Disaster Risk Assessment and Mapping Using Geospatial Technology in the Lowlands of Bale & East Bale Zones.

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DECLARATION

(FOR RESEARCH REPORT)

Researchers:- I/We, the undersigned, solemnly declare that this RESEARCH REPORT entitled "**Assessing disaster risk assessment using integrated Remote sensing and GIS based AHP in the lowlands of Bale & east Bale zones, South East Ethiopia",** funded by and carried out in Madda Walabu University under the ARTTCE Vice President Office and the Research, Publication, Ethics & Extension Directorate. I assert that the statements made and conclusions drawn are the outcome of the research/project work. I further declare that to the best of my knowledge and belief the project report does not contain part of any research work which has been previously conducted, published or submitted for the award of a degree/diploma/certificate in Madda Walabu University or any other University. I/We am/are aware that I/we will be held accountable.

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Abbreviation/Acronyms

AHP	Analytical Hierarchical Process
FAO	Food and Agricultural Organization
GDP	Growth Domestic Product
GIS	Geographic Information System
GPS	Global Positioning System
LULC	Land Use Land Cover
MCDA	Multicriteria Decision Making
MCE	Multicriteria Evaluation
NGOs	Non-Government Organizations
OLI	Operational Land Imager
PAP	Pastoral and Agro-pastoral
USGS	United States Geological Survey

Abstract

Disasters are a serious disruption of the functioning of a community or a society causing widespread human, material, economic or environmental losses which exceed the ability of the affected community or society to cope using its own resources' Damage from natural disasters is increasing worldwide, providing an impetus to hazard researchers to develop new tools to reduce economic losses and injuries from future disasters. Natural and man-made disasters are prevailing in Ethiopia mainly due to drought, floods, landslides, earthquake, volcanic eruptions, and disease epidemics. Although many studies involving hazard mapping have been conducted and produced valuable hazard maps, these are usually for one single or specific hazard only. Therefore, the aim of allocating and regulating land uses in line with managing multiple risks at the same time cannot be fully achieved. Therefore, it is vital to conduct study on Disaster risk assessment and mapping using integrated Remote sensing and GIS based AHP in the lowlands of Bale & east Bale zones. To meet the objective the study was use descriptive and GIS-based empirical research design. For non-spatial data the study was used both Primary and secondary data to assess disaster management practice in the study area. Primary data was obtained from respondents through interviews, FGD and questionnaires. From spatial data the study was used Landsat 8 Operational Land Imager (OLI) image of 2024 downloaded from USGS website to conduct Land-use/Land-Cover map and invasive /pest species prone area, whereas MODIS data to perform NDVI for identifying drought prone areas and for flood hazard mapping was computed using slope, drainage density, soil type, and land use land cover. Accordingly, the study revealed that 4538 km^2 of the study area was very high flood hazard area. Whereas, high, moderately, low and very low flood hazard area were covered an area of 11082, 14219,11695 and 3783 km^2, respectively. Multi hazard area assessment level was produced by hazard generating maps; those were flood, drought, and Prosopis juliflora distribution in the study area. The multi disaster area were classified as very high, high, moderate, low and very low respectively. Finaly, the study revealed that 3406 km^2 of the study area was very high multi disaster area. Whereas, high, moderately, low and very low were covered an area of 7281, 13482,13849 and 7299 km^2, respectively. Therefore, the study recommended that formulate clear evacuation strategies for areas at high risk of disasters to ensure the safety and preparedness of residents during emergencies and improve inter-agency collaboration in disaster management and strengthen community training programs to build resilience.

Keywords: AHP, Disaster; GIS; NDVI

1. INTRODUCTION

1.1. Background of the study

Disasters are a serious disruption of the functioning of a community or a society causing widespread human, material, economic or environmental losses which exceed the ability of the affected community or society to cope using its own resources' Natural and technological disasters affect approximately 190 million people worldwide each year, resulting in over 77 000 deaths (WHO,2015). It is a natural phenomenon or a combination of natural phenomena can cause many losses of lives and damage to the property. Almost no part of the earth's surface is free from the impact of natural hazards. Though, it may not be feasible to control nature and to stop the progress of natural phenomena but the efforts could be made to avoid disasters and alleviate their effects on human lives, infrastructure and property. It is almost impossible to prevent the occurrence of natural disasters and their damages. However, it is possible to reduce the impact of disasters by adopting suitable disaster mitigation strategies.

Drought, Floods, epidemics, landslides and other natural disasters can destroy communities with already fragile infrastructure and poorly developed livelihoods. They often lack diversified livelihoods, highly dependent on climate sensitive activities, lack safe house or very rural villages, clean water supplies, and have little access to health and other services. As a result, communities can suffer widespread disease, shortages in food, water and basic necessities. Hence the change and variability of climate increases frequencies of disaster, which intern affect the livelihood of poor communities (Demissie *et al*.,2010)

GIS technology provides effective tools for the handling, integrating and visualizing diverse spatial data sets (Parsons et.al.,2000). The use of earth observation (EO) products and geo information systems (GIS) has become an integrated, well developed and successful tool in disaster risk management. New GIS techniques, in particular, are revolutionizing the potential capacity to analyze hazards, vulnerability and risks, and plan for disasters. The assessment of multi-hazards and the subsequent risk assessment is a very data intensive procedure. The availability of certain types of (spatial) data can be one of the main limitations for carrying out specific types of analysis.

The AHP method, suggested by Saaty (1980), has become a popular tool for multi-criteria decision-making. It supports decision-makers to make the best decision, by reducing complex decisions to a series of comparative pairs and synthesizing the results.

The AHP disaggregates a complex decision problem into different hierarchical levels. This method allows quantifying opinions and transforming them into a coherent decision model (Saaty 1980).

One multi-attribute technique that has been incorporated into the GIS-based landslide analysis procedures is the Analytical Hierarchy Process that presented by Saaty (Saaty 1977). The study intended to conduct Climate and Human induced Disaster risk assessment using integrated Remete sensing and GIS based AHP in the lowlands of Bale & east Bale zones.

Ethiopia is highly vulnerable to a wide range of disasters. Out of many disasters, drought, flood, human and livestock epidemics, crop pests, as well as conflict, are main. From other disasters, drought remains the country‘s leading hazard; while the flood is second next.. Even though Ethiopia has a history of recurrent droughts that spans back to the 1970s, its magnitude, frequency, and impacts in affected areas have resulted in the severe expansion of desertification. This phenomenon is explained by increased climate variability, deforestation, land degradation, settlement patterns and rapid annual population growth rate (DRMESMF, 2011).

1.2. Statement of the Problem

Now adays, the world is facing disasters on an unprecedented scale: millions of people are affected by natural disasters globally each year and in the last decade, more than 80% of all disaster-related deaths were caused by natural hazards. About 95 percent of the disaster related casualties occur in developing countries, where more than 4.200 million people live. Economic losses attributable to natural hazards in developing countries may represent as much as 10% of their gross national product (WHO,2015).

Damage from natural disasters is increasing worldwide, providing an impetus to hazard researchers to develop new tools to reduce economic losses and injuries from future disasters. Natural and man-made disasters are prevailing in Ethiopia mainly due to drought, floods, landslides, earthquake, volcanic eruptions, and disease epidemics. In fact, in 2021, the bale was hit by natural disasters of drought, endemic disease and emerging diseases. However, within the last decade, increasing trend in disaster occurrence and loss has also been observed in various woredas of the bale and east bale zone.

Natural hazard risk assessment generally focuses on a single hazard type, such as earthquakes, landslides, or floods. However, most locations are simultaneously at risk to multiple, interacting hazards that generate cascading effects or synergies (Balew et.al.,2020)

The most commonly used weighting methods in current natural disaster risk evaluation studies are subjective weights represented by the expert scoring method and analysis hierarchical process (AHP) (Beccari, 2016). The subjectivity is the biggest shortcoming of the method, which relies heavily on the experience of decision-makers (Cutter et al., 2008; Yankson et al., 2017)

There is a tremendous development of different methodologies of producing hazard maps and models in the last decade. Uddin et al. (2013). Their works positively showed that the capabilities of GIS integrated with MCE technique could be a highly potential approach addressing natural disasters and would entail the active participation of experts and even the decision-makers in land use planning and mapping. Thus, even in the advances of decision-making approaches, the use of AHP has been applied more frequently, incorporating spatial analysis using GIS (Psomas et al., 2018), including natural hazards susceptibility mapping.

The advantage of using the MCE technique is that it can combine and compare spatially related criteria. Its goal is to integrate information from multiple criteria to produce an output map of suitability levels (Lai et al., 2013).

Although many studies involving hazard mapping have been conducted and produced valuable hazard maps, these are usually for one single or specific hazard only. Therefore, the aim of allocating and regulating land uses in line with managing multiple risks at the same time cannot be fully achieved. Therefore, it is vital to conduct study on Disaster risk assessment using integrated Remete sensing and GIS based AHP in the lowlands of Bale & east Bale zones.

1.3. **Research Objective**

1.3.1. General Objective

The general objective of the study is to assess disaster risk assessment using integrated Remote sensing and GIS based AHP in the lowlands of Bale & east Bale zones, South East Ethiopia.

1.3.2. **Specific Objectives**

- To assess the major types of disaster in the study area
- To develop multi disaster risk map of the study area
- To assess disaster risk management practice in the study area.

1.4. **Significance of the study**

Multi-disaster risk assessment and mapping in the Bale and East Bale Zones' lowlands is essential for understanding hazard patterns and vulnerability distributions. Using geospatial technology, authorities can establish real-time monitoring and early warning systems that enable effective disaster preparedness and response strategies. This comprehensive approach allows local governments and communities to develop targeted interventions for specific high-risk areas.

The implementation of disaster risk mapping helps ensure sustainable development by identifying areas unsuitable for human activities and infrastructure development. This proactive approach, supported by accurate geospatial data, aligns with international frameworks like the Sendai Framework for Disaster Risk Reduction. The system helps minimize economic losses by protecting property and infrastructure while ensuring efficient resource allocation in building resilient communities.

The disaster management framework facilitates effective emergency response through timely rescue, relief, and rehabilitation efforts while building local capacity to cope with hazards. This approach aims to strengthen community resilience, reduce vulnerability, and minimize both humanitarian and economic impacts. The findings from such assessments are particularly valuable for stakeholders, including NGOs and local authorities, in designing and implementing effective disaster risk reduction programs that enhance food security and support economic development.

1.5. Scope of the study

The study geographically delimited to Bale & east Bale zone of Oromia regional state. The scope of this study will be delimited thematically on disaster risk assessment using integrated remote sensing and GIS based AHP in the lowlands of Bale & east Bale zone, south east Ethiopia. For the purpose of standardized precipitation index (SPI) the study will be used thirty-three years rainfall data from 1990 – 2023.The study will use descriptive research design with qualitative and quantitative research approach. The study will use both spatial & aspatial data with purposive and simple random sampling techniques.

1.6. Organization of the study

This research work organized into five chapters. The first chapter encompasses the introduction part that includes background of the study, statement of the problem, significance and scope of the study. The second chapter is about reviews of related literatures. The third chapter contained the research methodology that encompasses the research approach and design, sampling design, data source, data collection instruments and methods of data analysis. The fourth and fifth chapters deals with data presentation, analysis and interpretation and conclusion and recommendations respectively.

2. Review of Related Literature

2.1. Concepts of Disaster

Disasters are difficult to plan and anticipate because they are innately different from common emergency events. Ethiopia has registered steady economic growth in the recent past, but it is also one of the most disaster-prone countries in Africa. (World Bank, 2010). The concept of multi-hazards was introduced by the United Nations Environment Programme through its policies on sustainable development and its call for "comprehensive investigation of multi-hazards" to plan and manage residential areas prone to natural disasters.

Studies of natural hazard risk frequently emphasize the impacts of an individual hazard, such as landslides (Althuwaynee et al., 2014; Pellicani et al., 2017), floods (Kazakis et al.,2015; Kabenge et al., 2017), earthquakes (Theilen-Willige, 2010; Dhar et al., 2017), drought (Lehner et al., 2006), sea level rise (Hinkel et al., 2014), tropical cyclones (Hoque et al., 2018), or wildfires (Adab et al., 2013). However, in reality, many locations are prone to multiple natural hazards that can occur simultaneously or manifest in a set of cascading events (Kappes et al., 2012).

Infectious diseases are a major public health problem in Ethiopia. While many infectious diseases like tuberculosis and malaria are endemic, some of them occasionally attain epidemic proportion. An epidemic refers to an increase, often sudden, in number of cases of a disease in a community clearly in excess of what is normally expected in that population. Epidemics are public health emergencies which disrupt routine health services and are major drain on resources. Epidemics include viral infections disease (mengitis, measles, dengue, polio, typhoid fever etc.) and Bacterial infectious diseases (cholera, diarrheoa etc.) The main causes for epidemic are non-availability of clean and hygienic drinking water contamination of drinking water sources, lack of awareness about sanitation, unhygienic food, overcrowding, biological conditions in addition to ecological factors. Besides direct costs in epidemic control measures and treatment of patients, the indirect costs due to negative impact on domestic and international tourism and trade can be significant.

