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Characterization of Afro-alpine and Sub-afro-alpine Biodiversity Using Geospatial Techniques: The Case of Gugu Mountain Ranges, Arsi-Bale Massif, South Eastern Physiographic Region of Ethiopia.

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Declaration

I, Demissie Tsega Mallie, declared that the thesis entitled as **"Characterization of Afro-alpine and Sub-afro-alpine Biodiversity Using Geospatial Techniques: The Case of Gugu Mountain Ranges, Arsi-Bale Massif, South Eastern Physiographic Region of Ethiopia"** is my original work that has not been done before, and that all sources of materials used for this paper have been acknowledged.

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Acronyms

amsl……… above mean sea level
AZFEDO....Arsi Zone Finance and Economic Development Office
CRGE…….Climate Resilient Green Economy
CSA………Central Statistics Agency
DEM…….. Digital Elevation Model
EARO…….Ethiopian Agricultural Research Organization
EBI……… Ethiopia Biodiversity Institute
EPCC…….Ethiopia Panel on Climate Change
ESA………European Space Agency
FAO………Food and Agricultural Organization
FDRE…. ...Federal Democratic Republic of Ethiopia
GIS……….Geographic Information System
GMR……. Gugu Mountain Ranges
GPS………Global Position System
GTP……….Growth and Transformation Plan
IBC…….... Institute of Biodiversity Conservation
LUCC…….Land Use/Land Cover Change
MDGs……Millennium Development Goals
MEA ………Millennium Ecosystem Assessment
MoA………Ministry of Agriculture
MoEFCC….Ministry of Environment, Forest and Climate Change
MoFED…….Ministry of Finance and Economic Development
NDVI…….Normalized Difference Vegetation Index
OLI………..Operational Land Imager
REDD+…...Reduction of Emission from Deforestation and Forest Degradation plus
RS……….. Remote Sensing
SHDI……..Shannon Diversity Index
SIDI………Simpson Diversity Index
SRTM…....Shuttle Radar Topographic Mission
TM………..Thematic Mapper
UNEP……..United Nations Environment Program
WRI……….World Resource Institute

Abstract

Due to favorability of highlands of Ethiopia for human habitation and agriculture, biodiversity resources in this ecosystem have been under a serious peril. The ultimate objective of this study was to characterize afro-alpine and sub-afro-alpine biodiversity resources using geospatial technologies at Gugu Mountain Ranges (GMR). Data were generated from Landsat imageries of 1989, 2001 and 2019; DEM (SRTM); 25 field plot measurement; and five key informant interviewees. Change detection (using image differencing and change vector analysis), fragmentation and disturbance analysis, diversity computation and weighted overlay analysis were used to analyze the collected data. The findings of the study showed that conversion rate of afro-alpine and sub-afro-alpine biodiversity habitat was rated as -2.17% between 1989 and 2019 predominantly to grazing/fallow land, farmland and settlement. Similarly, NDVI value testified decrease in dense vegetation which could be biodiversity habitat. Fragmentation indices revealed the presence of fragments which ranges from slight to high fragmentation. Fragments in the area resulted to patch diversity, and hence, albeit increased pressure species diversity computed by the Shannon and Simpson indices showed the presence of species richness in the area. Hereafter, the vulnerability level of the remnants of was estimated using road network, stream network, elevation, slope and land use land cover type. So that, weighted overlay analysis result showed that 85% of afro-alpine and sub-afro-alpine biodiversity areas were vulnerable to disturbances. To conclude, in the last 30 years afro-alpine and sub-afro alpine biodiversity at GMR faced greater disturbances and fragmented into patches, where it's remaining biodiversity reserves becomes susceptible to changes. Hence, it is recommended that improvement of local community livelihood, ecotourism development and community empowerment the save this habitat from extinction.

Key words*:* Afro-alpine, Biodiversity, Characterization, Disturbance, Ecosystem, Fragmentation, Geospatial technologies, Sub-afro-alpine

CHAPTER ONE

1. INTRODUCTION

1.1. Background of the Study

Biodiversity, conventionally, refers to variability among the living organisms from all sources including terrestrial and aquatic ecosystems (MEA, 2005; UNEP, 1992). Biodiversity is not simply the number of genes, species, ecosystems or any other group of things in a defined area (Noss, 1990). It has been taken as a pre-requisite for human survival (UNEP, 1992). In this regard, biodiversity contributes directly through provisioning, regulating and cultural ecosystem services, and indirectly through supporting ecosystem services to many of human well-being including security, materials for a good life, health, good social relations and freedom of choice and action (MEA, 2005).

Due to difficulty to measure everything of biodiversity, there have to be selection of few variables that will represent key components of biodiversity (Clergue et al., 2005; Ferris and Humphrey, 1999). To this effect, assessment of biodiversity status and trends is an established component of environmental observation and monitoring programmes which is performed at different scales (Cook et al., 2011; Bredemeir et al., 2007). Hence, the growing demand for conservation of biodiversity databases of species can be achieved at multiple level of biological organization through ecological, agronomical or patrimonial approaches (Bredemeir et al., 2007; Clergue et al., 2005; Fleming and Aagaard, 1993).

According to Evans and Kelley (2004), scale issues have significant implications for the analysis of social and biophysical processes in complex systems. So that, knowledge of geographic barriers for a species and incursion routes into area is essential to inform management and eradication of invasive species (Stevenson-Holt and Sinclair, 2015). Thus, an attempt to understand biodiversity has been made at global, sub-global (biogeographical realms), national (biogeographic region) and local (identifiable ecosystem) level. This is needed mainly as a result of geographic referencing before crucial conservation decisions have to be implemented (Fleming and Aagaard, 1993).

An assessment of species diversity in relatively large areas has always been a challenging task for ecologists (Roccini et al., 2013). Due to this fact, the selection of appropriate temporal and spatial scales as well as appropriate borders is crucial for ecosystem service assessment (Burkhard et al., 2012). Roy (2011) proposed that biodiversity is generally appreciated at the species level; it needs to be assessed and conserved at all levels of ecological organization and spatio-temporal scales. On other side, Fleming and Aagaard (1993) indicated that the best way to minimize species loss is likely to be to maintain the integrity of ecosystems. On the other hand, Mbui (2007) showed that large spatial scale studies of ecological processes provide an opportunity to determine trends which otherwise would not be apparent in small scale studies. So, scale wise all level studies would have possible advantages and disadvantages that need to be observed.

For Pakrasi et al. (2014) the goal of ecosystem science is to integrate information from studies of the interactions between individuals, populations, communities and their abiotic environments, including the changes in times. Thus, an application of ecosystem model implies comprehensive understanding of the interactions responsible for distinctive ecosystem types (Odum, 1969; Tansley, 1935). According to Secretariat of the Convention on Biological Diversity (2004), the ecosystem approach is based on the application of appropriate scientific methodologies focused on the level of biological organization functions and interactions among organisms and their environment.

The natural ecosystem provides a variety of products and it is region in which a number of vital ecological processes are presented without which human civilization would not be able to exist. Where communities of organisms persist in dynamic equilibrium for long periods of time and occupy the same physical space, ecosystem may appear to have distinct spatial configurations of interactions. But, ecosystem boundaries are usually determined for the convenience of the investigator rather than on the basis of known functional discontinuity with the adjacent ecosystem (Pakrasi et al., 2014).

Besides scale of coverage, understanding of relationship between natural and anthropogenic processes on biodiversity is complex. In order to investigate spatial and temporal dynamics, it is important to utilize different approaches. In this regard, geospatial techniques have a potential to make valuable contributions to biodiversity conservations through studying numerous aspects of biodiversity (e.g. Roy, 2011; Joseph et al., 2009; Mang et al., 2007; Schulman et al., 2007; Wood and Dragicevic, 2007; Vogiazakis et al., 2006; Tchouto et al., 2006; Cayeula et al., 2006; Harris et al., 2005; Shi et al., 2005). Presently, inclusion of geospatial techniques has expanded the studies of biodiversity into development of spatio-temporal models of biodiversity assessment.

Therefore, the study of biodiversity needs delimitation of level of organization of entities to be studied and selection of appropriate approaches. In the present study, considerations of biodiversity in afro-alpine and sub-afro-alpine ecosystem and geospatial techniques approaches were used. Hence, this study focused on characterization of Gugu Mountain Ranges (GMR) afro-alpine and sub-afro-alpine biodiversity using geospatial techniques.

1.2. Statement of the Problem

Biodiversity loss is apparent to the globe. Millennium Ecosystem Assessment reported that biodiversity has declined dramatically over the past few hundred years as a result of human activities (MEA, 2005).The greatest pressures on biodiversity are habitat loss, which is resulted from agricultural expansion, invasive alien species and climate change (Bellard et al., 2014; Hoffmann et al., 2010; Vitousek et al., 1997). Likewise, the reduction in the forest patch size and increase in edge density is likely to reduce greatly the value of many of the remaining patches of biodiversity conservation and may accelerate their complete destruction (Daye and Healey, 2015).

Ethiopia is a country characterized by diverse climatic conditions grouped into agro-ecological zones that host various flora and fauna (EARO, 2008; MoA, 2000; Hurni, 1995), but facing a serious environmental degradation (Adugnaw, 2014). Among others, afro-alpine and sub-afro-alpine ecosystem harbors a very unique habitat and wildlife species. But, these areas signify rugged topography dissected by deep gorges with slopes associated with diverse climate (Hurni et al., 2010) and such physiographic features requires careful agro-ecologically sustainable management (WB, 2006).

High elevation plants and animal communities are expected to be sensitive to climate variations, airborne contaminants, exotic pathogens and physical disturbances (EPCC, 2015). Contrary to this, highlands of Ethiopia are favorable for human habitation and for most significant economic activities. It covers fifty percent (50%) of total land, hosts over eighty five percent (85%) of population, sixty percent (60%) of livestock and ninety percent (90%) of cultivable land. As a result, land use land covers change become apparent to the highland areas of the country.

Various studies conducted on land use land cover dynamics of Ethiopia showed that there have been greater changes both spatially and temporally (e.g., Gashaw and Dinkayoh, 2015; Fentahun and Gashahun, 2014; Gebrehiwot et al., 2010; Woldeamlak, 2002; Zeleke and Hurni, 2001). These brought greater land degradation, which led to label Ethiopia among land degradation hotspots of the sub-Saharan African countries (Kirui and Mirzabaez, 2004). Land degradation reduces land performance with substantial negative ecological and economic consequences and undermines livelihood (Pacheco et al., 2018; Reed et al., 2015). Thus, there must be research works on sustainable land management and growing competition for land resources (Nyssen et al., 2015; Norris, 2001).

Conservation of biodiversity is essential in changing climate and increasing anthropogenic factors (Khare and Ghosh, 2016). The sustainability of human-environment systems is, hence, realized through better understanding of ecosystem processes (Leitao et al., 2015). Besides, there is an opportunity to reduce the rate of loss of biodiversity and associated ecosystem services if people place an emphasis on ecosystem protection, restoration and management (MEA, 2005). Subsequently, reliable biodiversity assessment methods are essential to bring sustainability (Nilsson et al., 2001).

Roy (2011) indicated that proper documentation of biological diversity is essential for conservation and sustainable use for the benefit of mankind. For proper acquisition and documentation, the roles of geospatial technologies are inevitably critical. The evolution of Geographic Information System (GIS), Global Positioning System (GPS) and Remote Sensing (RS) technologies has enabled the collection and analysis of field data in a ways that were not possible before the arrival of computers (Sonti, 2015). These technologies can be used separately or in combination for simple application like determining location, plotting maps or examining distribution; to more complex usage like prediction, modeling and tracking patterns (Upadhyay, 2009).

There were attempts to compile the biodiversity resources of Ethiopia in different time (*e.g.* Debisa and Yayehyirad, 2017; Abiyot et al., 2014; Teshome and Ensermu, 2014; Kindt et al., 2011; Lillesso et al., 2011; Friis et al., 2010; Teshomeet al., 2004). But, no geospatial tools were used in recording and documenting the biological richness of the country. Ethiopia Biodiversity Institute [EBI] (2015) showed as there are scanty data and information on biodiversity and ecosystem services in Ethiopia. Moreover, it is institutionally assured that there are areas that are not yet studied in terms of their biodiversity potential in the highlands of Ethiopia. In this regard Institute of Biodiversity Conservation [IBC] (2005) reported that apart from the Simien and Bale Mountains, most of the afro-alpine and sub-afro-alpine ecosystems in Ethiopia are not effectively conserved through effectively managed protected area or through sustainable use systems.

According to EPCC (2015), the original afro-alpine and sub afro-alpine natural communities are now restricted almost entirely scattered and not easily accessible areas, which are surrounded and isolated by agricultural areas. Likewise, Arbagugu, which was once highly forested with a rich cover of trees, has experienced diminishing resources, increasing vulnerability and growing rural poverty (Mohammed, 2013)**.** This study, therefore, was addressed data and information gaps in this afro-alpine and sub-afro-alpine environment through investigation of biodiversity potential of the GMR of Arsi Massif. Moreover, the complex geometry of land use patterns has necessitated the development of new tools for spatial analysis (Lacher, 1998). Hence, an introduction of GIS and image analysis for spatial pattern and process analysis allowed major advancement in the study and modeling of land uses. To this effect, this study was utilized geospatial technologies for the study of biodiversity potential of GMR.

1.3. Objectives of the Study

1.3.1. General Objective

The general objective of this study was to characterize afro-alpine and sub-afro-alpine biodiversity reserves at GMR.

1.3.2. Specific Objectives

Specifically, the study attempted to

- Compute the change in afro-alpine and sub-afro-alpine biodiversity of an area from 1989 to 2019.

- Determine disturbances that influence biodiversity reserves of an area.
- Quantify the current biodiversity richness in the study area using remotely sensed and field data.
- Map biodiversity susceptible areas in the study area.

1.4. Research Questions

This study answered the following basic questions:

- Which part of GMR has exercised a significant spatio-temporal change in biodiversity?
- To what extent have anthropogenic and natural factors been contributing to the change of the biodiversity resources of GMR?
- To what extent is the GMR rich in biodiversity?
- At what level biodiversity is vulnerable to change in the study area?

1.5. Significance of the Study

This study introduces the utilization of geo-spatial technologies for assessment of biodiversity resources in Ethiopia. Despite several studies have been conducted on biodiversity using different methods, an integration of GIS and RS creates options to encourage studies made in this area. For conservation measures, an in depth understanding is required. The result of this study, therefore, portrays where biodiversity resources in the area is highly harmed and/or become vulnerable; how much area is influenced due disturbances; how patches are distributed and what they seem. It, further, manifests spatio-temporal changes in biodiversity in the area. As a result, it enables to come up with hot-spot sites for interventions based on trends and real-time situations of biodiversity in the GMR. Hence, it supports decision and policy makers through the provision of relevant and timely database.

1.6. Scope of the Study

Content wise, the study was focused on characterization of biodiversity based on satellite imageries. In terms of areal coverage, it was delimited to afro-alpine and sub-afro-alpine ecosystem of GMR. Accordingly, areas beyond 3200 meters above mean sea level (amsl) were investigated. That is, areas beyond this elevation are considered as ericaceous belt and afro-alpine belt in Ethiopia (Friis et al., 2010). Thus, all activities were undertaken based on geospatial technologies. In the study, due focus was provided for plant diversity. On the other hand, to some extent, fauna diversity was considered based on habitat characteristics. Diversity assessment was conducted to show the habitat and species richness.

1.7. Limitations of the study

Biodiversity analysis requires high sophistication in terms of environmental set up and equipment. Hence, there were challenges that were, to some extent, needed to be considered by other researchers when moving to field to do research on this thematic area. Accordingly, probably due to season of field survey, i. e. during the month of March, most of grassy plants were dried out to the level not to distinguish their species type though differences are noted. On the other hand, extended shrubs of the forest patches were shadowing GPS to pinpoint the X, Y, Z values of the sample plots. Similarly, satellite imageries of Landsat7 was fully blurred due to strip in seasons of data capturing for the study area to the level of unable to classify areas even after making correction. This was replaced by Landsat 5 image of the same time. High resolution imageries were; indeed, better if they were affordable to the capacity. But, in this study only Landsat with 30m resolution was used.

1.8. Organization of the paper

This paper comprises five chapters. The first chapter is introduction that provides background, the statement of problem and objectives of the study. The chapter also contains significance, scope and limitations of the study. The second chapter focuses on the review of related literatures from theoretical, empirical and conceptual points of view. The third chapter details study area characteristics and methods used for this study. The fourth chapter presents results and discussion. Finally, this paper concludes and provides recommendation in the fifth chapter.

CHAPTER TWO

2. REVIEW OF RELATED LITERATURES

2.1. Theoretical Framework

2.1.1. Concepts and Definitions

According to Sarkar (2002), the term biodiversity was coined by Walter G. Rosen during the organization of the 21-24 September 1986 'National forum on BioDiversity' held in Washington D. C. There was no an intention more than shorthand for biological diversity. Then, the term biodiversity immediately found wide use.

In simple words, biological diversity or biodiversity is the variety of life, and refers collectively to variation at all levels of biological organization (Gaston and Spicer, 2004).Biological diversity means the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems (UNEP, 1992).

In 1935, Tansley coined the term ecosystem to emphasize the importance of interchanges of materials between inorganic and organic components as well as among organisms. Ecosystem ecology addresses the interactions between organisms and their environment as an integrated system. The ecosystem approach is fundamental in managing Earth's resources because it addresses the interactions that link biotic systems, of which humans are an integral part, with the physical systems on which they depend. According to WRI (2003), an ecosystem is a dynamic complex of plant, animal, and microorganism communities and the nonliving environment interacting as a functional unit. Humans are an integral part of ecosystems. Ecosystems vary enormously in size; a temporary pond in a tree hollow and an ocean basin can both be ecosystems. Similarly, an ecosystem is defined as a spatially explicit unit of the Earth that includes all of the organisms, along with all components of the abiotic environment within its boundaries (Likens, 1992).

As per WRI (2003), Biodiversity and ecosystems are closely related concepts. Biodiversity is the variability among living organisms from all sources, including terrestrial, marine, and other aquatic ecosystems and the ecological complexes of which they are part. It includes diversity within and between species and diversity of ecosystems. Diversity is a structural feature of ecosystems, and the variability among ecosystems is an element of biodiversity.

