reveals that 27.87% (224,951,390 m²), 27.64 % (223114500m²), 22.46 %

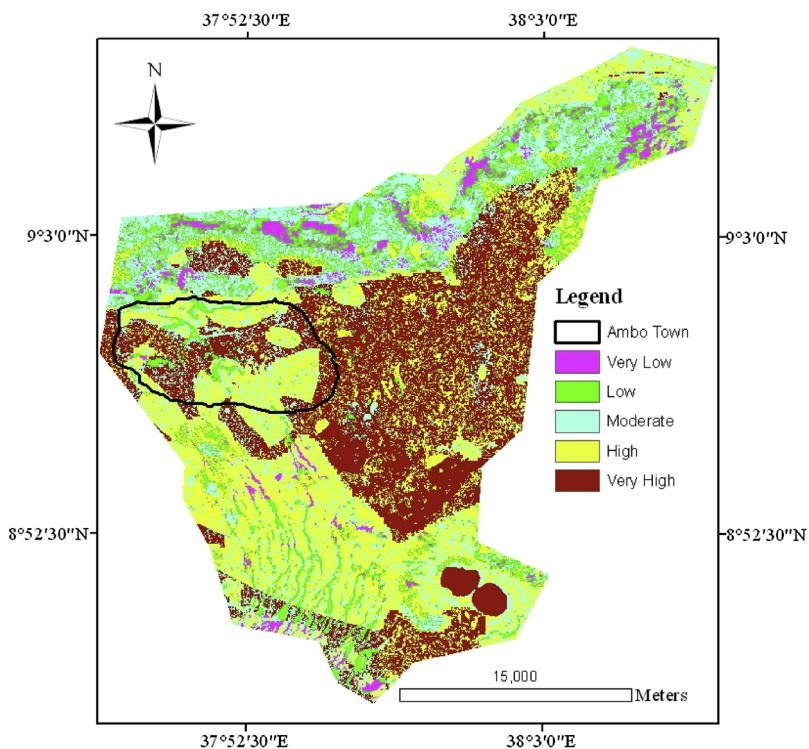


Fig. 4. Flooding hazard Map of the watershed.

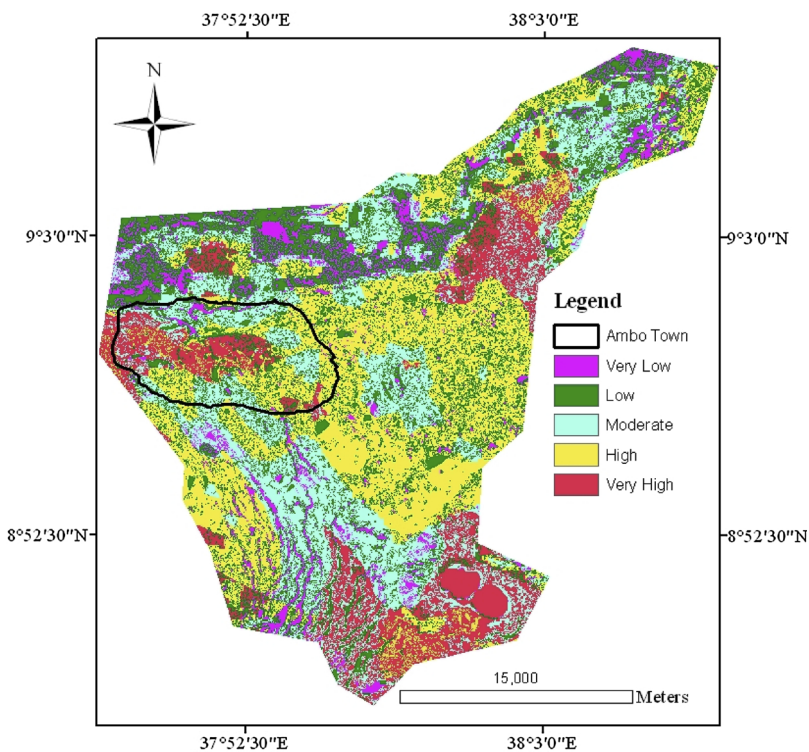


Fig. 5. Flood risk Map for the Watershed.

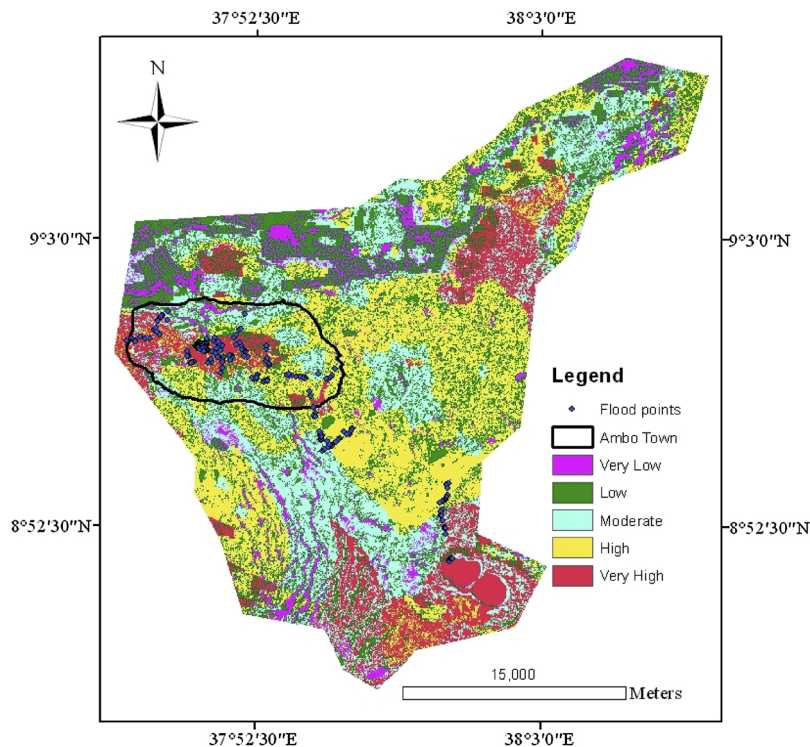


Fig. 6. Distribution of ground truth points of flood risk areas in the watershed.

(181287010m²), 13.79 % (111294900m²), and 8.25 % (66628800m²) of the watershed is high, low, moderate, very high, and very low flooding risk area respectively. This implies that more proportion of the watershed is high and very high flooding risk area (41.76 %). Moreover, 27.70 % (23506200m²) and 22.39 % (18997200m²) of Ambo town is high and very high flooding risk area respectively (Fig. 5). This implies that half of the town is high and very high flooding risk area (50.09 %).

3.3. Verification and observation of flood risk in Ambo Town's watershed

Verification and observation of flood risk was made during 2017 rainy season (June, July, August, and September) in Ambo town's watershed to compare the final flood risk mapping with the current real field condition in the watershed. To this end, 259 GPS reading ground truth data of flood affected areas across different land use and land cover types were registered and converted to shape file. These point shape files were superimposed with the flood risk map and the flood risk map was verified with the actual field situations (Figs. 6 and 7)

4. Discussion

Flood disasters are among the most frequent and devastating types of disasters over the world. It is necessary to analyze flood risk to ensure healthy and sustainable economic development, and flood risk assessment has become worldwide one of the hot issues in the field of natural science and technology (Yahaya et al., 2010; Zou et al., 2013). Scholars of sustainable urban flooding risk management assert that comprehensive flood risk assessment is a synthetic evaluation and consists of many factors, including the hazard of disaster-inducing factors and disaster-breeding environment, as well as the vulnerability of hazards-bearing bodies (Zerger and Smith, 2003; Sayers et al., 2013; Zou et al., 2013; Guo et al., 2014). For instance, assessing areas vulnerable to flooding disasters is one of the parameters in creating a flood-risk map for disaster mitigation and urban planning (Dang et al., 2011; Wang et al., 2011; Ouma and Tateishi, 2014; Islam et al., 2016; Gigović et al., 2017; Rimba et al., 2017).

This study considered land use/land cover, elevation, slope, drainage density, soil, and rainfall as important flooding hazard factors in Ambo town's watershed. Many scholars in the field of sustainable flooding hazard and risk management attest that land use/land cover change is one of the major contributor of flooding hazard as urban expansion increases, impervious cover increases and forest cover decreases in urban areas contributing to increase in run-off (Tucci, 2007; Jha et al., 2012; Mngutyo and Ogwuche, 2013; Migosi, 2014). For scholars like Gigović et al. (2017) elevation has a key role in controlling the movement of the overflow

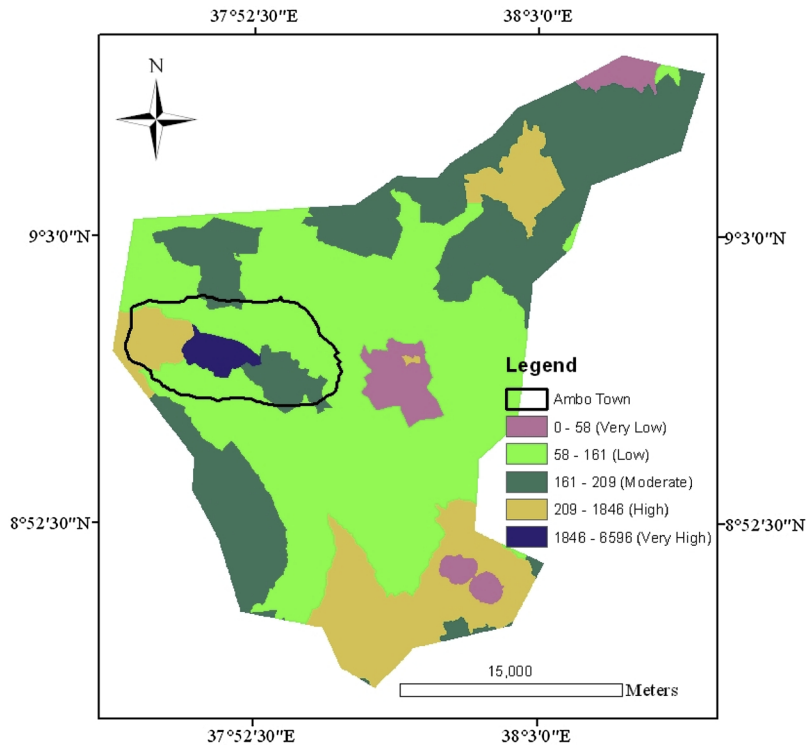


Fig. 7. Human Population Density of Ambo Town's Watershed.

direction and in the depth of the water level. Slope is a major factor in determining the rate and duration of water flow as flatter surface areas are riskier with respect to the occurrence of floods in relation to the steeper surfaces (Gigović et al., 2017; Rimba et al., 2017).

Drainage density is one of the important flooding hazard factors and it is an inverse function of infiltration (Chibssa, 2007; Ouma and Tateishi, 2014; Wondim, 2016). Soil characteristics in a watershed such as soil layer thickness, permeability, infiltration rate and the degree of moisture in the soil before the rain event have a direct effect on the rainfall-runoff process (Zhiyu et al., 2013; Ouma and Tateishi, 2014; Rimba et al., 2017). Observed and projected patterns of climate change can have an amplifying effect on existing flood risk. For example, changing local rainfall patterns may lead to more frequent and higher level of floods from rivers and more intense flash flooding (Andjelkovic, 2001; Few et al., 2004; Jha et al., 2012; Berggren et al., 2013; Hall et al., 2014).

This study considered flooding hazard layer, population density, and land use/land cover type as the three important factors for flooding risk mapping and these three factors were considered to be equally important in the weighted overlay process (Chibssa, 2007; Wondim, 2016). Scholars of sustainable urban flooding risk management contend that flooding risk is contributed to by two components, flood hazard and flood vulnerability. The flood hazard component represents physical processes, whereas flood vulnerability represents susceptibility to damage or loss, the risk of human lives, property or human activities (Dang et al., 2011). The flood risk maps thus developed are useful to policy-makers and responsible authorities, as well as to local residents in finding suitable measures for reducing flood risk in the study area (Dang et al., 2011). Without flood risk maps it is not easy to identify the areas at risk, and without a systematic way of making development decisions there will be no consistency in deciding how and where to reduce urban encroachment into at-risk areas. The availability of the land use plan gives readily available guidance to developers, planners and others on which areas may be developed for which uses, and allows the incorporation of flood risk information into their decisions and judgements (Zerger and Smith, 2003; Sayers et al., 2013).

Urbanization, as the defining feature of the world's demographic growth, is implicated in and compounds flood risk (Few et al., 2004; Jha et al., 2012; Santato et al., 2013). Few et al. (2004) contend that human vulnerability to floods is affected by drivers of change like population growth and settlement pattern. In other words, as cities become larger and larger, and as populations become more and more urbanized, urban environmental effects will increase (Andjelkovic, 2001; Few et al., 2004; Santato et al., 2013).

Population growth is asserted to be one of the contributors for urban flooding risk as human population in cities and towns in developing countries is rapidly growing and there is settlement of watersheds and valley bottoms greatly altering drainage patterns and destabilizing slopes and resulting in increasing the risks of flooding and landslides (Dewan et al., 2007; Diagne, 2007; Jha et al., 2012; Wilby and Keenan, 2012; Santato et al., 2013). Dewan et al. (2007) contend that increasing population pressure may force

many people to enter the vacant land of cities and towns of least developed countries by filling up of natural channels and floodplains which may result in increased flood risk. In other words, when population growth is faster than the rate at which the municipal authorities or the private sector can provide housing and basic infrastructure, risks can build up quickly. Moreover, settlement of watersheds and valley bottoms has greatly altered drainage patterns and destabilized slopes, increasing the risks of flooding and landslides (Diagne, 2007; Dewan et al., 2007; Few et al., 2004; Santato et al., 2013).

According to Jha et al. (2012), the accelerating urbanization and urban development could also increase significantly the risk of flooding independent of climate change. The impact of future urban growth on flood risk is influenced by the policies and choices of urban dwellers as they may or may not occupy areas at risk of flooding, or adopt suitable urban planning and design (Few et al., 2004; Pottier et al., 2005; Tucci, 2007; Jha et al., 2012). In other words, better planned and managed urban development can mitigate the expected growth in future flood risk (Tucci, 2007; Jha et al., 2012; Kobayashi and Porter, 2012; Mngutyo and Ogwuche, 2013).

5. Conclusions and recommendations

The study focused on analyzing flooding hazard and risk from Geographic Information Systems (GIS)-based multicriteria perspective in Ambo town and its watershed and proposed strategic measures for sustainable flooding disaster risk management in urban watershed. The flooding hazard factors were determined by literature review, personal observation, and discussion with experts and local residents. Accordingly, Land use/land cover, elevation, slope, drainage density, soil, and rainfall were considered as important flooding hazard factors in Ambo town's watershed. Analysis of flooding risk was undertaken for Ambo town's watershed using flooding hazard layer and the two elements at risk, namely human population and land use. Weighted linear combination (WLC) method was used in the process of criteria map aggregation for both flooding hazard and flooding risk.

The result of the flooding hazard in the watershed reveals that 32.24 % (260,287,200 m²), 28.34 % (228753900 m²), 23.95% (193336190 m²), 11.58% (93468600 m²), and 3.89% (31430700 m²) of the watershed is high, very high, moderate, low, and very low flooding hazard area respectively. This implies that more proportion of the watershed is high and very high flooding hazard area (60.58%). Moreover, 34.59% (29348100 m²) and 32.28% (27385200 m²) of Ambo town is high and very high flooding hazard area respectively. This implies that more proportion of the town is high and very high flooding hazard area (66.87%). The result of the flooding risk in the watershed reveals that 27.87% (224951390 m²), 27.64% (223114500 m²), 22.46% (181287010 m²), 13.79% (111294900 m²), and 8.25% (66628800 m²) of the watershed is high, low, moderate, very high, and very low flooding risk area respectively. This implies that more proportion of the watershed is high and very high flooding risk area (41.76%). Moreover, 27.70% (23506200 m²) and 22.39 % (18997200 m²) of Ambo town is high and very high flooding risk area respectively. This implies that half of the town is high and very high flooding risk area (50.09%).