Several factors related to microbes, environment and host susceptibility contribute to the occurrence of epidemics. Because of prevalence of these factors, developing countries are frequently affected by epidemics/ outbreaks which result in high morbidity and mortality and affect the public health and economy adversely.

2.2. GIS and Remote sensing Techniques for Disaster mapping

2.2.1. Normalized Difference Vegetation Index (NDVI)

Spatial data for drought assessment will be collected from the African real time monitoring and information system (ARTEMIS), operated by NASA and FAO, for monitoring rainfall and biomass deficiencies in the Sahel uses remote sensing data to issue early warnings to the governments of affected countries. Similarly, the African drought monitoring system based in Princeton uses in-situ data and real time remote sensing data to monitor drought condition in Africa.(http://hydrology.princeton.edu/nchaney/Africa_Drought_Monitor_Webpage/GMinterface.php).

The relationship examined between the NDVI and the drought risk map showed that there is a negative relationship between vegetation health and drought. The relationship examined between the rainfall and the drought risk map showed that there is a negative relationship between vegetation health and drought.

The NDVI is a measure of the "greenness," or vigor of vegetation. NDVI is a good indicator of green biomass, leaf area index, and patterns of production because, when sunlight strikes a plant, most of the red wavelengths in the visible portion of the spectrum (0.4–0.7 mm) are absorbed by chlorophyll in the leaves, while the cell structure of leaves reflects the majority of NIR radiation (0.7–1.1 mm). Healthy plants absorb much of the red light and reflect most NIR radiation. In general, if there is more reflected radiation in the NIR wavelengths than in the visible wavelengths, the vegetation is likely to be healthy (dense). If there is very little difference between the amount of reflected radiation in the visible and infrared wavelengths, the vegetation is probably unhealthy (sparse). However, this can also result from partially or non-vegetated surfaces. NDVI values range from −1 to +1, with values near zero indicating no green vegetation and values near +1 indicating the highest possible density of vegetation. Areas of barren rock, sand, and snow produce NDVI values of <0.1, while shrub and grassland typically produces NDVI values of 0.2–0.3, and temperate and tropical rainforests produce values in the 0.6–0.8 range.

Comparing the NDVI time series for a number of years at the same location provides information about the relative health of the vegetation in a given year. Interannual variations in the magnitude and evolution of the NDVI for a particular location are mainly governed by meteorological variables such as precipitation, temperature, and relative humidity; however, changes in land use and land cover can also cause interannual variations and trends in the NDVI.

It can be inferred that low productivity (lack of "greenness" or vigor) is caused, in part, by poor weather conditions, and that high productivity is due, in part, to favorable weather conditions. It should be noted that the interpretation of NDVI values is spatially dependent. This is because more productive ecosystems have different radiometric properties than less productive ones due to differences in climate, soil, and topography (Quiring and Ganesh, 2010). It is derived based on the known radiometric properties of plants, using visible (red) and near-infrared (NIR) radiation. NDVI is defined as:

$$NDVI = \frac{NIR - RED}{NIR + RED} \quad (1)$$

Where, NIR and RED are the reflectance in the near infrared and red bands.

2.2.2. Standardized Precipitation Index (SPI)

Standard Precipitation Index, developed by McKee et al. (1993) is the most widely used index for calibrating the magnitude and duration of drought events. According to Guttman (1998); Thavorntam and Mongkolsawat (2006) SPI is used to examine the severity and spatial patterns of drought distribution in a given region. It is designed to quantify the impacts of precipitation deficit on groundwater, reservoir storage, soil moisture, and stream flow for multiple time scales. SPI can be calculated at different time scales and hence can quantify water deficits of different duration. SPI was designed to show that it is possible to simultaneously experience wet conditions on one or more-time scales and dry conditions at another time scale. Therefore, it has been used in many studies to determine the frequency of precipitation distribution like the effect of the time scales on the drought parameters, and the spatial classification of drought patterns (Vicente-Serrano et al., 2006). According to the results of the study conducted by Ntale and Gan (2003) on each time scale of three different drought indices (PDSI, Bhalme-Mooley index, and SPI), SPI could use any time scale which would aid in measuring any type of drought in Eastern Africa.

Satellite-based remote sensing data have been applied to monitoring of desertification in Northeast Asia, mapping of land use and land cover (LULC) and the ascertainment of desertification indicators. One of the major applications of remotely sensed data obtained from Earth-orbiting satellites is change detection because of repetitive coverage at short intervals and consistent image quality. Change detection is useful in such diverse applications as land use change analysis, seasonal changes in pasture production, assessment of deforestation, study of changes in vegetation phenology and other environmental changes.

2.2.3. Spatial Multi-Criteria Decision Making

An important advantage in using a GIS to perform a spatial MCDM study is the ease with which one can develop valuation criteria based on neighborhood analysis operations. The quality of a site for a specific use often lies not only on the values of environmental variables at the site, but also on its vicinity (Pereira et al., 1993).

Spatial decision problems typically involve a large set of feasible alternatives, multiple conflicting and incommensurate evaluation criteria. The alternatives are often evaluated by a number of individuals (decision-makers, managers, stakeholders, interest groups). The individuals are typically characterized by unique preferences with respect to the relative importance of criteria on the basis of which the alternatives are evaluated. Accordingly, many spatial decision problems give rise to the GIS-based multi-criteria decision analysis. These two distinctive areas of research, GIS and MCDA, can benefit from each other (Laaribi et al., 1996; Malczewski, 1999; Thill, 1999, Chakhar and Martel, 2003; cited in Malczewski, 2006).

On the one hand, GIS techniques and procedures have an important role to play in analyzing decision problems. Indeed, GIS is often recognized 'as a decision support system involving the integration of spatially referenced data in a problem-solving environment' (Cowen, 1988). On the other hand, MCDA provides rich collection of techniques and procedures for structuring decision problems, designing, evaluating and prioritizing alternative decisions. At the most rudimentary level, GIS-MCDA can be thought of as a process that transforms and combines geographical data and value judgments (the decision-maker's preferences) to obtain information for decision making. It is in the context of the synergetic capabilities of GIS and MCDA that one can see the benefit for advancing theoretical and applied research on GISMCDA (Malczewski, 2006).

The general objective of MCDM is to assist the decision-maker in selecting the best alternative from the number of feasible choice-alternatives under the presence of multiple-choice criteria and diverse criterion priorities. The problem of multi-criterion (multi-objective) choice in decision making is the paramount challenge faced by individuals, public, and private corporations. The challenge of multi-criterion choice can be attributed to many spatial decision-making problems involving search and location/allocation of resources. These problems, often analyzed in GIS, include location kite selection for: service facilities, recreational activities, retail outlets, hazardous waste disposal sites, and critical areas for specific resource management and control practices (Jankowski, 1995).

3. Research Methodology

3.1. Study area description

The study is conducted in the lowlands of Bale zone and geographically it extends from 5° 20' 58" N to 8° 9' 29" N and 39° 12' 37" E to 42° 14' 6" E (Figure 1). The study area includes the district of Berbere, Dawe Kachen, Dawe Serer, Delo Mena, Ginir, Gura Damole, Lege Hida, Madda Walabu, Rayitu, and Seweyna. The topography of Bale lowlands dominated by deep gorges and river valleys, and flat plains, hills, and ridges. The elevation of the study area varies between 400-1500 m above sea level. The main vegetation types that exist in Bale lowlands include alpine vegetation, coniferous, podocarpus, broad-leafed, and junipers forest, woodland, savanna, and grasslands. Pastoralism is the dominant economic activity of Bale lowland communities. Besides, crop farming has some contribution to the source of livelihood. Some of the communities are also used a combination of livestock rearing and crop farming as a source of income. However, recurrent drought and uneven rainfall amount, emerging disease outbreak of camel, invasive plant species and pattern, rangeland degradation has been affecting the livelihood in the study area. (Atlas of Bale zone, 2004).

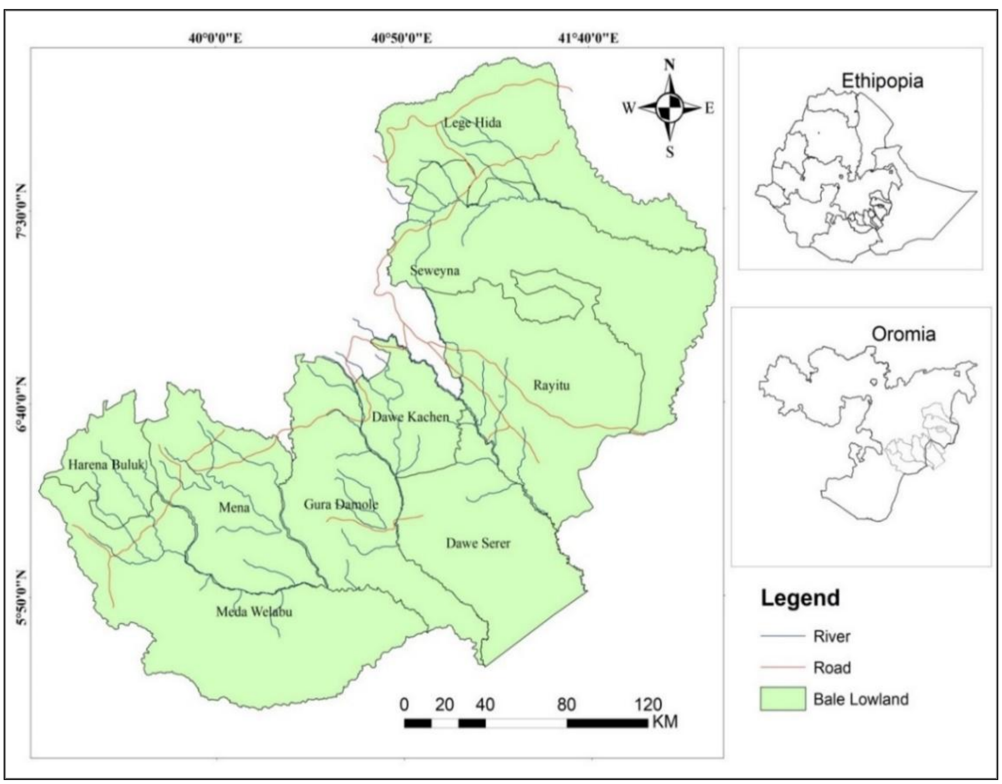

Figure 1: Location of the study area

3.2. Research Design

For each study design, the choice made by researchers must fully exploit the opportunities that the data are present, or enough data would be accessible (Park & Park, 2016). To meet the objective the study was used descriptive and GIS-based empirical research design.

3.3. Data Source and Type

The study was utilized both spatial and aspatial data. For aspatial data the study was used both Primary and secondary data to assess disaster management practice in the study area. Primary data was obtained from respondents through interviews, FGD and questionnaires. Interviews was conducted from Disaster risk management office experts and among selected elders and while the questionnaires will be used both close and open-ended questions are distributed to the Pastoral & agropastoral woredas household heads. FGD with a participant of seven member per woreda and interview will be held three individuals per woreda a total of fifty participants and thirty participants will be conducted for FGD & interview respectively. The entire questionnaires are expected to be held in the language of choice of participants. Regarding to secondary data the study will be used annual reports of disaster risk management offices and published documents related to disaster risk management.

From spatial data the study was used Landsat 8 Operational Land Imager (OLI) image of 2023 was downloaded from USGS website to conduct Land-use/Land-Cover map and invasive /pest species prone area, MODIS data was downloaded from USGS website to perform NDVI and rainfall data from metrology agency of the study area to identify drought prone areas Furthermore, epidemic and pandemic disease data was collected from woredas health sector offices.

Table 1 Data types and sources

Data type		Data Sources		
Epidemic		From woreda health offices		
GCP		GPS reading point to be collected from each LULC		
Socio economic data		From pastoralist of the woreda		
Imageries	Years	Resolution	Sources	Application
DEM		30m	ASTER	Slope
Landsat 8 (OLI)	2023	30m	USGS website	LULC, Deforestation and Invasive species.
MODIS	2023			NDVI

3.4. Target population, Sampling method and sample size selection

The total population of the study area is 792,377 population as shown by the following table. The study was employed purposive and simple random sampling methods. For the qualitative data, purposive sampling techniques was employed to select respondents. However, simple random sampling methods was applied to identify respondents for the questionnaire survey. For the purpose of this study probability sampling techniques by using simple random sampling technique was used to sample the respondents. The total sample size is calculated using yamane sampling formula.

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

Where n = sample size ,N = Population size

e= is the level of precision, i.e., e = 0.05

$$n = \frac{792{,}377}{1 + 792{,}377(0.05^2)}$$

$$n = \frac{792{,}377}{1981.9}$$

$$n = 399.8 = 400$$

3.5. Sampling Design

The proportions of sample from each house hold head for data collection from respondents are allocated in the following table below.