On the other hand, geospatial technologies encompass utilization of Remote Sensing (RS), Geographic Information System (GIS) and Global Position System (GPS) in combination. Remote sensing enables to generate data from earth without direct physical contact. Remote sensing, shortly, refers to the activities of recording, observing, and perceiving (sensing) objects or events in far-away (remote) places (Weng, 2010).

GIS is an extremely collaborative activity. Like any information system, a GIS is an organized accumulation of data and procedures that help people to make decisions (Harmon and Anderson, 2003). A GIS is, therefore, a computer based system that provides a sets of capabilities to handle geo-referenced data that includes data capture and preparation, data management, data manipulation and analysis, and data preparation (Huisman and de By, 2009).

The Global Position System (GPS) is a space-based global navigation satellite system. It provides reliable location and time information anywhere on earth and at all times when there is unobstructed line of site to at least four GPS satellites. It was created by the U. S. Department of Defense in 1973. The GPS provides accurate, continuous, worldwide, three-dimensional position and velocity information to users with the appropriate receiving equipment (Kaplan and Hegarty, 2006).

According to Teillard et al. (2016), characterization is calculation of the magnitude of the contribution of each classified input/output to their respective impact categories, and aggregation of contributions within each category. This requires a linear multiplication of the inventory data with characterization factors for each substance and impact category of concern. Biodiversity characterization, as a result, involves two different processes, the observational and characterization of the main units of variation (genes, species and ecosystems) and the quantification of variation within and between them. In reality, the analysis of pattern defines the unit and characterization of their variation. Characterization of biodiversity depends critically on the work of three scientific disciplines i.e., taxonomy, ecology and genetics. Organisms occur in an intricate spatial mosaic classified on a world scale into biogeographic zones, biomes, eco-regions and oceanic realms, and at a variety of smaller scales within landscape into ecosystems and communities (Roy and Behera, 2002). In general, characterization of biodiversity is not only a scientific exercise but a fundamental trait of humans deeply rooted within all cultures.

2.1.2. The Need for Biodiversity

According to Fleming and Aagaard (1983), the importance of biodiversity is beyond question. It provides goods and services that are essential to human welfare, sustaining our life-support systems on the planet. In addition, biodiversity is of fundamental social, ethical, cultural and economic value and unlike many other resources, biological resources are renewable if properly managed. Recently, it has become necessary to identify the values of biodiversity to a country's social and economic development in order to compete for government attention. This process, however, is not without serious problems which must be recognized.

Biodiversity is essential for the maintenance and sustainable utilization of goods and services from ecological system as well as from individual species. Hence, it serves for source of food, fodder and fuel, sources of medicine, pollution management, control on soil erosion, soil quality improvement, forming a healthy ecosystem, protection of resources, nutrients recycling, source of recreation, important for cultural development, water recycling, economic growth, knowledge about the species and their value in nature, ethical values, cultural values, for protection of our planet, for existence of the species, for environmental cleanup, recreational value, reduction of risk of climatic changes etc. (Patel, 2014).

According to Millennium Ecosystem Assessment (2005), improved valuation techniques and information on ecosystem services tells us that although many individuals benefit from the actions and activities that lead to biodiversity loss and ecosystem change, the costs borne by society of such changes is often higher. Even in instances where our knowledge of benefits and costs is incomplete, the use of the precautionary approach may be warranted when the costs associated with ecosystem changes may be high or the changes irreversible.

In spite of uses of biodiversity, a major difficulty lies in controlling the level of use. Even where use may be reasonably sustainable at low levels, it may significantly impact at higher levels. This highlights the potential tradeoffs between levels of use, the spatial extent of that use (to obtain the same resource, low levels of use have to be spread over greater areas), and the impacts of use (Gaston and Spincer, 2004). Such considerations span the extraction of products from natural tropical forests to the planting of genetically modified crops.

Environmental services from species and ecosystems are essential at global, regional and local levels. All services provided are serving in different dimensions if properly handled and managed. Due to this fact, understanding the values of the ecosystems allows decision makers to know the most important areas for conservation that should be untouched in order not to lose the ecosystem value (Paletto et al., 2015).

2.1.3. Threat to Biodiversity

Loss of biodiversity is one of the most severe threats to sustainability, and land use and land use changes are still the single most important factor (Michelsen and Lindner, 2015). The ultimate causes of biodiversity loss concern the size of the human population, the rate of human population growth and the scale of human enterprise (Gaston and Spicer, 2004). The biodiversity resources are sources of humankind wellbeing though bottlenecked by various challenges which needs an intervention of decision makers. It is identified that anthropogenic pressure was major factor that disturb and affect biodiversity (Khera et al., 2001).

As indicated by Gaston and Spicer (2004), losses of species and other declines in biodiversity resulted from direct exploitation, habitat loss and degradation, introduced species and extinction cascades. The scale of human direct exploitation of some species is incredibly high, and is not sustainable. For example, bush meat hunting, fuel wood extraction, marine fisheries and other direct exploitation of biodiversity. In the case of habitat loss, fragmentation and degradation has been also a feature of history of humankind. Likewise, introduced species have most frequently caused species extinctions through predation/parasitism. Also, the extinction of one species may lead to the extinction of others which shortly be named as extinction cascades (Gaston and Spicer, 2004).

Similarly, in his review, Teklu (2016) indicated as there are number of threats to biodiversity in Ethiopia. The environmental effects like air pollution, edge effect, invasive species, habitat destruction and fragmentation; and climate change (e.g. global warming) are of growing concern owing to increasing biodiversity loss levels. These problems associated to biodiversity loss not only lead to deteriorating environmental conditions but also have adverse effects on countries Economic, sustainable development and health of people and finally result on species extinction.

Moreover, studies conducted by Solomon and Dereje (2015) come up with existence of mismanagement, increased competition for settlement, deforestation (for fuel wood and charcoal production), illegal hunting or poaching, budget constraints and insufficient human resources as reason for biodiversity losses. These created a pronounced burden to ecotourism development. That is why, national parks of Ethiopia, experiences low visitation that may benefit both local community and country as a whole.

The growing tension on biodiversity resources of the earth lead to seek for conservation. In fact, conservation may not be successful unless supported and pillared by scientific evidences. To obtain scientifically substantiated mechanisms to protect resources from depletion and deterioration proper studying is required. Hence, such studies may utilize varieties of approaches to acquire relevant data and bring appropriate findings.

2.1.4. Toward Biodiversity Conservation

To live sustainably, the human population must do so within the biosphere's regenerative capacity drawing on its natural capital without depleting the capital stock (Gaston and Spicer, 2004). To achieve this, both in-situ and ex-situ conservations needs to be undertaken. Particularly, for success of in-situ conservation different studies have to be conducted based on sophisticated approaches that complement the real environmental conditions. Biodiversity mainstreaming can focus on enabling environments at local, national or global levels. It can also focus on development policy, legislation, land-use planning, finance, taxation, economic incentives, international trade, capacity building, research, and technology. In addition, it can focus on commodity chains and certification of major natural resources (Huntley and Redford, 2014).

Ethiopia hosts the Eastern Afro-montane and the Horn of Africa hotspots of biodiversity. Conservation of forest genetic resources is one of the priority areas of biodiversity conservation in Ethiopia (IBC, 2012). Biodiversity provides free of charge services worth hundreds of billions of Ethiopian Birr every year that are crucial to the wellbeing of Ethiopia's society. These services include clean water, pure air, soil formation and protection, pollination, crop pest control, and the provision of foods, fuel, fibers and drugs. As elsewhere, these services are not widely recognized, nor are they properly valued in economic or even social terms. Reduction in biodiversity affects these ecosystem services. The sustainability of ecosystems depends to a large extent on the buffering capacity provided by having a rich and healthy diversity of genes, species and habitats. Losing biodiversity is like losing the life support systems that we, and other species, so desperately depend upon (IBC, 2005).

The conservation of biodiversity is fundamental to achieving sustainable development. It provides flexibility and options for our current (and future) use of natural resources. Almost 85% of the population in Ethiopia lives in rural areas, and a large part of this population depend directly or indirectly on natural resources. Conservation of biodiversity is crucial to the sustainability of sectors as diverse as energy, agriculture, forestry, fisheries, wildlife, industry, health, tourism, commerce, irrigation and power. Ethiopia's development in the future will continue to depend on the foundation provided by living resources and conserving biodiversity (IBC, 2005).

The Ethiopian Government has put in place policies and strategies for sustainable natural resource management including biodiversity conservation. The country is taking various measures to mainstream biodiversity into sectoral and cross-sectoral plans and programmes. Devising and implementation of rules and regulations that will reduce adverse and promote beneficial impacts of different sectors on biodiversity are some of the measures that have been conducted in the past five years (MoFED, 2007).

The GTP (2010/11-2015) recognizes that environment is a vital pillar of sustainable development, and among the key strategic directions to be pursued during the plan period are building a Green Economy and implementation of ongoing environmental laws. In the Plan, issues of biodiversity are mainstreamed mainly through agriculture and tourism sectors. In the Plan period, the Ministry of Agriculture has planned activities that enhance biodiversity restoration. These include, among others, preparation of land use guidelines, rehabilitation of degraded areas, increased community based natural resource conservation, increased coverage of protected forest and land covered with multipurpose trees (MoFED, 2010).

Adoption of agricultural and land use efficiency measures and protecting and re-establishing forests for their economic and ecosystem services, which include using of them as carbon stocks, are among the actions that have direct relation with biodiversity conservation and sustainable use. As part of the CRGE Strategy, REDD+ is a policy incentive aimed at promoting forest and biodiversity conservation and enhancing carbon stocks. Ethiopia has adopted the Millennium Development Goals (MDGs). The targets under Goal 7 of the MDG, which are related to environment and biodiversity, require the country to integrate the principles of sustainable development into national policies and programmes and to reverse the loss of environmental resources (MoEFCC, 2017).

To effectively implement conservation, sustainable use and development of biodiversity; Ethiopia has established and restructured some institutions at federal and national regional states since 2010. In 2013, Council of Ministers of the FDRE issued a regulation for the re-establishment of the Ethiopian Biodiversity Institute, the former Institute of Biodiversity Conservation. Moreover, the Institute has signed memorandum of understandings with national universities working with biodiversity and international institutions (EBI, 2014).

2.1.5. Biodiversity Potential of Ethiopia

Ethiopia is a relatively vast country with a land area of 1.12 million square kilometers and wide variety of topography and climate. There is a great variation in altitude, ranging from 116 meters below sea level in the Danakil depression to 4620 meters above sea level at the top of Mount Ras Dashen. The great plains of Ethiopia sits atop two massive highland plateaus, cloven in the middle by the Great Rift Valley. Although much of the interior of Ethiopia is dominated by highland plateaus, all of which are home to numerous endemic species of flora and fauna, these are interrupted by deep gorges and twelve major river valleys (EBI, 2015; EBI, 2014; IBC, 2012).

The differences in altitude, coupled with topographic variations, has resulted in wide variations in rainfall, humidity and temperature and thus, the country comprises of nine ecosystems that range from afro-alpine at the highest elevations to desert and semi-desert ecosystems at the lowest elevations. As a result, Ethiopia is endowed with a wide variety of fauna and flora and the extreme ranges have resulted in unique and diverse suite of its biological resources (EBI, 2015; EBI, 2014; IBC, 2012).

The highlands of Ethiopia were widely covered with Afro-alpine moorlands and grasslands. But, man has altered large regions of the highlands for centuries, and the rate of change is very alarming and has endangered the original species richness. The extinction of many original species in vast regions has to be seen in connection with this process. Therefore, due to increasing human pressure into such fragile environments of the afro-alpine and sub-afro-alpine ecosystems, much more attention is needed to halt further threat and rate of destruction (EPCC, 2015).

2.2. Application of Geospatial Techniques Biodiversity Assessment

Waldhardt (2003) argued that assessment of biodiversity in managed landscapes remains a problem for two main reasons. Firstly, diversity measures strongly depend on the chosen spatio-temporal scale of the prevailing assessment and unfortunately there are no satisfying scaling functions applicable to transfer results to another scale. Additionally, relations between biodiversity and land use are very complex. Thus, the total species richness at the landscape scales as a criterion for the evaluation of sustainable land use but is impossible to assess it.

Biodiversity is more an end in itself than a measurable indicator. Four aspects have to be defined to understand biodiversity in the model context (Zebisch et al., 2004). Primarily, biodiversity can be observed on the various hierarchical levels among which three are very common in ecological studies: ecosystems, species and genes. Secondly, every computation of biodiversity strongly depends on the classification of scheme of elements. Thirdly, biodiversity is configured by three attributes of ecosystems: composition, structure and function. Lastly, biodiversity assessment depends on the extent of the area under consideration.

Biodiversity indicators are tools that summarize and simplify information, to help understand the status of biodiversity and threats to it, and to evaluate progress towards its conservation and sustainable use (Biodiversity Indicators Development National Task Force, 2010).There were empirical studies conducted to assess biodiversity using remote sensing (Petrou et al., 2015; Pettorelli et al., 2014; Gairola et al., 2013; Wang et al., 2010; Turner et al., 2003; Nagendra, 2001; Nagendra and Gadgil, 1997), GIS (Zlinszky et al., 2015; Iverson and Prasad, 1998; Davis, 1994; Greenwood and Marose, 1993) and Geo-informatics (Roy and Srivastava, 2012; Murthy et al., 2006; Murthy et al., 2003; Roy and Tomar, 2000). Hence, the main concerns of these studies were reviewed as following.

The potential for synergies between remote sensing science and ecology, especially satellite remote sensing and conservation biology, has been highlighted by many in the past (Pettorelli et al., 2014). There are two general approaches to using remote sensing in assessing biodiversity (Strand et al., 2007). One is direct remote sensing, which maps individual organisms, species assemblages, or ecological communities by use of airborne or satellite sensors. The other approach, indirect remote sensing, facilitates assessments of biodiversity elements through analysis of such environmental parameters as general land cover, geology, elevation, landform, human disturbance, and other surrogates for the actual features of interest. When mapping the distribution of species of interest (focal species), a common approach is to map specific habitat types by use of a combination of remote sensing and environmental data themes.

Roy and Tomar (2000) identified landscape fragmentation and degradation as fundamental reason for biodiversity loss. In their study, they have used landscape ecological principles for biodiversity characterization. Satellite remote sensing data have been used for characterization of the landscape and stratification of ground inventory.

Nagendra (2001) evaluated the potential of remote sensing for assessing species diversity. That is, remote sensing involves direct mapping of individual plants or associations of single species in relatively large units; habitat mapping using remotely sensed data and predictions of species distribution; and establishment of direct relationships between spectral radiance values recorded from remote sensors and species distribution patterns recorded from field observation may assist in assessing species diversity.

The greatest potential use of remote sensing techniques to estimate biodiversity is for the top most canopy of vegetation (Nagendra and Gadgil, 1997). Advances in the spatial and spectral resolutions of sensors now available to ecologists are making the direct remote sensing of certain aspects of biodiversity increasingly feasible distinguishing species assemblages or even identifying species of individual trees (Turner et al., 2003).

GIS has been used to spatially model disturbance regimes and to integrate the ground based non-spatial data with spatial characters of landscape (Roy and Tomar, 2000). To delineate spatial pattern of biological richness biodiversity attributes of landscape elements, land use change pattern, disturbance regimes of the landscape and terrain complexity have been used.

In research entitled as "Application of GIS to biodiversity monitoring," Salem (2003) used GIS tools to manage many and varied biodiversity information needs. That is, an important tool for monitoring biodiversity is a GIS, which accommodates large varieties of spatial and attribute data. The information embedded in a GIS is used to target surveys and monitoring schemes. Data on species and habitat distribution from different dates allow monitoring of the location and the extent of change.

In relation to biodiversity, GIS has provided a range of data on environmental properties as well as techniques to explore and use data to further understanding of biodiversity and aid its conservation (Foody, 2008).It has also been used GIS tools to assess the impact of land use on biodiversity. Hence, they indicated the utilization of GIS tools for reserve or conservation strategy design through assessing the representativeness of prospective reserve areas along with the number of rare species, occurrences of rare habitats, types of ownerships and other characteristics that are counted through the landscape accounting portion (Greenwood and Marose, 1993).

The holistic understanding of the complex mechanisms that control biodiversity, as well as their spatial and temporal dynamics, requires synergetic adoption of measurement approaches, sampling designs and technologies. In view of this, the combination of satellite remote sensing, Global Positioning System (GPS), and integrative tools (such as GIS and information systems) is an important complimentary system to ground-based studies (Murthy et al., 2003).

Methodologically, Nagendra et al. (2004) link spatial pattern to land use process by integrating geographic information systems (GIS), socio-economic, and remote sensing techniques with landscape ecological approaches. This issue brings and illustrates the diversity of methods necessary to evaluate the complex linkages between pattern and process in landscapes across the world. The analyses focus on major forces interacting at the earth's surface, such as the interface of agricultural and urban land, agriculture and forestry, and other pertinent topics dealing with environmental policy and management.

Roy and Tomar (2000) utilized geospatial technologies to characterize biodiversity at landscape level. In their work, they integrated satellite remote sensing and geographic information system for obtaining data and analyzing spatial data by inculcation of attribute data in the area. Hence, they were able to present information both in space and time. This approach will facilitate conservation prioritization, systematic inventory and continuous monitoring.

A GPS is a satellite-based positioning system operated by the U.S. Department of Defense (DoD). GPS allows the collection of information about the geographical position of any location using a network of satellites. It has a great potential in landscape ecology, as well as in many other related disciplines requiring geographic locations of the objects in the landscape. Coupled with GIS, it acts as a powerful tool to describe the geographical characteristics of ecological systems (Roy and Behera, 2002). A practical use of GPS has been in locating the sample plots and this information was used for mapping and spatio-statistical analysis.

2.3. Conceptual Framework

Biodiversity of landscapes depends on numerous landscape characteristics related to land use. It appears to be very unlikely that there should be one single indicator for landscape biodiversity. Sets of indicators must be determined and valid models of landscape biodiversity must include a sufficient number of indicator-response rules concerning consequences on biodiversity (Waldhardt, 2003).