As sustainable flooding risk management at urban watershed demand integrated flooding risk management measures (combination of structural and non-structural measures), the following recommendations are forwarded:

- Institutional framework should be strengthened in relation to institutional arrangements, content of urban flood management policies and plans, implementation process, and legislative framework;
- Timely mitigation and preparedness measures should be in place in order to minimize the likely adverse impacts of flooding on lives and livelihoods;
- Participatory planning should be encouraged as it can contribute to public acceptance and support avoiding potential conflicts;
- An integrated basin wide approach to flood management should be practiced as it is essential to address multiple water related issues at watershed level;
- Land use planning and regulation together with building and infrastructure codes and design practices can substantially reduce the vulnerability of the people and other urban activities;
- For sustainable water resources development and integrated flood management the long term and short term planning should be incorporated;
- No matter what approach is employed for effective management it will not work unless the principles of good governance are being practiced;
- Environmental education should be emphasized to build civic responsibility among the citizens;
- Sustainable Drainage Systems (SUDs) should be practiced in urban environment as it helps to minimize the impact of urban development on the flooding and pollution of waterways;
- The watershed management plan comprising afforestation, reforestation, soil and water conservation practices for the upland development should work to regulated discharge of water at downstream.
- Distributed rainwater hydrological circulation repair measures (examples: using water permeable bricks on squares and pavements; constructing concave down greenbelts, infiltration wells, infiltration tubes, infiltration channels and infiltration ponds in front and behind the buildings) should be taken to construct urban rainwater storage and infiltration spaces which are suitable to local circumstance;
- Establishing urban rainwater storage-infiltration system is helpful to reduce flood hazard;
- Constructing reservoirs to cut down the flood into downstream reach and to reduce the intensity of flooding disaster risk;
- Establishing flood-diversion area and flood storage area to change the spatial distribution of floods and consequently to reduce the flood threats on high population and assets density area;
- Constructing two-floor or higher buildings or flat-roof buildings with water-proof materials to facilitate in situ flood escape;
- Constructing flood escape transfer channel and temporary refuge facilities;

- Developing reliable communication and data acquisition network;
- Building flood alarm and emergency response plan;
- It is necessary to pay attention to the coordination between urban development and flood hazard through appropriate spatial planning and land use management; and
- Compiling flood hazard and risk maps and making region divisions on forbidden zone, restricted zone and area for development is necessary for sustainable flood risk management.

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Authors' contributions

Gemechu Shale Ogato actively participated in the project proposal development, data collection, and data analysis under close supervision of Amare Bantider, Davide Geneletti, and Ketema Abebe. Writing had been also substantially contributed by Gemechu Shale Ogato. Amare Bantider, Davide Geneletti, and Ketema Abebe had been involved in critically advising, revising the manuscript and made possible suggestions. All authors read and approved the final manuscript.

Declaration of Competing of Interest

The authors fully declare that they have no any competing interests in publishing the manuscript

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Annexes

Annex 1: Flooding hazard area in Ambo town's watershed

Flooding hazard value	Area (m ²)	Percent
Very Low	31430700	3.89
Low	93468600	11.58
Moderate	193336190	23.95
High	260287200	32.24
Very High	228753900	28.34
Total	807276590	100

Annex 2: Flooding hazard Area in Ambo town

Flooding hazard value	Area (m ²)	Percent
Very Low	185400	0.22
Low	5502600	6.49
Moderate	22425300	26.43
High	29348100	34.59
Very High	27385200	32.28
Total	84846600	100

Annex 3: Flooding Risk Area in the watershed

Flooding Risk Value	Area (M ²)	Percent
Very Low	66628800	8.25
Low	223114500	27.64
Moderate	181287010	22.46
High	224951390	27.87
Very High	111294900	13.79
Total	807276600	100

Annex 4: Flooding Risk Area in Ambo town

Flooding Risk Value	Area (M ²)	Percent
Very Low	2703600	3.19
Low	20907900	24.64
Moderate	18731700	22.08
High	23506200	27.70
Very High	18997200	22.39
Total	84846600	100

Appendix B. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:<https://doi.org/10.1016/j.ejrh.2019.100659>.

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RESEARCH

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Dynamics of land use and land cover changes in Huluka watershed of Oromia Regional State, Ethiopia

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Abstract

Background: Land use and land cover changes in urbanized watersheds of developing countries like Ethiopia are underpinned by the complex interaction of different actors, driving forces, and the land itself. Land conversion due to residential development, economic growth, and transportation is identified as the most serious environmental pressure on urbanized landscapes of the world. It results in the degradation of natural vegetation and significant increases in impervious surfaces. The purpose of the study was to analyze spatio-temporal changes in land use and land cover in the Huluka watershed with implications to sustainable development in the watershed.

Results: Forest land, cultivated land, urban built-up, bush/shrub land, bare land, grassland, and water body were identified as the seven types of land use and land cover in the Huluka watershed. Forest land decreased by 59.3% at an average rate of 164.52 ha/year between 1979 and 2017. Bush/shrub land decreased by 68.2% at an average rate of 318.71 ha/year between 1979 and 2017. Grassland decreased by 32.7% at an average rate of 228.65 ha/year between 1979 and 2017. Water body decreased by 5.1% at an average rate of 1.06 ha/year between 1979 and 2017. Urban built-up area increased by 351% at an average rate of 16.20 ha/year between 1979 and 2017. Cultivated land increased by 105.3% at an average rate of 692.76 ha/year between 1979 and 2017. Bare land increased by 41.9% at an average rate of 4.00 ha/year between 1979 and 2017. Infrastructural and agricultural expansion, increased demand for wood, local environmental and biophysical drivers, rapid human population growth, economic drivers, technological drivers, policy and institutional drivers, and local socio-cultural drivers were perceived by residents as drivers of land use and land cover changes. Increased flooding risk, increased soil erosion, increased sedimentation into water resources like lakes and rivers, decrease in soil fertility, loss of biodiversity, loss of springs, decrease in annual rainfall, and increase in heat during the dry season were perceived by residents as negative local effects of land use and land cover changes.

Conclusions: Changes in land use and land cover in the study watershed imply the need for integrating sustainable watershed planning and management into natural resources management strategies. In other words, practices of appropriate land use planning and management, family planning, participatory planning and management, appropriate environmental impact assessment (EIA), and proper planning and management of development projects and programmes are of paramount importance to promote sustainable development in the Huluka watershed and beyond.

Keywords: Drivers, Effect, Family planning, Land use and land cover, Management

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Background

Land use and land cover changes in urbanized watersheds of developing countries like Ethiopia are underpinned by the complex interaction of different actors,

driving forces, and the land itself (Zeleeke 2000; Bewket 2003; Li et al. 2009; Claes et al. 2012; Fura 2013; Hall et al. 2014). In other words, it is mostly seen as the result of the complex interaction between changes in social and economic opportunities linked with the biophysical environment (Tucci 2007; Jha et al. 2012; Berggren et al. 2013; Dodman et al. 2013; Mngutyo & Ogwuche 2013).

Land conversion due to residential development, economic growth, and transportation is identified as the most serious environmental pressure on urbanized landscapes of the world (Nuissl et al. 2009; Wheeler and Evans 2009; Adebayo et al. 2010; Santato et al. 2013; Zewdie et al. 2017). Individual ecosystem services that are affected by land-use transition include the production of food, regulation of energy and matter flows, water supply, the supply of recreational space, biodiversity or natural aesthetic values (Nuissl et al. 2009; Birkinshaw et al. 2010; Berggren et al. 2013; Santato et al. 2013). Development policies, strategies, and planning instruments are encouraged to address the problem of land-use transition as an ongoing process to get possible feedback dynamics which underpins their success (Ebi and Semenza 2008; Nuissl et al. 2009; Adebayo et al. 2010; Alfasi et al. 2012; Mngutyo and Ogwuche 2013).

Land use and land cover changes are affirmed to represent the most widely increasing and significant sources of contemporary changes in the earth's land surface (Balaban 2012; Claes et al. 2012; Mngutyo and Ogwuche 2013). They underpin the degradation of natural vegetation and significant increases in impervious surfaces (Parkinson 2003; Few et al. 2004; Birkinshaw et al. 2010; Berggren et al. 2013; Hao et al. 2015). High population growth rate and negative local impacts of climate change are confirmed to exacerbate the changes leading to modification or complete replacement of the land surface in rapidly urbanizing Ethiopian cities and towns with different environmental implications (Cordaid and IIRR 2011; Berggren et al. 2013; Fura 2013; Mngutyo and Ogwuche 2013; Ogato 2013; Hao et al. 2015; Ogato et al. 2017; Ogato et al. 2020).

Understanding the dynamics of land use and land cover changes in rapidly urbanizing local watersheds contributes immensely to promoting sustainable urban and rural local development in a watershed. Even though there were different studies on the dynamics of land use and land cover changes in the Northern part of Ethiopia, such studies are scant in Oromia Regional State and the study area (Huluka watershed). Hence, this study analyzed changes in land use and land cover, examined their drivers, and investigated their local effects in the Huluka watershed with environmental implications for sustainable watershed planning and management.

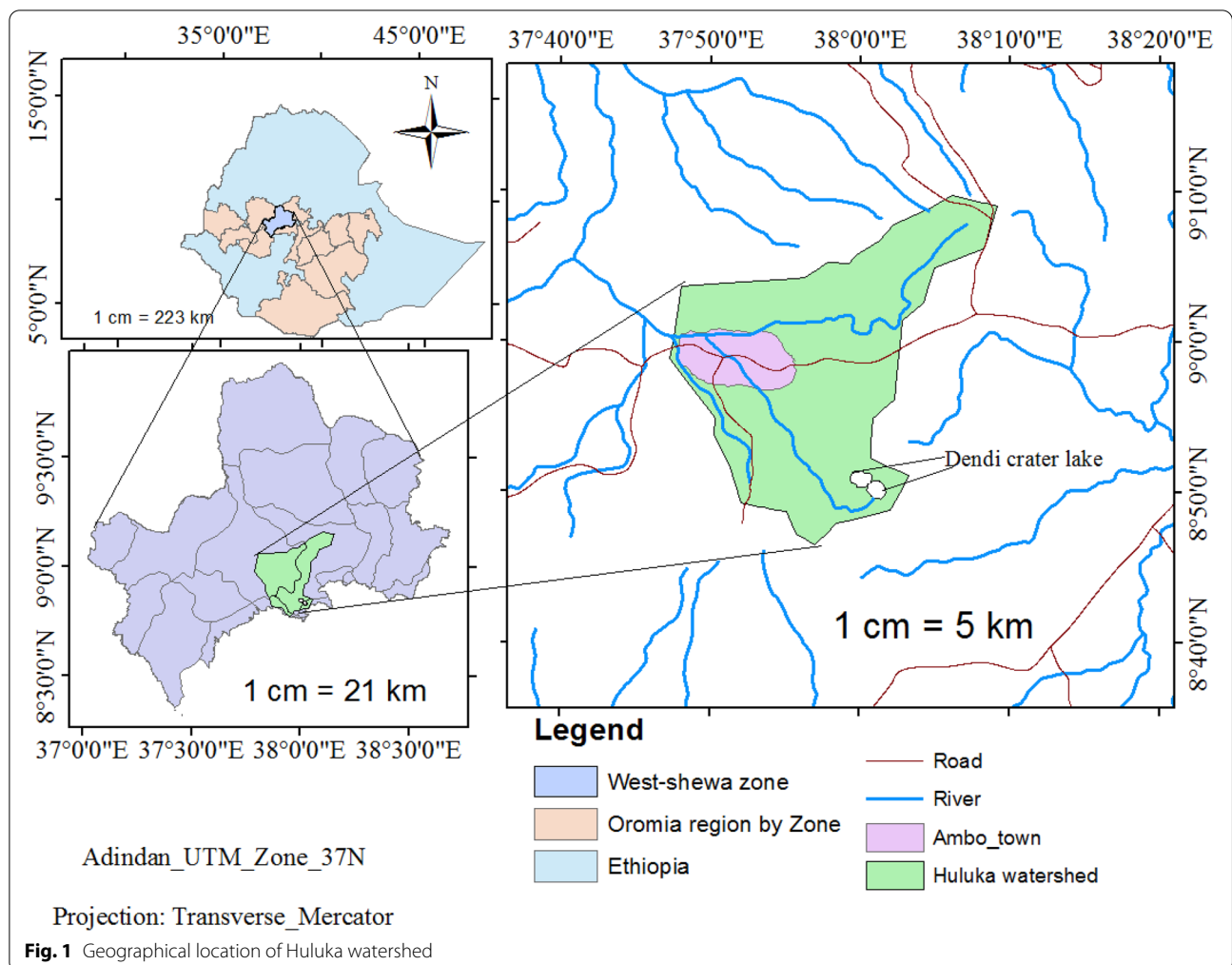
Methods

Description/Features of the Study Area

Huluka watershed is located in West Shoa Zone, Oromia Regional State, Ethiopia. The watershed is located between 8° 49' 26" to 8° 55' 22" N lat. and 37° 49' 50" to 38° 8' 08" E long (Fig. 1). The total land area of the Huluka watershed is 81237 ha and composed of villages mainly from Ambo, Dawo, Dendi, Elfeta, Jeldu, TokeKutaye, and Wonchi districts and Ambo town. The total human population of the watershed was reported to be about 303,416 in the year 2017 (CSA 2017). Forest, cultivated land, urban built-up, bush/shrub land, bare land, grassland, and water body were identified as the seven land use and land cover types in the watershed (Fig. 2). Forest land use and land cover in the watershed is characterized by areas covered with dense trees including Eucalyptus and Coniferous trees, and riverine trees. Bush/shrub land use and land cover is characterized by land with shrubs and bushes and scattered small trees mixed with grasses. Grassland land use and land cover is characterized by land predominately covered with grasses, forbs, and grassy areas used for communal grazing. Cultivated land use and land cover is characterized by areas used for rain-fed crop production and scattered rural settlements. Areas occupied by urban residential houses, buildings, and industrial uses. Urban Built-up land use and land cover is characterized by areas occupied by urban residential houses, buildings, and industrial uses. Water land use and land cover is characterized by areas covered by lake water in the watershed permanently. Bare land is characterized by areas with no or very little vegetation cover and characterized by shallow and rocky surface along the flooding area of the local stream valleys, over gentle and steep mountain slopes.

As the percentage change of transformation of urban built-up, and cultivated land use and land cover types in the watershed are high currently, environmental problems like flooding, soil erosion, biodiversity loss, climate change, decrease in soil fertility and agricultural production are typical features of Huluka watershed. Rapid human population growth in the watershed and lack of sustainable watershed management strategies has exacerbated the environmental problems in the watershed and beyond (Ogato et al. 2017, 2020).

The highest elevation in the watershed is 3253 m above sea level while the lowest elevation of the watershed is 1834 m above sea level. The highest slope in the watershed is 32.5% while the lowest slope is 0%. Chromic Luvisols, Chromic Vertisols, Eutric Cambisols, Eutric Nitisols, Leptosols, Orthic Luvisols, and Pellic Vertisols are identified as the types of soils in the watershed. The highest mean total annual rainfall of the watershed over 32 years (1984–2015) is 1181 mm while the lowest is



1036 mm (Fig. 3). The rainfall of the area was identified to be bimodal, with unpredictable short rains from March to April and, the main season ranging from June to September (Ogato et al. 2017).

Data types and sources of data

Satellite images were used as the data for the analysis of land use and land cover changes of the study periods. To this end, Landsat TM and ETM⁺ imagery for the periods 1979, 1984, 2009, and 2017 were used. These years were chosen to understand the changes in land use and land cover with their drivers and local effects in the watershed. Accordingly, 1979, 1984, and 2009 were chosen to understand the dynamics of land use and land cover changes over four decades. To this end, the year 1979 was chosen as a reference year representing the 1970s due to the availability of good quality Landsat image for the decade for the Huluka watershed. The year 1984 was considered as it was the census year in Ethiopia. 2009 was considered also as the year close to

the census year in Ethiopia (2007) with good quality land sat image for the study watershed. The year 2017 was chosen to represent the current year.