Table 2 Sample size proportion of the study area

District Name	HH	Sample size
Dawe Kachen	38,349	19.38
Dawe Serer	54,913	27.72
Dolo Mena	100,487	50.73
Ginir	151,722	76.59
Guradamole	35,222	17.78
Harena Buluk	97,426	49.18
Legehida	76,956	38.85
Meda Welabu	120,245	60.7
Rayitu	38,110	19.24
Seweyna	78,947	39.85
Total	792,377	400

Source: Projection for 2017

3.6.Methods of Data analysis

To achieve this objective, major disasters that are common in Ethiopia was taken into consideration. These disasters have their own factor the factors were evaluated, and then factor weight and class weight was assigned to each of the associated factors. Disaster vulnerability occurrence in the study area depends on several factors. Firstly, we determine the most important factors since it is the most important goal of this study. The study was used Drought, epidemic disease and invasive/pest species as the major disaster in the study area. Assessing these parameters is important to provide crucial information about the disaster-prone areas.
A Landsat 8 Operational Land Imager (OLI) image of January 2023 with a 30 m resolution was used to extract LULC classes to identify Invasive/ pest species prone area. Cloud and haze-free Landsat images was freely acquired during the dry season from the United States Geological Survey (USGS) web page (http://earthexplorer.usgs.gov/). Basic image preprocessing such as atmospheric correction and image enhancement was employed to improve the accuracy of image classification. A supervised maximum likelihood classifier was applied to extract LULC classes. In addition to this, frequent field observation was carried out to collect the ground truth of Land-use/Land-Cover using handheld Global Positioning System (GPS).

Remote sensing data and spectral analysis could be beneficial to map and detect *Prosopis juliflora using* spatial data of landsat image. *During* image interpretation P. juliflora was identified visually when the patch is found in dense, particularly when it is found in a wide coverage. Moreover, as P. juliflora is an evergreen tree or shrub that is found in any season, which differ from most of the other species found in the area, the spectral reflectance depicts more differently. P. juliflora invaded land have a reflectance signature colour of very bright red which was totally different from other land-use /land cover in the study area. Above all, the satellite image used for this study was captured during February which is the dry season in the area.

The drought prone area or risk zone identification is usually carried out on the basis of historic data analysis of rainfall and evaporation or from Normalized Difference Vegetation Index (NDVI) which is derived from multispectral, multi-temporal satellite imagery, combined supervised classification methods such as maximum likelihood classification (Rembold et al., 2015)

The remote-sensing based method for identification of drought prone areas (Jeyaseelan et al., 2002) uses historical vegetation index data derived from NOAA satellite series and provides spatial information on drought prone area depending on the trend in vegetation development, frequency of low development and their standard deviations.

Regarding to diseases data, the epidemic disease data was used in this study are secondary data obtained from related agencies. Secondary data consists of administrative maps, District Data in 2021-2022 obtained from the Central each district health center and livestock health posts. The information will contain certain details about disease, such as the type of disease, Month and date of occurrence, Exact area of occurrence, Number of patients. The next stage is importing study area shapefile and excel data then after, through the application of table joint the imported excel data was merged or joined with spatial data base and through opening working attribute and by application selection feature selected disease outbreak areas, accordingly. Finally, through vector overlay operations (intersect and union) finding each district that faced disease outbreaks for the consecutive two years (2021 and 2022) and total districts of each epidemic disease outbreak occurred areas.

Besides, several analytical and statistical models was used to map the spatial distribution of diseases in the study area. An initial spatial analysis of the data was based on the use of classification tools within the ArcGIS Software. These analytical tools simplify the spatial distribution of diseases at the level of each district.

We computed the frequencies of each event and generated maps showing the frequency and distribution of each event. We will categorize in to three levels based on the frequency of events -level 1, 10 or more events, level 2, 5–9 events, and level 3, less than 5 or no event

Table 3 Disaster evaluation criteria and their vulnerability classes.

Criteria	Extreme	Severe	Moderate	Slight
Drought (NDVI)	Below -50	-25 to -50	-10 to -25	0 to -10
Drought (SPI)	< -2	-1.5 to -1.99	-1 to -1.49	0 to -0.99
Invasive/pest (ha)	55-80	30-55	15- 30	0-15
Epidemic disease	>10 or more	5–9 events	5–9 events	

(Frequency of event)	events			

3.6.1. Criteria Rating and Standardization

The aforementioned factors were independently evaluated to prepare the thematic layers. The factors were reclassified in the ArcGIS 10.5 environment to rate the criteria and make each thematic layer suitable for overlay analysis. Furthermore, before the weights was assigned, each factor was standardized into four classes, such as extreme, sever, moderate and slight based on the. Criteria weights are assigned based on the literature and the nature of the environment under investigation.

Factor Reclassification. All factors were resampled to a 30 m resolution to conduct overlay analysis. Besides, the factors that are used for disaster are reclassified and standardized into four classes as shown in Table 3. Invasive species occurrence was reclassified into four different classes to evaluate their risk. Moreover, factors such as NDVI, SPI and Endemic disease was classified into extreme, sever, moderate and slight

Reclassification analysis was also conducted to extract for each criterion. In reality, pastoral and agropastoral are found under multiple disaster. To implement this reality, minimize the impacts of disaster, this study analyzed disaster risk assessment based on five criteria.

Assigning Criteria Weights. A GIS-based MCDA model was used to analyze the factors employed in this study (Figure 2). The model has three basic procedures. In the first stage of the model, each criterion was reclassified in ArcGIS, and the map was standardized to a common scale. Accordingly, the factors of drought, endemic disease, invasive species was reclassified into four classes (extreme, sever, moderate and slight). In the second stage, criteria weights were computed from a pairwise comparison matrix in the IDRISI 17 AHP environment, and the consistency ratio was derived from the matrix. AHP is one of the most commonly used approaches for multi-criteria evaluation, which used for spatial analysis and sound decision making. the evaluation process has components of goal, criteria, alternative solutions, experts, and decision making and expected decision outcomes. The AHP is very capable of managing different and complex criteria and enabling us to make better decisions. With the use of AHP, the relevant factor's relative significance was obtained after the construction of a pairwise comparison matrix (Mu and Pereyra-Rojas 2017). However, the AHP approach has some subjectivity in ranking criteria and determining weights for the criteria.

Therefore, to minimize the effect of subjectivity and achieve better weighted evaluation of this study, the AHP model was guided by the goals of the problem to be achieved, alternative solutions, experience, knowledge, and skills of researchers, the realities of the environment of the study area, and researchers' experience in the study area. In the third stage, the standardized criteria maps and their weights was combined in the weighted overly analysis. The overall methodological procedures of this study are presented in Figure 2. The figure indicates the criteria was used as input parameters. And, different GIS analyses was implemented to obtain criteria maps and a final multi disaster prone map.

The flowchart shows the sequential steps involved to carry out this study as shown in Figure 2.

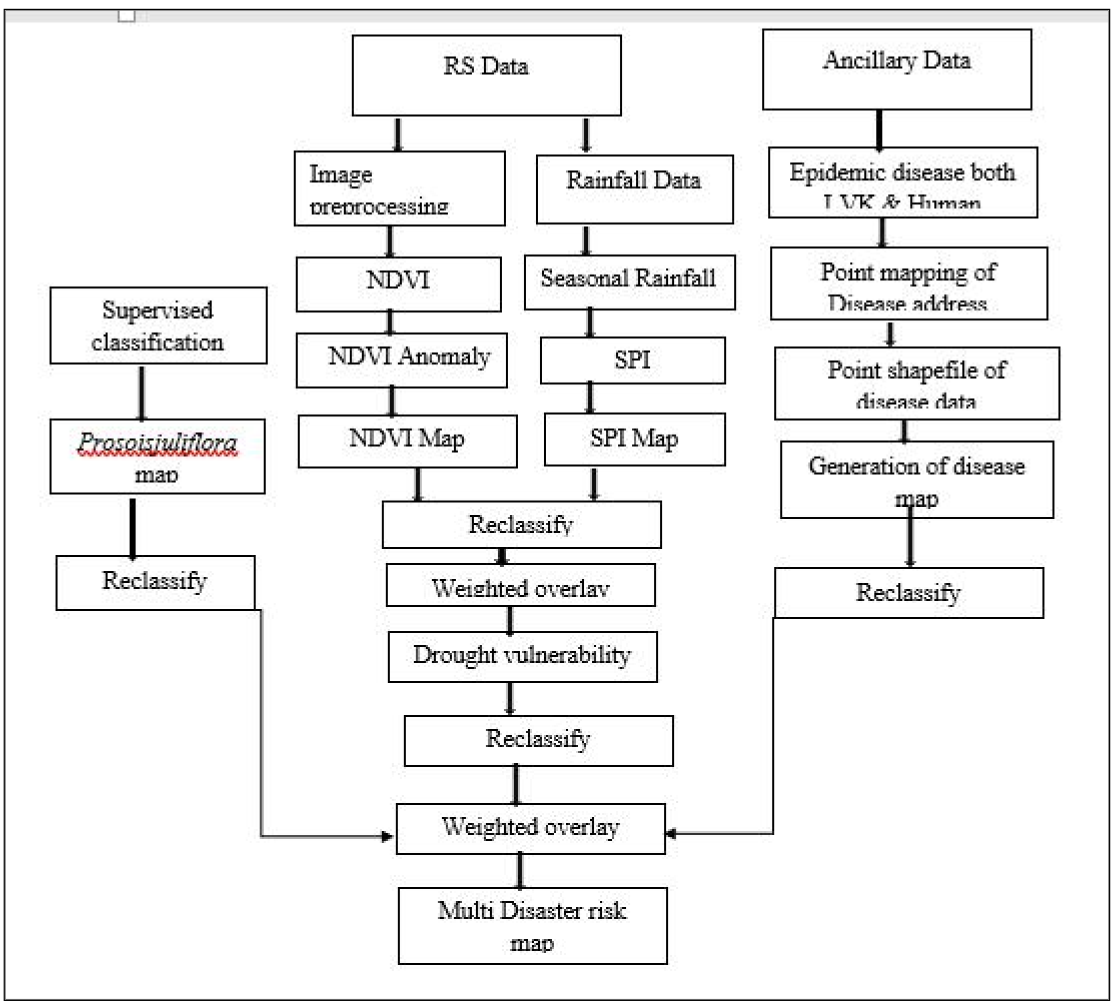

Figure 2: Methodology flow chart

4. Result and Discussion

4.1. Demographic Characteristics of the Respondents

This section presents characteristics of the respondents who were responded the questionnaires and interviewed to answer the basic questions of this study. For the purpose of this study, 400 copies of questionnaires (316 for males and 84 for female respondents) were distributed. Of these, 400 (100%) were filled in and returned back

Table 6 Socio economic characteristics of respondents

Gender		
Sex	Frequency	Percent
Male	316	79
Female	84	21
Total	400	100.0
Age		
Age Group	Frequency	Percent
20-29	57	14.2
30-39	130	32.6
40-49	61	15.3
50-59	48	12.1
60 and More	104	25.8
Total	400	100.0
Education Status		
	Frequency	Percent
Illiterate	229	57.4
First cycle (Grade 1-4)	141	35.3
Second cycle (Grades 5-8)	30	7.4

Total	400	100

Source: Questionnaire Survey 2024

The above Table 4 depicts the respondents' characteristics in terms of gender across the respondents of the study. As can be seen from the Table 4 of the total respondents, the male group constituted 316 (79%) while the females make up only 84 (21%). Therefore, the above figure indicates that the relevant data for this study were mainly obtained from male respondents. Besides, it shows that there are small numbers of female respondents in the study area. All the interviewee's respondents were male respondents.

Age is another general characteristic of the respondents considered in this study. As age distribution indicated in the above Table majority of the respondents were found within the two age categories. That is age categories "30-39years" and "60 and More years" which accounts for about 130 (32.6 %) and 104 (25.8 %) of respondents respectively. This means, out of the total 400 respondents, 234 of them found within these two age categories. The rest 61 (15.31 %), 57 (14.2%) and 48 (12.1 %) of the male respondents found in the age categories of 40-49 years, 20-29years and 50-59 ages of years, respectively.

Again, the educational levels of respondents of the study summarized in the above table. From the total 400 respondents 30 (7.4%) were second cycle (Grades 5-8), 141 (35.3%) first cycle (Grade 1-4) and others are uneducated 229 (57.4 %) (Table 4).

Table 4 Marital Status and Religion of Respondents

Marital Status		
	Frequency	Percent
Married	310	77.4
Divorced	61	15.3
Widowed	30	7.4
Total	400	100.0

Source: Questionnaire Survey 2024

As the study result shows, from 400 questionnaire respondents about 310(77.4%) of are married, 61 (15.3%) are divorced and 30 (7.4%) are widowed. This revealed that most of the respondents were married.