Assessment of characterization units and techniques leave rather a dissected view of biodiversity at different levels of description. The remote predictors or surrogates often play very significant role to measure richness. The habitat surrogates including classification of vegetation, details on the physical environment, factors determining the biodiversity loss in a spatial context may be of practical information value and could reduce sampling intensity. This information base could also guide detailed sampling on the ground. These larger scale surrogates include entire functional system and are more likely to promote population viability in the ecosystem (Roy and Behera, 2002).

In conservation, this is likely to differ with earlier measures of ecological diversity formulated with the narrower aim of representing differences in abundance among species, exploring distribution of resources within community. If the value of biodiversity to a conservationist is associated with its use to people then this ought to be separated carefully from issues of rarity, viability and threat. If the biodiversity value is associated with richness in a currency of characters of organism then the higher level of biological organization (or environmental factors affecting its distribution) will have to be used in surrogate measures. Choosing a surrogate level from this scale is a compromise between the precision of the measure on the one hand, and the availability of the data and the cost of data compilation on the other. Higher-level surrogates should have the additional advantage of implicitly integrating more of the functional processes that favor viability. The taxonomic inventories in the past have only beenable to reach partial level of understanding the richness (Roy and Behera, 2002).

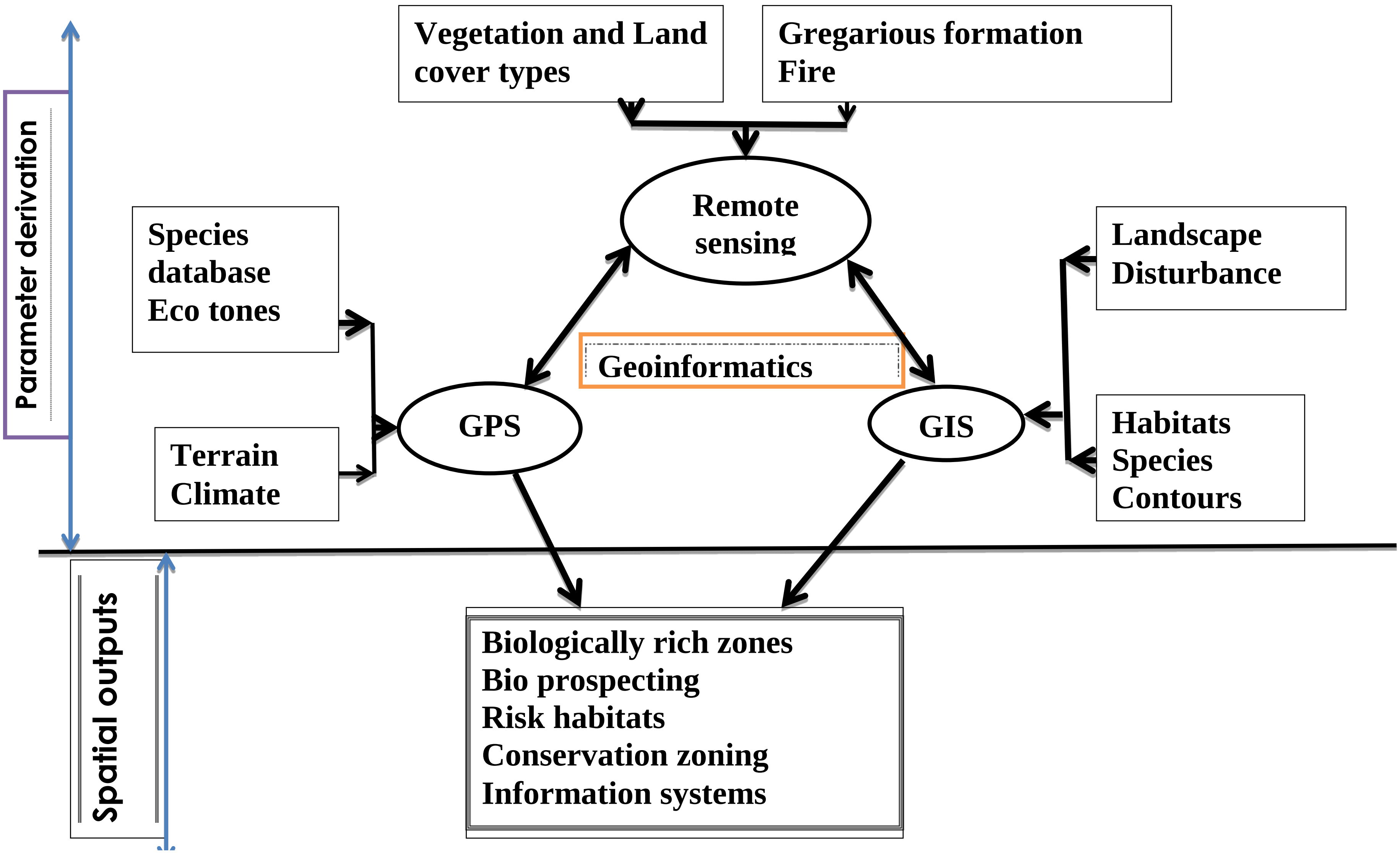


Figure 1: Conceptual Framework

Source: Adopted from Murthy et al. (2003)

CHAPTER THREE

3. METHODS AND MATERIALS

3.1. Description of the Study Area

3.1.1. Location of Study Area

The study area was confined in the highlands of Arbagugu, which is the continuity of Arsi Bale Massif. It covers parts of the highlands of Guna, Gololcha and Chole *woredas* among others (Mohammed 2006). As a result, it is bordered by rural kebeles of these woredas. In terms of absolute location, it extends from 8^{0}05'North to 8^{0}20'North and 39^{0}50'East to 40^{0}05'East (Figure 2).

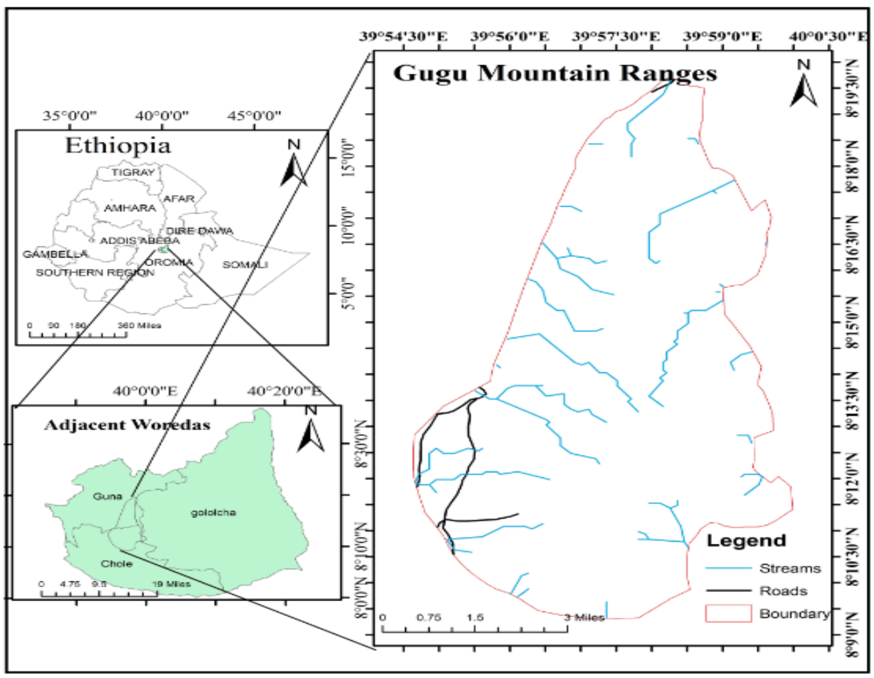


Figure 2: Location of the Study Area in South East Ethiopia
Source: Author, 2019

3.1.2. Topography and Climate

Daniel (1988) indicated that land over 3000 meters above mean sea level (amsl) in Ethiopia accounts 1.3% of the total land area of the country and distributes in Gonder, Gojjam, Wello, Shewa, Bale, Arsi, Gamogofa, Sidamo and Tigray. Specifically, the study area possesses an altitude that extends 3575 meters above mean sea level (amsl). It covers more than 11,355.6 hectares. This mountainous region is one of the peaks located in Arsi-Bale massif and characterized by cool, cool-temperature and temperate agro-climatic zone. According to Hedberg (1964), the climate of afro-alpine ecosystem is governed by geographical circumstances such as vicinity to the equator and the altitude, and seasonal variations are less important than the diurnal one. To this effect, it possesses temperature ranging from 10 to 17.5 degree centigrade (^{0}C), and rainfall estimated between 1000 to 1200 millimeters (AZFEDO, 2018).

Moreover, due to dome shaped nature of the mountain region it serves as water tower for the surrounding *woredas*. As a result, most of the streams in the area radiates from the study site. Henceforth, the ongoing deterioration in the area will consequences multidimensional problems unless checked timely and intervened scientifically.

3.1.3. Vegetation and Wildlife

There were no detailed studies conducted to identify the life in the study area. However, long list that the surrounding woredas offices working on the area makes are similar with what have been differentiated by some scholars conducted on mountainous areas like Bale. Accordingly, EPCC (2015) compiled the list of the Ethiopian afro-alpine and sub-afro-alpine areas floristic studies as *Lobelia rhynchopetalum, Rosularia semiensis, Knifofia floliosa, Euphorbia dumalis, Alchemilla haumannii, Alchemilla ellenbeckii, Hypericum revolutum, Hagenia abyssinica, Erica aroborea, Erica trimera, Philippia keniensis, Thymus schimperi, Hebenstreitia dentata, Cineraria abyssinica, Helichrysum citrispinum, H. splendidum, H. gofense, H. formosissimum, Festuca abyssinica, Haplocarpha ruppellii, Haplocarpha schimperi, Carex monostachya, Euryops prostratus, Aira caryophyllea, Anthemis tigreensis, Arabis alpina, Conyza stricta, Geranium arabicum, Erigeron affroalpinum, Euphorbia dumalis, Satureia biflora, Senecio schultzii, S. steudelii, S. unionis, S. vulgaris, Swertia volkensii, Trifolium burchellianum, Trifolium acaule, Romulea fischeri, Cerastium octandrum, Ranunculus multifidus, R. oreophytus, Stachys sidamoënsis, Veronica glandulosa, Sagina afroalpina, Silene burchellii, Anagallis serpens, Bartsia petitiana, Cotula abyssinica.*

Similarly, major faunal resources of the afro-alpine and sub-afro-alpine areas are: The Ethiopian wolf (*Canis simensis*), Gelada baboon (*Theropithecus gelada*), Walia ibex (*Capra ibex walie*), Mountain nyala (Tragelaphus buxtoni), Giant molerat (Tachyoryctes macrocephalus), Grass rat (*Arvicanthis abyssinicus*), Klipspriger (*Oreotragus oreotragus*), Golden jackal (*Canis aureus*), Serval cat (*Leptailurus serval*), Caracal (*Felis caracal*), Ratel (*Mellivora capensis*), Rock hyrax (*Procavia capensis*), Grey duiker (*Sylvicapra grimmia*), Anubis baboon (*Papio anubis*), Porcupine (*Hystrix cristata*) and Abyssinian hare (*Lepus capensis*), and birds that include Wattled ibis (*Bostrychia carunculata*), the White-collared pigeon (*Columba albitorques*), Thick-billed raven (*Corvus crassirostris*), Blue-winged goose (*Cyanochen cyanopterus*) etc. (EPCC, 2015). Hence, some of and some other than listed types of life can be found in the study areas.

3.1.4. Population Characteristics and Economic Activities

According to population projection of Central Statistical Agency of Ethiopia, the surrounding *woredas* of the study area hosts a total of 115, 871 (Chole), 119,977 (Merti) and 220, 159 (Gololcha) households (CSA, 2013). In this projection, the total number of residents in rural areas were accounting more than 90% of the total population. Reports showed that majority of residents in the study area depend on agriculture (AZoFED, 2018; CSA, 2009; CSA, 1984). Hence, the maps prepared to show the land utilization level of Ethiopia also assured that the surrounding of the study area is ranked as intensively and moderately cultivated area (Figure 3). In addition, EPCC (2015) and IBC (2009) indicated that Afro-alpine and Sub-afro-alpine ecosystem is under pressure from growing human and livestock population of the surrounding areas and subsequent expansion of agricultural and grazing lands to the area.

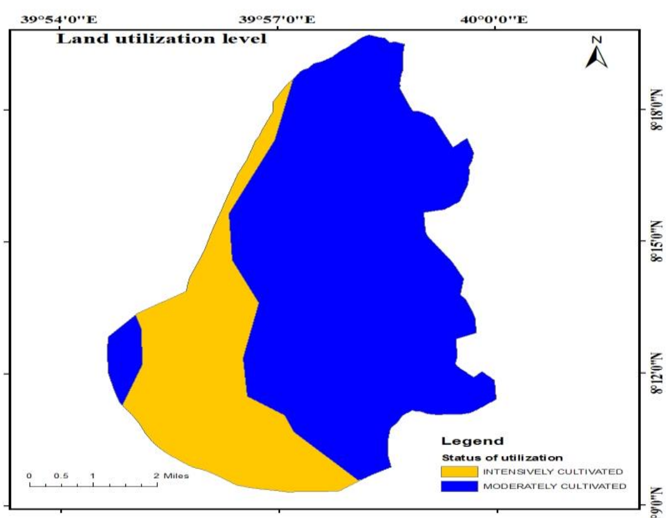


Figure 3: Intensity of land utilization
Source: Ethiopia land-use map, 2009

According to the FAO soil classification, the study area is covered by six different soil types. These soils include *Chromic Cambisols*, *Chromic Luvisols*, *Eutric Cambisols*, *Eutric Fluvisols*, *Eutric Regosols* and *Pellic Vertisols* (FAO, 2002a).

3.2. Research Approach and Design

The cross-sectional study design was employed for this study. Cross-sectional study design is used to when the objective of the study is aimed at assessing the current status of the issue under investigation. This design enabled to obtain all necessary data with the given time and cover the study area (Kumar, 1999). Both quantitative and qualitative approaches were utilized in this study. Therefore, data obtained from field from sample plots and those data obtained from satellite imageries were combined and used to achieve the intended objectives of this study.

3.3. Sampling Design

Twenty five (25) sample plots were taken beginning from 3100 meters up to the highest point through stratified random sampling that kept 100 meters elevation interval with varied areal size that ranges 25 square meters (for grassy areas) and 200 square meters (bush areas). Using transect walk sample plots were covered from smaller elevation in the ecosystem to highest point. Therefore, the study area was stratified into five strata based on elevation, i. e., *3100* to *3199; 3200* to *3299; 3300* to *3399; 3400* to *3499; and >3500* meters. From each stratum, five sample plots were taken as the transect follows west to east side of the mountain range.

3.4. Sources of Data

The major data sources for this study were satellite images of different years downloaded from glovis.usgs.gov (table 1), SRTM (Shuttle Radar Topography Mission), key informants and field inventory. Satellite imageries were obtained from glovis.usgs.gov to trace changes that have been observed in the last thirty years. The year 1991, in Ethiopia history, is known for change of regime. As a result of change of regime, there might be competition to control land. On other hand, 2005 and 2008/9 were years in which some environmental changes have been occurred. After national election of 2005, government was providing land from forest region to unemployed and landless that can become a challenge to the ecosystem. Contrary to this, 2008/9 was noted for the starting of Oromia Forest and Wildlife Enterprise to delineate and protect the forest region in this particular ecosystem. Moreover, elevation, slope and stream network buffer were extracted from DEM/SRTM. Road data, on the other hand, were clipped from EthioGIS prepared by Oromia National Regional State that includes newly constructed regional roads.

Table 1: Information about satellite images used

Satellite	Image date*	Resolution	Path	Row
Landsat 8-OLI	01/02/2019	30m	167	054
Landsat 5-TM	25/12/2001	30m	167	054
Landsat 5-TM	23/02/1989	30m	167	054

Source: glovis.usgs.gov

*All are pertaining to the same season locally named as *Bega* (sunny season were cloud cover is minimized) which includes three months named as December, January and February.

3.5. Data Collection

To generate relevant data, the following data collection techniques were used. These were:

Field observation: GMR forest region was visited to obtain insight knowledge. The natural and anthropogenic activities practiced along GMR were observed. During field observation, GPS points and photographs were taken. The possible evidences on disturbances (e.g. fire, tree felling, dung, grazing, etc.), wildlife (e.g. sightings, droppings, etc.) and other incidents found in the area were critically examined and recorded. In order to generate data of species richness, field measurement was used. To realize this, transect walk by the researcher was made from the west foot of the mountain range to the foot in the east side. In the course of the walk, the required sample measurements were conducted within 100 meters elevation intervals.

Key informants interview: To obtain detailed information of an area, involvement of three farmers that have been lived in the area for longer time and two experts working in the area was essential, and were selected purposively based on the help of administrator of Chole woreda and district manager of Arbagugu Forest and Wildlife Enterprise. To this effect, they were involved to acquire data about wildlife, forest fire and other anthropogenic activities observed in the area some years back and currently. Therefore, unstructured interview was conducted.

Software: Software such as ArcGIS10.3, ERDAS IMAGINE2014, Map source, FRAGSTAT 4.2 and excel were applied. ArcGIS10.3 was utilized to create and use maps, compile geographic data, analyze mapped data, and manage geographic information database. ERDAS imagine 2014, likewise, allowed processing multiple tasks. That is, it was used for classification, ortho-rectification, mosaicking, layer stacking, image interpretation and change detection. Map source was used to map data generated from GPS points. FRAGSTAT 4.2, on the other hand, was utilized to compute fragmentation and diversity indices.

3.6. Data Analysis

3.6.1. Land Use Land Cover Classification and Description

Based on the recognized features, raw remotely sensed satellite images was categorized into a fewer number of individual LUCC classes. According to Rees (2001), image classification is the process of making quantitative decisions from image data, grouping pixels or regions of the image into classes intended to represent different physical objects or types. It can be realized by supervised and unsupervised classification.

For this study, a supervised image classification technique based on maximum likelihood algorithm was used. Supervised classification training the computer for classification by identifying a few training field of known land cover type that can be used to classify the entire image (Malczewski, 1999). Maximum likelihood algorithm in effect models the probability distributions for each class, using training data, from which it is possible to estimate the likelihood that a given pixel belongs to a particular class (Rees, 2001). This helps to make most probable assignment and probability threshold can be imposed (Rees, 2001; Malczewski, 1999).