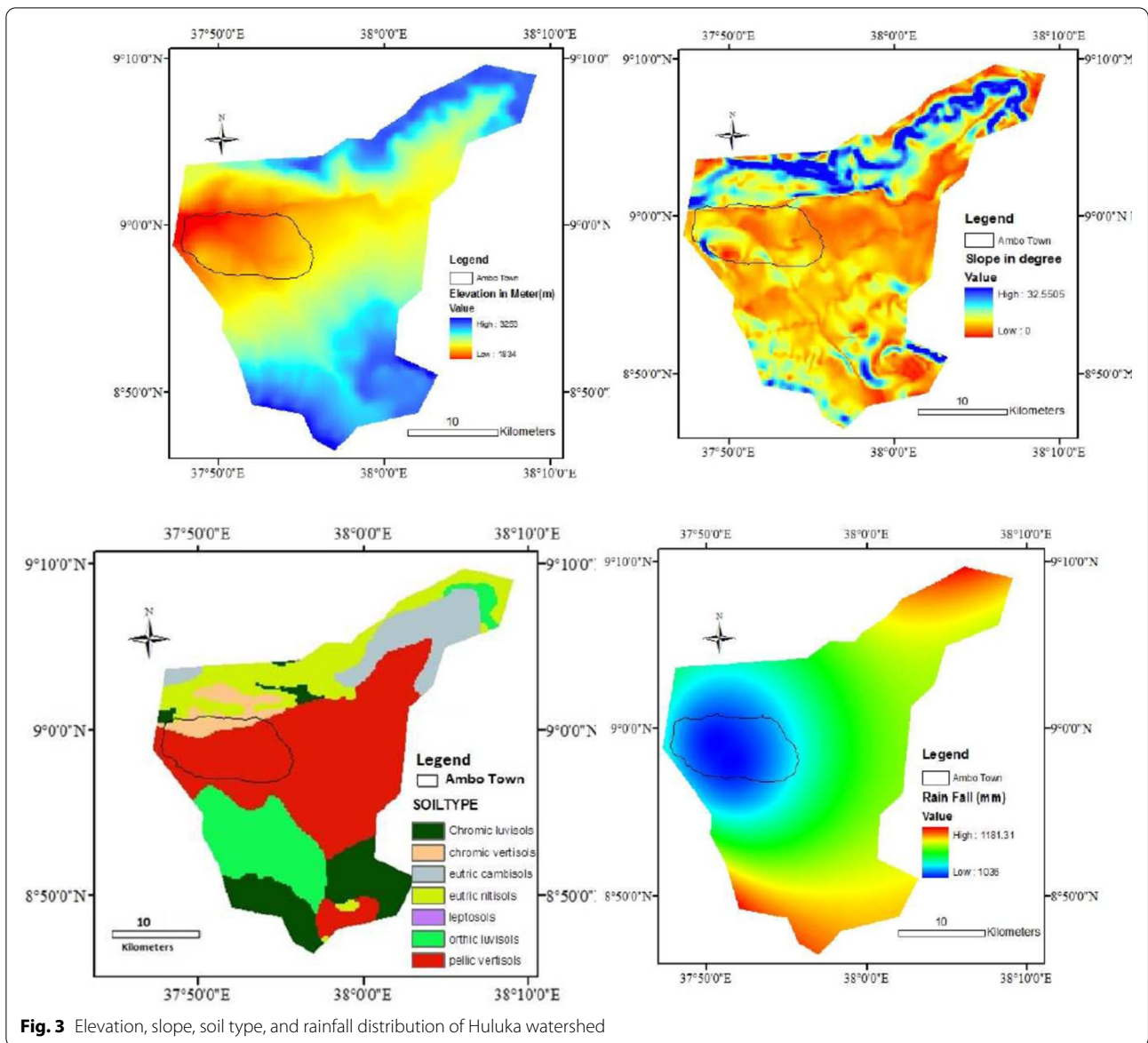
A Digital map on a shapefile with a scale of 1:50,000 from the Ethiopian Mapping Authority was used as supporting spatial data for delineating the boundary of the study watershed. Global positioning system (GPS) points collected during field observation were used to collect GCP (ground control point) to successfully undertake the image classification. To this end, 300 sample-training sites were used in each year from ancillary data like high-resolution Google Imagery while 300 sample training sites were used from field observation for the year 2017. Other sources of data included: Central Statistical Authority (CSA), Ethiopian Mapping Agency (EMA), Landsat website of www.glovis.USGS.gov, urban and rural communities in Huluka watershed, urban planners of Ambo town, and land use planners in Huluka watershed.



Methods of data collection

To collect relevant data to analyze the dynamics of land use/land cover change in the watershed for the periods considered, online Satellite Imagery (Monkkonen 2008; Gondo and Zibabgwe 2010) was employed. Besides, participant observation (Kawulich, 2005) focus group discussion (Onwuegbuzie et al. 2009; Kassie 2017; Nyumba et al. 2018), and key informant interview (Strauss 1987; Burnard 1991; Kun et al. 2013; Gardner et al. 2019) were employed to collect qualitative data relevant for the study. Accordingly, six focus group discussions (three

men focus group discussions and three women focus group discussions), and fifteen key informant interviews (local men and women key informant interviews) were undertaken to collect qualitative data. The number of focus group discussions and key informant interviews was determined based on the saturation level of the information generated. Participants of focus group discussions and key informant interviews were selected purposively as they were expected to be experienced and knowledgeable about the issues under investigation. Accordingly, local men and women residents who have



been living in the watershed for more than 50 years were included in the focus group discussions and key informant interviews.

Methods of data analysis

Geographic information system (GIS) and remote sensing technology-based analysis of land use and land cover changes

Based on prior knowledge of the study area, data collected from the local communities in the watershed, characteristics of Landsat images, ancillary data like Google Earth and field observation, seven land use and land cover classes (Table 1) were used for image classification and land use and land cover change analysis.

Arc GIS 10.1 software and ERDAS IMAGINE 9.1 software (Huang et al. 2007; Monkkonen 2008; Gondo and Zibabgwe 2010) were employed for the intended image classification, land use and land cover change detection and mapping. While ERDAS IMAGINE 9.1 software was employed to classify images and detect change over time, ArcGIS10.1 software was employed for geospatial analysis of the classified images and developing maps of land use and land cover change.

The analysis of images involved the key steps of pre-processing; post-processing, overlaying and change detection, and creation of maps of land use/land cover change from Landsat TM imagery for the period, 1979–2017. The Pre-processing step involved geo-referencing

Table 1 Description of land use and land cover categories considered in image classification

LULC	Description
Forest	Areas covered with dense trees including Eucalyptus and coniferous trees, and riverine trees
Cultivated land	Areas used for rain-fed crop production and scattered rural settlements
urban Built-up area	Areas occupied by urban residential houses, buildings, and industrial uses
Bush/shrub land	Land with shrubs and bushes, scattered small trees mixed with grasses
Bare land	Areas with no or very little vegetation cover and are characterized with the shallow and rocky surface along the flooding area of the local stream valleys, over gentle and steep mountain slopes
Grassland	Land predominately covered with grasses, forbs, grassy areas used for communal grazing
Water	Areas covered by Lake in the catchment permanently

the Landsat images, radiometric correction, layer stacking, resolution merge, image enhancement, and adding vector information from the administrative boundary of the study area.

The post-processing step involved image classification which was undertaken using hybrid classification methods involving both unsupervised and supervised techniques among different classification algorithms. To this end, the maximum likelihood was used for supervised classification by taking ground control points for the seven major land use and land cover classes. These land use and land cover (LULC) types were identified with the help of visual interpretation elements and the different reflection characteristics of the feature in the satellite images of 1979, 1984, 2009, and 2017. In other words, the supervised classification involved selecting pixels that represent land cover classes that were recognized by the researcher. Accuracy assessment was also undertaken in the post-processing step. Accordingly, an accuracy assessment was carried out to verify to what extent the produced classification is compatible with what exists on the ground (Anderson et al. 1976; Congalton 1991). All the output maps for the study period (1979, 1984, 2009, and 2017) fulfilled the required standard (which is a minimum of 85% accuracy).

The overlaying and change detection step involved: interpretation of changes in land use and land cover in various years and analysis of their environmental implications in the watershed. In other words, the post-classification method was employed for change detection. This technique helps to generate a change matrix where different transfers from one land use and land cover type to another can be visually observed. Accordingly, change metrics for detecting land use and land cover change were constructed between 1979 and 2017 through pixel-to-pixel comparisons. The classified data were then taken into the ArcGIS 9.1 environment to calculate the area for each land use and land cover type and produce the land use and land cover

maps of the area. These land cover maps were compared pixel by pixel with the final results showing both change-no-change information as well as 'from to' land cover change information. The land use and land cover change detection (percentage change) was made using the following formula (Fura 2013; Gashaw et al. 2017a, b; Miheretu and Yimer 2017):

$$\text{PercentofChange} = \frac{(A2 - A1)}{A1} \times 100 \quad (1)$$

where, A1 = amount of land use and land cover type in year 1, A2 = amount of land use and land cover type in year 2.

The rate of change in land use and land cover (hectares/year) between two study periods was determined using the following formula (Gashaw et al. 2017a, b; Miheretu and Yimer 2017):

$$\text{RateofChange} = \frac{(A2 - A1)}{Z} \quad (2)$$

where, A1 = amount of land use and land cover type in year 1, A2 = amount of land use and land cover type in year 2, Z is the time interval between A1 and A2 in years.

The final step was the creation of maps of land use and land cover change. Accordingly, the analysis of images ended with the creation of maps of land-use and land cover change from Landsat TM imagery for the period, 1979–2017.

Qualitative analysis of socio-economic data

The qualitative data collected through focus group discussions, key informant interviews, and participant observation were analyzed by employing the thematic content analysis technique (Strauss 1987; Burnard 1991; Onwuegbuzie et al. 2009; Kassie 2017; Gardner et al. 2019). The responses from the focus group discussions and the key informant interviews were recorded by hand on the notebook as the participants preferred not to be recorded by any audiovisual tools. However, relevant

environmental events were recorded through audiovisual tools and hand during participant observation and transect walk sessions. As the number of focus group discussions (six) and key informant interviews (15) were manually manageable and the researcher is familiar with the data, no software was employed to analyze the qualitative data.

The major criteria underpinning the application of thematic content analysis were: transparency, maximizing validity, maximizing reliability, comparative analysis, and reflexive approach in the process of analysis (Kassie 2017; Asnake et al. 2019; Gardner et al. 2019). The application of thematic content analysis technique in this study to analyze the qualitative data involved the following steps:

Step one: Reading and Re-reading the recorded qualitative data to be familiar with the content;

Step two: Organizing the qualitative data by questions;

Step three: Coding the data into exhaustive, mutually exclusive, and specified categories or themes;

Step four: Reviewing and revising the coding system;

Step five: Looking for patterns across categories or themes; and.

Step six: Summarizing findings, and recognizing limitations of the data.

Results

This section presents results on the composition of land use and land cover in Huluka Watershed, analysis of land use and land cover change dynamics, and perceived drivers and local effects of land use and land cover changes.

Composition of land use and land cover in huluka watershed

Forest, cultivated land, urban built-up, bush/shrub land, bare land, grassland, and water body were identified as the seven types of land use and land cover in the watershed. Forest land use and land cover in the watershed is characterized by areas covered with dense trees including Eucalyptus and Coniferous trees, and riverine trees. Bush/shrub land use and land cover is characterized by land with shrubs and bushes, and scattered small trees mixed with grasses. Grassland land use and land cover is characterized by land predominately covered with grasses, forbs, and grassy areas used for communal grazing. Cultivated land use and land cover is characterized by areas used for rain-fed crop production and scattered rural settlements. Areas occupied by urban residential houses, buildings, and industrial uses. Urban Built-up land use and land cover is characterized by areas occupied by urban residential houses, buildings, and industrial uses. Water land use and land cover is characterized by areas covered by lake water in the watershed permanently. Bare land is characterized by areas with no or very

little vegetation cover and characterized by shallow and rocky surface along the flooding area of the local stream valleys, over gentle and steep mountain slopes.

Dynamics of land use and land cover changes in huluka watershed

The overall classification accuracy for the output maps was 92.28%, 92.67%, 93.27%, and 90.19% for the years 1979, 1984, 2009, and 2017 respectively. The overall kappa coefficient for the study period was 0.89, 0.90, 0.91, and 0.80 for the years 1979, 1984, 2009, and 2017 respectively (Table 2).

The spatio-temporal dynamics of land use and land cover changes in the watershed for forest land, cultivated land, urban built-up area, bush/shrub land, bare land, grassland, and waterbody between 1979 and 2017 are presented hereunder.

Forest land

Forest land was represented by areas covered with dense trees, which include both Eucalyptus and coniferous trees, and riverine trees. Forest land covered 10,550.52 ha (13%) in 1979, 8925.75 ha (10.9%) in 1984, 4232.253 ha (5.2%) in 2009 and 4298.85 ha (5.3%) in 2017. It decreased by 15.4% (324.95 ha/year) between 1979 and 1984 and 52.6% (187.74 ha/year) between 1984 and 2009. However, it increased by 1.6% (8.33 ha/year) between 2009 and 2017. It decreased by 59.3% (164.52 ha/year) between 1979 and 2017. The decrease of forest land in the watershed was attributable to its transformation to other land use and land cover types. It was largely transformed to cultivated land (4641.69 ha) and grassland (2221.13 ha) between 1979 and 2017 (Tables 3, 4, 5, and 6; Figs. 4 and 5).

Cultivated land

Cultivated land was represented by areas used for rain-fed crop production and scattered rural settlements usually associated with cultivated lands. Cultivated land covered 25,005.24 ha (30.8%) in 1979, 28,639.27 ha (35.3%) in 1984, 43,833.98 ha (54%) in 2009 and 51,329.96 ha (63.2%) in 2017. It increased by 14.5% (726.81 ha/year) between 1979 and 1984, 53.1% (607.79 ha/year) between 1984 and 2009, 17.1% (937.00 ha/year) between 2009 and 2017, and 105.3%

Table 2 Accuracy assessment of the land use/land cover classification for the study period

Accuracy	1979	1984	2009	2017
Overall classification accuracy (%)	92.28	92.67	93.27	90.19
Overall Kappa coefficient	0.89	0.90	0.91	0.80

Table 3 Proportion of land use/land cover change in Huluka/Ambo Town's Watershed (1979–2017)

No.	Land use/cover	Area of land use/cover class							
		1979		1984		2009		2017	
		Ha	%	Ha	%	Ha	%	Ha	%
1	Forest	10,550.52	13	8925.75	10.9	4232.253	5.2	4298.85	5.3
2	cultivated land	25,005.24	30.8	28,639.27	35.3	43,833.98	54	51,329.96	63.2
3	Urban built-up area	175.32	0.2	349.74	0.4	425.79	0.5	790.74	1
4	Bush and shrub land	17,746.11	21.8	12,767.1	15.7	7907.733	9.7	5635.09	6.9
5	Bare land	362.16	0.4	368.2	0.5	431.46	0.5	513.97	0.6
6	Water	789.48	1	811.98	1	748.44	0.9	749.07	0.9
7	Grassland	26,607.96	32.8	29,374.75	36.2	23,657.14	29.1	17,919.11	22
8	Total	81,236.79	100	81,236.79	100	81,236.79	100	81,236.79	100

Table 4 Changes of land use and land cover in Huluka Watershed (Percentage)

No.	Land use/cover class	Change of land use and land cover (%)			
		1979–1984	1984–2009	2009–2017	1979–2017
1	Forest	– 15.4	– 52.6	1.6	– 59.3
2	cultivated land	14.5	53.1	17.1	105.3
3	Urban built-up area	99.5	21.7	85.7	351
4	Bush and shrub land	– 28.1	– 38.1	– 28.7	– 68.2
5	Bare land	1.7	17.2	19.1	41.9
6	Water	2.9	– 7.8	0.1	– 5.1
7	Grassland	10.4	– 19.5	– 24.3	– 32.7

Table 5 Rate of changes of land use and land cover in Huluka Watershed (ha/year)

No.	Land use/cover class	Rate of change of land use and land cover (hectares/year)			
		1979–1984	1984–2009	2009–20,017	1979–2017
1	Forest	– 324.95	– 187.74	8.33	– 164.52
2	cultivated land	726.81	607.79	937.00	692.76
3	Urban built-up area	34.88	3.04	45.62	16.20
4	Bush and shrub land	– 995.80	– 194.38	– 284.08	– 318.71
5	Bare land	1.21	2.53	10.31	4.00
6	Water	4.5	– 2.54	0.08	– 1.06
7	Grassland	553.36	– 228.70	– 717.25	– 228.65

(692.76 ha/year) between 1979 and 2017. The increase of cultivated land in the watershed was attributable to the transformation of other land use and land cover types into cultivated land. A large proportion of grassland (17,552.41 ha), shrub/bush land (11,085.04 ha), and forest land (4641.69 ha) was transformed into cultivated land between 1979 and 2017 (Tables 3, 4, 5, and 6; Figs. 4, 5).