Table 7 respondents' occupation

Major occupation		
Occupations	Frequency	Percent
Pastoral	240	61.1
Mixed farming	160	38.9
Total	400	100.0
What is family size of your household		
Family size	Frequency	Percent
1-4	97	24.2
5-8	208	52.1
9-12	55	13.7
≥13	40	10.0
Total	400	100.0

Source: Questionnaire Survey 2024

Households were also asked to state their dominant sources of livelihood. Accordingly, the majority240 (61.1%) of respondents were dependent on livestock raring(pastoral), 160 (38.9%) of respondents were dependent of mixed farming whereby farmers practiced both crop production and animal husbandry on the same plot of land. On the other hand the key informant interview result shows that the farm land owned by the heads of household is distributed among family members. Since there are no additional alternatives economic activities, the only chance they have is to increase additional agricultural land at the expenses of vegetation. Some respondents said that the lack of other nature economic activities in their local area forced them to engage in the selling forest products and the producing timber.

The above table also depicts the size of the households per family. Of the total surveyed respondents, 208 (52.1 %) of them had a family size between of 5-8 children. About 97 (24.2%) of the respondents had a family size between 1-4 children. About 55 (13.7%) of the respondents had a family size between 9-12 children. Only 40 (10%) of the sampled households had a family size above 13 children. This study reveals that, like most parts of the country, the study area contains large families. The mean size of the HH is 6 people per household. This, in turn, indicates alongside an increase in household size, that there has been related change in the pattern of natural resource, which increases the risk of disaster area (MOA,1993).

4.2. Type of Disaster in the Study Area

According to reports released by several agencies, between 1980 and 2005, between 75 and 85 percent of the world's population that live in disaster-prone areas experienced at least one earthquake, tropical storm, flood, or drought (Excerpts from ECB3 Ethiopia, 2007). According to Backes et al. (2003), Ethiopia frequently experiences natural calamities such as earthquakes, floods, conflicts, droughts, and insect infestations. They also stated that food crises brought on by drought and violence have been frequent in Ethiopia, having a significant effect on a number of different communities there, including pastoralists and rain-fed farmers. Ethiopia is one among the community of such nations exposed to intermittent flooding and drought induced disasters that exacerbate vulnerability of the poorer section of the population (Excerpts from ECB3 Ethiopia, 2007).

Ethiopia is one of the most disaster-prone countries in Africa, with numerous small and large scale incidents including drought, famine, floods, hail storms, plant pests and insects, as well as epidemic health issues and the threat of violent conflict (Emergency Capacity Building Project, 2007). These different hazards occur with varying frequency and severity (Leaving Disasters Behind, 2007). Based on this, the study used drought, flood, disease, conflict and pest/ invasive species are listed as type of disasters in the study area. As a result, the study result shows that, about 52 % of respondents are responded that drought is the main type of disaster in the study area followed by disease and pest/ invasive species those responded by 22.75% and 17.25% respectively. And about 5.75% of the respondents responded that flood is one of the disaster type in the study area. Finally, only 2.25% of respondents responded as conflict is another type of disaster in the study area (Table 5).

Table 5 Type of Disaster

No	Type of Disaster	Frequency	Percent
1	Drought	208	52
2	Flood	23	5.75
3	Disease	91	22.75
4	Conflict	9	2.25
5	Pest/ invasive species	69	17.25
Total		**400**	**100.0**

Source: Questionnaire Survey 2024

4.2.1. Drought

Drought is inarguably one of the most challenging and complex natural disasters (Sivakumar, 2014, Van and Anne, 2015; Wilhite et al., 2007) from management perspective (Wilhite et al. 2007). It has been a part of the climate, and it has affected many countries in the world (Gutierrez et al., 2014) and this included Ethiopia and the horn of Africa and many other Sub-Saharan countries. The droughts in the 1970s were longer and more intense, and occurred most of the time in both short and long rainfall seasons.

The questionnaire respondents also responded that drought is one of the main type of disaster in the study area. This also supported by the finding of Tilahun et al. (2001) which revealed that, Ethiopian lowlands are affected by frequent existence of drought, which have eroded the resource base and aggravated the repeated food shortages caused by drought. As about 52 % (208) respondents of questioner responded, drought is the major type of disaster frequently existed in the study area.

According to the data from FGD and interview, drought leads to loss of agricultural productivity and loss of livestock's, and displacement. According to the key informants, due to absence of clear forest tenure system the forest trees of the catchment were indiscriminately destroyed there is frequent existence of drought in the study area which in turn resulted with loss of farm and livestock deaths. This is similar with Birtukan, (2014) finding, she found that the 1974 drought resulted in the death of approximately 250,000 people. Since then, the adverse climatic variability and extreme climatic events increased in the magnitude of the social, economic and environmental impacts.

The drought became more frequent in recent years and many writers gave varying recurrence period; between five and ten years (WIC, 1999) and between three and five years (O'Brien, 2016, WB, 2006), this also agree with the finding of the study. Others suggest that drought occurred every 3 to 5 and 6–8 years in northern Ethiopia and every 8–10 years for the whole country (Haile, 1988). Successive droughts hit the country in 2015 and 2016. In 2017, a torrential and exceptionally higher main season rainfall occurred covering large part of the country.

4.2.2. Disease

Disasters have been defined as ecologic troubles or severe and high-magnitude emergencies resulting in deaths, injuries, illnesses, and profound damages that cannot be successfully managed using ordinary procedures or resources and require external support (Landesman LY. 2005); this is also true in the Oromia region and the results reveal that it is similar to the study area. As about 22.75 (91) respondents of questioner responded, disease is the major type of disaster in the study area. This implies that, disease is the second major type of disaster in the study area.

Furthermore, according to Ligon BL. (2006), the major causes of communicable disease in disasters can be categorized into four areas: Infections due to contaminated food and water, respiratory infections, vector and insect borne diseases, and infections due to wounds and injuries. The most common causes of morbidity and mortality in this situation are diarrheal disease and acute respiratory infections (Waring et al., 2005). This also agreed with the findings of the study which means as the FDG and key informant interview revealed, there are disease such as contaminated water, insect borne diseases, and infections in the study area.

4.2.3. Pest/ invasive species

The other type of disaster is the Pest/ invasive species in the study area. As mentioned by Sebua S et al., (2012), plant invasion is a strong threat to the species diversity around the world during the 21st century after habitat loss, the same is true in the study area as the respondents of questionnaire responded.

According to the response of questioner about 17.25% respond pest/invasive plant species is the third type of disaster in the study area. For instance, the KI of the study area presents invasive plant species and its invasion is increasing from time to time. It is evident that during the group discussion and interview, with key informants and officials responds that the institutions have a role to address ecosystem management problem in the study area and surrounding regarding these pests.

In addition to this, KI and FGD participant responded that invasive plants such as *parthineum* and *prosopis juliflora* are highly distributed in the study area and affecting the land use of the area. They also revealed that the distribution of these invasive plant species is resulted with the replacement of pastures and farm lands with these pests and it has harmed the wellbeing of local people. Similarly, Tabosa *et al*., 92006) reported that, invasive plants has negative impacts on pastures and farm lands and it affects the socioeconomic activity of the communities directly through damages on human and animal health.

Large number species of invasive plants are introduced to native country in the world and few of these become problematic. However, invasions by invasive plants are one of the largest threats to the ecosystems of the earth, and the services. Few aggressive invasive species which are threatening biodiversity in Ethiopia and elsewhere in the world (Moyo and Fatunbi , 2010). Similar study of Tesfaye (2015) indicates that the planting of exotic tree species negatively impacted the water bodies around them. Therefore, the lowlands of the study area are damaged and dried easily.

According to Tesfay (2018), flood is a natural disaster. However human activities in many circumstances change flood behavior. Activities in the catchment such as land clearing for agriculture may increase the magnitude of flood which increases the damage to the properties and life. Among the water-related hazards, flood hazards have the most destructive impacts.

In addition to this, the finding of Tesfay (2018), floods occur whenever the capacity of the natural or manmade drainage system is unable to cope with the volume of water generated by rainfall. In Ethiopia context, the rainy season 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.

4.2.4. Flood

As Table 5 clearly shows, the majority 5.75% of the respondents replied that flood was the major type of disaster in the study area. As the key informant revealed in the study area there is flood which affect the lowland parts of the study area by destroying their farm around the river bank. This finding is similar with the findings of Tesfay (2018), which shows that, some people with low income are forced to sprawl over river bed and around the river bank. This has aggravated the flood hazard disaster in the rainy seasons. As a result he recommended that, in Ethiopia, Emergency outcomes are expected to be widespread in the northern drought and conflict-affected areas and in the pastoral flood-affected areas still recovering from drought.

The KI respondents also responded that, rainy season flooding is one of the major environmental problems of the people living in the study area. Similarly, Tesfay (2018), revealed that, rainy season flooding is one of the major environmental problems of the people living in the total Ethiopia. High flood, which is normally due to the intensive rainfall in the up lands of the watershed, sparse vegetation cover, steep slopes and low infiltration capacity of the ground surface. Finally, the FGD result shows that, the floods washed away thousands of homes, destroyed farmlands and made roads impassable. Drinking water sources were contaminated, increasing the risk of disease outbreak. This is similar with the above finding of HCEFS, (2018) which shows that, more than 165,000 people were affected by the flooding, which killed at least two people and forced more than 1,600 families to leave their homes.

4.2.5. Conflict

According to FEWS (2024), the conflict situation continues to be characterized by extensive looting of public and private property including assets and food stocks; widespread damage to critical infrastructure; disruption of markets, trade flows, and delivery of humanitarian assistance; and the displacement of 7 million people as of the end of December 2023.

Ethiopia is a conflict-prone country, characterized by ideological, religious regional, ethno-linguistic and sociological divisions (Alemayehu and Befekadu, 2003). The consequences have been devastating: loss of life and the destruction of infrastructure, and a negative impact on growth and development. At times even the very existence of the Ethiopian polity has been threatened (Alemayehu, 2002).

As a result, the study result shows that, about 225 % of respondents are responded that conflict is the main type of disaster in the study area. This statistic of respondents implies that conflict is the fifth type of disaster in the study area which responded only by 9 questionnaire respondents (Table 5). As KI and FGD agreed on, currently there is no conflict in the study area except few kebeles in the remote woredas. As a result they revealed and approved that, conflict is the almost not the major type of disaster in the study area at this time of the study in the study area. But, KI and FGD participant revealed that at a time of conflict, the local people seriously affected. They revealed that, during conflict there is disruptions farming system, displacement and lack of food as a disaster in the study area. This is similar with the finding of FEWS (2024), the expansion of fighting into important crop production areas is a serious threat to national food production and availability.

4.3. Multi Disaster Risk Mapping

4.3.1. Flood Hazard Mapping

Flooding has been highlighted as the most damaging one "Flood risk" can bear different definitions as it refers to natural disasters, depending on their adverse impacts on humans, lives, and the economy. From the flood risk management point of view, flood risk mapping is a crucial factor. Flood mapping is limited to flood-prone hazard mapping

Flood causative factors particularly in the study area were identified from literature and field survey. Accordingly, slope, drainage density, soil type, and land use land cover were listed to flood hazard. Therefore, the following factor developed for flood hazard mapping.

4.3.1.1. 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, erodibility of surface materials, vegetation, slope and time. 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. DEM was used to extract the drainage network, to calculate the drainage density of the streams.

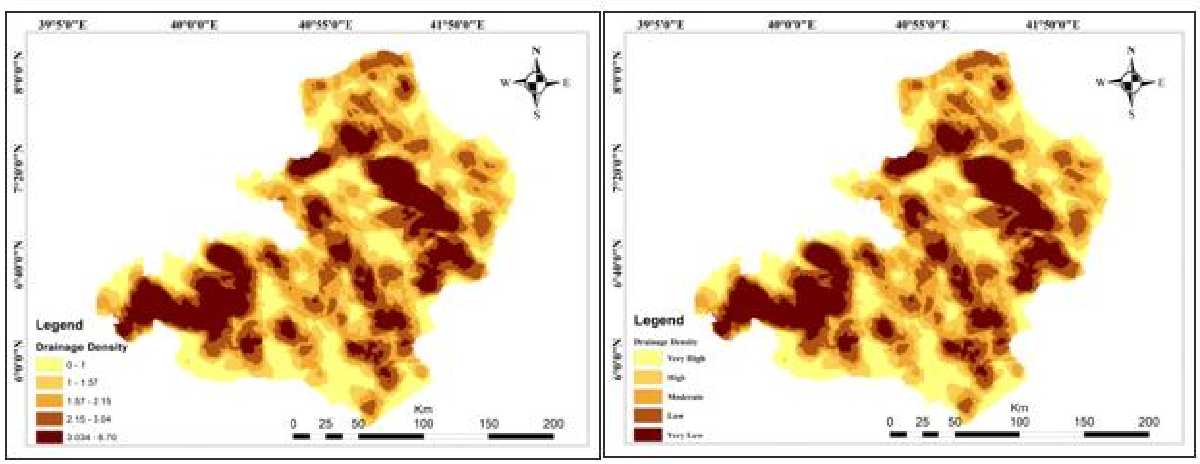

Figure 3 Drainage density class and reclassified drainage density map

4.3.1.2. Soil Type Factor

Soil data which was collected from harmonized world soil database (HWSD) was used to extract soil texture information in the ArcGIS 10.5 environment. The soil factors influencing the rate of infiltration are: sandy soils have higher saturated hydraulic conductivities than finer textured soils because of the larger pore space between the soil particles. As such, the infiltration rate of clayey soils is much lower than that of sandy soils (Ward & Robinson,1990; Maidment, 1993;).Porous soils with stable soil aggregates have higher saturated hydraulic conductivity values than soils that are compact and dense (Hill,1980).