Six classes were utilized to estimate land use land cover of the study area. Thus, it was classified into afro-alpine and sub-afro-alpine, upper afro-montane, swamps, grazing/fallow/open areas, settlement and farmland (Table 2). In the study site, farmers are using grazing land, fallow and open forest regions interchangeably. Particularly, fallowed lands were done either to secure tenure or due to demarcation of farm plots toward forest region. As a result, grazing, fallow and open lands were coined together.

Table 2: Description of classes

Class name	Description
Afro-alpine and sub-afro-alpine	Vegetation that covers elevation above 3200 meters above mean sea level.
Upper afro-alpine	Vegetation type that covers areas whose elevation extending from 2600 to 3200 meters above mean sea level.
Swamps	Areas that have wetlands
Settlement	Includes hamlets, villages and small towns in the area.
Farmland	Include areas that are used for crop production and most particularly used for cereal crops and cash crops.
Grazing	Areas that are used as source of forage for livestock.
Fallow	Areas that were used as farmland but now left idle.
Open areas	Areas in the forest region but not covered by vegetation.

3.6.1.1. Accuracy Assessment

The Kappa Index of Agreement was used to assess the accuracy of the classification result. This index compares two images, that is, image that contains interpreted land cover map and image that contains the result of ground truth investigations. It was, therefore, created an error matrix that tabulate different land cover classes to which ground control points was assigned.

Using reference data obtained from pre-classification satellite images, errors that were observed in classifying LULC were assessed for each year. Accordingly, 483, 478 & 484 reference points were taken to assess accuracy of 1989, 2001 and 2019 LULC classification respectively. Based on table 3, the results were decided whether there was or there was no agreement exists.

Table 3: Kappa agreement

Kappa coefficient result	Agreement
<0	Less than chance agreement
0.01-0.20	Slight agreement
0.21-0.40	Fair agreement
0.41-0.60	Moderate agreement
0.61-0.80	Substantial agreement
0.81-0.99	Almost perfect agreement

Source: Veirra and Garrett (2005)

3.6.2. Change Detection

Minu and Shetty (2015) showed the application of various algorithms for change detection. Of these, image differencing and change vector analysis were used for this study. Based on image differencing of Minu and Shetty (2015), change in the amount of Afro-alpine and Sub-afro-alpine ecosystem was generated using the following formula (Formula 1). Image differencing involves substation of the first date image from a second date image, pixel by pixel. If value is positive it suggests an increase where as if negative value it implies decrease in that particular land use land cover.

Total LUCC in hectares=Area $_{\text{final year}}$-Area $_{\text{initial year}}$……………………………1

To compute the rate of change of each land use land cover, the following formula that was standardized by Puyravaud (2003) was used.

$$\text{Rate of LUCC}=\frac{1}{t2-t1}\times \ln\frac{A2}{A1} \quad \ldots\ldots 2$$

Where t_1-recent year LUCC; t_2-Initial year LUCC; *ln*-natural logarithms; A_2-area of category in recent time and A_1-area of the category at initial year.

Additionally, change vector analysis was also used to compute change. The change vector analysis involves two variables: the magnitude of variation and the angle of the change vector (Minu and Shetty, 2015). So that, normalized difference vegetation index (NDVI) was used.

$$\text{NDVI}=\frac{NIR-RED}{NIR+RED} \quad \ldots\ldots 3$$

Holme et al. (1987) showed as NDVI can compute the vegetation of a given area by differentiating from that of bare soil due to absorption of visible light and reflection of near infrared. Zaitunah et al. (2018) classified NDVI values into six categories which manifests increase in vegetation dense as NDVI values increases (Table, 4)

Table 4: NDVI Value Classification

Class	NDVI
No vegetation	<0
Lowest dense vegetation	0 to 0.15
Lower dense vegetation	0.15 to 0.3
Dense vegetation	0.3 to 0.45
Higher dense vegetation	0.45 to 0.6
Highest dense vegetation	>0.6

Source: Zaitanuh et al. (2018)

3.6.2. Fragmentation and Disturbance Analysis

In their response to the Fletcher et al (2018) critics on the finding of Fahrig (2017), Fahrig et al. (2019) indicated that fragmentation control for habitat amount is neither generally good nor generally bad for biodiversity. Fahrig (2003) suggested that fragmentation should be limited to breaking apart of habitat. For her, fragmentation has no consistently negative effects on biodiversity like habitat loss. And, she finally summarized habitat fragmentation as changes in habitat configuration that result from the breaking apart of habitat, independent of habitat loss (Fahrig 2003).

Franklin et al. defined it as “the discontinuity resulting from a given set of mechanisms, in the spatial distribution of resources and conditions present in the area at a given scale that affects occupancy, reproduction, or survival in a particular species” (Franklin et al., 2002). As a result, habitat fragmentation is the mixture of habitat and non-habitat. In this study, we are looking fragmentation as a challenge to biodiversity due to the fact that fragmentation increase isolation of patches and decline of species and disruption of ecosystem processes (Fletcher et al., 2018; Millhouser and Singer, 2018; Munir et al., 2018; Ibanez et al., 2017; Fuller et al., 2015; Flaspohler et al., 2010; Broadbent et al., 2008).

Though there is no perfect metrics for habitat fragmentation analysis but used under certain conditions and biological questions (Wang et al., 2014), image that is classified using ERDAS imagine2014 was converted to polygon to adjust the projection and reconverted to raster after reclassification, and exported to FRAGSTAT 4.2.1 for area, shape and aggregation metric computation. Therefore, area, perimeter, radius of gyration, largest patch index, edge index, shape index, fractal dimension index, percentage of like adjacencies, interspersion and juxtaposition index, patch cohesion index, splitting index, aggregation index and contagion index were used to analyze fragmentation and disturbances.

The **patch size** information was used to model patch occupancy and species distribution patterns in the ecosystem. Area metrics, therefore, was used to quantify the composition but not configuration. As a result, the area of a patch comprises landscape mosaic whereas radius of gyration measures patch extent. All other things equal, the larger the patch the larger radius of gyration. Ecologically, **radius of gyration** measures average distance an organism can move within a patch before encountering patch boundary.

Due to its ability to measure the complexity of patch shape compared to a standard shape of the same size, shape index is used for ecological research. **Shape index** is equals to one when the shape is square and increases if irregular. Irregularity shows existence of disturbance in the area. Similarly, **fractal dimension index** result ranges from one to two, approached to one for regular shape and approach to two if otherwise.

For measuring level dispersion (spatial distribution of patches or classes), interspersion (spatial intermixing of different patch types or classes), subdivision (degree to which patch types broken into separate patches or fragments) and isolation (degree to which patches are spatially isolated from each other) aggregation metrics were used. **Aggregation index** which is zero showed maximal fragmentation and 100 that is maximally aggregated. **Percentage of like adjacencies** measures zero if patches are maximally disaggregated and 100 if area under study has single patch. **Splitting index** that equals to one showed a single patch but increased value represents high more fragments. **Patch cohesion index** is zero if patches are less physically connected and 100 if there is high physical connectedness. **Interspersion and Juxtaposition Index** approaches to zero if patch type is adjacent to only one other patch type and number of patch type increase and 100 if patch type is equally adjacent to all other patch type. **Contagion index** approaches to zero if the patch types are maximally disaggregated and interspersed and 100 if all patch types are maximally aggregated.

3.6.3. Species Richness Analysis

Species richness was computed using two important mechanisms. The first method was based on the patch diversity computed by FRAGSTAT. Secondly, data obtained from field was used to compute floristic species diversity. In order to compute both patch diversity and species diversity Shannon diversity index (SHDI) and Simpson diversity index (SIDI) were utilized.

$$\text{SHDI} = -\sum_{i=1}^{s} Pi\ ln\ (pi) \qquad \text{.......} 4$$

Where:

SHDI-the Shannon diversity index; **Pi**- the proportion of the total community abundance represented by i^th species; **Ln** (**Pi**)- is natural log of **Pi**; **S**-number of species encountered

$$\textbf{SIDI} = 1 - \left(\frac{\sum n(n-1)}{N(N-1)}\right) \quad \ldots\ldots 5$$

Where:

SIDI-the Simpson diversity index; **n**-total number of organisms of particular species; **N**-the total number of all species

With Simpson diversity index zero represents lower diversity where as one represents high diversity. Hence, as values increases it reflects increment of diversity. Similarly, non-zero Shannon diversity index result also indicates an existence of richness in the particular areas (Daly et al., 2018).

3.5.5. Biodiversity Vulnerability Mapping

In order to estimate vulnerability of biodiversity, parameters such as land use land cover, population density, terrain impendence and naturalness index (Roy and Srivasta 2012), and slope gradient, proximity to roads, land use management classes, species richness, patch size, shape and level of fragmentation (Sloan et al. 2014; Zelalem 2007) were forwarded. Based on these, the following parameters were identified to map biodiversity vulnerability of afro-alpine and sub-afro-alpine ecosystem of the study area (see Table 5).

Table 5: Parameters for mapping biodiversity vulnerability

Variable	**Ranges**	**References**
Proximity to Road networks **(in KM)**	<1; 1 to 2; 2 to 3; > 3	Geparaju et al. (2017)
Proximity to stream networks **(in KM)**	<1; 1 to 1.5; >1.5	Areendran et al. (2011); Oslon et al. (2007)
Elevation **(in M amsl)**	>3500; 3400 to 3499; 3300 to 3399; 3200 to 3299; <3200	Friis et al. (2010)
Slope **(%)**	0; 0 to 5; 5-10; 10-25; 25-35; <35	Geparaju et al. (2017)
Land use land cover	Afro-alpine and sub-afr-alpine; Swamps; Upper afro-montane; Grazing/Fallow/Open; Farmland; Settlement	Arunyawat and Shrestha (2016); Sloan et al., (2014); Areendran et al. (2011); Haines-Young (2009)

3.6. Ethical Considerations

In biodiversity analysis, field data collection was needed. Hence, both floristic and fauna diversity were observed in proper way. In all course of action, there were no unwanted intervention and disturbance of habitat under the study. The mountain border delimited in for this study area was also used for this study only and represents area needed for the study alone.

Letters of cooperation were submitted to *Arbagugu* District Forest and Wildlife Enterprise and *Choleworeda* administration offices. Accordingly, permission letter were attained from them and helps to realize cooperation of *kebele* administration and farmers around study area.

4. Methodological Flowchart

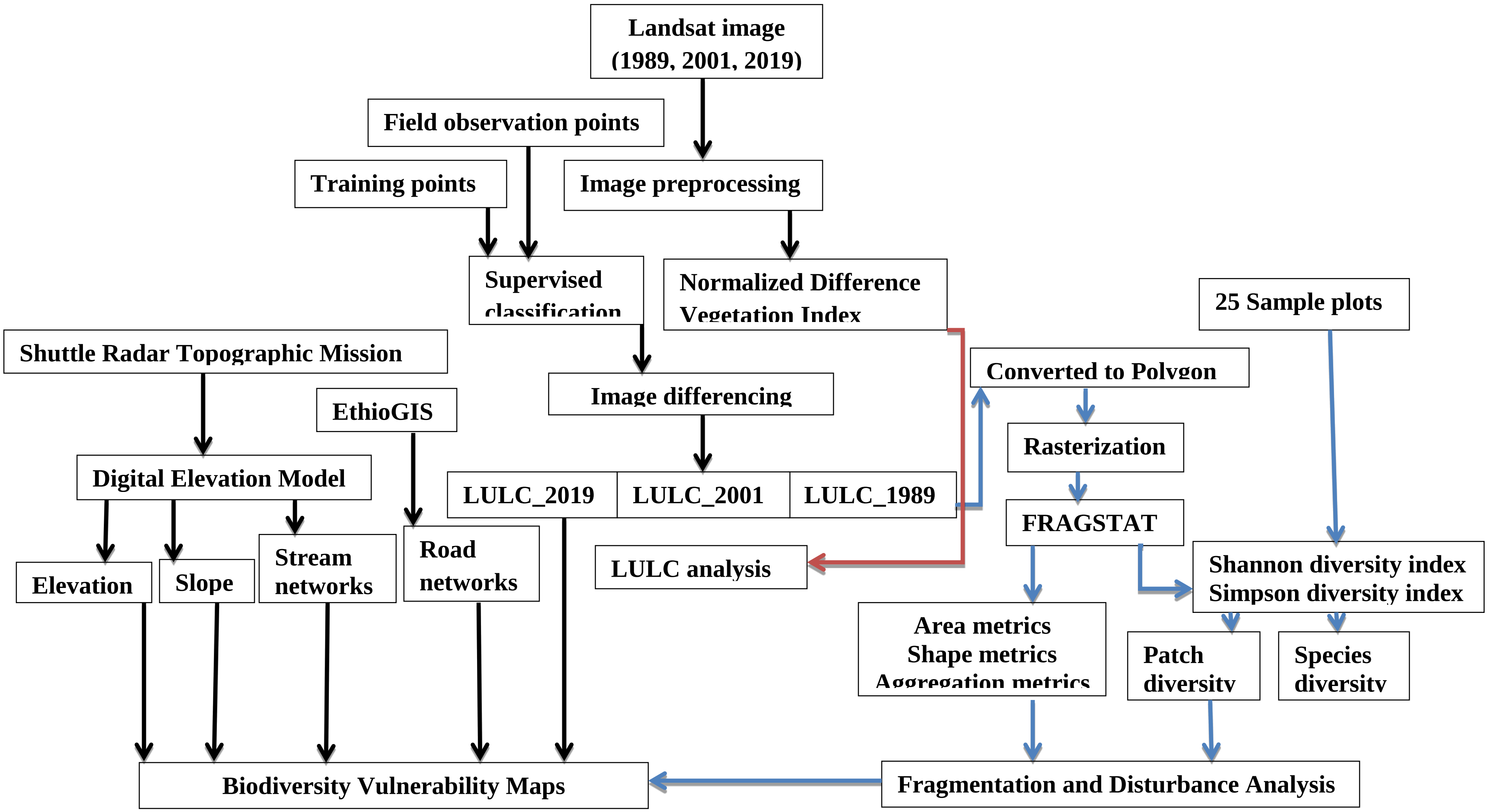


Figure 4: Methodological Flowchart

CHAPTER FOUR

4. RESULTS AND DISCUSSION

4.1. Land Use Land Cover (1989, 2001 and 2019)

Loss of biodiversity caused by land-use changes is one of the most severe threats to sustainability (Michelsen and Lindner, 2015). Land use and land cover are ways of observing earth's surface, and helps to answer: what is this (land cover)? And what is it for (land use)? (Ellis, 2007). That is, land cover refers to the bio-physical cover of the earth surface which includes water, vegetation, bare soil and/or artificial structures. On the other hand, land use is more complicated than land cover. But, it is viewed as syndromes of human activities such as agriculture, forestry and building that alter land surface processes including biogeochemistry, hydrology and biodiversity; or viewed as social or economic purposes and contexts for and within which land are managed (Ellis, 2007; Lambin et al., 2003).

Land use and land cover change is a reflection of the impact of biotic and abiotic drivers on the prevalent land use and land cover of the region (Roy and Roy, 2010). According to Ellis (2007), biodiversity is reduced dramatically by LULC. Hence, this under this heading the LULC of the study area was presented based on the satellite image data.

In order to map LULC of the study area, Landsat images of 1989, 2001 and 2019 were used. Based on observed features, six categories were utilized to estimate LULC of an area. Thus, it was classified into afro-alpine and sub-afro-alpine, upper afro-montane, swamps, grazing/fallow/open areas, settlement and farmland (Figure 5).

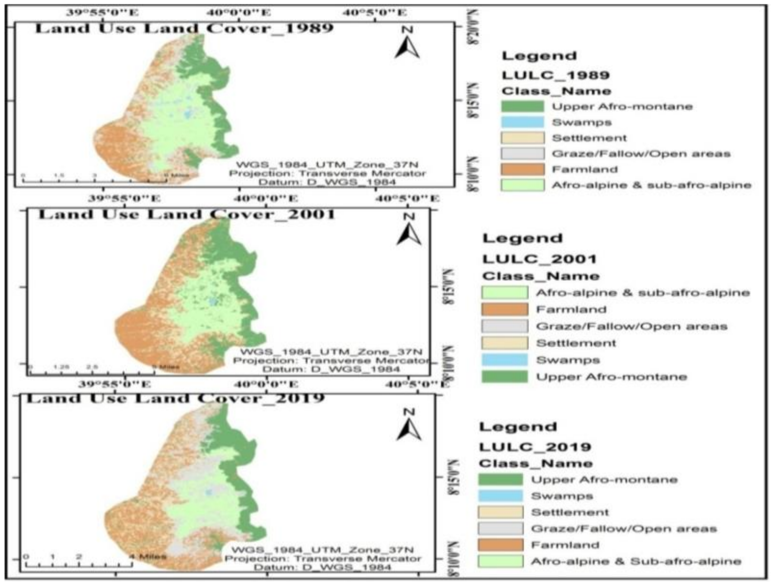


Figure 5: Land use land cover of 1989, 2001 and 2019

Source: Author, 2019

According to Table 6 below, in 1989 afro-alpine vegetation was covering larger parts of the study area (31.18%) and followed by farmland (23.03%) and upper afro-montane (18.49). The remaining parts were covered by Grazing/fallow/open areas (17.62%), settlement (8.7%) and swamps (0.98%). Likewise, in 2001 majority of the study area was farmland (35.44%) and the remaining were classified as afro-alpine and sub-afro-alpine (26.08%), upper afro-montane (24.09%), settlement (12.91%), grazing/fallow/open areas (1.12%) and swamps (0.37%).Currently, in 2019, the proportion of classes in the study area showed that farmland (26.41%), Grazing/fallow/open areas (24.53%), upper afro-montane (18.61%), afro-alpine and sub-afro-alpine (16.27%), settlement (14.03%) and swamps (0.16%).