Urban built-up area

Urban built-up area was represented by areas occupied by urban residential houses, buildings, and industrial uses. Urban built-up area covered 175.32 ha (0.2%) in 1979, 349.74 ha (0.4%) in 1984, 425.79 ha (0.5%) in 2009 and 790.74 ha (1%) in 2017. It increased by 99.5% (34.88 ha/year) between 1979 and 1984, 21.7% (3.04 ha/year) between 1984 and 2009, 85.7% (45.62 ha/year)

Table 6 Matrix for land use and land cover changes for 1979 to 2017 in Hectares (ha)

		To 2017							
		Forest	Cultivated	Built-up	Bush/shrub	Bare	Water	Gras,	Total
From 1979	Forest	2355.048	4641.698	91.98	1207.098	30.6	2.97	2221.126	10,550.52
	Cultivated	389.592	17,788.73	177.57	1245.042	246.69	4.14	5153.472	25,005.24
	Built-up	20.52	0	127.89	4.86	0.45	0	21.6	175.32
	Bushishrab	782.388	11,085.04	118.53	1377.676	111.15	2.43	4268.898	17,746.11
	Bare land	2.43	257.58	0	17.37	9.88	0	74.9	362.16
	water	0	4.5	0	0.36	0	736.02	48.6	789.48
	Grass	748.872	17,552.41	274.77	1782.684	115.2	3.51	6130.51:	26,607.96
	Total	4298.85	51,329.96	790.74	5635.09	513.97	749.07	17,919.11	81,236.79

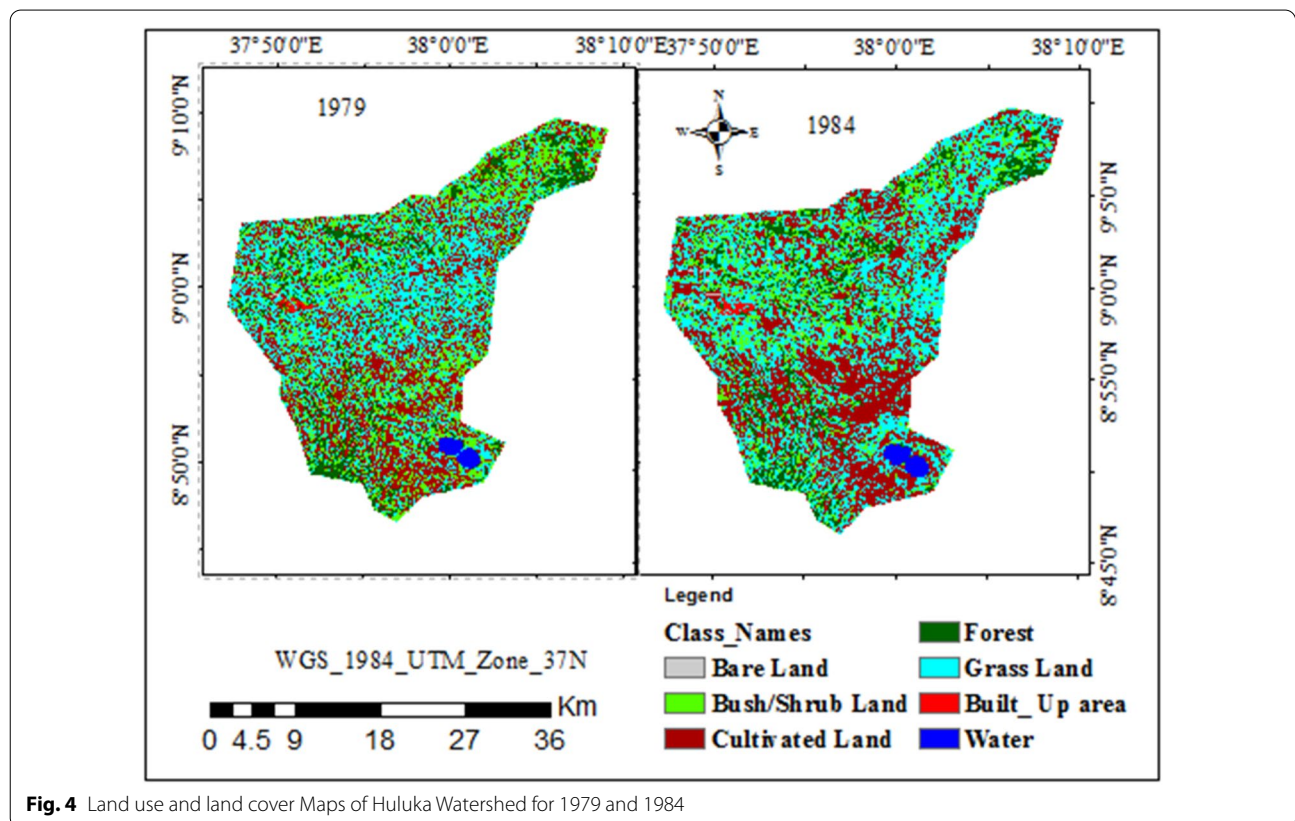
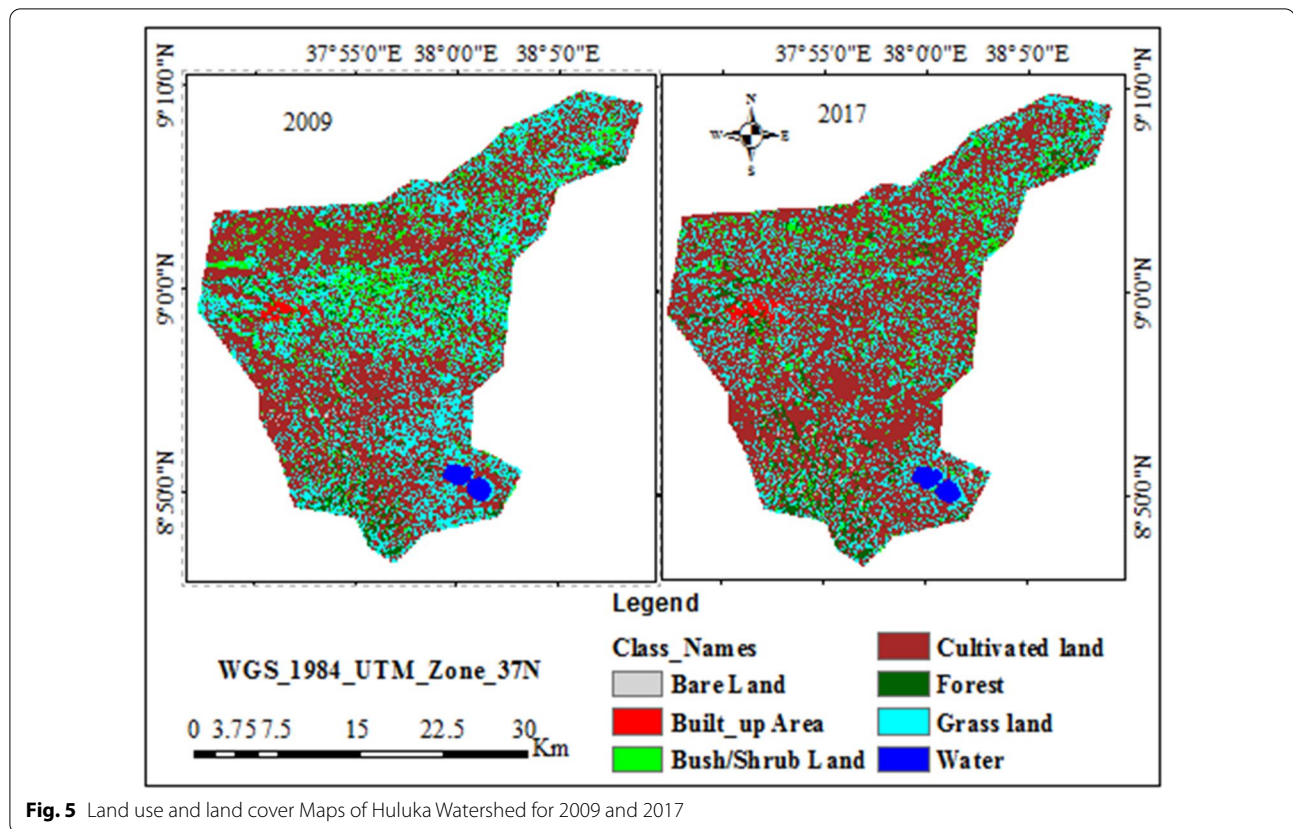


Fig. 4 Land use and land cover Maps of Huluka Watershed for 1979 and 1984

between 2009–2017, and 351% (16.20 ha/year) between 1979 and 2017. The increase of urban built-up areas in the watershed was attributable to the transformation of other land use and land cover types into urban built-up areas. A large proportion of grassland (274.77 ha), cultivated land (177.57 ha), shrub/bush land (118.53 ha), and forest land (91.98 ha) was transformed into urban built-up area between 1979 and 2017 (Tables 3, 4, 5, and 6; Figs. 4, 5).

Bush/Shrub land

Bush/shrub land was represented by land covered by shrubs and bushes and sometimes with scattered small trees mixed with grasses. Bush/Shrub land covered 17,746.11 ha (21.8%) in 1979, 12,767.1 ha (15.7%) in 1984, 7907.733 ha (9.7%) in 2009 and 5635.09 ha (6.9%) in 2017. It decreased by 28.1% (995.80 ha/year) between 1979 and 1984, 38.1% (194.38 ha/year) between 1984 and 2009, 28.7% (284.08 ha/year) between 2009 and 2017,



and 68.2% (318.71 ha/year) between 1979 and 2017. The decrease of bush/shrub land in the watershed was attributable to its transformation to other land use and land cover types. Its large proportion was transformed into cultivated land (11,085.04 ha) and grassland (4268.89 ha) between 1979 and 2017 (Tables 3, 4, 5, and 6; Figs. 4, 5).

Bare land

Bare land was represented by areas with no or very little vegetation cover and characterized by shallow, and rocky surface along the flooding area of the local stream valleys, over gentle and steep mountain slopes. Bare land covered 362.16 ha (0.4%) in 1979, 368.2 ha (0.5%) in 1984, 431.46 ha (0.5%) in 2009 and 513.97 ha (0.6%) in 2017. It increased by 1.7 (1.21 ha/year)% between 1979 and 1984, 17.2% (2.53 ha/year) between 1984 and 2009, 19.1% (10.31 ha/year) between 2009 and 2017, and 41.9% (4.00 ha/year) between 1979 and 2017. The increase of bare land cover in the watershed was attributable to the transformation of other land use and land cover types into bare land. A large proportion of cultivated land (246.69 ha), grassland (115.20 ha), and shrub/bush land (111.15 ha) was transformed into bare land between 1979 and 2017 (Table 3, 4, 5, and 6; Figs. 4 and 5).

Waterbody

Waterbody was represented by areas covered by lake water in the catchment permanently. Waterbody covered 789.48 ha (1%) in 1979, 811.98 ha (1%) in 1984, 748.44 ha (0.9%) in 2009 and 749.07 ha (0.9%) in 2017. It increased by 2.9% (4.5 ha/year) between 1979 and 1984. However, it decreased by 7.8% (2.54 ha/year) between 1984 and 2009. It increased by 0.1% (0.08 ha/year) between 2009 and 2017. It decreased by 5.1% (1.06 ha/year) between 1979 and 2017. The decrease of the waterbody in the watershed was attributable to its transformation to other land use and land cover types. Its large proportion was transformed into grassland (48.6 ha) and cultivated land (4.5 ha) between 1979 and 2017 (Table 3, 4, 5, and 6; Figs. 4, 5).

Grassland

Grassland was represented by land predominately covered with grasses, forbs, grassy areas used for communal grazing. Grassland covered 26,607.96 ha (32.8%) in 1979, 29,374.75 ha (36.2%) in 1984, 23,657.14 ha (29.1%) in 2009 and 17,919.11 ha (22%) in 2017. It increased by 10.4% (553.36 ha/year) between 1979 and 1984. It decreased by 19.5% (228.70 ha/year) between 1984 and

2009, 24.3% (717.25 ha/year) between 2009 and 2017, and 32.7% (228.65 ha/year) between 1979 and 2017. The decrease of grassland in the watershed was attributable to its transformation to other land use and land cover types. It was largely transformed into cultivated land between 1979 and 2017 (Tables 3, 4, 5, and 6; Figs. 4, 5).

Drivers and local effects of land use and land cover changes in Huluka watershed

Drivers of land use and land cover changes in Huluka watershed

The major themes of the thematic content analysis of qualitative data were drivers of land use and land cover changes and the relationship between the drivers and land use and land cover changes in the Huluka watershed. The summary of findings from focus group discussions indicates that the local communities in the watershed felt that the land use and land cover changes in their watershed are visible and underpinned by infrastructural and agricultural expansions, increased demand for wood, local environmental and biophysical drivers, rapid human population growth, economic drivers, technological drivers, policy and institutional drivers, and local socio-cultural drivers. The entire key informants also felt that the aforementioned drivers underpin land use and land cover changes in their watershed. The perceived causal relationship between land use and land cover changes and the drivers are summarized hereunder.

Infrastructural and agricultural expansion All the focus groups confirmed that unplanned expansion of infrastructure and agriculture are among the major drivers of land use and land cover changes in the Huluka watershed. This finding was further confirmed by the entire key informants who felt that many of the infrastructural and agricultural expansions are not planned and land use and land cover changes in the watershed are underpinned by unplanned expansions. Many of the key informants emphasized that they appreciate the planned expansion of relevant infrastructures like roads, electrification, and telecommunication. However, they suggested that appropriate environmental impact assessment must precede any infrastructural expansion in their watershed. It was also possible to observe the unplanned infrastructural and agricultural expansions in the watershed through participant observation.

Increased demand for wood All the focus groups affirmed that there is currently an increased demand for wood (fuelwood and wood for construction) in the Huluka watershed. The women focus groups emphasized that the challenge of fuelwood is visible in their environment as they do not find easily trees in their environment despite their increased demand for it. This affirmation was further supported by the assertion of the entire

key informants who felt that trees in the watershed are at big risk as humans need them for fuelwood and construction purposes without thinking to plant or replace them for future sustainable use. Key informants from the down-stream of Huluka watershed where Ambo town is situated further attest that there is increased demand for wood for construction purposes in the watershed especially in the urbanized part of the watershed. It was also possible to observe the increased demand for fuelwood and wood for construction through participant observation.