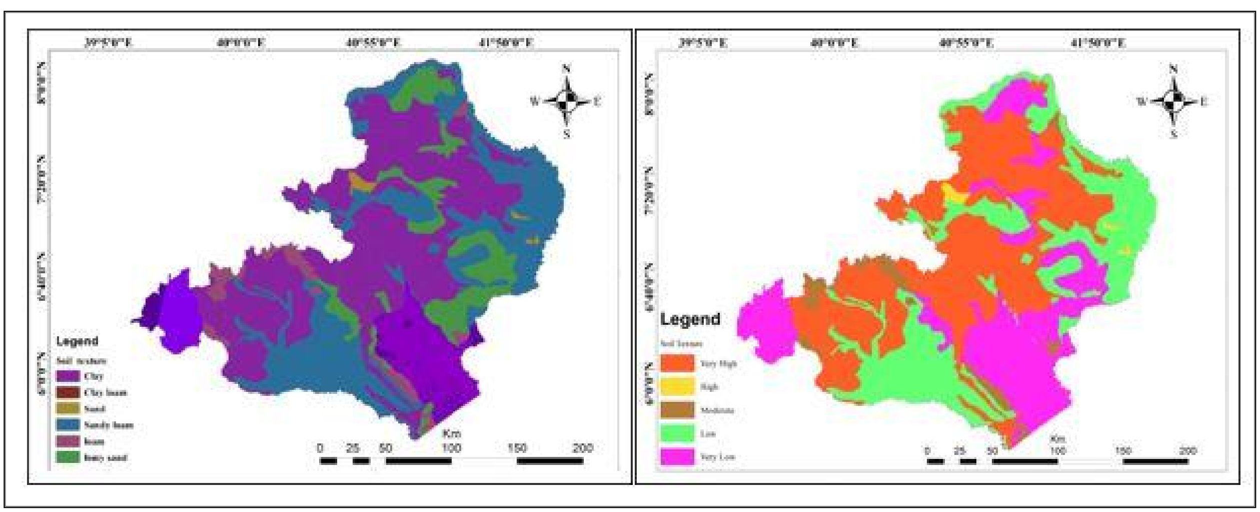

Figure 4 Soil texture map and reclassified texture map

4.3.1.3. Elevation Factor Map

Elevation plays a major role in flood hazard mapping. It has a great influence on flood hazard assessment because it governs the amount of surface runoff produced the precipitation rate and displacement velocity of water over the potential surface. Practically high rating is assigned to low elevation for the gentle gradient of the floodplain where as low rating is assigned for high elevation.

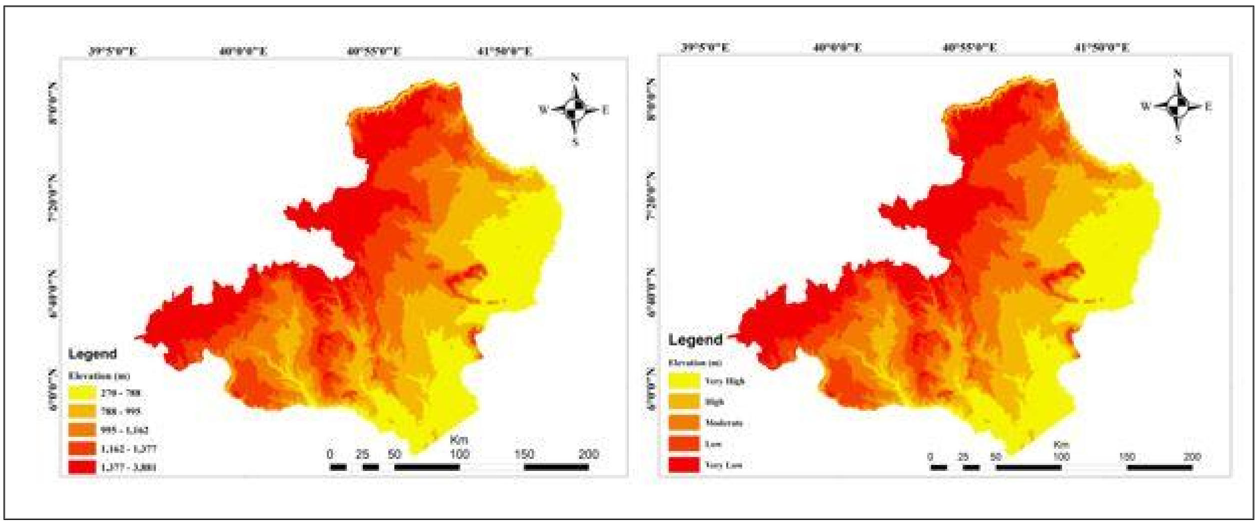

Figure 5 Elevation class and reclassified elevation map

4.3.1.4. Land Cover Factor

The land use land cover map gives the spatial extent and classification of various land use land cover of the study area. The land use land cover data combined with soil data generates the hydrologic characteristics of the study area. Land use land cover is essential influences on runoff. The study area has highly coved by shrub and grassland. Land use in the study area has been classified into six categories; forest, shrubland, grassland, cropland bare land, and settlement.

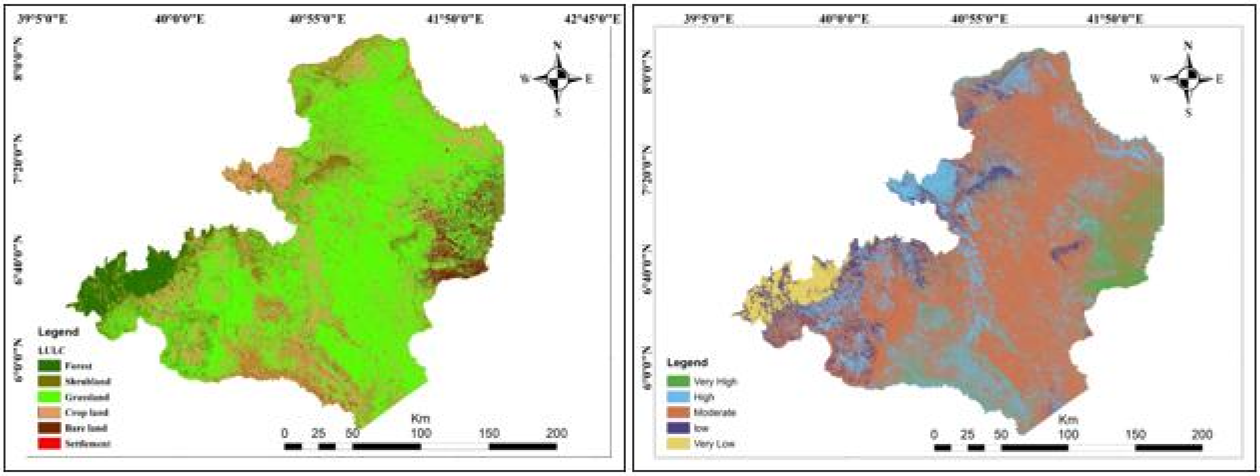

Figure 6 LULC class and reclassified LULC map

Table 6 Flood hazard evaluation criteria and their classes

Factor	Sub factor	Naming	Area (ha)
Elevation	270 – 788	Very high	9063.78
	788 – 995	High	9088.42
	995 – 1162	Moderate	9104.22
	1162 - 1377	Low	9042.83
	1377 – 3881	Very low	9018.55
Drainage density	0 – 1	Very high	8992.36
	1 – 1.5	High	8922.36
	1.57 – 2.15	Moderate	9427.36
	2.15 – 3.04	Low	9093.36
	3.04 – 8.70	Very low	8882.36
Soil	Clay, clay loam	Very high	17700
	Sand	High	3194
	Loam	Moderate	4185
	Sandy loam	Low	13313
	Loamy sand	Very low	6925
LULC	Built-up, Bare land	Very high	3547.77
	Cultivate land	High	10417.60
	Grassland	Moderate	25968.32
	Shrub land	Low	3707.37
	Forest	Very low	1676.63

4.3.1.5. Final Flood Hazard Analysis

Flood hazard analysis was computed by Weighted Sum Overlay of elevation, drainage density, land use/cover and soil types developed factors. The weights for each factor were given through discussion with concerned bodies and based on literature.

A GIS-based MCDA model was used to handle, and analyze the factors employed in this study. The model has three basic procedures. In the first stage of the model, each criterion was reclassified in ArcGIS, and the map was standardized to a common scale. Accordingly, factors of LULC, drainage density, elevation, and soil types were reclassified into five classes. In the second stage, criteria weights were computed from a pair-wise comparison matrix in IDRISI 17 AHP environment, and the consistency ratio was derived from the matrix (Table 6). In the third procedure, standardized criteria maps and their weights were combined in weighted overly analysis as explained in equation 1.

$$S = \sum_{i=1}^{n} W_i * C_i * \prod_{j=1}^{m} r_j \qquad (1)$$

This GIS-based MCDA model can be explained as given below.

$$S = ((\mathrm{LUw} \times \mathrm{LUc}) + (\mathrm{Ew} \times \mathrm{Ec}) + (\mathrm{DDw} \times \mathrm{DDc}) + (\mathrm{STw} \times \mathrm{STc})) \times (\mathrm{LUr} \times \mathrm{Er} \times \mathrm{DDr} \times \mathrm{STr} \times) \qquad (2)$$

Where: C_i represents criterion, r is the rate of i criterion, w is the weight of i criterion, $\prod$ is the product, LU (LULC), E (elevation), DD (drainage density), and ST (soil types).

Table 7 Criteria weights of the pair-wise comparison matrix

Factors	Weight
Elevation	0.6055
Drainage density	0.2355
Soil	0.0545
LULC	0.1045
Consistency ratio	0.05

Flood hazard assessment level was produced by flood generating factors; those were slope, elevation, drainage density, soil and LULC of the study area. The flood hazard area or maps were classified as very high hazard level, high hazard level, moderate hazard level, low hazard level and very low hazard threats level respectively. Accordingly, the study revealed that 4538 km^2 of the study area was very high flood hazard area. Whereas, high, moderately, low and very low flood hazard area were covered an area of 11082, 14219,11695 and 3783 km^2, respectively. (Table 8 and Figure 7).

Table 8 Final flood hazard area

Flood hazard areas	Naming	Area (ha)	Area (%)
	Very high	4538	10.01
	High	11082	24.45
	Moderate	14219	31.38
	Low	11695	25.81
	Very low	3783	8.35

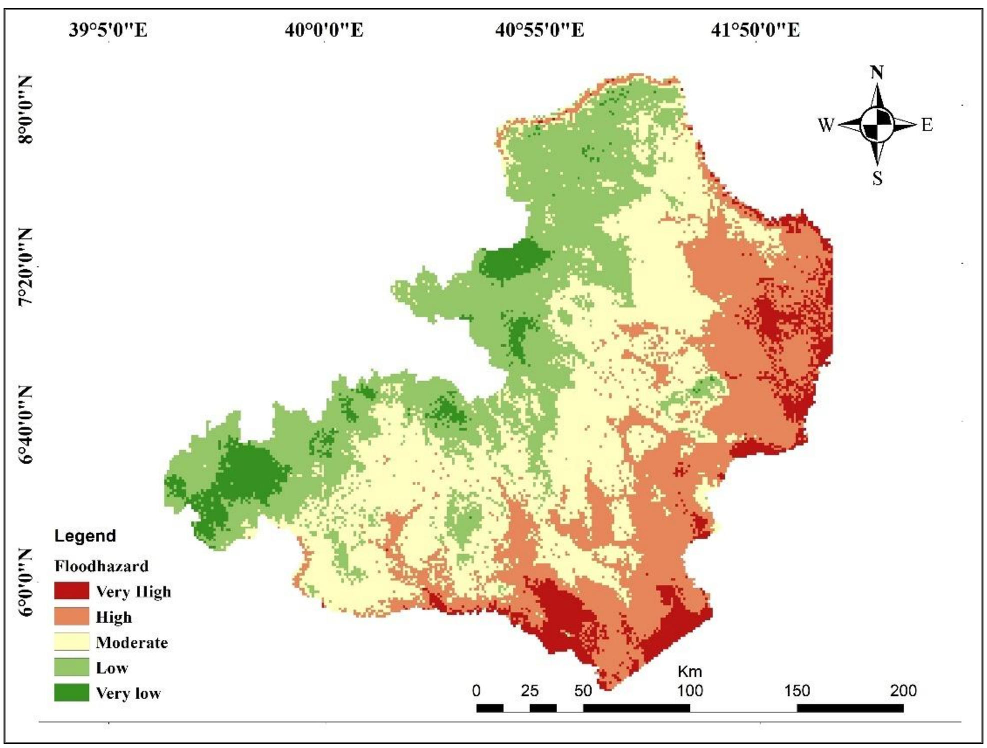

Figure 7 Final flood hazard map

4.3.2. Drought indices for drought characterization

Satellite derived drought indicators calculated from satellite-derived surface parameters have been widely used to study droughts. Normalized Difference Vegetation Index (NDVI), Vegetation Condition Index (VCI), and Temperature Condition Index (TCI) are some of the extensively used vegetation indices.