Table 6: Land use land covers area in hectares

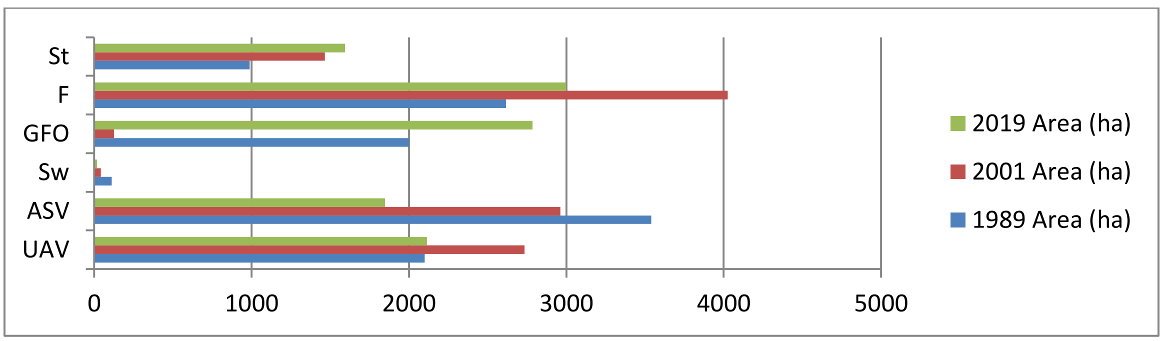
Class name	1989		2001		2019	
	Area (ha)	%	Area (ha)	%	Area (ha)	%
UAV	2099.61	18.49	2735.1	24.09	2113.61	18.61
ASV	3540.63	31.18	2961.72	26.08	1846.98	16.27
Sw	110.88	0.98	42.48	0.37	17.775	0.16
GFO	2000.55	17.62	125.63	1.12	2785.68	24.53
F	2615.49	23.03	4024.78	35.44	2998.51	26.41
St	988.2	8.70	1465.65	12.91	1592.8	14.03
Total	**11355.36**	**100**	**11355.36**	**100**	**11355.36**	**100**

UAV*-Upper Afro-montane Vegetation;* ***ASV****-Afro-alpine and sub-afro-alpine vegetation;* ***Sw****-Swamps;* ***GFO****-Grazing/Fallow/Open areas;* ***F****-Farmlands;* ***St****-Settlement.*

Source: Author, 2019

4.1.1. Trend of Land Use Land Cover Change

The LULC was extremely changing in 1989, 2001 and 2019. As a result, some of the classes exhibited an increase and others diminished and equivocated. As specified in Figure 6, Afro-alpine and sub-afro-alpine vegetation and swamps cover were declined from 1989 to 2019. Settlement areas were increased in the three cover situations. But, farmland and upper afro-montane vegetation cover were showing increment 1989 to 2001 but decreased from 2001 to 2019. According to informants, decrease of farmland between 2001 and 2019 was happened due to demarcation of farmland nearby forest region by Oromia forest and wildlife enterprise and prohibited to plough it up to date. On the other hand, grazing/fallow/open areas was greatly reduced from 1989 to 2001 and vastly amplified from 2001 to 2019. Hence, farmland, settlement and grazing/fallow/open areas were expanded at the costs of afro-alpine ecosystems in the last 30 years.



***UAV**-Upper Afro-montane Vegetation; **ASV**-Afro-alpine and sub-afro-alpine vegetation; **Sw**-Swamps; **GFO**-Grazing/Fallow/Open areas; **F**-Farmlands; **St**-Settlement.*

Figure 6: Land use land cover trend from 1989 to 2019

Source: Author, 2019

The rate of change of land use land cover for afro-alpine and sub-afro-alpine classes was approximately -1.49% from 1989 to 2001, and -2.62% from 2001 to 2019. The overall rate of change from 1989 to 2019 was -2.17%. This showed that there has been an increase trend of rate of diminishing of afro-alpine and sub-afro-alpine biodiversity in the last 30 years.

4.1.1.1. Normalized Difference Vegetation Index (NDVI)

NDVI can be used in vegetation studies. According to Holme et al. (1987), healthy vegetation absorbs most visible light and reflects large portion of the near infrared light. Contrary to this, if vegetation is unhealthy and sparse the reflection of visible light will be more; while near infrared light reflection will be lesser. Bare soil, on the other hand, reflects both red and infrared portions of the electromagnetic spectrum moderately.

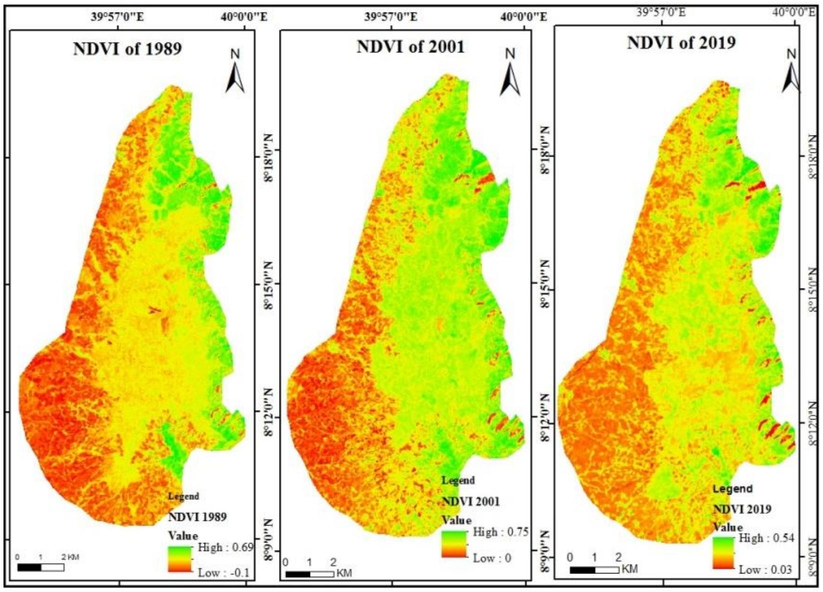


Figure 7: NDVI values of 2019, 2001 and 1989
Source: Author, 2019

In 1989, the minimum value was -0.1 and maximum value was 0.69 with mean value of 0.29 and standard deviation of 0.23. Similarly, in 2001 minimum and maximum values were 0 and 0.74 respectively. And their mean value was 0.37 while standard deviation was 0.22. Moreover, in 2019 minimum, maximum, mean and standard deviation of NDVI value of the study area were 0.03, 0.54, 0.29 and 0.15 respectively (Table 7). Standard deviation of 1989, 2001 and 2019 were 0.23, 0.22 and 0.15 respectively that manifested decreasing trend. Hence, the standard deviation result clearly showed that there was decline in vegetation cover.

Table 7: Statistical computation of NDVI values

Computed statistics	NDVI_1989	NDVI_2001	NDVI_2019
Minimum	0.10	0.00	0.03
Maximum	0.69	0.74	0.54
Mean	0.29	0.37	0.29
Standard deviation	0.23	0.22	0.15

Source: Author, 2019

For detailed analysis, six classes of NDVI values and areas of each class were calculated on ERDAS IMAGINE 2014. It appears that, dense and above vegetation found to be high in 2001(8350.74 ha) compared to 1989 (6430.88 ha) and 2019 (3108.915 ha). Contrary to this, 2019 was characterized by high proportion of low and no vegetation (8246.44 ha) but in 2001 and 1989 it was 3004.62 and 4924.26 hectares. Therefore, it was observed that there are clear decline in vegetation cover that contribute for high NDVI values.

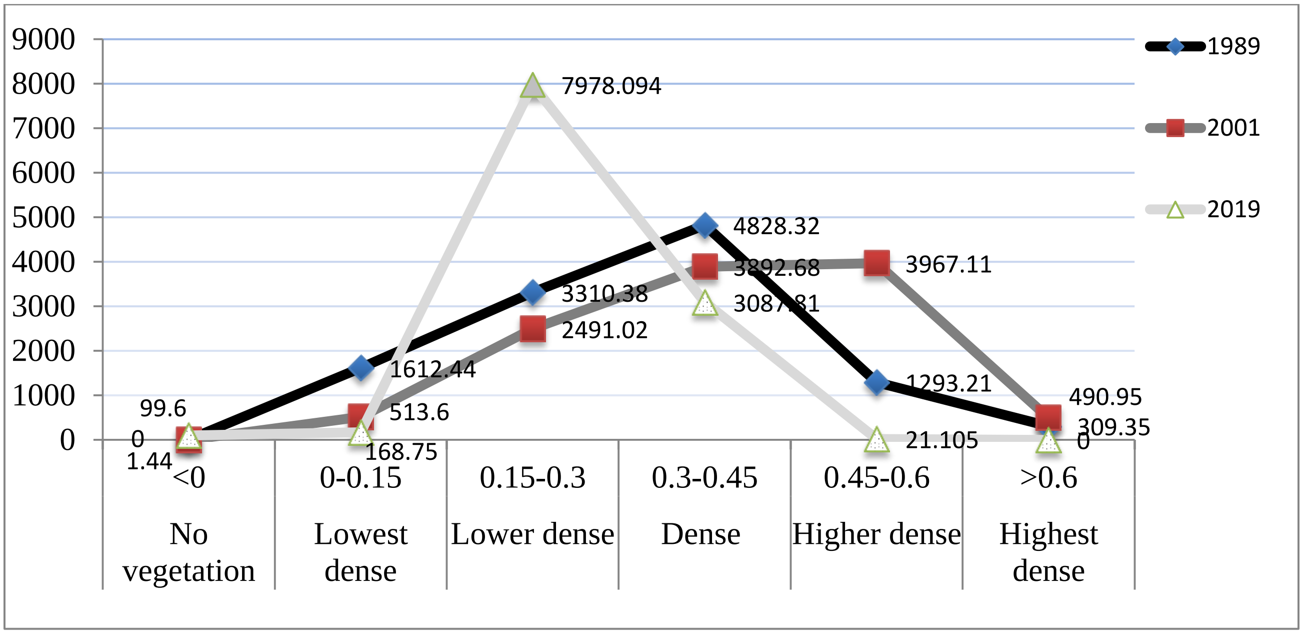


Figure 8: NDVI values of study area in 1989, 2001 and 2019
Source: Author, 2019

4.1.1.2. Change Computed by Image Differencing

Image differencing is performed by subtracting the digital numbers (DN) value of one date for a given band from the DN value of the same pixel for the same band of another date (Macleod and Congalton, 1998). In the process of classification, it needs to assign the appropriate 'from' and 'to' identifiers. According to Table 8, vegetation cover that was classified as afro-alpine was converted 'from' and 'to' this class. Between 1989 and 2001, afro-alpine and sub-afro-alpine vegetation lost 578.91 ha and only 355.44 ha were converted to afro-alpine. Hence, there was conversion of afro-alpine vegetation conversion primarily to settlement and farmland.

Table 8: Change matrix of 1989 and 2001

Final LULC (2001)	Classes	Initial state of LULC (1989)						
		UAV	ASV	Sw	GFO	F	St	Total
	UAV	**1882.08**	120.24	0.45	0.36	55.08	41.4	**2099.61**
	ASV	181.26	**2606.28**	7.02	3.33	289.71	453.23	**3540.83**
	Sw	21.06	45	**32.13**	0.72	10.53	1.44	**110.88**
	GFO	430.74	165.69	1.89	**59.13**	1017.3	325.8	**2000.55**
	F	178.92	22.5	0.63	32.31	**2004.66**	376.47	**2615.49**
	St	41.04	2.01	0.36	30.03	647.46	**267.3**	**988.2**
	Total	**2735.1**	**2961.72**	**42.48**	**125.88**	**4024.74**	**1465.64**	

***UAV**-Upper Afro-montane Vegetation; **ASV**-Afro-alpine and sub-afro-alpine vegetation; **Sw**-Swamps; **GFO**-Grazing/Fallow/Open areas; **F**-Farmlands; **St**-Settlement.*

Source: Author, 2019

As indicated in Table 9, between 2001 and 2019, afro-alpine and sub-afro-alpine vegetation cover highly threatened and around 1114.74 ha were converted to other land use and land cover. But, only 111.95 hectares were converted from other LULC to afro-alpine vegetation. Unlike previous years, most afro-alpine and sub-afro-alpine vegetation was converted to graze/fallow/open areas. Hence, change of afro-montane vegetation increased and most land areas covered by such ecosystem was converted by human activities (other land use) than any other cover that can harm being habitat.

Table 9: Change matrix of 2001 and 2019

Final LULC (2019)	Classes	Initial state of LULC (2001)						
		UAV	ASV	Sw	GFO	F	St	Total
	UAV	**1789.16**	44.7975	0.27	562.05	253.215	85.6125	**2735**
	ASV	132.547	**1735.06**	0.2475	896.85	76.005	121.005	**2962**
	Sw	0.1575	2.565	**17.0775**	20.34	1.26	1.08	**42.48**
	GFO	2.565	0	0	**53.5725**	42.2775	12.465	**110.9**
	F	129.533	15.1875	0.18	772.81	**2069.93**	993.6	**3981**
	St	59.6475	49.365	0	421.808	555.818	**378.967**	**1466**
	Total	**2113.61**	**1846.98**	**17.775**	**2727.4305**	**2998.51**	**1592.73**	

***UAV**-Upper Afro-montane Vegetation; **ASV**-Afro-alpine and sub-afro-alpine vegetation; **Sw**-Swamps; **GFO**-Grazing/Fallow/Open areas; **F**-Farmlands; **St**-Settlement.*

Source: Author, 2019

Generally, from the year 1989 to 2019 land use land cover has been observed indicated in matrix table 10 and its trend was summarized and presented in table attached as appendix Ia. Accordingly, afro-alpine and sub-afro-alpine class, in the last 30 years, was converted to grazing/fallow/open area (1125.758 ha), settlement (286.785 ha), farmland (203.985 ha) and upper afro-montane vegetation (122.9625 ha) respectively, whereas classes only below 50 ha was converted from upper afro-montane vegetation, swamps, grazing/fallow/open areas, farmlands and settlement to afro-alpine and sub-afro-alpine class. Hence, from its initial year total coverage, i. e., 3540.83 ha, above 29% (nearly 1700 ha) of it was converted to other classes. This brings greater challenge to afro-alpine and sub-afro-alpine biodiversity.

Table 10: Change matrix of 2001 and 2019

	Classes	Initial sate of LULC (1989)						
		UAV	**ASV**	**Sw**	**GFO**	**F**	**St**	**Total**
Final LULC (2019)	UAV	1720.328	122.9625	0.135	145.35	108.855	15.975	**2113.605**
	ASV	23.1075	1801.35	1.1475	14.85	1.575	4.95	**1846.98**
	Sw	0	0	17.5275	0.2475	0	0	**17.775**
	GFO	211.2975	1125.758	89.1675	906.163	255.465	154.935	**2742.786**
	F	108.3825	203.985	1.8225	634.3425	1576.778	473.1975	**2998.508**
	St	36.495	286.785	1.08	256.5	672.8175	339.0525	**1592.73**
	Total	**2099.61**	**3540.84**	**110.88**	**1957.453**	**2615.49**	**988.11**	

UAV-*Upper Afro-montane Vegetation;* ***ASV***-*Afro-alpine and sub-afroalpine vegetation;* ***Sw***-*Swamps;* ***GFO***-*Grazing/Fallow/Open areas;* ***F***-*Farmlands;* ***St***-*Settlement.*

Source: Author, 2019

4.1.1.3. Accuracy Assessment

In order to verify accuracy of classification, commission and omissions were identified and producer and user accuracy were checked. Furthermore, to assess accuracy of overall classification in each year, overall accuracy and Kappa coefficient of agreement was computed. LULC classification undertaken for 1989, 2001 and 2019 encountered commission and omission problems. These errors were computed based on information on appendix Ib.

Consequently, the level of commission and omission producer and user accuracy were calculated and the result showed that classification of grazing/fallow/open areas encountered high commission that brought lower amount of producer accuracy. Relatively, higher accuracy assessment in both producer and user accuracy except grazing/fallow/open areas afore mentioned (see appendix Ib). Finally, the overall accuracy of 1989, 2001 and 2019 were 96.48%, 86.19% and 95.66% respectively (see table 11). This showed that there are high agreement between classified data and reference data. Similarly, Kappa coefficient results of the 1989, 2001 and

2019 satellite image classification were 95.66%, 82.74% and 94.64% respectively. These results found within 0.81 to 0.99 which is labeled as almost perfect agreement.

Table 11: : Overall accuracy and Kappa coefficient (1989, 2001 and 2019)

	1989	2001	2019
Overall accuracy	0.9648	0.8619	0.9566
Kappa coefficient	0.9566	0.8274	0.9464

Source: Author, 2019

4.1.2. Fragmentation and Disturbance Computation

For the fragmentation and disturbance analysis, FRAGSTAT version 4.2.1 was utilized and analyzed at patch, class and study area level for the year 1989, 2001 and 2019. The following were the output results of FRAGSTAT for the study area.

4.1.2.1. Area Metric

In order to analyze the fragmentation level of the GMR, the area metrics such as area, perimeter, radius of gyration, class (total) area, largest patch index, total edge and edge density were computed.

As indicated on table 12, patch area and radius of gyration decreased from 1989 to 2019. But, perimeter of afro-alpine and sub-afro-alpine vegetation was showed an increment from 1989 to 2001 and decreased from 2001 to 2019.

Table 12: Patch metrics of afro-alpine and sub-afro-alpine class

Year	No. of patches	Patch Area (in hectares)				Perimeter (in kilometers)				Radius of gyration
		Min.	Max.	Mean	Total	Min.	Max.	Mean	Total	
1989	544	0.09	3215.79	6.48	3540.63	0.12	276.16	0.85	460.08	30.96
2001	884	0.09	2666.97	3.35	2951.72	0.12	276.18	0.57	507.18	25.20
2019	377	0.02	1587.89	4.9	1846.98	0.02	228.87	0.89	335.61	22.99

Source: Author, 2019

Table 13 showed that there was ups and down on the total edge and edge density. But, the total edge and edge density of settlement and farmland depicted an increasing trend. In the year 2019, there is greater increase of total edge and edge density of grazing/fallow/open areas. Hence, potentially settlement, farmland and grazing/fallow/open areas have impacts on afro-alpine and sub-afro-alpine vegetation area. In terms of largest patch index, afro-alpine and sub-afro-alpine vegetation decreased from 1989 to 2019. Grazing/Fallow/Open areas remained dominant in the year 1989 and 2019; whereas farmlands become dominant in 2001.