Local environmental and biophysical drivers All the focus groups attested that vulnerable soil quality, hilly topography, and lands without forest, bushes/shrubs, and grass cover are the local environmental drivers exacerbating the land use and land cover changes in the Huluka watershed. They affirmed also that flooding is one of the contributing local bio-physical drivers for land use and land cover changes. The entire key informants also agreed with the aforementioned attestation as they felt that these local environmental and bio-physical factors contribute much to land use and land cover changes in the watershed. The key informants from the urbanized part of the watershed emphasized that vulnerable soil types in their locality and hilly topography contribute to land use and land cover changes in the watershed. They also felt that flooding exacerbate the aforementioned undesirable environmental situation. It was also possible to observe some local environmental, and biophysical drivers through participant observation (Fig. 6).

Rapid growth of human population All the focus groups asserted that the rapidly growing human population in the watershed is one of the major drivers of land use and land cover changes in the Huluka watershed. The entire key informants agreed with the above assertion as they further emphasized that the rapidly growing human population in the watershed demands much resources from the natural environment which threatens the natural environment resulting in the degradation of natural resources. The key informants from the urbanized part of the watershed felt that the demand for shelter and food certainly hasten the transformation of land use and land cover to urban built-up areas and cultivated land. This threatens forest land, grassland, and bush/shrub land as they attested. It was also possible to observe the detrimental effect of human unplanned settlement in the watershed exacerbating the land use and land cover changes (Fig. 6).

Economic drivers All the focus groups confirmed that market growth and commercialization, urban expansion, and price increase are among the major economic drivers contributing to land use and land cover changes in the watershed. The entire key informants agreed with



the above confirmation as they further emphasized that the economic needs of different stakeholders in the watershed significantly drive the land use and land cover changes in the watershed. It was also possible to observe some economic drivers through participant observation.

Technological Drivers All the focus groups affirmed that agro technical change and agricultural production factors are among the major technological drivers contributing to land use and land cover changes in the watershed. The entire key informants agreed with the above affirmation

as they further emphasized that land use and land cover changes in the watershed are much affected by access to technologies by different stakeholders in the watershed. It was also possible to observe some technological drivers through participant observation.

Policy and institutional drivers All the focus groups confirmed that formal land policy, property rights, and the absence of relevant institutions are among the major drivers of land use and land cover changes in the Huluka watershed. The entire key informants agreed with the

above confirmation. For instance, key informants from the urbanized part of the watershed felt that urban development policy and land use policy contribute much to land use and land cover changes that threaten their livelihoods. Most of the key informants felt that the absence of strong and stringent environmental protection policies and strategies underpins the degradation of natural resources in the Huluka watershed. They also felt that the property rights issue affects their attitude towards the conservation of natural resources. It was also possible to observe some of the policy and institutional drivers through participant observation.

Local socio-cultural drivers All the focus groups asserted that religious institutions, public attitudes, and beliefs, and individual and household behavior are among the socio-cultural drivers contributing to land use and land cover changes in the Huluka watershed. The entire key informants agreed with the above confirmation. For instance, many key informants felt that forest land cover is more conserved in religious institutions as they promote living in peace with nature. They also affirm that the conservation or degradation of natural resources in the watershed is determined by public attitudes and beliefs, and individual and household behavior. It was also possible to observe some of the socio-cultural drivers through participant observation.

Local effects of land use and land cover changes in Huluka watershed

The major themes of the thematic content analysis of qualitative data were local negative effects of land use and land cover changes on farmers' livelihoods, the reciprocal cause-effect relationship between flooding risk and land use and land cover changes, strengths, and weaknesses of the current community-based soil and water conservation measures practiced, and effective adaptation measures to land use and land cover changes. A summary of the findings for the aforementioned themes is presented hereunder.

Local negative effects of land use and land cover changes on farmers' livelihoods All the focus groups attest that land use and land cover changes in the Huluka watershed have negative local effects on their livelihoods. Accordingly, they identified increased flooding risk, increased soil erosion, increased sedimentation into water resources like lakes and rivers, decrease in soil fertility, loss of biodiversity, loss of springs, decrease in annual rainfall and increase in heat during the dry season. The entire key informants also felt that the negative local effects of land use and land cover changes on their livelihoods are current realities and affirmed that many of the environmental disasters in the watershed are highly attributable to the land use and land cover changes. It

was also possible to observe some of the negative local effects.

Reciprocal cause-effect relationship between flooding risk and land use and land cover changes All the focus groups affirmed that flooding risk in their watershed is highly linked to land use and land cover changes as the transformation of land use and land cover from forest land, grassland, and bush/shrub land to cultivated land, and urban built-up areas exacerbate flooding risk caused by other factors. They also asserted that flooding risk in the watershed also exacerbated land use and land cover changes as it hastens the transformation of productive land use and land cover into degraded land use and land covers. The entire key informants also felt that a reciprocal cause-effect relationship exists between land use and land cover change and flooding risk. They attest that land areas without forest, grass, bush/shrub, and water are much vulnerable to flooding risk. They also confirmed that flooding risk in their watershed is highly underpinned by the changes in land use and land cover in the watershed. Hence, the existence of the reciprocal cause-effect relationship between flooding risk and change in land use and land cover was attested by the focus groups and the key informants. It was also possible to observe the negative effects of flooding risk on different land use and land cover types.

Strengths and weaknesses of the current community-based soil and water conservation measures All the focus groups affirmed that the current community-based soil and water conservation measures practiced in the watershed have contributed to increased soil fertility, healing of degraded land areas, conservation of soil and water resources, local adaptation to the flooding risk, improvement in yield from crop production, and improvement in social capital among local farmers, and between farmers and agricultural development professionals. However, they identified weaknesses that require careful attention in future interventions for sustainable watershed management. Accordingly, they identified poorly supervised and managed soil and water conservation measures in some places, lack of planting appropriate tree species on the established soil and water conservation structures, lack of considering rehabilitation of degraded lands in the soil and water conservation measures practiced, negative downstream impacts of some practiced measures, interference of livestock in the established structures, and lack of mainstreaming non-structural measures. The entire key informants also felt that the aforementioned strengths and weaknesses properly characterize the current community-based soil and water conservation measures practiced in the Huluka watershed. It was also possible to observe some of the strengths and weaknesses.

Effective adaptation measures to land use and land cover changes All the focus groups suggested compost preparation and use, the practice of crop rotation, effective planning to rehabilitate degraded lands through structural and non-structural soil and water conservation measures, strengthening the ongoing community-based soil and water conservation practices, institutionalizing appropriate environmental impact assessment into any local development projects, planting appropriate tree species and management on established soil and conservation structures, and establishing an appropriate institutional framework for forest and other natural resources' management as effective adaptation measures to land use and land cover changes. The entire key informants also felt that the aforementioned suggestions by local communities for sustainable watershed development are vital.

Discussion

Dynamics of land use and land cover changes and implications

The increase in urban built-up area land use and land cover by 351% at an average rate of 16.20 ha/year over 38 years (1979–2017) was confirmed in the Huluka watershed. This is similar to the previous study by Oluwayemisi et al. (2020) who confirmed the drastic increase in built-up area coverage over 20 years (1999–2019). Abebe et al. (2019) assert that rapid population growth and economic development underpin expansions of built-up areas in Ethiopia. Gashaw et al. (2017a, b) reported increased coverage of built-up areas over 30 years (1985–2015) with similar predicted trends for 2030 and 2045.

The increase in urban built-up areas has grave implications for promoting sustainable development in the Huluka watershed and beyond. Scholars in the field assert that land use is closely related to the urban development process of rapid urbanization that takes place in most developing countries (Miheretu and Yimer 2017; Abebe et al. 2019). In other words, how land has to be allocated to a variety of functions such as roads, utilities, housing industrial estates, shopping centers, offices, schools, hospitals and other elements of the physical organization of a city are attested to have far-reaching socio-economic, cultural, political, technical and ecological implications (Andjelkovic 2001; Parkinson 2003; Tucci 2007; Claes et al. 2012; Santato et al. 2013).

The continued high rate of urbanization, in general, is affirmed to lead to problems such as urban poverty, a lack of urban services, especially to the urban poor, poor provision of urban services, considerable strain on existing urban infrastructural facilities, street children, urban unemployment, urban transportation problems, displaced persons, urban crime, a proliferation of slums

and squatter settlements, and urban environmental degradation (Balzerek et al. 2003; Ujoh et al. 2010; Hao et al. 2015; Abebe et al. 2019). These urban challenges were also confirmed to affect the urban development process in the Huluka watershed where Ambo town is situated. As the aforementioned challenges are underpinned by unplanned urban expansion, only sustainable land use planning and management and sustainable urban development are feasible solutions (Gashu and Gebre-Egziabher 2018). In other words, protecting land from the urban expansion is affirmed to be imperative for countries whose economic viability and environmental sustainability are increasingly threatened by growing population pressures on a limited natural resource base, the agricultural expansion of marginal lands, deforestation to meet growing demands for food, energy, and construction, and climate change (Brown 2011; FDRE-MUDHC 2014; Miheretu and Yimer 2017; Worku et al. 2017; Abera et al. 2020).

The increase in cultivated land use and land cover by 105.3% at an average rate of 692.76 over 38 years (1979–2017) was confirmed in the Huluka watershed. This is similar to a previous study by Abera et al. (2020) who reported that cultivated land use and land cover increased at an average rate of 1515.7 ha/year between 2000 and 2018. Wubie et al. (2016) reported a consistent expansion of cultivated land use and land cover over the four decades analyzed (1957–2005). Hassen and Assen (2017) reported the expansion of cultivated land by about 57.68% (91.5 ha/year). Miheretu and Yimer (2017) reported an increase in cultivated land by 7.13% over 50 years (1964–2014). Woldeesenbet et al. (2020) reported an increase in area coverage for the cultivated land-use system over 30 years. Deribew and Dalacho (2019) reported an increase in cultivated land cover by 36.70% over 60 years (1957–2017). Gashaw et al. (2017a, b) reported increased coverage of cultivated land cover over 30 years (1985–2015) with similar predicted trends for 2030 and 2045.

The increase in cultivated land use and land cover has grave environmental implications for the Huluka watershed and beyond. For instance, the increase in cultivated land was at the expense of forest land, grassland, and bush/shrub land use and land cover and this affects the livelihoods of the human population and other members of the ecosystem in the watershed. In other words, elements of the ecosystem in the watershed are much vulnerable to disaster risks like flooding and soil erosion. Scholars of sustainable development recommend integrated watershed management to address diverse water-related issues in the watershed. In other words, sustainable land management (SLM) is attested to have a vital contribution. The main objective of SLM is affirmed

to be integrating people's coexistence with nature over the long-term, so that the provisioning, regulating, cultural, and supporting services of ecosystems are ensured (Ali et al. 2011; Liniger et al. 2011; FDRE-MUDHC 2014).

The increase in bare land use and land cover by 41.9% at an average rate of 4.00 ha/year over 38 years (1979–2017) was confirmed in the Huluka watershed. This is similar to the previous study by Hassen and Assen (2017) who reported an exceptional expansion of bare land by 11.37 ha/year underpinned by the presence of unsustainable land management practices. Contrary to our finding, the decrease in bare land use and land cover by 46.8% at an average rate of 27 ha/year (2000–2018) was confirmed by a previous study conducted in Ethiopia by Abera and his colleagues. They identified the expansion of built-up areas at the expense of bare land as the underpinning reason (Abera et al. 2020).

The decrease in the forest land use and land cover by 59.3% at an average rate of 164.52 ha/year over 38 years (1979–2017) was confirmed in the Huluka watershed. This is similar to some previous studies in Ethiopia which confirmed the decrease in forest land use and land cover. For instance, Negassa et al. (2020) confirmed a reduction in dense and open forest cover in the Komto forest priority area of East Wollega Zone, Ethiopia. A reduction in forest land use and land cover by 59.9% at an average rate of 745.2 ha/year was also confirmed by the current similar study conducted in the Chewaka district of Ethiopia (Abera et al. 2020). Woldesenbet et al. (2020) also confirmed a decrease in area coverage for forest land-use systems over 30 years. Oluwayemisi et al. (2020) also confirmed a drastic decrease in forest land coverage over 20 years (1999–2019). Deribew and Dalacho (2019) also reported a decrease in forest land cover by 39.79% over 60 years (1957–2017). Gashaw et al. (2017a, b) reported decreased coverage of forest land use and land cover over 30 years (1985–2015) with similar predicted trends for 2030 and 2045.

The reduction in forest land use and land cover has serious implications for exacerbating environmental problems in the watershed and beyond. For instance, deforestation and logging are regularly affirmed for exacerbating the disastrous effects of floods generated by extreme rainfall (Gebresamuel et al. 2015). In other words, deforestation tends to generate higher flows, net erosion, and nutrient losses. To avert this undesired human impact on the natural environment, afforestation is recommended as it tends to reduce groundwater recharge and net water availability. In other words, trees are attested to have the capacity to intercept part of the precipitation and, owing to their deeper root systems, transpire more water than grasses during the drier periods (Birkinshaw et al. 2010; Santato et al. 2013).

The urban areas, which are growing rapidly, are attested to need forests to improve the human well-being of the urban population by creating green spaces. Besides this, forests are asserted to provide multiple ecosystem services for people living in rural areas (Dessie & Tadesse 2013; Gashu and Gebre-Egziabher 2018). Furthermore, the importance of forests for sustainable development is increasingly being recognized, not only as a source of wood and timber, but also for carbon sequestration, as a source of renewable energy, for cultural and spiritual values, and recreation, among others (Muller and Reinstorf 2011; Dessie and Tadesse 2013; Abera et al. 2020). Abera et al. (2020) attest that developing a proper land-use plan and limiting population growth through family planning are of paramount importance to conserve and protect forest land use and land cover. Hence, conservation and wise use of forest land resources in the Huluka watershed is of paramount importance to promote sustainable watershed development.

The decrease in shrub/bush land use and land cover by 68.2% at an average rate of 318.71 ha/year over 38 years (1979–2017) was confirmed in the Huluka watershed. This is similar to the finding of Gashaw et al. (2017a, b) who reported decreased coverage of shrub/bush land use and land cover over 30 years (1985–2015) with similar predicted trends for 2030 and 2045. The decrease in shrub/bush land use and land cover implies that land without shrub/bush cover is vulnerable to soil erosion, flooding, and climate change. Moreover, the livelihoods of local communities are affected since feed shortage and fuelwood shortage are exacerbated in the watershed and beyond.

The decrease in grassland use and land cover by 32.7% at an average rate of 228.65 ha/year over 38 years (1979–2017) was confirmed in the Huluka watershed. This is similar to the study by Woldesenbet et al. (2020) who reported a decrease in area coverage for grassland use systems over 30 years. Oluwayemisi et al. (2020) reported a drastic decrease in grassland coverage over 20 years (1999–2019). Gashaw et al. (2017a, b) reported decreased coverage of grassland use and land cover over 30 years (1985–2015) with similar predicted trends for 2030 and 2045. The decrease in grassland use and land cover has grave environmental implications for the Huluka watershed and beyond. For instance, the reduction in grassland use and cover implies a shortage of grazing land and feed shortage for livestock affecting the mixed crop-livestock farming system in the watershed and beyond. Reduction in grassland use and land cover also mean increased risk of land to flooding and soil erosion.

The decrease in waterbody by 5.1% at an average rate of 1.06 ha/year over 38 years (1979–2017) was confirmed in the Huluka watershed. This is similar to a previous study

conducted by Oluwayemisi et al. (2020) who confirmed a drastic decrease in water body coverage over 20 years (1999–2019).

The decrease in water body has serious environmental implications for the watershed and beyond, as ecosystem services from the water body (Dendi lake) are detrimentally affected by human-induced and natural factors. Some of the ecosystem services provided by lake include Habitat for aquatic birds, other animals and plants; fish and shellfish production; biodiversity; food production; water storage, including mitigating the effects of floods, and droughts; groundwater recharge; shoreline stabilization, and storm protection; water purification; nutrient cycling; sediment retention and export; recreation and tourism; climate change mitigation; timber production; education and research; and aesthetic, and cultural value (Ozesmi and Baur 2002; Abunie 2003; Galbraith et al. 2005; Millennium Ecosystem Assessment 2005; Wetlands International 2010). Hence, sustainable wetland conservation and restoration policies and strategies should be integrated into sustainable local development and poverty alleviation policies and strategies as environmentally sound economic development underpin sustainable development that creates livelihood options and employment opportunities for current as well as future generations (Ogato 2013; Yohannes et al. 2020).