NDVI is the most commonly used vegetation index. It varies from +1 to -1. Since climate is one of the most important factors affecting vegetation condition, AVHRR- NDVI data have been used to evaluate climatic and environmental changes at regional and global scales (Ji nd Peters 2003; Singh, Roy et al. 2003; Li &Lewis et al. 2004). NDVI has been used successfully to identify stressed and damaged crops and pastures but only in homogenous terrain. In more heterogeneous terrain regions, their interpretation becomes more difficult (Vogt et al. 1998; Singh et al.2003). The study concluded that NDVI can be used as a main indicator to evaluate drought.

Accordingly the study result reviled that lowest NDVI values are recorded at Seweyna ,Rayitu and some parts of Deleomena whereas, the highest value of NDVI were recorded at Berbere and Guradamole and Ginnir. As mentioned in Tan et al., (2010), the NDVI value is greater than 0.1 for normal healthy vegetation, while for rock and soil, the NDVI values are close to zero, and water bodies give a negative reading for the NDVI value. For computing the area of each cell covered with either water, bare soil or vegetation, the raster file of the NDVI was converted to shape file in ARCGIS extension tools.

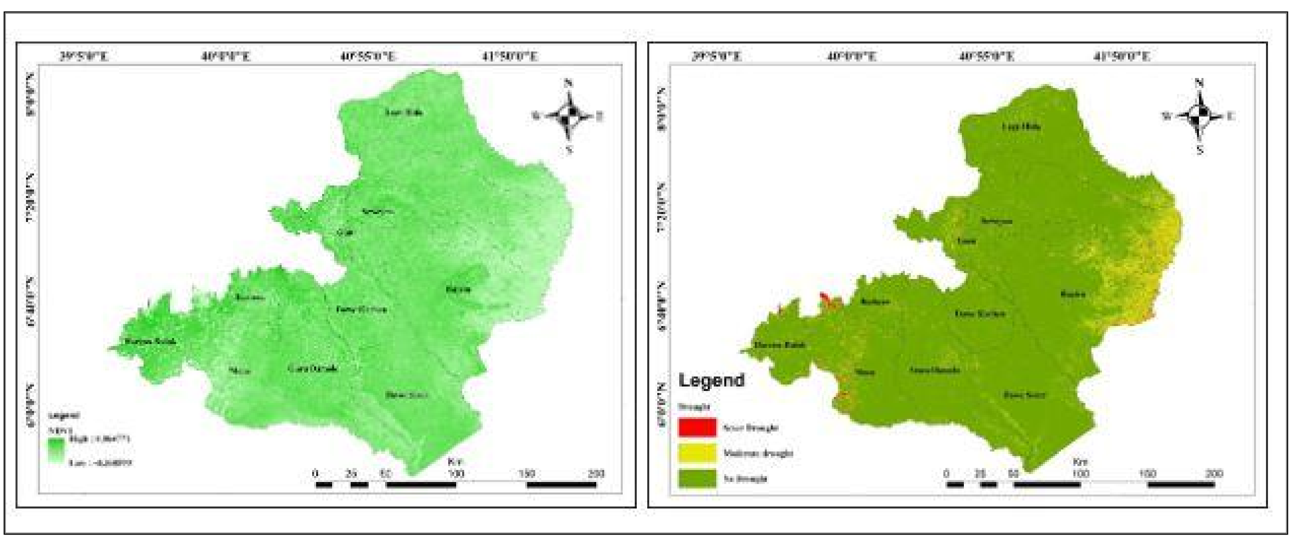

Figure 8 NDVI Map and NDVI threshold values

Using the Reclassify Tool Assign classes (e.g., severe drought, moderate drought, no drought) based on NDVI thresholds or anomalies if NDVI < 0.1: Severe drought, 0.1 ≤ NDVI < 0.2: Moderate drought and NDVI ≥ 0.2: No drought.

Table 9 NDVI threshold values and respective area

S/N	Drought	Area (ha)	Percent
1	Severe Drought	187.87	0.42
2	Moderate drought	3512.37	7.75
3	No drought	41617.57	91.83
		45317.81	100

Based on NDVI anomaly of 2023, the drought maps have been generated to show the spatial patterns of drought severity levels that ranged from no to extreme drought. In generated drought maps, green colors represent positive NDVI anomalies, indicating the normal condition; and, red, orange, yellow, white colors show negative NDVI anomalies, meaning the mild, moderate, severe and very severe drought condition, respectively.

The NDVI-based drought analysis in Bale lowlands revealed that 0.42% of the area is under severe drought, 7.75% is experiencing moderate drought, and 91.83% shows no drought. The limited extent of severe drought indicates localized hotspots of extreme vegetation stress, likely in areas with persistent water scarcity, overgrazing, or highly degraded soils. Severe drought areas, although small in coverage, often have significant impacts on local communities. These areas are typically more vulnerable due to their reliance on rainfall-dependent agriculture and limited access to alternative water sources. Studies show that localized severe droughts can result in critical food shortages and economic hardships, especially in regions where agriculture contributes significantly to livelihoods (UNICEF, 2022).

Moderate drought, affecting 7.75% of the area, points to a wider zone where vegetation shows signs of stress due to insufficient rainfall or prolonged dry periods. These regions may still sustain agricultural or grazing activities, but at reduced productivity levels. Moderate drought areas serve as a warning sign for potential progression into severe conditions if rainfall deficits persist. The European Commission (2023) highlights the compounding effects of moderate droughts, including reduced crop yields, diminished grazing capacity, and early signs of food insecurity. Interventions such as supplemental irrigation, sustainable water management, and livelihood diversification can help mitigate the risks and prevent further deterioration in these areas.

The majority of the area (91.83%) showing no drought conditions is a positive outcome, indicating relatively stable vegetation and sufficient rainfall to sustain ecological and agricultural systems. These areas provide resilience and opportunities to support the regions under drought stress. Sustainable land management practices and the integration of water harvesting techniques are essential to maintain this favorable status. As highlighted by GIZ (2023), promoting adaptive measures such as participatory rangeland management and afforestation in these regions can enhance overall resilience to climate variability. Furthermore, leveraging the stability in these areas to support drought-affected regions through resource sharing and strategic planning can build a more balanced and sustainable ecosystem.

4.3.3. The current extent of Prosopis *spp*. in the lowlands of bale and east bale

Land sat image was selected to reviled the current extent of p.juliflora. During image interpretation P. juliflora was identified visually when the cover is found in dense, found in a wide coverage, have evergreen to semi-evergreen leaves, shedding leaves completely only under stressful and drought conditions. Moreover, it is an evergreen tree or shrub that is found in any season, which differ from most of the other species found in the area, which dry out or shed their leaves during the dry season in the study area, the spectral reflectance shows more differently all of which are useful traits for remote detection of tree species. P. juliflora invaded land have a reflectance signature color of very bright red which was totally different from other land-use /land cover in the study area. Above all, the satellite image used for this study was captured during March, which is the dry season in the area.

In terms of coverage, the areas' most adversely affected nationally include the Afar and Somali Regions in the east and southeast of the country and the area around Dire Dawa city. (Steele et al., 2009).

The statistical information derived from Landsat images indicates that prosopis cover 3565.37 km2 in 2023. The study by Rezene Fessahaie (2006), showed that the species invaded different land use farm land, pasture land, rangeland irrigation schemes and cause land use land cover change due to the aggressive nature of the species repeated themselves simultaneously.

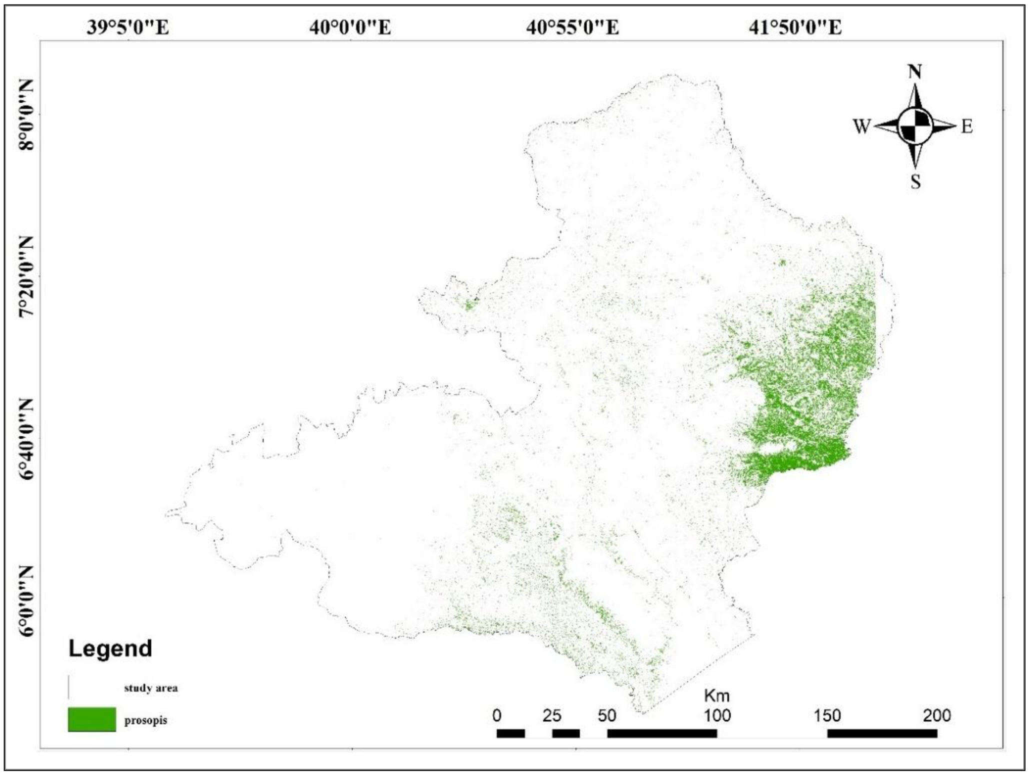

Figure 10 Prosopis juliflora species distribution

Table 9 Criteria weights of the pair-wise comparison matrix

Hazard	Weight
Flood	0.26
Drought	0.64
Invasive spps	0.13
Consistency ratio	0.04

Multi hazard area assessment level was produced by hazard generating maps; those were flood, drought, and p.juliflora distribution in the study area. The multi hazard area or maps were classified as very high hazard level, high hazard level, moderate hazard level, low hazard level and very low hazard threats level respectively. Accordingly, the study revealed that 3406 km^2 of the study area was very high multi disaster area. Whereas, high, moderately, low and very low flood hazard area were covered an area of 7281, 13482,13849 and 7299 km^2, respectively.