Table 13: Class metrics of each class

Year	Class type	Area (in hectares)	Total edge (in km)	Edge Density (in km)	Largest patch index
1989	GFO	2000.55	953.91	50.416	26.054
	St	988.2	439.26	23.216	0.2435
	ASV	**3540.63**	**460.08**	**24.316**	**16.996**
	F	2615.49	854.73	45.174	7.5536
	UAV	2099.61	296.1	15.65	9.5552
	Sw	110.88	57.42	3.0348	0.1755
2001	F	4024.78	931.23	49.217	49.245
	St	1465.65	630.75	33.336	1.5307
	ASV	**2961.72**	**507.18**	**26.805**	**14.095**
	GFO	125.63	98.34	5.1975	0.0342
	UAV	2735.1	600.3	31.727	10.091
	Sw	42.48	21.78	1.1511	0.1061
2019	GFO	2785.68	1140.975	60.256	46.639
	St	1592.8	950.43	50.193	0.8516
	F	2998.51	1380.66	72.914	5.9635
	UAV	2113.61	391.305	20.665	9.3011
	ASV	**1846.98**	**335.61**	**17.724**	**8.3858**
	Sw	17.775	4.14	0.2186	0.0899

***UAV**-Upper Afro-montane Vegetation; **ASV**-Afro-alpine and sub-afro-alpine vegetation; **Sw**-Swamps; **GFO**-Grazing/Fallow/Open areas; **F**-Farmlands; **St**-Settlement.*

Source: author computation, 2019

4.1.2.2. Shape Metrics

Shape influences inter-patch processes such as animal migration, plant colonization and animal forage strategies. Shape index, measure of the complexity of the patch shape compared to a standard shape of the same size, and fractal dimension index, that is applied to spatial features over variety of scales, were used in this study. As indicated on Table 14, shape index of afro-alpine vegetation areas showed oscillating trend. On the other hand, fractal dimension index increases slightly with passage of time that showed slight increment in shape complexity.

Table 14: Shape metrics of afro-alpine vegetation areas

Measures	1989	2001	2019
Shape index	19.33	23.3	19.52
Fractal dimension index	1.03	1.03	1.04

Source: Author, 2019

4.1.2.3. Aggregation Metrics

Aggregation refers to the tendency of patch types to be spatially aggregated, that is, to occur in large aggregated or contagious distributions. Aggregation describes dispersion, interspersion, subdivision and isolation. In this paper, number of patches (NP), patch density (PD), percentage of like adjacencies (PLADJ), interspersion and juxtaposition index (IJI), patch cohesion index (COHESION), splitting index (SPLIT), aggregation index (AI) and contagion index (CONTAG).

Therefore, in this study those indices were considered as follows. Firstly, an increase number of patches show existence of fragmentation. Secondly, maximum patch density attained when every cell is separate patch. Thirdly, percentage of like adjacencies is lower if patch types are maximally aggregated. Fourth, increase in splitting index shows as patch type is increasingly reduced in area and sub-divided into smaller patches. Fifth, patch cohesion index measures the physical connectedness of the corresponding patch type. An increase in this index increasingly subdivided and less physically connected. Sixth, maximum interspersion and juxtaposition index shows as corresponding patch type is equally adjacent to all other patch types. Seventh, as aggregation index approaches to zero it shows as maximal disaggregation exists. Lastly, the result of contagion index approaching to zero shows maximal disaggregation and interspersed.

As indicated on Table 15, NP, PD, SPLIT, COHESION and IJI were manifested higher values that indicate the existence fragmentation. On the other hand, PLADJ and AI showed value approaching to 100 implies lower fragmentation. But, since the values are not exactly 100 it is an indication of existence of fragmentation.

Table 15: Aggregation metrics results of each class

Year	TYPE	NP	PD	PLADJ	IJI	COHESION	SPLIT	AI
1989	**GFO**	1488	7.8644	92.081	83.59	98.30	12.08	92.36
	St	723	3.8212	66.658	45.98	87.69	27627.66	67.30
	ASV	**544**	**2.8751**	**90.213**	**73.86**	**99.34**	**34.61**	**90.67**
	F	994	5.2535	75.486	65.53	98.05	171.68	75.93
	UAV	417	2.2039	89.419	66.56	99.06	108.72	90.01
	Sw	181	0.9566	61.161	41.44	80.75	271101.1	62.98
2001	**F**	671	3.5464	93.607	72.74	99.81	3.95	93.87
	St	1026	5.4226	67.722	44.21	93.92	2983.82	68.26
	ASV	**884**	**4.6721**	**87.157**	**69.32**	**99.17**	**50.32**	**87.64**
	GFO	410	2.1669	33.482	38.93	58.23	2928510	34.48
	UAV	1010	5.338	83.536	61.27	98.32	96.65	84.02
	Sw	114	0.6025	61.547	64.61	72.84	832367.9	64.56
2019	**GFO**	1784	9.4214	95.662	80.31	99.75	4.58	95.80
	St	1897	10.0182	77.624	43.57	94.69	8629.29	77.92
	F	2433	12.8488	82.733	58.39	99.12	200.44	82.96
	UAV	1188	6.2739	93.057	74.87	99.1	115.33	93.36
	ASV	**377**	**1.991**	**93.186**	**41.26**	**99.58**	**140.69**	**93.51**
	Sw	6	0.0317	91.266	4.71	95.73	1235190	94.68

***UAV**-Upper Afro-montane Vegetation; **ASV**-Afro-alpine and sub-afro-alpine vegetation; **Sw**-Swamps; **GFO**-Grazing/Fallow/Open areas; **F**-Farmlands; **St**-Settlement.*

Source: Author, 2019

Like aggregation indices of class, at study area scale level, the variables used to check existence and absence of fragmentation showed presence of fragments (see Table 16). As a result, aggregation metrics applied in the study area showed as there were fragmentations at different expressed in different magnitudes.

Table 16: Aggregation metrics result of the GMR

Year	Total area	NP	PD	CONTAG	PLADJ	IJI	COHESION	SPLIT
1989	11355.36	4347	22.9747	48.621	87.6343	74.0339	98.4247	7.8911
2001	11355.36	4115	21.7486	57.01	88.7122	66.563	99.3549	3.5259
2019	11355.36	7685	40.5849	53.825	91.5611	65.575	99.3875	4.1789

Source: Author, 2019

4.1.3. Diversity Metrics

4.1.3.1. Patch Diversity

FRAGSTATS computes three diversity indices which are influenced by richness and evenness. For this paper, landscape level diversity was analyzed using patch richness (PR), patch richness density (PRD), Shannon diversity index (SHDI) and Simpson diversity index (SIDI). Patch richness corresponds to types of classes. Patch richness density, on the other hand, shows more diversity as its value increases. Shannon diversity index increases as the value higher for calculated landscape. Simpson diversity index ranges from zero to one, where it shows more diversity as it approaches to one.

Table 17: Patch diversity

Year	PR	PRD	SHDI	SIDI
1989	6	0.0317	1.3595	0.6747
2001	6	0.0317	1.1117	0.5724
2019	6	0.0317	1.3082	0.6462

Source: Author, 2019

As indicated on Table 17, patch richness corresponds to classes used to characterize the study site, that is, six in total for all years. Similarly, patch richness density result was different from zero which implies diversity exists in the area. The values of SHDI need to be above one to consider an area possesses patch diversity. So, those patch diversity in the three years was above one and decreased in 2019 compared to 1989. At the same time, SIDI results expected to be between zero and one, if it is approaching to zero in the absence of diversity. Hence, the SIDI result of the computation showed that there were moderate diversity in the area.

4.1.3.2. Species Diversity

From the selected 25 sample plots, the minimum and maximum SHDI values were 0.042 and 4.74 respectively. This can also be supported by SIDI that ranges from minimum value 0.14 and maximum value was 0.87. Consequently, the results from field samples showed diversity index computed for SHDI and SIDI were 1.896 (ranging 0.042 to 4.74) and 0.79 (ranging 0.14 to 0.87) respectively. Both testifies as there floristic diversity in the sub-afro-alpine ecosystem.

Likewise, key informants in the area and documents in *Chole* and *Guna woreda* showed existence of fauna diversity in the study site, perhaps could not be quantified in this paper. During field observation, indicators like feces, footprints, sound and habitat were noted as clues for presence of wild fauna. There were also chances to see some bird species, apes, Minilik bushbuck and amphibians at course of activities. According to informants, nowadays some wildlife is not seen and some are even disappeared. So that, they believed that cat species wildlife are nowadays highly threatened.

4.1.4. Biodiversity Vulnerability Parameters

4.1.4.1. Slope

To evaluate the vulnerability level in the study area, slope was generated from the digital elevation model of the study area (Figure 9A). Slopes can be analyzed as leveled for the value is equal to 0 %; gentle for the value ranging from 0 to 5%; moderate for the value ranging from 5 to 10%; strong for the value ranging from 10 to 25%; steep for the value ranging from 25 to 35% and very steep if above 35% (Geparaju et al 2017). In most case, peoples prefer to settle and farm in gentle areas. Due to this, biodiversity's in highly steep areas is less vulnerable compared to gentle areas. So that, the steeper a given slope, the lesser the vulnerability to the human impacts.

4.1.4.2. Elevation

In most parts of Africa, elevations beyond 3500 meters are labeled as afro-alpine and sub- afro-alpine suitable ecosystems but in Ethiopia it extends up to 3200 meters above mean sea level (Friis et al. 2010). Likewise, study area was categorized by 100meters altitudinal difference until potential habitat for afro-alpine and sub-afro-alpine ecosystem ceases. Then, those areas whose elevations below 3200 m were categorized under one classes (Figure 9B).

4.1.4.3. Streams

Streams were generated from DEM (SRTM) using ArcGIS by filling, flow direction generation, flow accumulation preparation and final conversion to polylines (Figure 10A). Based on polylines, areas were buffered using distance variation that extends from 0 to 1 km; 1 to 1.5 km;

and >1.5 km (Areendra et al. 2011). On the other hand, from the stand point of biological diversity, rivers and streams are both rich in species and severely imperiled (Allan and Flecker 1993). Moreover, for human habitation areas beyond a kilo meter distance was preferred to be away from the effects river/stream over flow. Hence, as distance from stream increased, the level of influence on riverine biodiversity reserves by human activities will also be increased.

4.1.4.4. Roads

Roads maps that were prepared by Oromia National Regional State were utilized from EthioGIS. So that, all weathered roads and intermittent roads were clipped for the study area and used for this analysis (Figure 10B). Meanwhile, buffer analysis bench marks that includes below 1 km, 1 to 2 km, 2 to 3 km and above 3 km were used by (Geparaju et al. 2017). This implied that biodiversity reserves that are nearer to roads are highly vulnerable to change and deterioration than those that are away.

4.1.4.5. Land use land cover

Biodiversity creates typical habitats, including species related to ecosystem functioning (Clergue et al. 2005). Due to this ecosystem functioning, biodiversity has been threatened by humankind. In the following figure (Figure 11), six land use land cover classes were considered. The first two (swamps, and afro-alpine and sub-afro-alpine) have no significant effects on biodiversity of afro-alpine and sub afro-alpine ecosystem. But, upper afro-montane expansion has some effect in modifying ecology of afro-alpine and sub-afro-alpine. On the other hand, grazing and fallowing challenges the biodiversity adversely due to continual pressure. Likewise, farming and settlement affected biodiversity at large and greatly.

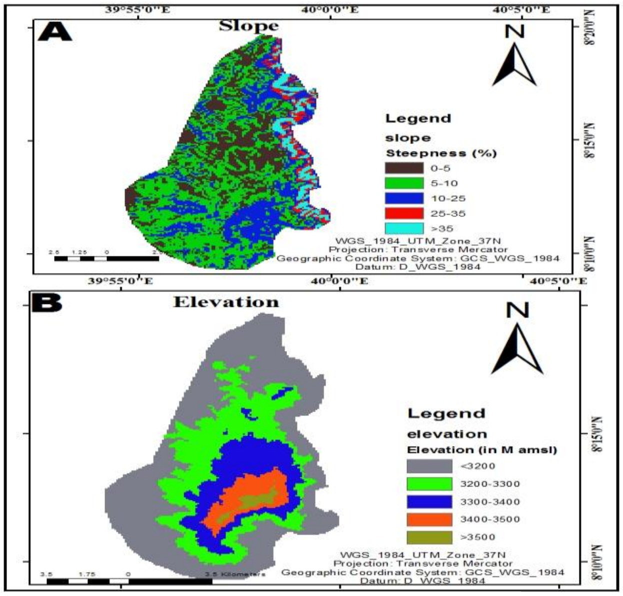


Figure 9 A) Slope of study area; B) Elevation of the study area

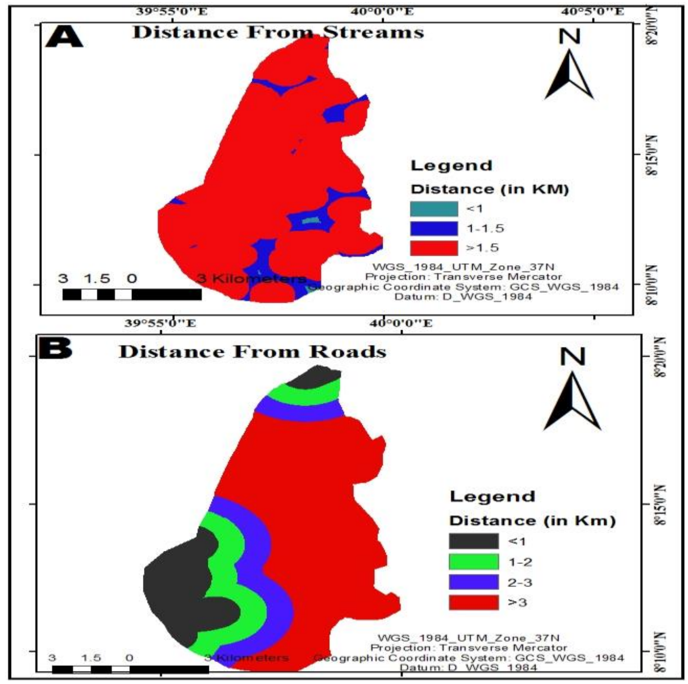


Figure 10: A) Distance of areas from stream networks; B) Distance of areas from roads

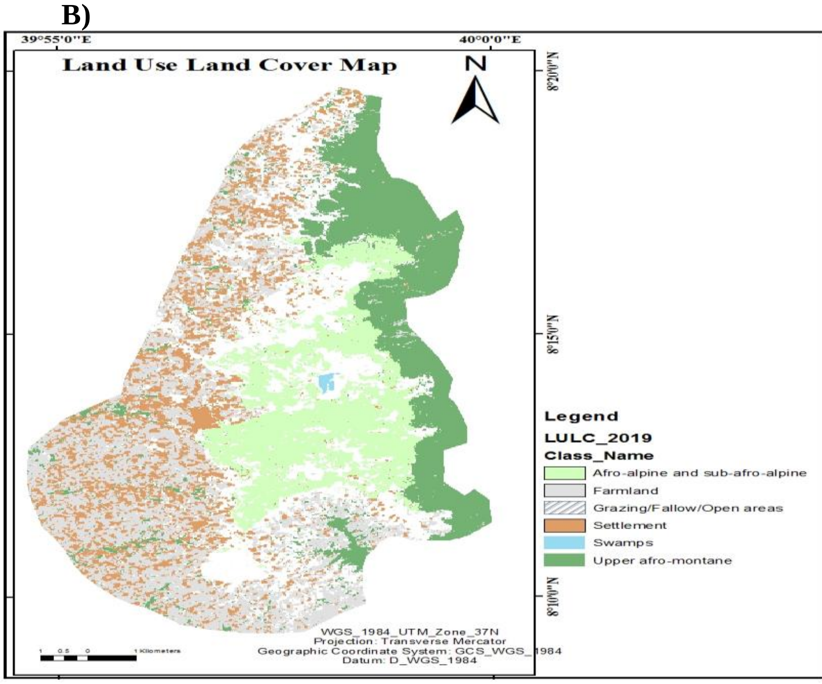


Figure 11: Current land use land cover of the study area

Source: Author, 2019

4.1.5. Weighted Overlay Analysis

Based on their level of influence, the selected parameters were ranked as land use land cover (1st), Roads (2nd), Elevation (3rd), Slope (4th) and Streams (5th). The first two parameters appeared to be highly significant and ranked at top since they have happened due to human activities. The remaining three naturally exist but hinder and favor human activities that can challenge biodiversity reserves located in areas of interest. As a result, elevations that are mostly important for human habitation in Ethiopia ranked 3rd and followed by slope and stream located in the vicinity.

Next to the ranking, weight for each criterion was determined using rank sum weight. Though criticized for its lack of theoretical foundation, ranking sum methods are very attractive due to their simplicity (Malczewski 1999). Therefore, the following formula was used to determine weight and results were shown on the following Table 18 and 19.

$$W_j = \frac{(n - rj) + 1}{\sum((n - rk) + 1)} \quad \text{...6}$$

Where: w_j-weight of jth criterion; n-number of criterion (k=1, 2,…., n); r_j-rank position of the criterion.

Table 18: Rank sum weight

No.	Parameter	Rank	*Rank sum*		
			Weight (n-rj+1)	Normalized weight	Rate (%)
1	Road network	2	4	0.267	26.7
2	Stream network	5	1	0.067	6.7
3	Elevation	3	3	0.200	20
4	Slope	4	2	0.133	13.3
5	LULC	1	5	0.333	33.3
			15	**1.000**	**100**

Table 19: Parameters for vulnerability mapping

Weight	Criteria	Class	Scale	Rank
13	Slope (%)	0-5	Gentle (high vulnerability)	1
		5-10	Moderate	2
		10-25	Strong	3
		25-35	Steep	4
		>35	Very steep (less vulnerability)	5
20	Elevation (in m amsl)	<3200	Very highly vulnerable	1
		3200-3300	Highly vulnerable	2
		3300-3400	Moderately vulnerable	3
		3400-3500	Less vulnerable	4
		>3500	Least vulnerable	5
27	Distance from Road (in KM)	<1	Highly vulnerable	1
		1-2	Moderately vulnerable	2
		2-3	Less vulnerable	3
		>3	Not vulnerable	4
7	Distance from stream (in KM)	<1	Less vulnerable	3
		1-1.5	Moderately vulnerable	2
		>1.5	Highly vulnerable	1
33	Land use land cover classes of 2019	Settlement	Very highly vulnerable	1
		Farmland	Highly vulnerable	2
		Grazing/fallow/open	Moderately vulnerable	3
		Upper afro-montane	Slightly vulnerable	4
		Swamps	Least vulnerable	5
		Afro-alpine and sub-afro-alpine	No vulnerability	6

Based on weighted overlay results (Figure 12A & B), most biodiversity in the study area are vulnerable to disturbances. That is, from the total areas 1791.8 hectares (critical), 4716.9 hectares (high), 3300.9 hectares (moderate) and 1626.74 hectares (less) severities were identified at the study area toward biodiversity vulnerability.