Drivers of land use and land cover changes and implications

The finding of the study indicates that infrastructural and agricultural expansions, increased demand for wood, local environmental and bio-physical drivers, the rapid growth of human population, economic drivers, technological drivers, policy and institutional drivers, and local socio-cultural drivers were the perceived drivers of land use and land cover changes in Huluka watershed. While technological drivers, local environmental and bio-physical drivers, and socio-cultural drivers were not well confirmed by previous studies in Ethiopia, drivers like rapid growth of human population, increased demand for wood, policy, and institutional drivers were well confirmed as discussed hereunder.

Scholars in the field affirm that the main drivers of land use and land cover changes are the combination of bio-physical processes, demographic dynamics, urbanization, and successive government policies (Jember 2014; Gashaw et al. 2017a, b; Karki et al. 2018; Deribew and Dalacho 2019; Megersa et al. 2019; Yesuph and Dagne 2019). An increase in the human population is confirmed to be the major driver for land use and land cover changes in Ethiopia (Kindu et al. 2013; Gashaw et al. 2017a, b; Abebe et al. 2019; Hassan et al. 2016; Wubie et al. 2016; Miheretu and Yimer 2017; Worku et al. 2017; Abera et al.

2020). For instance, Worku et al. (2017) and Wubie et al. (2016) assert that Population growth increases demands of more cultivated land, fuelwood, charcoal, and infrastructural development. Abera et al. (2020) assert that rapid population growth and high population density induce increased demand for resources and exacerbate the rate of resource depletion in the area. Local environmental and biophysical drivers are affirmed to underpin land use and land cover changes in Ethiopia (Kindu et al. 2013; Gashaw et al. 2017a, b; Yesuph and Dagne 2019). For Gashaw et al. (2017a, b), the reduction of land productivity underpinning the intension of the people for getting new fertile cultivable lands is one of the biophysical drivers.

Policy and institutional drivers are also attested to contribute to land use and land cover changes in Ethiopia (Kindu et al. 2013; Hassen and Assen 2017; Zewdie et al. 2017; Gashu and Gebre-Egziabher 2018; Yesuph and Dagne 2019; Abera et al. 2020). For instance, Gashu and Gebre-Egziabher (2018) assert that policy and institutional drivers underpin the dynamics of land use and land cover changes in Ethiopia. Economic drivers are also affirmed to contribute to land use and land cover changes in Ethiopia (Kindu et al. 2013; Minale 2013; Gebresamuel et al. 2015; Hassan et al. 2016; Hassen and Assen 2017; Yesuph and Dagne 2019; Abera et al. 2020). For instance, Hassan et al. (2016) identified economic development, climate change, population growth, rapid urbanization, and deforestation as drivers of land use and land cover changes.

The above discussions imply that diverse drivers of land use and land cover changes in the Huluka watershed should be considered in planning and managing sustainable development projects and programmes in the watershed and beyond. This requires the participation of stakeholders, coordination of different activities, and collaboration of all development partners to ensure the sustainability of development initiatives in the watershed and beyond.

Local effects of land use and land cover changes and implications

The finding of the study indicates that increased flooding risk, increased soil erosion, increased sedimentation into water resources (lake and rivers), decrease in soil fertility, loss of biodiversity, loss of springs, decrease in annual rainfall, and increase in heat during the dry season were the perceived local negative effects of land use and land cover changes in Huluka watershed. While there are limited empirical pieces of evidence linking annual rainfall and environmental heat to changes in land use and land cover in Ethiopia, other local effects were well documented as discussed hereunder.

Increased flooding risk was one of the perceived negative local effects of land use and land cover changes in the Huluka watershed. This perception is similar to the attestations by previous studies in Ethiopia which attested that flooding risk in Ethiopia is underpinned by land use and land cover changes. For instance, scholars in the field affirm that the hydrology of a watershed is much affected by land use and land cover changes resulting in flooding risk (Assen 2011; Gebresamuel et al. 2015; Gashaw et al. 2017a, b; Megersa et al. 2019; Yesuph and Dagne 2019). Scholars also assert that urban built-up area is characterized by urban runoff which is defined as streamflow or the sum of surface runoff and subsurface runoff from an urban area (Zhiyu et al. 2013; Gashu and Gebre-Egziabher 2018). Increased soil erosion was one of the perceived negative local effects of land use and land cover changes in the Huluka watershed. This perception is similar to the confirmations by previous studies in Ethiopia which confirmed that soil erosion is the result of land use and land cover transformation. For instance, scholars in the field attest that cultivated land use and land cover, and bare land use and land cover are vulnerable to soil erosion (Assen 2011; Wubie et al. 2016; Miheretu and Yimer 2017; Tellen and Yerima 2018; Megersa et al. 2019; Yesuph and Dagne 2019; Girma and Gebre 2020).

Increased sedimentation into water resources was one of the perceived negative local effects of land use and land cover changes in the Huluka watershed. This perception is similar to the assertions of scholars in the field who assert that land use and land cover changes underpin water pollution and threaten the lives of globally important species dependent on wetlands like lakes and rivers (Esa et al. 2018; Karki et al. 2018). The decrease in soil fertility was one of the perceived negative local effects of land use and land cover changes in the Huluka watershed. This perception is similar to the assertion of scholars who assert that decline in soil fertility is underpinned by the transformation of land use and land cover (Wubie et al. 2016; Bekele et al. 2018; Karki et al. 2018).

The above discussed negative local effects of land use and land cover changes have critical implications for sustainable watershed management in the study area. Scholars attest that appropriate strategic measures should be practiced to reduce the negative local effects of land use and land cover changes (Gashaw et al. 2017a, b; Hassen & Assen 2017; Hishe et al. 2017; Kassie 2017; Mekuriaw 2017; Worku et al. 2017; Zewdie et al. 2017; Gella 2018). Many of them strongly affirm that it is vital to institutionalize sustainable biological and physical soil conservation measures to mitigate land degradation and improve the livelihood of the local community in the watershed (Amdihun et al. 2014; Wolancho 2015; Wolka et al. 2015; Yimer et al. 2015; Tadesse et al. 2017; Deribew

and Dalacho 2019; Kidane et al. 2019). Others assert that integrated water resources planning and management is vital as one of the elements of natural resources management (Laekemariam et al. 2016; Qayum et al. 2016; Seyoum 2016; Teshome 2016; Miheretu and Yimer 2017; Meshesha and Khare 2019). Others attest that payments for ecological services are vital for the sustainable management of natural resources (Tolessa et al. 2017; Bogale 2020; Hasan et al. 2020).

Conclusions

Forest land, cultivated land, urban built-up area, bush/shrub land, bare land, grassland, and water body were identified as the seven land use and land cover types in the Huluka watershed. There were dynamic spatio-temporal changes in land use and land cover in the study watershed and the study periods. Urban built-up area increased by 351% at an average rate of 16.20 ha/year over 38 years (1979–2017). Cultivated land increased by 105.3% at an average rate of 692.76 ha/year. Bare land increased by 41.9% at an average rate of 4.00 ha/year. Forest land decreased by 59.3% at an average rate of 164.52 ha/year over 38 years (1979–2017). Shrub/bush land decreased by 68.2% at an average rate of 318.71 ha/year. Grassland decreased by 32.7% at an average rate of 228.65 ha/year. Waterbody decreased by 5.1% at an average rate of 1.06 ha/year.

Drivers and local effects of land use and land cover changes were identified. Infrastructural and agricultural expansions, increased demand for wood, local environmental and bio-physical drivers, the rapid growth of human population, economic drivers, technological drivers, policy and institutional drivers, and local socio-cultural drivers were identified as the perceived drivers of land use and land cover changes in Huluka watershed. Increased flooding risk, increased soil erosion, increased sedimentation into water resources (lake and rivers), decrease in soil fertility, loss of biodiversity, loss of springs, decrease in annual rainfall, and increase in heat during the dry season were identified as the perceived local negative effects of land use and land cover changes in Huluka watershed.

To promote sustainable local development in the watershed and beyond, the following recommendations are forwarded:

- Appropriate land use planning and management in the watershed should be practiced to reduce the negative local effects of land use and land cover change in the watershed;
- Family planning should be encouraged in the study area since rapid human population growth under-

pins land use and land cover changes and their negative effects in the Huluka watershed and beyond;

- Appropriate environmental impact assessment (EIA) should be conducted before initiating any local development projects;
- Appropriate institutional framework for integrated watershed management should be established for proper planning and management of the watershed development activities;
- Compost preparation and use, and crop rotation should be encouraged to improve the productivity of soil resources in the watershed;
- Rehabilitation of degraded lands through structural and non-structural soil and water conservation measures should be properly planned and managed;
- The ongoing community-based integrated watershed management should be strengthened;
- Appropriate tree species should be planted and managed on the established soil and water conservation structures;
- Local socio-cultural development in the watershed should be properly planned and managed to promote sustainable socio-cultural development in the watershed; and
- Local economic development in the watershed should be properly planned and managed to promote sustainable economic development in the watershed.

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Authors' contributions

Data were collected and analyzed by GSO who was the first and the corresponding author. Writing had been substantially contributed by GSO, AB, and DG had been involved in critically advising, revising the manuscript and made possible suggestions for improving the quality of the manuscript. All authors read and approved the final manuscript.

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ANNEX TWO: TOOLS FOR PRIMARY DATA COLLECTION**Tool 1: Semi-Structured Questionnaire for Urban Households****GENERAL INFORMATION**

Date of interview:-----

District/Town:-----;Village/PA:-----Zone/Got:-----Garee:-----

PART-I: HOUSEHOLD BACKGROUND INFORMATION

1. Name of the household head:-----

2. Household title: A. Male Headed B. Female Headed

3. Age of the household head:-----

4. Sex of the household head: A. Male B. Female

5. Family Size of the household:-----

6. Family details

Members	Sex	Age	Occupation	Income/Month

7. Marital status of the respondent: A. Single B. Married C. Divorced D. Widow E.Widower F. Separated

8. Educational qualification in years:-----

9. Employment status: A. Employed B. Self-employed C. Dependant D. RetiredOfficer E. Other employment status: Explain:-----

10. Total annual household income (ETB):-----

11. No of years/ months that you have lived in this area:-----

12. Ownership details of residence:

 A. Owner B. Private rented C. Government rented D. Leased E. Any Other (Specify):-----**PART II: LAND HOLDING AND PROPERTY OWNERSHIP**

13. What type of building material has been used for the walling of your residential house?

 A. Mud B. Stones C. Bricks D. Iron sheet E. Wood F. Other (specify)-----

14. What is the nature of the floor of your residential house?

 A. Concrete B. Wood C. Earthen D. Other (specify) -----

15. Area of the plot: -----

16. Built area of the houses:-----

17. Total land holding: A. Now----- B. 10 years ago----- C. 20 years ago----- D. 30 years ago-----18. Do you think that land is becoming scarce in your area? A. Yes B. No

19. If yes, why is land becoming scarce?

- A. Because of population increase B. Because the proportion of fertile land is Diminishing C. Land has fallen in fewer hands D. Land has been converted to non-agricultural uses E. Land has been given to developers
- F. Other, Specify:-----

PART-III: URBAN HOUSEHOLDS' PERCEPTION ON TYPES, CAUSES AND EFFECTS OF URBAN FLOODING

A. Types and Causes of Urban Flooding

20. In your perspective, what type of urban flooding is common in Ambo town?

- A. River or fluvial floods B. Pluvial or overland floods C. Flash floods D. All E. Any other (specify):-----

21. In your perspective, what is the possible cause of urban flooding in Ambo town?

- A. A severe rainstorm proceeded by a long-lasting moderate rainfall that saturates the soil
 B. Inadequate land use and channelization of natural waterways
 C. Failure of the city protection dikes
 D. Inflow from the rivers/streams during high stages into urban drainage system
 E. Soil erosion generating material that clogs drainage system and inlets
 F. Inadequate street cleaning practice that clogs street inlets
 H. Continuing Urbanization
 I. Any other (specify):-----

B. Negative and Positive Effects of Urban Flooding

22. Do you think that one or more of the aforementioned types of urban flooding has negative effects in Ambo town A. Yes B. No

23. If yes, what is the possible negative effect of urban flooding in Ambo town?

- A. Loss of human life
 B. Flooding of housing, commercial and industrial properties
 C. Flooding of streets, intersections and transportation systems, causing traffic delays
 D. Damage to public and personal property
 E. Exacerbating health risks in the home and local environment
 F. Disrupting infrastructure and access to services such as water supply
 F. Delays in public transportation
 G. Cleanup demands
 H. Adverse effects upon the aesthetics
 I. Disturbance of wildlife habitats
 J. disrupting or suspending trade/business activities
 K. Any other (specify):-----

24. What is the possible negative effect that your community has ever incurred due to floods between 2005-2015?

- A. Displacement from home B. Loss of vital infrastructures such as housing
 C. Loss of food storage D. Loss of transport and communications

- E. Contamination of water supplies
- F. Increase expenses
- G. Loss of income generating activities
- H. Time lost from work/school
- I. Stress
- J. Damaged property
- K. Health problems
- L. Increased prevalence of disease-carrying vectors and incidence of disease
- M. Other (Specify):-----

25. In your perspective, which of the following social groups in Ambo town are much affected by negative effects of urban flooding? A. Old persons B. Children C. Women D. Women and children E. Any other (specify):-----

26. Who are the most vulnerable households to floods? A. Male Headed B. Female Headed

27. What are the underlying causes of vulnerability to urban flooding risk?
 A. Residing in a flood prone area B. Poverty
 C. Lack of alternative livelihood(s) D. Any other (specify):-----

28. Do you think that one or more of the aforementioned types of urban flooding has positive effects in Ambo town A. Yes B. No

29. If yes, what is the possible positive effect of urban flooding in Ambo town?
 A. Cleaning the town
 B. facilitates sand mining
 C. facilitates mud-based wall making
 D. promotes flood based urban farming
 E. Any other (specify):-----

30. How do you evaluate the trend of urban flooding over time?

	2015	5 years ago/2010	10 years ago/2005	20 years ago/1995	30 years ago/1985
Severity of flooding ¹					
Extent of flooding ²					
Signs of urban flooding ³					

1: very light; 2: light ; 3: moderate; 3: severe; 4: very severe
 2: 1: absent; 2: present on vulnerable land units; 3: widespread everywhere
 3: 1: soil erosion; 2: gully formation; 3: destruction of physical infrastructures like roads and bridges; 5: deterioration in surface and ground water quality; 6: others (specify):-----

31. Duration of urban flooding 2005-2015:
 A. More than 14 days B. 7 to 14 days C. 1 to 6 days D. less than a day
32. Frequency of urban flooding between 2005-2015:
 A. Once a year B. Twice a year C. Thrice a year
 D. Other frequency (Specify):-----
33. Is your area usually flooded? A. Yes B. No
34. If yes, what is your experience with urban flooding every year between 2005- 2015?
 A. Suffered due to urban flooding B. Not suffered due to urban flooding
35. What was the depth of flooding between 2005-2015?-----

36. In which month(s) and how often was your residence flooded last year (2015)?

1	2	3	4	5	6	7	8	9	10	11	12
-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----