Table 11 Multi Disaster Risk Area

Multi hazard areas	Naming	Area (km2)	Area (%)
	Very high	3406	7.515943244
	High	7281	16.06681819
	Moderate	13482	29.75042479
	Low	13849	30.56027539
	Very low	7299	16.10653839

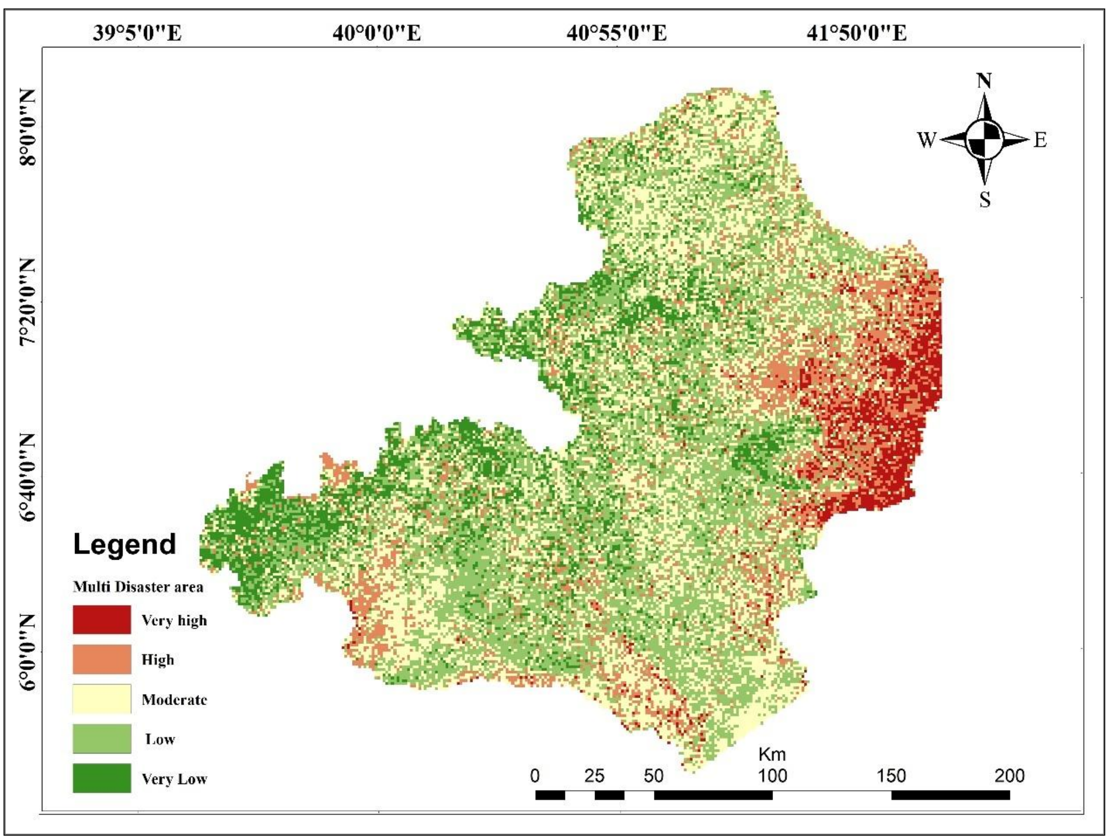

Figure 11 Final Multi Disaster Risk Area Map

4.4. Disaster Risk Management Practice

Disaster risk management is the application of disaster risk reduction policies and strategies to prevent new disaster risk, reduce existing disaster risk and manage residual risk, contributing to the strengthening of resilience and reduction of disaster losses. For this study, management practices, which take place in order to manage the losses or take advantage of the opportunities presented by a disaster risk. It is the process of managing disasters and cope with changes in different conditions across time scales, from short-term to the long-term. The goal of a disaster risk management should then be to increase the capacity of a system to survive external shocks or changes. Based on the household survey data collected from the study area, almost all respondents have experienced disasters over time. Then after, sampled households were asked their response to mitigate the impact of disaster through disaster management practice.

A number of disaster management practice are used by respondents in the study area have been identified. Accordingly, the following disaster management practice have been identified as a prominent disaster risk management practice used by farmers in the study area. It is found that the study area communities are using improved crop and livestock variety (disease resistant and productive), mixed farming, savings and credit, soil and water conservation and water harvesting structures Soil and Water Conservation, Mixed Farming and using of small-scale irrigation are, disaster risk management practices used to reduce the negative impact of disasters by which we can manage disaster risk.

4.4.1. Regression Analysis

4.4.1.1. Determination of the Model goodness of fitness

Table 10 Model Summary

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate

1	.931[a]	.866	.864	.139

Data source: Questionnaire 2024

Dependent Variable: Disaster Risk Management Practice

The overall model overview of the study's variables was shown in Table (11). Consequently, the model's R, R square, and Adjusted R square values were.931a,.866, and.864, correspondingly. As a result, the percentage of the variation in the answers (independent variables/practices having an impact on disaster risk management) that can be described by the model connecting Y to X1, X2, and X7 can be defined as the coefficient of determination. Thus, the study found that enhanced crop and animal diversity, mixed farming, savings and credit, soil and water conservation, and water harvesting structures all contribute to 93.1% of the variability of disaster management techniques and disaster risk management. However, the remaining 6.9% can result from the influence of other factors.

4.4.1.2. Determination of Coefficients

The data in the "Beta" column under "Standardized Coefficients" is comparable; however, all values for X and Y have been standardized, or adjusted to a mean of zero and a standard deviation of one, prior to the computation of the weights. The value of b0 (α), which is always 0, is not included in the regression equation in this case. Standardizing all variables enables a more realistic comparison of regression weights, since the unstandardized weights are a function of the variance of the X variables (Muijs, 2004). Assuming all other variables are included in the model, the statistical significance of a variable is displayed in the "Sig." column of the "Coefficients" table.

Table 11 Coefficients of the Independent Variables

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	.079	.020		3.923	.000
	Improved Crop & Lvk Variety	.188	.030	.206	6.271	.000
	Mixed Farming	.036	.030	.008	.217	.829

	Small scale Irrigation	.167	.017	.215	5.419	.000
	Improved Crop Variety	.503	.032	.528	15.964	.000
	Savings and Credit	.222	.026	.250	8.528	.000
	Soil and Water Conservation	.030	.020	.039	1.490	.137
	Water Harvesting Structures	.004	.028	.005	.130	.897
a. Dependent Variable: Disaster Risk Management Practice						

Data source: Questionnaire 2024

Dependent Variable: Disaster Risk Management Practice

The improved crop and livestock variety (0.1880), mixed farming (0.006), small-scale irrigation (0.007), improved crop variety (0.503), savings and credit (.222), soil and water conservation (0.030), and water harvesting structures (.004) are the four independent variables that are shown to have positive unstandardized coefficients in table 13. All four independent variables (improved crop & livestock variety, small-scale irrigation, improved crop variety, and savings and credit) have t-statistic values of 6.271, 5.419, 15.964 and 8.528 at $p < 0.001$, with the exception of three (mixed farming, soil and water conservation, and water harvesting structures).

Furthermore, the standardize coefficients illustrate the impact of individual variables on disaster risk management practices. Therefore, a unit increase in its improved crop & livestock variety will result in a.206 rise in disaster risk management if the disaster risk management techniques keep the same in independent variables. A unit increase in small-scale irrigation will directly lead to a.215 increase in disaster risk management, assuming the other six independent variables remain same. This is similar to how small-scale irrigation affects disaster risk management. Better crop variety affects disaster risk management; a unit increase in enhanced crop variety will immediately translate into a.528 improvement in disaster risk management if the other independent variables stay the same. Similarly, credit and savings have an impact on disaster risk management; a unit increase in credit and savings will lead to a.250 increase in disaster risk management provided the other six independent variables stay the same.

Table 11 above illustrates that all four of the independent variables that were examined were statistically significant, with the exception of three independent variables (water harvesting structures, soil and water conservation, and mixed farming) that had P-values less than 0.05. The null hypothesis is rejected and the alternative hypothesis is accepted for all four variables, with the exception of the three variables (mixed farming, soil and water conservation, and water harvesting structures), despite the fact that these independent variables (soil and water conservation, mixed farming, and water harvesting structures) have little bearing on the management of disaster risk. Furthermore, all of the independent variables' values are positive, indicating a direct impact on the disaster risk management initiatives. These show that every independent variable in disaster risk management aside from mixed farming, soil and water conservation, and water collecting structures have a positive and notable impact on the practice of disaster risk management.

The equation that follows is based on the description above and the independent variables' coefficients; Based on the Unstandardized Coefficients; Disaster risk management = .079+.188X1+.006+.007+.503+.222+.030+.004 OR

Based on the Standardized Coefficients; Disaster risk management = +.188X1+.006+.007+.503+.222+.030+.004 X7.

4.4.2. Hypothesis Testing

All of the independent variables better crop and livestock variety, mixed farming, savings and credit, soil and water conservation, and water harvesting structures related to disaster risk management were found to be significant in the multiple line regressions on the coefficients displayed in the above table.

Based on the standardized coefficients, Disaster risk management = +.188X1+.006+.007+.503+.222+.030+.004 X7. The proposed hypotheses was tested as indicated below;

4.4.2.1. Improved crop and livestock variety Vs. Disaster risk management

The following were the framed null hypotheses put forth to forecast the association between increased crop and livestock variety and disaster risk management:

H04: There is significant relationship between improved crop and livestock variety and Disaster risk management.

Ha4: There is no significant relationship between improved crop and livestock variety and Disaster risk management.

Better crop and livestock diversity has a positive (beta =.188) and significant (p =.000) link with disaster risk management, as the regression table above illustrates. As a result, the alternative hypothesis was rejected and the null hypothesis was accepted. Regression analysis results thus demonstrate that this independent variable has a statistically significant impact on catastrophe risk management. These farmers rely heavily on crop output, and they choose short maturing, drought- and disease-resistant crop types as a means of reducing their exposure to potential disasters. This finding is in agreement with the findings of the study conducted by Alison M.R. et al., (2016), breeding programs are continuously striving to increase yield, enhance quality, and improve tolerance to diseases and pests. They also found that, crop improvement is essential to meet the demands of a changing world (eg, increased population, disaster, climate change and decreasing land base).

4.4.2.2. Small scale Irrigation Vs. Disaster risk management

The framed null hypothesis and its alternative proposed to predict the effect of Small scale Irrigation on disaster risk management activities is as indicated below:

H01: There is significant relationship between Small scale Irrigation **and Disaster management.**

Ha1: There is no significant relationship between Small scale Irrigation **and Disaster management.**

The regression results show that the independent variables and their effect is positively (Beta =.167) linked to client disaster management and has a statistically significant correlation (P=.000). As a result, the null hypothesis was accepted and the alternative hypothesis was rejected. This outcome would suggest that a 1% increase in the small scale irrigation would result in a.167 increase in disaster risk management. This is why the small scale irrigation in the disaster management directly and significantly affects the disaster risk management. Thus, small scale irrigation is one of the main independent variable that affects the disaster risk management, according to the regression analysis's findings. The results of Ahmed (2019) and this study concur that irrigation is essential for providing domestic agro-industries with the necessary quantity and quality of raw materials, as well as for boosting export revenues. Contributions of irrigation include increasing agricultural productivity through crop diversification and intensification, boosting household income from jobs on and off the farm, providing animal feed, enhancing human health through a balanced diet and easy access to medication, preventing soil and ecological degradation, and asset ownership. Adoption of developing the culture of using irrigation helps farmer to cope up disaster such as climate change impact and risks by diversifying income level because households engaged indifferent type of activities. It supplies farmers and cattle with drinking water as well. Consistent with our findings, irrigation water is an essential resource for numerous productive and livelihood activities. It also plays a positive role in disaster management, encompassing drought, floods, and climate change (Worku, 2011).

By implementing irrigation and agricultural water management, any country can boost productivity and reduce its vulnerability to climatic fluctuations (MoFAD, 2012; MOFAD, 2013).

4.4.2.3 Savings and Credit Vs. Disaster risk management

The framed null and its alternative hypotheses proposed to predict the relationship between savings and credit and disaster risk management were as follows:

H02: There is significant relationship between savings and credit and disaster risk management.

Ha2: There is no significant relationship between savings and credit and disaster risk management.

The savings and credit has a positive (B=.222) and statistically significant (P=.000) effect on the disaster management, according to the regression results. Consequently, since the coefficient of B is positive, the null hypothesis is accepted and the alternative hypothesis is rejected. The savings and credit is currently the determining factor in the disaster risk management because it has a positive relationship with the latter. This demonstrates that the savings and credit has a big effect on the disaster risk management. Farmers who have access to credit service are more likely to adapt and cope up from disaster by using the above prominent disaster risk management practices. It enables farmers to change their management practices in response to changing climatic factors and to buy fertilizers, seedlings, drought tolerant varieties, irrigation technologies like water pumps and other inputs to smoothening production and reduce the negative impact of climate change. This result is consistent with Gadédjisso-Tossou (2015) that found farmers who have access to credit are more likely to adopt planting short season varieties.

Thus, researchers generally conclude that without adequate saving and credit service, it is extremely difficult to create resilient community which is similar with this/our finding.

4.4.2.4. Mixed farming Vs. Disaster risk management

The encircled null and its alternative hypotheses proposed to predict the relationship between mixed farming and disaster risk management were as follows:

H07: There is significant relationship between mixed farming and disaster risk management.

Ha7: There is no significant relationship between mixed farming and disaster risk management

As the regression results indicates that there was a positive (Beta=.006) and insignificant (P=.829) association between mixed farming and disaster risk management. The effect of mixed farming on disaster risk management in coefficient results of the regression analysis was found to be insignificant, depicting that the alternative hypothesis was accepted; while the null hypothesis was rejected. This also means that the mixed farming is not effective of the quality of education. The result is somewhat inconclusive and mixed farming doesn't necessarily mean it is not vital for disaster risk management in the study area.

But, the findings of KIs and FGD result revealed that, Mixed farming provide concrete disaster management which increase production and also improve the life of the farmers. The respondents also revealed that proper mixed farming system help to promote income diversification. There is this believe that, when farmers practice mixed farming with appropriate farming system and instruments they easily become disaster resistant and resilient community. The findings of KIs and FGD also revealed that farmers having experience of mixed farming most of the times, they have ability to cope up from disaster and absence of important mixed farming system exposes farmers to not be resilient community. This result would imply that if there is no mixed farming system, the management of disaster risk will be declined. Hence, based on the findings of KIs and FGD analysis, mixed farming is one of the major effect that determine the disaster risk management. Thus, mixed farming has significant effect on disaster risk management.