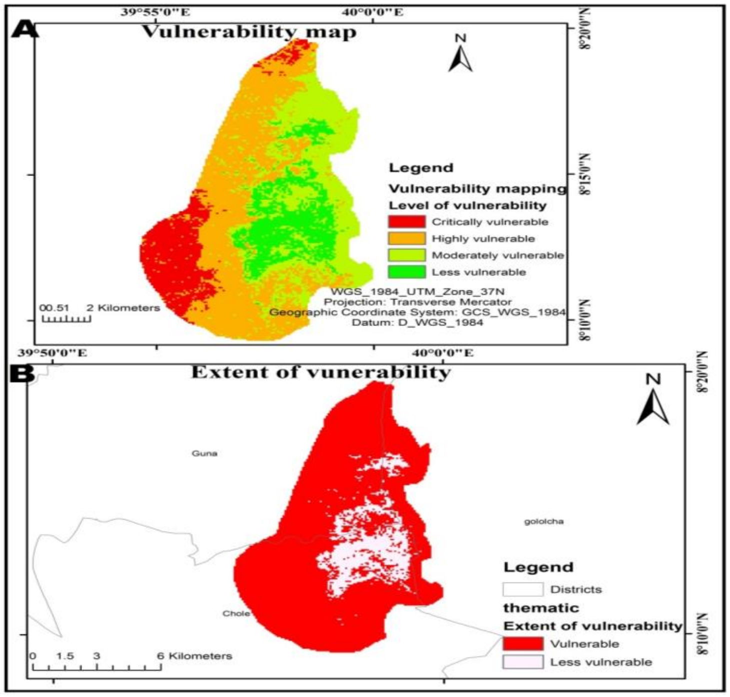


Figure 12: Biodiversity vulnerability map A) Level of vulnerability in the mountain region B) Extent of vulnerability among districts in which mountain is located

Source: Author, 2019

4.2. Discussion

4.2.1. Biodiversity change and status analysis

Based on land use land cover analysis result, with the highest agreement of kappa coefficient and overall accuracy, afro-alpine and sub-afro-alpine ecosystem of GMR has been diminished. But, the rate of change was not significantly consistent among years. For instance, from 1989 to 2001 was changed by the rate of -1.49% and from 2001 to 2019 by the rate of -2.62%. The trend of afro-alpine and sub-afro-alpine change showed a continued decrease in the last 30 years by the rate of -2.17%. In line with this, IBC (2005) indicated the rate of change to be very alarming resulting in the reduction of the original species richness of afro-alpine and sub-afro-alpine environments and restricted to scattered areas that are not easily accessible areas. Specifically, after his historical survey from 1975 to 1991, Mohammed (2013) showed the diminishing nature of forested areas with rich trees and increasing vulnerability.

Similarly, NDVI computation result depicted that the decreased trend of greenness of the study area in which standard deviation of NDVI values were failed from 0.23 (in 1989) to 0.22 (in

2001) and 0.15 (in 2019). At the same time, the area covered by dense vegetation in 2019 was dropped to 3109.92, even though increment were observed from 1989 (6430.9 ha) to 2001 (8350.7 ha) due to increase in upper afro-montane vegetation. Moreover, NDVI values were also assured decreased in swampy areas from 1989 to 2019 in which negative values were not observed in recent years. Alatorre and Begueria (2010) used NDVI to analyze vegetated and degraded areas and concluded that results were spatially consistent and coincided with the spatial distribution of land use land cover. In addition, Anand et al. (2018) stated that the negative NDVI values showed barren lands, snow, rocks and sand.

In terms of biodiversity, patch diversity and species diversity computed for the study area and showed the presence of diversity. Accordingly, Shannon diversity index showed that there have been patch diversity in the three study years of 1989 (1.36), 2001 (1.11) and 2019 (1.31). Subsequently, Simpson diversity index also showed 0.67, 0.57 and 0.65 in 1989, 2001 and 2019 respectively. This showed the presence of biodiversity in the study area. On the other hand, the current species diversity of the study area showed that SHDI of 1.896 and SIDI of 0.79. Perhaps high pressure has been observed and its number showed tremendous decrease, wild animals were also found in this particular region. According to Fleming and Aargaad (1993), diversity within species is the ultimate source of biodiversity at higher levels. The ability of species to provide many of the goods and services needed by humans are intimately linked to within species diversity.

4.2.2. Biodiversity disturbance and fragmentation analysis

It is not only loss that is problem for wild plants and animals but also the degree of fragmentation of their habitat (FAO, 2002b). Thus, Gugu Mountain Ranges afro-alpine and sub-afro-alpine environments were characterized by disaggregation patches that range from slight to high level. Almost all computed parameters of fragmentation showed that the presence of disaggregation. Even though effects of fragmentation depends drivers of fragmentation, time it takes, agents of fragmentation, size of resulting fragments and type of species (Fuller et al., 2015), it causes population losses and affects habitat quality (Flaspohler et al., 2010; Broadbent et al., 2008).

The result showed that patches area and perimeter of patches of current time (2019) was declined compared to initial year (1989). This could affect biodiversity in the study area negatively since fragmentation can also be linked with patch size (Jaybhaye et al., 2016) and its effect depends up on size of the resulting fragments (Fuller et al., 2015). Shape index result depicted some complexity whereas fractal dimension result did not assure shape complexity since its value approaches to one. Simpler shapes allow higher survival of population. Ragub and Bagarina (2012) agreed that increased complexity of shape increased likelihood of contact between interior and edge species. But, it is the interplay between size and shape that determines the survival of population dynamics (Alharbi and Petroskii, 2016; LaGro, 1991). Lesser fragmentation result of shape indexes cannot be assured suitability of habitat for afro-alpine and sub-afro-alpine biodiversity. In their study of tropical forest fragments, Hill and Curran (2003) accounted area, shape and isolation for sharply decreasing of variability of species diversity.

Number of patches observed from 544, 884 and 377 in 1989, 2001 and 2019 respectively. Patch density was also more than zero that showed presence of fragmentation. Percentage of like adjacencies result were approaching to maximal value, but not 100, showed as there were contagious distributed. Interspersion and juxtaposition index result of the 1989, 2001 and 2019 approaches to 100 depicted that a patch is equally adjacent to all other patch types. Splitting index of the computation showed as focal patch type were reduced and subdivided into smaller patches. Aggregation index indicated lesser disaggregation of afro-alpine and sub-afro-alpine class which results were 90.67, 87.64 and 93.51. Likewise, contagion index of the whole study area on average showed disaggregation.

The results of total edge and edge density higher values with slight decrease, and largest patch index values were smaller with decreasing trend. This implied the presence of fragmentation. According to Liu et al. (2017), the higher the value of edge density the greater fragmentation it shows. Similarly, Jaybhaye et al. (2016) reported that decrease in largest patch density as an indicator of fragmentation. To this effect, largest patch index result of afro-alpine and sub-afro-alpine class was declined from 16.99% (in 1989) to 14.1% (in 2001) and to 8.4% (in 2019). Consequently, they indicated as decrease in largest patch size happens due to increase in density of small patch as already seen in this study, that is, 544 in 1989, 884 in 2001 and 377 in 2019. At the same time, radius of gyration showed that decreased patch extent which measures the wild animals' length to move from center to edge clearly declined from 30.96 meters, 25.2 meters and 22.99 meters in 1989, 2001 and 2019 respectively.

Thus, most parameters indicated disaggregation that ranges from slight to high level. This implies almost all parameters that were used to compute fragmentation showed existence of disaggregation. The fragmentations of an area were resulted by different factors that were attributed by land use land cover change. Based on the land use land cover analysis result, expansion of grazing land, farmland and settlement were taken as disturbances that cause fragmentation. That is, between the year 1989 to 2001 afro-alpine class was converted to settlement (453.23 ha), farmland (289.71 ha) and graze land (3.33 ha). Correspondingly, between 2001 and 2019, it was converted to graze land (896.85 ha), settlement (121.005 ha) and farmland respectively (see table 7 and 8). In line with this, studies showed that loss of biodiversity can be resulted by land use changes which are driven by anthropogenic activities (Teillard et al., 2016; Mutia, 2009; Gaston and Spicer, 2004; Murthy et al., 2003).

4.2.3. Biodiversity vulnerability mapping

The biodiversity is vulnerable if there are disturbances nearby and upon it. Disturbances are mainly resulted from the influences of human activities. For various human activities, the role of natural features like elevation, slope and stream, and anthropogenic features such as road networks are inevitably important. To this effect, biodiversity vulnerability map of the study area was generated parameters like land use land cover, road network, elevation, slope and stream network (Geparaju et al., 2017; Arunyawat and Shrestha, 2016; Sloan et al., 2014; Areendren et al., 2011; Friis et al., 2010; Haines-Young, 2009; Oslon et al., 2007).

The weighted overlay result showed the higher vulnerability of biodiversity resources in afro-alpine and sub-afro-alpine ecosystem of GMR. In line with this, various studies reported that highland areas of Ethiopia are under serious degradation (EPCC, 2015; Woldeamlak, 2002; Zeleke and Hurni, 2001; Badege, 2001).

CHAPTER FIVE

5. CONCLUSION AND RECOMMENDATION

5.1. CONCLUSION

GMR supports patch diversity that was estimated to be 1.31 (SHDI) and 0.64 (SIDI) in 2019. Patch diversity provides chances for biodiversity in the area. Similarly, SHDI and SIDI used for measuring floristic diversity and the result found to be 1.9 and 0.79 respectively. These are indicators for the presence of species richness in the area. However, the patch diversity over the last 30 years showed that diversity is in a declining trend. This can be resulted from shrinking of habitat and increased fragmentation caused by disturbances.

The LULC analysis computed for GMR indicated that afro-alpine and sub-afro-alpine region has been diminished from 3540.63 ha (in 1989) to 1846.98 ha (in 2019) at the rate of -1.46% from 1989 to 2001 and -2.62% from 2001 to 2019, and -2.17% from 1989 to 2019. This further observed in NDVI values computed for the same images in which standard deviation decreased from 0.23 (in 1989) to 0.15 (in 2019). The total area covered by dense vegetation, based on NDVI, estimated at8350.74 ha (in 1989) to 3108.92 ha (in 2019). To this effect, these image differencing results and change vector analysis showed decline in species diversity in the study area.

Similarly, the GMR was characterized by fragmented patches. This was indicated by large number of patches, non-zero patch density, contagious distribution of percentage of like adjacencies, adjacency to all other patch types of interspersion and juxtaposition index, subdivided focal patch of splitting index, shape irregularity of shape index, disaggregation of aggregation index and reduced large patch size of patch index. To some extent, fractal dimension index and cohesion index showed slight fragmentation.

Disturbances and fragmentation of habitat that can support afro-alpine and sub-afro-alpine ecosystem were caused by human activities such as settlement, farming expansion and grazing. In the past three decades, farmlands were increased from 2615.49 ha (in 1989) to 2998 ha (in 2019). Settlement was, also, enlarged from 988.2 ha (in 1989) to 1592.68 ha (in 2019).

Moreover, grazing/fallow/open areas inflamed from 2000.55 ha (in 1989) to 2785.68 ha (in 2019). Therefore, by fragmenting habitat into different patches and shrinking habitat into smaller patches that were triggered by settlement, graze and farming.

The weighted overlay result alarms as almost large proportion of the study site was highly vulnerable to biodiversity loss. Only below 15%of it is less vulnerable to degradation. Therefore, the growing land use land cover change combined with habitat fragmentation brought greater loss of biodiversity in GMR.

5.2. RECOMMENDATION

GMR is under a serious environmental challenge that can degrade its biodiversity momentarily unless interfered proximately. Accordingly, I suggest that environmentally friendly livelihood improvement strategies (e.g. bee-keeping), eco-tourism development and empowerment of local community as options to safeguard the biodiversity for deprivation. Hence, these can be practical in the following mechanisms.

- Improvement of local community livelihood by increasing the production and productivity of the farm plots and livestock through increasing modern techniques that can minimize burden natural environment. Additionally, facilitating environmentally friendly income generating techniques that preserve ecology like beekeeping.
- The study area has greater potential for tourist attraction including biodiversity resources and attractive land configuration. It is better to construct infrastructure that can facilitate ecotourism development. Moreover, awareness creation among society needs to be done on ecotourism and environmental protection both governmental and non-governmental actors.
- Increase the engagement of societies in every steps to preserve biodiversity resources in the area to increase sense of belongingness, and maximize responsibility and accountability to any illegal actions.

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APPENDICES

Appendix Ia: Land use land cover converted 'From' and 'To'

S. No.	Class Names	Land use land cover change (in hectare)		
		1989 to 2001	**2001 to 2019**	**1989 to 2019**
1	UAV to ASV	61.02	87.7495	-99.855
2	UAV to Sw	20.61	-0.1125	-0.135
3	UAV to GFO	430.38	-559.485	65.9475
4	UAV to F	123.84	-123.682	-0.4725
5	UAV to St	-0.36	-25.965	20.52
6	ASV to UAV	-61.02	-87.7495	-99.855
7	ASV to Sw	37.98	2.3175	1.1475
8	ASV to GFO	162.36	-896.85	-1110.908
9	ASV to F	-267.21	-60.8175	-202.41
10	ASV to St	-451.22	-71.64	-281.835
11	Sw to UAV	-20.61	0.1125	-0.135
12	Sw to ASV	-37.98	-2.3175	-1.1475
13	Sw to GFO	1.17	-20.34	-88.92
14	Sw to F	-9.9	-1.08	-1.8225
15	Sw to St	-1.08	-1.08	-1.08
16	GFO to UAV	-430.38	559.485	65.9475
17	GFO to ASV	-162.36	896.85	1110.908
18	GFO to Sw	-1.17	20.34	88.92
19	GFO to F	-984.99	730.5325	-378.8775
20	GFO to St	-295.77	409.343	-101.565
21	F to UAV	-123.84	123.682	-0.4725
22	F to ASV	267.21	60.8175	202.41
23	F to Sw	9.9	1.08	1.8225
24	F to GFO	984.99	-730.5325	378.8775
25	F to St	270.99	-437.782	-199.62
26	St to UAV	0.36	25.965	20.52
27	St to ASV	451.22	71.64	281.835
28	St to Sw	1.08	1.08	1.08
29	St to GFO	295.8	-409.343	101.565
30	St to F	-270.99	437.782	199.62

***UAV**-Upper Afro-montane Vegetation; **ASV**-Afro-alpine and sub-afroalpine vegetation; **Sw**-Swamps; **GFO**-Grazing/Fallow/Open areas; **F**-Farmlands; **St**-Settlement.*

Appendix Ib: Error matrix of 1989, 2001 and 2019 LULC

Classified data_1989	**Reference data_1989**						
	UAV	ASV	GFO	Sw	St	F	**Total**
UAV	**90**	1	0	0	0	0	91
ASV	0	**107**	3	0	0	0	110
GFO	0	0	**69**	0	1	0	70
Sw	0	0	4	**16**	0	0	20
St	0	0	0	0	**84**	0	84
F	0	0	4	0	4	**100**	108
Total	90	108	80	16	89	100	**483**
Classified data_2001	**Reference data_2001**						
	UAV	ASV	GFO	Sw	St	F	**Total**
UAV	**118**	2	33	0	1	0	154
ASV	2	**80**	3	0	0	0	85
GFO	0	0	**62**	0	0	1	63
Sw	0	0	0	**12**	0	0	12
St	0	0	0	0	**56**	0	56
F	0	0	23	0	1	**84**	108
Total	120	82	121	12	58	85	**478**
Classified data_2019	**Reference data_2019**						
	UAV	ASV	GFO	Sw	St	F	**Total**
UAV	98	0	0	8	2	0	**108**
ASV	0	88	0	0	0	0	**88**
GFO	0	0	14	0	0	0	**14**
Sw	1	0	1	86	0	0	**88**
St	0	0	0	6	97	2	**105**
F	0	0	0	0	1	80	**81**
Total	**99**	**88**	**15**	**100**	**100**	**82**	**484**

***UAV**-Upper Afro-montane Vegetation; **ASV**-Afro-alpine and sub-afroalpine vegetation; **Sw**-Swamps; **GFO**-Grazing/Fallow/Open areas; **F**-Farmlands; **St**-Settlement.*

Appendix Ic: Commission, Omission, and producer and user accuracy (1989, 2001 and 2019)

Classified data	Percentage of											
	Commission			Omission			Producer accuracy			User accuracy		
	1989	2001	2019	1989	2001	2019	1989	2001	2019	1989	2001	2019
UAV	1.1	23.4	9.26	0	1.67	1.01	100	98.3	98.9	98.9	76.6	97.7
ASV	2.73	5.88	0	0.93	2.44	0	99.1	97.6	100	97.3	94.1	100
GFO	1.43	1.58	0	13.8	48.8	6.67	86.3	51.2	93.3	98.6	98.4	100
Sw	20	0	2.27	0	0	14	100	100	86	80	100	97.7
St	0	0	7.62	5.62	3.45	3	94.4	95.6	97	100	100	92.4
F	7.43	22.2	1.23	0	1.18	2.44	100	98.8	97.6	92.6	77.8	98.8

UAV-*Upper Afro-montane Vegetation;* ***AsV***-*Afro-alpine and sub-afroalpine vegetation;* ***Sw***-*Swamps;* ***GFO***-*Grazing/Fallow/Open areas;* ***F***-*Farmlands;* ***St***-*Settlement.*