37. Do you think flooding in your area has become really serious in the last five years? A. Yes B. No

38. How serious do you think urban flooding will become in the next ten years (tick one)?

A. very high B. high C. moderate D. less E. very less

39. What is the period of occurrence of urban flooding in Ambo town?

A. June, July, August, September B. July, August, September

C. June, July, and August D. Other period (Specify):-----

40. Does urban flooding occur in the same manner like before? A. Yes B. No

41. If no, why do you think that urban flooding does not occur in the same manner like before?

42. How concerned are you personally about urban flooding (tick one)?

A. very highly B. highly C. moderately D. less E. very less

43. What measures/actions, if any, have you taken to minimize the negative effect of urban flooding?

44. Do you think anything can be done to minimize the after-effects of urban flooding?

By government:-----

By community:-----

By Other organizations:-----

45. During the floods last year, did any member of your household have to leave to avoid the flood temporarily?

A. Yes B. No

46. Before the floods, what action(s) did you take to cope with them?

47. How many days did you spend preparing for coping with or preventing potential damage to be caused by the coming floods?-----

48. How much money did you spend to prepare for coping with or preventing potential damage to be caused by the coming flood?-----

49. During the floods, what action(s) did you take to cope with them?

50. How many days did you spend in preparing to protect your house from the floods?

51. How much money did you spend?-----

52. What did you lose during the floods?

53. Did any members of your household lose any income because of the floods (e.g. could not get to work, or their place of work was closed etc.)? A. Yes B. No

54. Was there any structural damage to your residential house? A. Yes B. No

55. If yes, what was the cost of the structural damage to your home? -----

56. Did any members of your household contract any diseases associated with the after-effects of flooding? []
 A. Yes [] B. No

57. If yes, how many household members were affected and how much did the family spend on medical treatment in total?

Disease	Number of family members affected	Did you receive any treatment?	Total cost to treat the family (doctor's fees, medicine, transport etc.) in Eth.Birr

58. How many days did you need to repair or clean up your home after the floods?

59. What was the monetary cost to you for labour and supplies to clean up the structure and contents of your house after the flood?-----

60. How high (in centimeters) did the water come to relative to the front entryway of your house?

C. SENSITIVITY OF SOCIAL SERVICE PROVIDING SECTORS TO URBAN FLOODING RISK AND ADAPTIVE CAPACITY OF URBAN HOUSEHOLDS

61. Do you think water supply system in Ambo town is sensitive to urban flooding? [] A Yes [] B. No

62. If yes, rate the sensitivity of water supply system in Ambo town:

[] A. Very high [] B. high [] C. moderate [] D. low [] E. very low

63. How is your water during flooding: [] A. Clear [] B. turbid [] C. With suspended Matter

64. How does your water taste during flooding: [] A. Good soft [] B. Bad salty

[] C. Bad muddy taste [] D. Any other (Specify):-----

65. Does your water during flooding smell? [] A. Yes [] B. No

66. Do you boil your water during flooding? [] A. Yes [] B. No

67. What kind of solid waste disposal mechanism does your household use?

[] A. Dust bins [] B. Into the River [] C. Open Spaces D. Land fills

68. Who is in charge of solid waste collection in this area? [] A. The City Council [] B. Private waste collectors [] C. Community based organizations [] D. Other (specify)-----

69. Where do you dispose off your used water? -----

70. Do you think sanitary service providing sectors in Ambo town are sensitive to urban flooding?

A Yes B. No

71. If yes, rate the sensitivity of sanitary service providing sectors to urban flooding:

A. Very high B. high C. moderate D. low E. very low

72. Do you think energy facilities in Ambo town are sensitive to urban flooding? A Yes B. No

73. If yes, rate the sensitivity of energy facilities:

A. Very high B. high C. moderate D. low E. very low

74. Do you think health facilities in Ambo town are sensitive to urban flooding? A. Yes B. No

75. If yes, rate the sensitivity of health facilities in Ambo town:

A. Very high B. high C. moderate D. low E. very low

76. Do you think road networks in your area are sensitive to urban flooding? A Yes B. No

77. If yes, rate the sensitivity of road networks in Ambo town:

A. Very high B. high C. moderate D. low E. very low

78. Do you think education facilities in Ambo town are sensitive to urban flooding? A Yes B. No

79. If yes, rate the sensitivity of education facilities in Ambo town:

A. Very high B. high C. moderate D. low E. very low

80. Do you think that urban flooding has negative impact on private and public infrastructure? A. Yes. B. No

81. If yes, rate the sensitivity of private and public infrastructure in Ambo town:

A. Very high B. high C. moderate D. low E. very low

82. In your village, what are the economic activities that are affected by urban flooding?

83. What are the infrastructures most affected by urban flooding in your village?

84. Describe the situation of the basic infrastructures (schools, Health centers, roads, town hall, football fields etc.) in term of accessibility during urban flooding in your locality.

85. Do your friends, relatives or neighbors ever help when you are sick (e.g. taking you to hospital, help with medicines, childcare etc.)? A. Yes B. No

86. Do you ever offer help to your friends, relatives or neighbor? A. Yes B. No

87. What kind of help did you offer?

88. Are you aware of urban flooding risk management activities by Ambo town administration?

A. Yes. B. No

89. If yes, would you explain the urban flooding risk management activities by Ambo town administration?

90. Has there been any forum to discuss disaster management in the community? A. Yes. B. No

91. If yes, who led the process?-----

92. What do you want the town administration undertake to manage urban flooding risk?

PART-IV: URBAN HOUSEHOLDS' PERCEPTION ON RESPONSES TO URBAN FLOODING RISK

A. Current governance of urban flooding Risk

93. Urban households' perception on governance of urban flooding risk

How do you rate the current governance of urban flooding risk in Ambo town in relation to the following principles of good governance?	Rate				
Accountability	Very high	High	Moderate	Low	Very Low
Legality	Very high	High	Moderate	Low	Very Low
Impartiality	Very high	High	Moderate	Low	Very Low
Transparency	Very high	High	Moderate	Low	Very Low
Participation	Very high	High	Moderate	Low	Very Low
Coordination	Very high	High	Moderate	Low	Very Low
Effectiveness	Very high	High	Moderate	Low	Very Low
Education/Awareness	Very high	High	Moderate	Low	Very Low
Subsidiarity	Very high	High	Moderate	Low	Very Low

B. Effectiveness of current urban flooding risk management measures

94. Do you think that Ambo town administration is currently employing structural measures of urban flooding management? A. Yes B.No

95. If yes, which structural measure is currently being employed in Ambo town?

A. Drainage system construction

B. Dam construction

C. Flood wall construction

D. River bank elevation

E. Channel modification

F. Any other (specify):-----

96. If yes, how do you rate the effectiveness of drainage system construction as structural measure of urban flooding management in Ambo town?

[] A. Very good [] B. Good [] C. Fair [] D. Poor [] E. very poor.

97. Do you think that Ambo town administration is currently employing non-structural measures of urban flooding management?

[] A. Yes [] B.No

98. If yes, which non-structural measure is currently being employed in Ambo town?

- [] A. Land use planning [] B. Capacity building
- [] C. Enactment of rules & regulations [] D. Flood risk preparedness
- [] E. Any other (specify):-----

99. How do you rate the effectiveness of land use planning as non-structural measure of urban flooding management in Ambo town?

[] A. Very good [] B. Good [] C. Fair [] D. Poor [] E. very poor.

100. How do you rate the effectiveness of capacity building as non-structural measure of urban flooding management in Ambo town?

[] A. Very good [] B. Good [] C. Fair [] D. Poor [] E. very poor.

101. How do you rate the effectiveness of enactment of rules & regulations as non-structural measure of urban flooding management in Ambo town?

[] A. Very good [] B. Good [] C. Fair [] D. Poor [] E. very poor.

102. How do you rate the effectiveness of flood risk preparedness as non-structural measure of urban flooding management in Ambo town?

[] A. Very good [] B. Good [] C. Fair [] D. Poor [] E. very poor.

C. HOUSEHOLDS’ ADAPTATION STRATEGIES FOR URBAN FLOODING RISK

103. With urban flooding, what strategies have you and your family planned?

104. Do you ever participate in any activities/training/programmes related to urban flooding?

[] A. Yes [] B. No

105. How much of your income do you save? (ETB/month):-----

106. Do you have access to credit? [] A. Yes [] B. No

107. Do you have any insurance? [] A. Yes [] B. No

108. If yes, what kind of insurance?-----

109. What strategy does your household use to cope with the flood events and their effects?

- [] A. Migrate to safer places [] B. Selling of properties to get income

- C. Drop out of school to earn income
- D. Social capital
- E. Flood relief from government/agencies
- F. Early warning system
- G. Other (Specify):-----

110. Which of the following preventive measures did you practice to adapt to urban flooding 2005-2015:

- A. Preventative investment into yard
- B. Preventative investment into house
- C. Preventative cleaning of drainage
- D. Other (Specify):-----

111. Which of the following element of social capital helped your household in the process of adapting to urban flooding?

- A. Informal contact
- B. Participation in community group
- C. Apply for monetary assistance to government
- D. Other (Specify):-----

112. Which of the following measures did you practice during urban flooding 2005-2015:

- A. Helping others
- B. Piling up furniture
- D. Other (Specify):-----

113. Which of the following measures did you practice after urban flooding 2005-2015:

- A. Cleaning and/or repairing homes
- B. Cleaning drainage afterward
- C. Other (Specify):-----

114. Do you think the coping mechanisms you have been using have helped to reduce effects of floods? A. Yes B. No

115. If yes, how long on average does it take to fully recover from the flood-induced losses?

116. What do you think should be done to accelerate recovery from flood-induced losses?

117. Overall, in your opinion, how have flood events affected poverty levels in your community?

D. The role of spatial planning in urban flooding risk management

118. Do you think that spatial planning matters for flooding management? A. Yes B.No

119. If yes, how do you rate the extent to which spatial planning affect management of urban flooding? A. very high B. high C. moderate D. low E. very low

120. What is the possible effect that spatial planning may have on urban flooding management?

A. Planning may lead to reduced flooding/surface run-off

B. Planning may result in improved stormwater drainage facilities

C. Planning may result in reduced informal settlements

D. Planning may result in reduced flooding risks

E. Planned areas may ease Stormwater drainage system maintenance

F. Don't know/No response

H. Any other (specify):-----

121. Do you think that proper implementation of spatial planning and land use management policies and regulations have effects on urban flooding management? A. Yes B.No

122. What is the possible effect of proper implementation of spatial planning and land use management policies and regulations on urban flooding management?

A. Informal settlement may be reduced

B. Unplanned development may be avoided

C. Ignorance of building bylaws and regulations may be reduced

E. Planning policies and regulations may be adhered to

F. No response

H. Any other (specify):-----

123. Do you think that stakeholders' involvement matters for sustainable urban flooding risk management?

A. Yes B.No

124. If yes, what is the possible effect of Stakeholders' involvement in sustainable urban flooding risk management?

A. Solid Waste may be properly disposed

B. Sense of ownership may be developed or increased

C. Maintenance of drains may be enhanced

E. Awareness may be created on warning signs of flooding

F. Flooding risks may be reduced

H. No response

I. Any other (specify):-----

125. Do you think that stakeholders' awareness campaigns and education matters for sustainable urban flooding risk management? [] A. Yes [] B.No

126. If yes, what is the best possible effect of stakeholders' awareness campaigns and education in sustainable urban flooding risk management?

[] A. Solid waste may be properly disposed

[] B. Encroachment on stormwater drains may be reduced

[] C. Drainage infrastructure may be protected due to sense of ownership

[] E. Public may be sensitized on flooding risks

[] F. Community may be made aware of warning signs

[] H. No response

[] I. Any other (specify):-----

127. Do you think that urban communities in Ambo town need urban flooding risk management strategy?

[] A. Yes [] B. No

128. If yes, how do you rate the extent to which urban flooding risk management strategy is needed at community level?

[] A. very high [] B. high [] C. moderate [] D. low [] E. very low

129. Do you think that Ambo town needs urban flooding risk management strategy? [] A. Yes [] B. No

130. If yes, how do you rate the extent to which urban flooding risk management strategy is needed for Ambo town?

[] A. very high [] B. high [] C. moderate [] D. low [] E. very low

131. Do you think that urban households in Ambo town need urban flooding risk management strategy?

[] A. Yes [] B. No

132. If yes, how do you rate the extent to which urban flooding risk management strategy is needed at household level?

[] A. very high [] B. high [] C. moderate [] D. low [] E. very low

E. Alternative urban flooding risk management measures

133. Which type of floodplain development do you propose in Ambo town?

[] A. Preventing development from constricting floodway and allowing the flood fringes to be preserved for agricultural or recreational purpose.

B. Preventing development from constricting floodway and allowing the flood fringes to obtain housing, commercial or industrial purpose as long as the encroachment results in only insignificant increase in the water surface elevation.

C. Restricting the use of the flood plain and leaving it in its original unoccupied state.

D. Others, (Specify):-----

134. Which development and land use technique for flood management may you propose for Ambo town?

A. Permanent evacuation

B. Open space programs

C. Zoning ordinances for limiting types of land use

D. Regional planning

E. Subdivision regulation

F. Building codes of practice

G. Housing codes of practice

H. Sanitary and other utility codes of practice

I. Redevelopment policies such as proper design of utilities

J. Source pollution control

K. Public acquisition

L. Flood proofing

135. In your perspective, which urban flooding/stormwater management strategy is sustainable in the context of Ambo town?

A. Build dams to collect water

B. Reduce degradation

C. Construct big drainage systems

D. Other strategy (Specify):-----

136. Do you think that mainstreaming urban flooding risk management into urban land use planning contributes to reduce future flooding risk in Ambo town?

A. Yes. B. No

137. If yes, explain how mainstreaming urban flooding risk management into urban land use planning contributes to reduce future flooding risk in Ambo town:

Tool two: Checklist for Key informant interview with local elders in Huluka watershed

1. Are you aware of the land use changes that have occurred in the area?

2. If yes, what changes have taken place?-

3. Has the changes in land use affected you in any way?

4. If yes, are you better off now than you were before?

5. How do you perceive the change in land Use/ land Cover Change in your area?

6. Do you think infrastructure expansion in your locality did contribute for land use/ land cover change?

7. If yes, how does infrastructure expansion in your locality contributed for land use/ land cover change?

8. Do you think agricultural expansion in your locality did contribute for land use/ land cover change ?
9. If yes, how does agricultural expansion in your locality contributed for land use/ land cover change?
10. Do you think increased demand for wood in your locality did contribute for land use/ land cover change?
11. If yes, how does increased demand for wood in your locality contributed for land use/ land cover change?
12. Do you think local environmental factors in your locality did contribute for land use/ land cover change?
13. If yes, how do local environmental factors like soil quality and topography did contribute for land use/ land cover change?
14. Do you think local biophysical drivers in your locality did contribute for land use/ land cover change?
15. If yes, how do local biophysical drivers like fires, droughts, and floods did contribute for land use/ land cover change
16. Do you think local social events in your locality did contribute for land use/ land cover change?
17. If yes, how do local social events like social disorder, sudden displacement, and abrupt policy shifts in your locality did contribute for land use/ land cover change?
18. Do you think demographic factors in your locality did contribute for land use/ land cover change?
19. If yes, how do demographic factors like natural increase, migration, population density and population distribution in your locality contributed for land use/ land cover change?
20. Do you think economic factors in your locality did contribute for land use/ land cover change?
21. If yes, how do economic factors like market growth and commercialization, economic structure, urbanization, and price increase in your locality contributed for land use/ land cover change
22. Do you think technological factors in your locality did contribute for land use/ land cover change?
23. If yes, how do technological factors like agro technical change (intensification) and agricultural production factor in your locality contributed for land use/ land cover change?
24. Do you think policy and institutional factors in your locality did contribute for land use/ land cover change?
25. If yes, how do policy and institutional factors like formal policy and property right in your locality contributed for land use/ land cover change?
26. Do you think cultural factors in your locality did contribute for land use/ land cover change?
27. If yes, how do cultural factors like public attitudes and beliefs and individual and household behavior in your locality contributed for land use/ land cover change?
28. List the problems you are personally faced with due to increases in land use/land cover change in your area.