Generally, a number of studies revealed different practices will improve the disaster risk management and play a key role for making the community self-reliant and resilient. There is a dire need for improvement of disaster risk management practices in terms of attitude and perception to meet the objective of disaster risc management (Worku, 2011). Therefore, we conclude that, the concerned bodies may provide support to their community for the enhancement of mixed farming system which in turn result in resilient community.

5.Conclusion and Recommendation

5.1. Conclusion

This study was intended to assess multi disaster area GIS and RS technique in lowlands of bale and east bale zone southeastern Ethiopia. The major disaster that are found n the study area was flood, drought, conflict epidemic disease and pest.

As a result, the study result shows that, about 52 % of respondents are responded that drought is the main type of disaster in the study area followed by disease and pest/ invasive species those responded by 22.75% and 17.25% respectively. And about 5.75% of the respondents responded that flood is one of the disaster types in the study area. Finally, only 2.25% of respondents responded as conflict is another type of disaster in the study area.

The finding shows that flood hazard assessment level was produced by flood generating factors; those were slope, elevation, drainage density, soil and LULC of the study area. The flood hazard area or maps were classified as very high hazard level, high hazard level, moderate hazard level, low hazard level and very low hazard threats level respectively. Accordingly, the study revealed that 4538 km^2 of the study area was very high flood hazard area. Whereas, high, moderately, low and very low flood hazard area were covered an area of 11082, 14219,11695 and 3783 km^2, respectively.

The Environmental Policy of Ethiopia (EPE) and the Biodiversity Strategy and Action Plan (NBSAP) have identified invasive species as posing a major threat to biodiversity and economic wellbeing of the population. However, only little attempt to assess the status of Invasive Alien

Species (IAS) has been made so far and hence those species known to be threats are already widespread. Therefore, of land sat image was selected to reviled the current extent of p.juliflora it have evergreen to semi-evergreen leaves, shedding leaves completely only under stressful and drought conditions Besides having evergreen leaves, P. juliflora forms dense thickets and dominates the canopy layer, all of which are useful traits for remote detection of tree species.

The statistical information derived from Landsat images indicates that prosopis cover 3565.37 km2 2023.

Accordingly the study result reviled that lowest NDVI values are recorded at Seweyna ,Rayitu and some parts of Deleomena whereas, the highest value of NDVI were recorded at Berbere and Guradamole and Ginnir. As mentioned in Tan et al., (2010), the NDVI value is greater than 0.1 for normal healthy vegetation, while for rock and soil, the NDVI values are close to zero, and water bodies give a negative reading for the NDVI value. For computing the area of each cell covered with either water, bare soil or vegetation, the raster file of the NDVI was converted to shape file in ARCGIS extension tools.

Furthermore, all of the independent variables' values are positive, indicating a direct impact on the disaster risk management initiatives. These show that every independent variable in disaster risk management aside from mixed farming, soil and water conservation, and water collecting structures have a positive and notable impact on the practice of disaster risk management. The equation that follows is based on the description above and the independent variables' coefficients; Based on the Unstandardized Coefficients; Disaster risk management = .079+.188X1+.006+.007+.503+.222+.030+.004

5.2. Recommendation

- Create a robust database utilizing remote sensing and GIS technology to analyze historical disaster data. This will facilitate the creation of hazard maps that highlight at-risk areas, enhancing disaster management planning and informing decision-makers.
- Implement farming techniques that are resilient to drought to ensure food security and maintain agricultural sustainability in vulnerable regions.
- Utilize Prosopis for its economic benefits, including products such as charcoal and animal feed, which can support and strengthen local economies.
- Formulate clear evacuation strategies for areas at high risk of disasters to ensure the safety and preparedness of residents during emergencies.
- Improve inter-agency collaboration in disaster management and strengthen community training programs to build resilience. Additionally, focus on sustainable land use planning and improve drainage systems in flood-prone areas to reduce disaster impacts.

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Annex I

Survey Questionnaires to be filled by pastoral households

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Survey questionnaires to be filled by pastoral households

Dear respondent! The purpose of this questionnaire is to gather information on Disaster risk assessment using integrated Remote sensing and GIS based AHP in the lowlands of Bale & east Bale zones. The success of the study entirely depends on your cooperation. There is no right and wrong answer, so you are kindly requested, to give your genuine responses to the following questions. Your responses will be kept confidential and will only be used for research purposes.

Thank you in advance

Questionnaire N<u>o</u>.: ☐

Questionnaire Code: ☐

Location: 1 ☐ Berbere 2 ☐ Seweyna 3 ☐ M/ Welabu 4 ☐ Ginnir 5. ☐ D/ Serer
6 ☐ Rayitu 7 ☐ H/ Buluk 8 ☐ Legehida 9 ☐ D. Kachen 10 ☐ D/Mena

			DATE OF INTERVIEW		________
Locality Name:	____________________		TIME:	Beginning	________
Name of *interviewed*:	____________________	Sign: _________		End of interview	________
Name of *interviewer*:	____________________	Sign: _________			________
Name of Supervisor:	____________________	Sign: _________			

Instruction I: Please circle it your response

1. Sex: i. Male ii. Female
2. Age: ____________
3. Marital status: i Single ii Married iii Divorced iv Widowed/Widower
4. Do you know disaster?

   A. Yes B. No

5. If your response for Q4 is yes, What type disaster in the study area?

   A. Natural induced   B. Human induced

6. If your response for Q4is Natural, which type of natural disaster are common?

   A. Drought
   B. Flood
   C. Disease
   D. Conflict
   E. Pest/ invasive species

7. If your response for Q6 is Drought, do you perceive/think the climate has changed over the last 30 (thirty) years in your area?

   A. Yes   B. No   C. Not sure

8. If your response for Q7 is yes, what is the main cause for the climate is changing?

   A. God's curse   B. Deforestation   C. Normal trend

9. How would you describe the overall trend in climatic conditions?

   A. Becoming wild
   B. Becoming more unpredictable
   C. Becoming Better
   D. Becoming Worse
   E. If other specify

10. If your response for Q 7 is yes, do you think the temperature is changing?

    A. Yes   B. No

11. If your response for Q 7 is yes, which direction is it changing?

    A. Warming
    B. Cooling
    C. More extreme
    D. Not sure

12. What evidence can you mention for this, if you feel it is changing?

    A. Daily temperature: 1. Increasing (warming) 2. Decreasing (cooling) 3. Not sure

    B. Nightly temperature: 1. Increasing (warming) 2. Decreasing (cooling) 3. Not sure

13. Which season do you think is changing more in terms of temperature?

    A. Summer
    B. Autumn
    C. winter
    D. Spring

14. If your response for Q 7 is Yes, is the rainfall changing?

    A. Yes   B. No   C. Not sure

15. What aspects of rainfall characteristics did you see changes in?

    A. Amount
    B. Intensity
    C. Seasonal
    D. Duration

16. Do you think this year's rainfall is different from others in the recent past?

    A. Yes   B. No

17. If seasonal change is happening, which season do you think is changing most?

    A. Summer
    B. Winter
    C. Autumn
    D. Spring

18. Did you have access to the following human capital in the last year?

S/N	Human capitals	Yes,	No
1	Health facilities		
2	Adequate nutrition		
3	Education		
4	Skill		
5	Trainings/workshops		
6	Others, specify__		

19. Did you have access to use the following natural capital in the last year?

S/N	Natural capital	Yes	No
1	Grazing land/pasture		
2	Water accessibility		
3	Forest products		
4	Others, specify__		

20. Did you have access to the following financial resources in the last year?

S/N	Financial capital	Yes	No
1	Livestock		
2	Saving		
3	Credits		
4	Remittances		
5	Pensions		
6	Wages		
7	Jewelry		

21. Did you have the following Social Capital with your clan/ethnic groups?

S/N	Social Capital	Yes	No
1	Good network and connection		
2	Trust and Mutual support		
3	Formal and informal groups		
4	Common rules and sanctions		
5	Collective representations		
6	Participation in decision making and leadership		
7	Supporting each other (informal insurance)		

22. Did you have access to the following physical capital in the last year?

S/N	Physical capital	Yes	No
1	Access to all weather road and transport		
2	Housing and safe buildings		
3	Access to water and sanitation		
4	Clean and affordable energy sources (electricity, solar, etc)		

5	Access to communication/information		
6	Tools and equipment for production		
7	Access to agricultural inputs		

23. Do you think that your means of living is vulnerable to climate change? A. Yes B. No

S/N	Livestock	No. owned	No. died	Main reason for death? 1= diseases 2= drought 3 = floods 4= conflicts 5= predation 6= slaughter
1	Cattle			
2	Camels			
3	Goats			
4	Sheep			
5	Equines			
6	Chickens			

24. What is the contribution of the following sources of income to annual household income?

S/N	Income source	Rank (1 being the most important contributor to household income)
1	Animal rearing	
2	Bush products (fuel wood)	
3	Honey	
4	Remittances	
5	Daily wage labour	
6	Pension	
7	Petty trading	
8	Rent Development aid projects	

25. Does drought is the major natural disaster that affect your household?

A. Yes B. No

26. Have your household been affected by drought in the last 10 years?

A. Yes B. No

27. How many times have your household been affected by drought in the last 10 years?

A. Nine out of 10 years or more
B. Eight out of 10 years
C. Seven out of 10 years
D. Six out of 10 years
E. Five out of 10 years
F. Four out of 10 years
G. Three out of 10 years
H. Two out of 10 years
I. one out of 10 year

28. Please indicate month if the disaster happens every year. (Ethiopian month)

29. In Which month and year did your household experience the heaviest losses due to drought?

(Express the reason) Month, Year

30. What types of losses did your household experience from this hazard affecting your household?
    A. Loss of life/death of family members
    B. Physical damages on houses & property
    C. Health problems
    D. Crop damage express → in quintal/money
    E. Livestock damage → express in number / money
    F. Loss of income/saving
    G. Lost access to water
    H. Lost access to grazing land
    I. Other damages
31. Have you been able to recover from the losses suffered from this hazard?
    A. Yes
    B. No
32. What types of measures did your household take to cope with this hazard?
    A. Reduce expenditure on non-essential items
    B. Sell livestock
    C. Borrowing food (credit)
    D. Sending children for work
    E. Seasonal labor migration
    F. long term migration
    G. Others
33. Is there any hazard warning system that make you and your household members ready and protect from the hazard?
    A. Yes
    B. No
34. How you warn against hazard threating your household?
    A. By community leader/ elders
    B. By NGOs
    C. By fiends/ neighbors
    D. By ourselves
    E. By mass media (TV, radio, newspaper)
    F. By national or local authorities
    G. Other
    H. No warning
35. Have got aid to recover from the hazard?
    A. Yes
    B. No
36. From whom have you received support to recovered from the hazard?
    A. National/ local authorities
    B. NGOs (specify)
    C. Family members
    D. Friends/ neighbors
    E. Charity organizations
    F. Others

G. None

37. What type of support have you received?
   A. Emergency aid (water shelter, food, cloth, etc.)
   B. Capital for re-construction of house/ property
   C. Access to loan for adaptation/ protection measures
   D. Access to loan for re-construction
   E. Livestock replacement
   F. New houses
   G. Other

38. What type of interventions that would help your family cope with hazard?
   A. Food aid
   B. Subsidized food
   C. Rental subsidies
   D. Subsidized health care
   E. Better job
   F. School fee for children
   G. Financial subsides
   H. Other

39. Did you know *Prosopis Juliflora*?
   A. Yes
   B. No

40. If your response for Q4 is yes, What Sims likes the status of the species in the study area?
   A. Increasing
   B. Decreasing
   C. No change

41. *Dose Prosopis Juliflora has effect?*
   A. Yes
   B. No

42. If your response for Q6 is yes,
   A. Physical injuries on animals and human health
   B. Loss of pasture and rangelands for both domestic
   C. Falling out cattle teeth and reduction of their ability to graze
   D. Rangeland areas have been degraded and forage grass productivity has declined
   E. Decline in livestock production and productivity
   F. Range land degradation
   G. Reduction of crop production

43. What will be the solution for impact?
   A. Applying different controlling method
   B. Awareness creation

44. What method do you apply to control the invasion?

A. Mechanical B. Chemical C. Biological

45. Who involved for controlling invasive Species? For
    A. Government organization
    B. None government organization
    C. Member of a community as campaign

46. What is your major challenge for controlling?
    A. Lack of Equipment
    B. Lack of skilled manpower
    C. Remoteness as well as the rugged and undulating topography

47. What will be the solution for of the constraints?
    A. Enact legislation of legal frameworks
    B. Awareness creation
    C. If other_________________

48. Do you know the values of the products?
    A. Yes B No

49. If your response for Q15is yes what are contributions for local communities?
    A. livestock feed and for making human foods
    B. Env'tal services provided by nitrogen fixation, shade, shelter, live and dead fencing
    C. Traditional Medicinal
    D. Erosion control, soil improvement and reclamation are remarkable
    E. Honey, edible exudates gums, mulch, bio pesticides and medicines