29. What do you think can be done to adapt to the changes in land use in your area?
30. Do you think land use/land cover change in your locality did contribute for flooding disaster risk in your locality?
31. If yes, how does land use/land cover change in your area contribute for flooding disaster risk?
32. What land management practices have been employed to cope with natural disasters like flooding disaster risk in your locality?
33. What are the economic (production) effects of climate change in your area?
34. What are the social effects of climate change in your area?
35. What are the environmental effects of climate change in your area?
36. How are you adapting to negative impacts of changes in climatic parameters?
37. What challenges for adaptation to climate change did you experience in your area?

Tool three: Focus group discussion checklist for urban communities

Name of the Village: -----

Focus Group Category (Male FGD/Female FGD):-----

The following checklists were used during the focus group discussion sessions:

1. People's major livelihood activities, how they are organized.
2. Socio-economic facilities that exist in the area (health facilities, markets, banks, waste tipping sites, drinking water supply, cooperative unions, schools etc) and distances/locations; costs (if any) for payment for services facilities. Problems associated with the facilities.
3. Land tenure and land acquisition. How is land acquired, cost of land, problems related to land ownership and management.
4. Urbanflooding andWaste collection: how is it organized and forms of contribution if any?
5. People's perception of urban flooding. What perceptions do they hold regardingcauses and impacts of urban flooding? What solutions are available (policy, strategy, structural organization, legal issues for law enforcement)?Common diseases associated with urban flooding that are prevalent in the area. A Five-stepprocess will be employed to articulate vulnerability of urban communities to urban flooding risk.
6. Progress in solving urban flooding in Ambo town. What else could be done if the urban flooding problem continues?
7. Why don't low-income communities act to reduce urban flooding disaster risk in Ambo town?
8. What are the main adaptation options of the people affected by floods?
9. What are the factors influencing successful adaptation?
10. How do you know areas that will be affected by flooding in the community?
11. Are there signs to show that flooding will occur soon?
12. If yes, what are some of the sign that indicate that flooding will occur?
13. How did you know about the signs that show that flooding will occur soon? (a) stories (b)

experience (c) others

14. What do you do to avoid the flood from destroying your properties?

15. How does the community reduce the effect of flooding?

16. Do these preventive measures help? (a) Yes (b) No

17. What other measures have you used in reducing the impacts of flooding in this community?

18. In your own view, are these measures effective? (a) Yes (b) No

19. Suggest ways to improve the measures used in managing flood in the community

20. Main adaptation options of the people affected by floods;

21. Individual and community level adaptive and planning strategies(ex-ante and ex-post strategies) responding to the crucial impact of urban flooding in Ambo town;

22. Different stages and factors that influence the success of an urban flooding adaptation process in Ambo town;

23. Different safety nets available to urban communities;

24. Key factors that determine the differences in outcomes; and

25. Appropriate policy measures to enhance people's adaptive capacity in a sustainable manner.

26. How does flooding affect health outcomes?

27. Who is vulnerable to the health impacts and how do they respond?

28. How do health systems and other services prevent or reduce health impacts, and maintain services during floods?

29. What can enhance adaptation in the face of increased health risks posed by flooding?

30. Community profile for urban flooding impacts on water and sanitation sector in Ambo town

Impacts on Water and sanitation Sector	Impacts on Livelihoods

31. Community profile for urban flooding impacts on transport sector in Ambo town

Impacts on Water and sanitation Sector	Impacts on Livelihoods

32. Community profile for urban flooding impacts on health sector in Ambo town

Impacts on Water and sanitation Sector	Impacts on Livelihoods

33. Community profile for urban flooding impacts on energy sector in Ambo town

Impacts on Water and sanitation Sector	Impacts on Livelihoods

34. Resource table on best-practice community-based climate change adaptation experiences in Ambo Town (Local Communities' Perspective)

Vulnerable Sectors	Impacts of Climate Variability	Adaptation Measures

35. What are the principal natural hazards faced by local communities in Ambo town?
36. What are the major impacts of these hazards and which elements/groups of the system/population are most vulnerable to these hazards?
37. Why are these elements/groups particularly vulnerable?
38. What measures would reduce the vulnerability of these elements/groups?
39. What are the factors that determine whether these measures are taken?
40. Can we assess these factors in order to measure the capacity of the system population to implement these measures?
41. What are the external and internal barriers to the implementation of these measures?
42. How can capacity constraints be removed from key barriers to adaptation?
43. List down the climate hazards in Ambo town (Hint: Floods, droughts/water stress, wind storms, heat waves, cold waves, extreme rainfall events, hail storms, dust storms, etc.)
44. Develop local criteria to prioritize among the climate hazards
45. Conduct a pair-wise matrix ranking exercise based on the locally developed criteria.
46. Discuss on the prioritized impacts and build consensus.
47. Conduct seasonal calendar on seasonal occurrence of climate hazards in Ambo town.

Tool four: Key informant interview checklists for urban planners in Ambo town

The following checklists were used in the process of interviewing urban planners in Ambo town

1. Urban planners' perception on autonomous adaptation to urban flooding (households carrying out adaptation to urban flooding? households better managing solid wastes, households voluntarily relocated from areas which are very vulnerable to negative impacts of urban flooding? people trying to reduce their electricity consumption and showing willingness at community level to reduce greenhouse gas emissions? Any evacuation strategy by urban households or communities?)
 2. Narrate the national, regional, zonal, and local, Urban flooding adaptation institutional responses in Ethiopia.
 3. What is the institutional structure for urban flooding risk management in Ethiopia from national level to town level?
 4. Vulnerable People, Places and Sectors
 5. The Five key characteristics of local adaptive capacity
- Adaptive capacity of Ambo town municipality was assessed based on the following five key characteristics of local adaptive capacity:

- **The asset base:** Are key assets available for the town administration to respond to urban flooding? If yes/no, how?

- **Institutions and entitlements:** Is there an appropriate and evolving institutional environment that allows fair access and entitlement to key assets and capitals in Ambo town? If yes/no, how?
- **Knowledge and information:** Does the town's administration have ability to collect, analyse, and disseminate knowledge and information in support of adaptation and urban flooding risk management activities? If yes/no, how?
- **Innovation:** Is the town administration capable to create enabling environment to foster innovations, experimentation, and the ability to explore niche solutions in order to take new opportunities? If yes/no, how?
- **Flexible and forward looking decision-making and governance:** Is the urban governance system of Ambo town able to anticipate, incorporate, and respond changes with regard to its governance structure and future planning? If yes/no, how?

6. Enablers and barriers to governance of urban flooding risk reduction in Ambo town

- **Political enablers and barriers:** what are the political enablers and barriers for urban flooding risk governance in Ambo town?
- **Socio-economic enablers and barriers:** What are the socio-economic enablers and barriers for urban flooding risk governance in Ambo town?
- **Socio-cultural enablers and barriers:** What are the socio-cultural enablers and barriers for urban flooding risk governance in Ambo town?
- **Institutional enablers and barriers:** What are the institutional enablers and barriers for urban flooding risk governance in Ambo town?
- **Bio-Physical enablers and barriers:** What are the bio-physical enablers and barriers for urban flooding risk governance in Ambo town?

7. Governance of urban flooding risk reduction in Ambo town

- **Political Support & Leadership:** is there evidence of strong commitment of High-level government leadership in formulating & implementing city's urban flooding management initiative?
- **Institutional Capacity:** is there a dedicated city department unit or task-force or council or equivalent body to govern urban flooding management process in Ambo town?
- **Awareness & Participation:** Does the urban flooding management process involve participation from key actors, (academic and scientific organizations, community-based organizations and small business, government agencies, international NGOs, UN and international financial institutions, & large scale industry or business etc.?)
- What are the institutional Challenges of urban flooding governance in Ambo town? (human resources, financial constraints, and logistical constraints).

8. The urgency and necessity of tackling flood risk before an event and to help in dealing with an actual flooding

- What impact does flooding have on urban areas of Ambo town?
- Who and what are affected and for how long in Ambo town?
- How can resources be targeted to protect those most vulnerable?
- What effect does urbanization have on flood risk in Ambo town
- What effect does anthropogenic climate change have on flood risk in Ambo?
- What effect does population growth and settlement pattern have on flood risk in Ambo town?
- What effect does governance failure have on flood risk in Ambo town?
- What effect does poor adaptive capacity have on flood risk in Ambo town?

Tool five: Checklist for Personal Observation

The following checklists were used in the process of conducting personal observation:

1. Observable causes and effects of flooding in Ambo town and Huluka watershed
2. Observable causes and effects of land use/land cover change in Huluka watershed
3. Natural environment in Huluka watershed
4. Observable vulnerability factors in Huluka watershed
5. Livelihood strategies and local adaptation practices in Ambo town and Huluka watershed.

Tool six: Multi_criteria_pairwise_matrix ranking of flood hazard contributing factors in Huluka Watershed where Ambo Town is situated (key informant interview checklist for local residents and experts)

DESCRIPTION OF FLOOD CAUSING FACTORS

The flooding hazard factors were determined by literature review, personal observation, and discussion with experts and local residents. Accordingly, Land use/land cover, elevation, slope, drainage density, soil, and rainfall were considered as important flooding hazard factors in Ambo town's watershed. Description of each factor is presented hereunder to help you get some clue in the ranking process.

1. **Land Use/Land Cover Factor:** Many scholars in the field of flooding risk management attest that land use/land cover change is one of the major contributor of flooding as urban expansion increases, impervious cover increases and forest cover decreases in urban areas contributing to increase in run-off (Tucci, 2007; Jha et al., 2012; Fura, 2013; Mngutyo & Ogwuche, 2013; Migosi, 2014).

2. **Slope Factor:** The slope is the ratio of steepness or the degree of inclination of a feature relative to the horizontal plane (Rimba et al., 2017). Slope is an important indicator of surface zones, which are highly prone to flooding. Slope is a major factor in determining the rate and duration of water flow. On the flatter surface, water is moving more slowly, collects longer and accumulates so these areas are riskier with respect to the occurrence of floods in relation to the steeper surfaces (Gigović et al., 2017; Rimba et al., 2017).

3. **Rainfall Factor:** Generally, a warmer atmosphere can hold more water vapour, which may increase heavy precipitation and therefore floods (Hall et al., 2014; Ouma & Tateishi, 2014). More extreme rainfall means more likelihood of floods, particularly flash floods (Few et al., 2004; Guo et al., 2014). Moreover, flooding is one of the most widespread of climatic hazards and poses multiple risks to human health (Andjelkovic, 2001; Few et al., 2004; Dang et al., 2011).

4. Drainage Density Factor: Drainage density (DD) a fundamental concept in hydrologic analysis is defined as the ratio of the length of drainage per basin area. Drainage density is controlled by permeability, erodability of surface materials, vegetation, slope and time. Flooding in Africa has been attributed to inadequate drainage causing overland flow and poor waste collection which can block drainage and water channels causing overland and river (fluvial) flooding (Few et al., 2004; Tucci, 2007; Rimba et al., 2017). Drainage density is an inverse function of infiltration. Greater drainage density indicates high runoff for basin area along with erodible geologic materials, and less prone to flood. Thus, the rating for drainage density decreases with increasing drainage density(Chibssa, 2007; Wondim, 2016). The drainage density of the watershed is calculated as (Ouma & Tateishi, 2014):

$$D = L / A \dots\dots\dots 3$$

, where, *D* = drainage density of watershed; *L* = total length of drainage channel in watershed (km); *A* = total area of watershed (km²).

5. Soil Factor: The chance of flood hazard increases with decrease in soil infiltration capacity, which causes increase in surface runoff. When water is supplied at a rate that exceeds the soil’s infiltration capacity, it moves down slope as runoff on sloping land, and can lead to flooding (Ouma & Tateishi, 2014).

6. Elevation Factor: Elevation has a key role in controlling the movement of the overflow direction and in the depth of the water level(Gigović et al., 2017).

DESCRIPTION OF ANALYTICAL HIERARCH PROCESS (AHP)

The analytical hierarchy process (AHP) is a weight evaluation method which, with regard to the development of weights has already been called one of the most promising techniques (Bathrellos et al., 2012).AHP is a multi-criteria, mathematically based technique that combines qualitative and quantitative factors for ranking and evaluating alternative scenarios, among which the best solution is ultimately chosen. The major concept behind the AHP is the implementation of a hierarchical representation of a decision-making problem and the reduction of the complex problem into pair-wise comparisons. The GIS is a very useful utility that enables the combined used of spatial multi-criteria methods of decision making (Bathrellos et al., 2012).

The purpose of the AHP is to quantify the qualitative preferences among components or subcomponents as well as indicators or categories. The pairwise comparison of a set of objects (either criteria or alternatives) is used to evaluate interactive weights to the components. The scoring of pairwise judgments is based on the rule of Saaty (author) with a 9-point system from 1 (in case of two activities contributing equally to the objective) to 9 (in case of the evidence strongly favoring one activity over another). The other scores such as point 3 refers to weak importance, point 5 is assigned to obvious preference, point 7 for a case of strong significance, and the even numbers, 2, 4, 6, and 8, are used when a compromise is needed between the odd numbers (Dang et al., 2011).

The major concept behind the AHP is the implementation of a hierarchical representation of a decision-making problem and the reduction of the complex problem into pair-wise comparisons. The first step in the AHP is the computation of the pair-wise comparison matrix, where each entry represents the relative significance of a factor to the others. The relative importance between two factors is measured according to a numerical scale from 1 to 9. The correlation between the numerical values and the intensity of importance is the following: 1 = equal importance, 2 = weak or slight, 3 = moderate importance, 4 = moderate plus, 5 = strong importance, 6 = strong plus, 7 = very strong, 8 = very, very strong, 9 = extreme importance (Bathrellos et al., 2012). It is this first step which required the PhD candidate to undertake multi-criteria pair-wise ranking of flood hazard contributing factors underpinned by rational support of well experienced researchers in the research area to enable him reduce subjectivity by taking the average of the ratings of the involved researchers. Hence, I kindly request you to compare the flood hazard contributing factors based on the above mentioned numerical scale from 1 to 9 in the following table.

Remark: number 1 was filled as the factor can not be compared with itself. You are kindly requested to fill only the spaces with no color/not shaded. The shaded cells will be filled by the PhD candidate as these cells will be filled with the inverse (**Examples:** 1/2, 1/3, 1/4, 1/.....1/9) of what the researchers are going to fill. Put the abbreviations for the factor you favor

compared to other factor with the rate you give between 1 and 9 (**Examples: 2S, 3RF, 5DD, 3LC, 7E, 9ST**). Example done by the PhD Candidate is presented in table 2 below.

MULTI_CRITERIA_PAIRWISE_MATRIX RANKING OF FLOOD HAZARD CONTRIBUTING FACTORS IN HULUKA WATERSHED WHERE AMBO TOWN IS SITUATED (KEY INFORMANT INTERVIEW, AMBO UNIVERSITY)

Table 1. Multi_criteria_pairwise_matrix ranking of flood hazard contributing factors by Researchers from Ambo University

Flood Hazard Factors	Land Cover (LC)	Slope (S)	Soil Type(ST)	Rainfall (RF)	Drainage Density(DD)	Elevation(E)
Land Cover	1					
Slope		1				
Soil Type			1			
Rainfall				1		
Drainage Density					1	
Elevation						1
Total						

Table 2. Multi_criteria_pairwise_matrix ranking of flood hazard contributing factors (Example by the PhD candidate_Gemechu Shale Ogato).

Flood Hazard Factors	Rainfall(RF)	Land Cover(LC)	Soil Type(ST)	Slope(S)	Drainage Density(DD)	Elevation(E)
Rainfall	1	RF (3)	RF(3)	RF(5)	RF(7)	RF(9)
Land Cover	0.33	1	LC(3)	LC (3)	LC(5)	LC(7)
Soil Type	0.33	0.33	1	ST(3)	ST(3)	ST(5)
Slope	0.2	0.33	0.33	1	SI(3)	SI(5)
Drainage Density	0.14	0.2	0.33	0.33	1	DD(3)
Elevation	0.11	0.14	0.2	0.2	0.33	1
Total	2.11	5	7.86	12.53	19.33	30