Appendix IIa: Floristic Diversity of Study area

no.	L. name	sc. Name	Total	SHDI	SIMI_V
1	Saatoo	*erica arborea*	22056	-0.35768	486445080
2	Xosinyii	*thymus schimper ron.*	3187	-0.13127	10153782
3	Halaanduu		645	-0.03987	415380
4	Magaxoo		13590	-0.30534	184674510
5	Yemidir Koosoo		394	-0.02686	154842
6	Maxanee	*tages minuta l.*	1251	-0.06663	1563750
7		*haplocarpha rueppellii*	43	-0.00416	1806
8	dead (Grassy)		4720	-0.17049	22273680
9	Shushube	*primula verticillata*	358	-0.02485	127806
10	caarree/qaxanaa	*helichrysum citrispinum*	4927	-0.17523	24270402
11	gaalee hantuutaa	*stephania abyssinica*	300	-0.02151	89700
12	Baalaadoo	*chenopodium album l.*	467	-0.03081	217622
13	arrii mukaa		438	-0.02926	191406
14	deefoo (grassy)		22828	-0.36006	521094756
15	Doobii	*urtica simensis hochst*	1484	-0.07577	2200772
16	Euclaptus		2	-0.00027	2
17	Yekoksar	*anthoxanthum aethopicum l. hedberg*	24	-0.0025	552
18	Ameraro	*discopidium penninerxium hochst*	16	-0.00175	240
19	Injorii	*rubus aethopicus R. A. grah*	5	-0.00062	20
20	Aramaa	*ageratum conyzoides L.*	102	-0.00873	10302
21	Heexoo	*hagenia abyssinicca*	6	-0.00073	30
22	Inqooqoo	*embelia scimperi*	44	-0.00424	1892
23	Tultii	*rumex hepalensis*	50	-0.00474	2450
24	Shikookoo		13	-0.00146	156
25	ras kimirii	*leonotis raineriana*	100	-0.00859	9900
26	Sokoruu		12	-0.00136	132
27	Goraa	*rosa abyssinica lindley*	1	-0.00015	0
28	Dedehoo	*euclea schimperi*	3	-0.00039	6
29	Guwaasaa		19	-0.00204	342
30	wedeessa (waanzaa)	*cordia africana lam*	18	-0.00194	306
31	ebicha (girawa)	*veronia amydalina*	12	-0.00136	132
32	Gaatiraa	*juniperus procera*	11	-0.00126	110
33	Geeshoo	*rhamnus prinoide l. herit*	4	-0.00051	12
34	Sardoo	*cynodon dactylon l. pers*	36	-0.00357	1260
35	Wulkifaa	*dombiya torrida p. bamps*	8	-0.00095	56
36	gaalee naachaa	*clemantis hirsuta perr. Gill*	25	-0.00259	600
37	gaalee adii	*jasminium abyssinicum hochstex dc*	29	-0.00295	812

38	dogomaa (bisanaa)	*croton macrostachyus st.*	51	-0.00482	2550
39	Kombolcha	*maytenus ovatus*	10	-0.00116	90
40	Bosoqee	*kalanches petitiana A. richa*	14	-0.00156	182
41	Feexoo	*lipidium satinun*	33	-0.00331	1056
42	bokoluu (ras kimir)	*leonotis raineriana*	10	-0.00116	90
43	Handoodee	*phytolacca dodecandra l. hen*	1	-0.00015	0
44	guuloo (qooboo)	*ricinus communis*	1	-0.00015	0
45	Irreetii	*aloe spp.*	10	-0.00116	90
46	Insilaala	*foeniculum vulgare mill*	9	-0.00105	72
47	birbirsa (zigba)	*pedocarpus falcatus (thum) mirb*	4	-0.00051	12
48	Ashikitii	*galium asperiodes forssk*	72	-0.00649	5112
49	Koshiimii	*doryalis verrucosa (hochst) warb*	21	-0.00223	420
			77464	**1.89625**	**1253914280**
				(77464*(77464-1))=	6000593832
			SIDI	**(1-(1253914280**/6000593832))=	**0.791034968**

Appendix IIb: Floristic diversity at plot level

no.	L. name	total	Shannon Diversity Index	Elevation (m)	plot no.	SIDI		
1	Saatoo	2562	-0.34835358	3532	1	0.064864731		
2	Xosinyii	625	-0.172646896	3532	1	0.003855534		
3	Halaanduu	81	-0.038830347	3532	1	6.40612E-05		
4	Magaxoo	6250	-0.295652015	3532	1	0.386109476		
5	Yemidir Koosoo	125	-0.054531342	3532	1	0.000153233		
6	Maxanee	63	-0.031775532	3532	1	3.86147E-05		
7	*haplocarpha rueppellii*	32	-0.018295129	3532	1	9.8069E-06		
8	dead (Grassy)	312	-0.107736486	3532	1	0.000959257		
9	Shushube	8	-0.005676422	3532	1	5.53615E-07		
Total		**10058**	**1.07349775**			**0.543944733**		
1	Saatoo	2200	-0.312520901	3538	2	0.034402373		
2	Xosinyii	19	-0.01031214	3538	2	2.43202E-06		
3	Halaanduu	7	-0.00438861	3538	2	2.98669E-07		
4	Magaxoo	7000	-0.311176193	3538	2	0.34839709		
5	Yemidir Koosoo	200	-0.068851083	3538	2	0.000283024		
6	Maxanee	420	-0.118310718	3538	2	0.001251422		
7		3	-0.002095176	3538	2	4.2667E-08		
8	dead (Grassy)	59	-0.026384602	3538	2	2.43344E-05		
9	caarree/qaxanaa	800	-0.181885867	3538	2	0.004545454		
10	gaalee hantuutaa	187	-0.065435552	3538	2	0.00024734		
11	Baalaadoo	90	-0.037043	3538	2	5.69604E-05		
12	arrii mukaa	122	-0.047084257	3538	2	0.000104975		
13	deefoo (grassy)	745	-0.173855832	3538	2	0.003941574		
14	Doobii	7	-0.00438861	3538	2	2.98669E-07		
Total		**11859**	**1.36373254**			**0.606742381**		

1	Saatoo	200	-0.230519348	3571	**3**	39800	3982020	0.009994927
2	Xosinyii	800	-0.366448388	3571	**3**	639200		0.160521544
3	Maxanee	18	-0.042461682	3571	**3**	306		7.68454E-05
4	dead (Grassy)	78	-0.126698871	3571	**3**	6006		0.00150828
5	Doobii	900	-0.359145854	3571	**3**	809100		0.203188332
		1996	**1.12527414**					**0.62471007**
1	Saatoo	3500	-0.213725986	3509	**4**	12246500	21608552	0.566743204
2	Xosinyii	254	-0.158829121	3509	**4**	64262		0.002973915
3	Halaanduu	100	-0.082582001	3509	**4**	9900		0.000458152
4	dead (Grassy)	500	-0.239814941	3509	**4**	249500		0.011546354
5	caarree/qaxanaa	95	-0.079501054	3509	**4**	8930		0.000413262
6	arrii mukaa	200	-0.135344808	3509	**4**	39800		0.001841863
	Total	**4649**	**0.90979791**					**0.41602325**
1	Saatoo	2879	-0.236569941	3500	**5**	8285762	15988002	0.518248747
2	Xosinyii	315	-0.200171667	3500	**5**	98910		0.006186514
3	Halaanduu	415	-0.23510659	3500	**5**	171810		0.010746183
4	Maxanee	150	-0.123149449	3500	**5**	22350		0.001397923
5	Baalaadoo	197	-0.148308924	3500	**5**	38612		0.002415061
6	arrii mukaa	25	-0.031726205	3500	**5**	600		3.75281E-05
7	Doobii	15	-0.020951798	3500	**5**	210		1.31348E-05
8	Shushube	3	-0.00539774	3500	**5**	6		3.75281E-07
		3999	**1.00138231**					**0.46095453**
1	Saatoo	700	-0.304798676	3401	**6**	489300	1344440	0.363943352
2	Maxanee	19	-0.067347405	3401	**6**	342		0.000254381
3	dead (Grassy)	200	-0.303078951	3401	**6**	39800		0.029603404
4	gaalee hantuutaa	87	-0.194270037	3401	**6**	7482		0.005565142
5	Shushube	154	-0.268069218	3401	**6**	23562		0.017525512
	Total	**1160**	**1.13756429**					**0.58310821**
1	dead (Grassy)	1200	-0.357932277	3463	**7**	1438800	17635800	0.081584051
2	caarree/qaxanaa	3000	-0.240337312	3463	**7**	8997000		0.510155479
	Total	**4200**	**0.59826959**					**0.40826047**
1	Saatoo	600	-0.33309148	3409	**8**	359400	1237656	0.290387636
2	Xosinyii	177	-0.29240219	3409	**8**	31152		0.02517016
3	Halaanduu	20	-0.072220702	3409	**8**	380		0.000307032
4	Yemidir Koosoo	15	-0.058042644	3409	**8**	210		0.000169676
5	Maxanee	300	-0.353377864	3409	**8**	89700		0.072475712
6	Euclaptus	1	-0.006302618	3409	**8**	0		0
	Total	**1113**	**1.1154375**					**0.38851022**
1	Saatoo	1200	-0.346316756	3426	**9**	1438800	5738420	0.250731037
2	Xosinyii	344	-0.278662154	3426	**9**	117992		0.020561757
3	Halaanduu	13	-0.028303792	3426	**9**	156		2.71852E-05
4	Magaxoo	226	-0.222700641	3426	**9**	50850		0.008861324
5	Yemidir Koosoo	19	-0.038357772	3426	**9**	342		5.95983E-05
6	Maxanee	97	-0.129826362	3426	**9**	9312		0.001622746
7	X	8	-0.019038779	3426	**9**	56		9.75878E-06
8	dead (Grassy)	39	-0.067029123	3426	**9**	1482		0.000258259
9	caarree/qaxanaa	320	-0.268879461	3426	**9**	102080		0.017788869
10	Baalaadoo	115	-0.145747805	3426	**9**	13110		0.002284601
11	Doobii	5	-0.012880046	3426	**9**	20		3.48528E-06
12	Shushube	10	-0.022867157	3426	**9**	90		1.56838E-05
	Total	**2396**	**1.58060985**					**0.69777569**
1	Saatoo	3000	-4.697378627	3424	**10**	8997000	12848640	0.700229752
2	Xosinyii	151	-0.013298653	3424	**10**	22650		0.001762832
3	Magaxoo	82	-0.006054613	3424	**10**	6642		0.000516942

4	Yemidir Koosoo	18	-0.000948392	3424	**10**	306		2.38158E-05
5	dead (Grassy)	205	-0.019983446	3424	**10**	41820		0.003254819
6	caarree/qaxanaa	12	-0.000587283	3424	**10**	132		1.02735E-05
7	gaalee hantuutaa	15	-0.000764015	3424	**10**	210		1.63441E-05
8	Baalaadoo	20	-0.001075166	3424	**10**	380		2.95751E-05
9	Arrimukaa	7	-0.000312984	3424	**10**	42		3.26883E-06
10	deefoo (grassy)	61	-0.004176938	3424	**10**	3660		0.000284855
11	Shushube	14	-0.000704209	3424	**10**	182		1.41649E-05
	Total	**3585**	**4.74528432**					**0.29385336**
1	Saatoo	400	-0.76543981	3342	**11**	159600	609180	0.26199153
2	Xosiinyii	70	-0.037158255	3342	**11**	4830		0.007928691
3	yemidir koosoo	1	-0.000192237	3342	**11**	0		0
4	yeayit hareg	2	-0.000429133	3342	**11**	2		3.2831E-06
5	Yekoksar	4	-0.000971059	3342	**11**	12		1.96986E-05
6	Ameraro	4	-0.000971059	3342	**11**	12		1.96986E-05
7	Injorii	3	-0.000690625	3342	**11**	6		9.84931E-06
8	Magaxoo	12	-0.00367963	3342	**11**	132		0.000216685
9	Maxannee	129	-0.09172383	3342	**11**	16512		0.027105289
10	marga du'aa	115	-0.076865636	3342	**11**	13110		0.021520733
11	Halaanduu	9	-0.002581847	3342	**11**	72		0.000118192
12	Baalaadoo	25	-0.009300709	3342	**11**	600		0.000984931
13	Shushubee	7	-0.001901061	3342	**11**	42		6.89451E-05
	Total	**781**	**0.99190489**					**0.68001248**
1	Saatoo	800	-0.108157197	3359	**12**	639200	816312	0.783033938
2	Xosiinyii	32	-0.118268795	3359	**12**	992		0.001215222
3	yemidir koosoo	1	-0.007529678	3359	**12**	0		0
4	yeayit hareg	8	-0.04183529	3359	**12**	56		6.86012E-05
5	Yekoksar	10	-0.049825711	3359	**12**	90		0.000110252
6	Ameraro	2	-0.013525846	3359	**12**	2		2.45004E-06
7	Injorii	1	-0.007529678	3359	**12**	0		0
8	Magaxoo	10	-0.049825711	3359	**12**	90		0.000110252
9	Maxannee	40	-0.137962385	3359	**12**	1560		0.001911034
	Total	**904**	**0.53446029**					**0.21354825**
1	Saatoo	15	-0.000996826	3385	**13**	210	8205360	2.5593E-05
2	Xosiinyii	150	-0.017749679	3385	**13**	22350		0.002723829
3	marga du'aa	2000	-1.942234733	3385	**13**	3998000		0.487242485
4	caarree/qaxanaa	700	-0.173375384	3385	**13**	489300		0.059631753
	Total	**2865**	**2.13435662**					**0.45037634**
1	Saatoo	650	-0.268258155	3370	**14**	421850	939930	0.448810018
2	Xosiinyii	250	-0.34944205	3370	**14**	62250		0.066228336
3	yemidir koosoo	15	-0.064472874	3370	**14**	210		0.000223421
4	yeayit hareg	1	-0.007089996	3370	**14**	0		0
5	Yekoksar	10	-0.047161969	3370	**14**	90		9.57518E-05
6	Ameraro	2	-0.012750822	3370	**14**	2		2.12782E-06
7	Injorii	1	-0.007089996	3370	**14**	0		0
8	Magaxoo	10	-0.047161969	3370	**14**	90		9.57518E-05
9	Maxannee	15	-0.064472874	3370	**14**	210		0.000223421
10	marga du'aa	12	-0.054338838	3370	**14**	132		0.000140436
11	Shushubee	4	-0.022643306	3370	**14**	12		1.27669E-05
	Total	**970**	**0.94488285**					**0.48416797**
1	Shushubee	158	-0.035249151	3375	**15**	24806	490954806	5.0526E-05
2	Deefoo	22000	-0.007105124	3375	**15**	483978000		0.985789311
	Total	**22158**	**0.04235428**					**0.01416016**
1	Saatoo	900	-0.132129154	3200	**16**	809100	1101450	0.734577148

2	Balaadoo	10	-0.044323432	3200	**16**	90		8.17105E-05
3	Aramaa	100	-0.223940501	3200	**16**	9900		0.008988152
4	Heexoo	1	-0.006625281	3200	**16**	0		0
5	Deefoo	12	-0.051104443	3200	**16**	132		0.000119842
6	Inqooqoo	15	-0.060692789	3200	**16**	210		0.000190658
7	Tultii	12	-0.051104443	3200	**16**	132		0.000119842
	Total	**1050**	**0.56992004**					**0.25592265**
1	Shikookoo	10	-0.171237123	3293	**17**	90	26406	0.003408316
2	Doobii	45	-0.355330963	3293	**17**	1980		0.074982958
3	ras kimirii	98	-0.305893907	3293	**17**	9506		0.359993941
4	Sokoruu	10	-0.171237123	3293	**17**	90		0.003408316
	Total	**163**	**1.00369912**					**0.55820647**
1	Saatoo	650	-0.332963165	3253	**18**	421850	1450820	0.290766601
2	Balaadoo	10	-0.039764728	3253	**18**	90		6.20339E-05
3	Shikookoo	1	-0.005887332	3253	**18**	0		0
4	Doobii	500	-0.364990352	3253	**18**	249500		0.171971713
5	ras kimirii	2	-0.010624212	3253	**18**	2		1.37853E-06
6	Sokoruu	2	-0.010624212	3253	**18**	2		1.37853E-06
7	Goraa	1	-0.005887332	3253	**18**	0		0
8	Aramaa	2	-0.010624212	3253	**18**	2		1.37853E-06
9	Dedehoo	1	-0.005887332	3253	**18**	0		0
10	Deefoo	10	-0.039764728	3253	**18**	90		6.20339E-05
11	Inqooqoo	11	-0.04287115	3253	**18**	110		7.58192E-05
12	Tultii	15	-0.054599809	3253	**18**	210		0.000144746
	Total	**1205**	**0.92448856**					**0.53691292**
1	Saatoo	1100	-0.036092841	3299	**19**	1208900	1303022	0.927766377
2	Guwaasaa	19	-0.068148731	3299	**19**	342		0.000262467
3	Dedehoo	2	-0.011116268	3299	**19**	2		1.53489E-06
4	Heexoo	1	-0.006165093	3299	**19**	0		0
5	Inqooqoo	18	-0.065414154	3299	**19**	306		0.000234839
6	Tultii	2	-0.011116268	3299	**19**	2		1.53489E-06
	Total	**1142**	**0.19805336**					**0.07173325**
1	Saatoo	700	-0.018065582	3251	20	489300	507656	0.963841657
2	Doobii	12	-0.068744596	3251	20	132		0.000260019
3	Bargamoo	1	-0.009213859	3251	20	0		0
	Total	**713**	**0.09602404**					**0.03589832**
1	wedeessa (waanzaa)	12	-0.227051483	3159	21	132	15006	0.008796481
2	ebicha (girawa)	3	-0.090574928	3159	21	6		0.00039984
3	Gaatiraa	1	-0.03912345	3159	21	0		0
4	Geeshoo	4	-0.111411057	3159	21	12		0.00079968
5	Tultii	2	-0.066976214	3159	21	2		0.00013328
6	Sardoo	4	-0.111411057	3159	21	12		0.00079968
7	Wulkifaa	3	-0.090574928	3159	21	6		0.00039984
8	gaalee naachaa	5	-0.130192945	3159	21	20		0.0013328
9	gaalee adii	5	-0.130192945	3159	21	20		0.0013328
10	arrii mukaa	78	-0.28883814	3159	21	6006		0.400239904
11	dogomaa (bisanaa)	6	-0.147337799	3159	21	30		0.0019992
	Total	**123**	**1.43368495**					**0.58376649**
1	wedeessa (waanzaa)	2	-0.18053668	3176	22	2	870	0.002298851
2	Kombolcha	1	-0.113373246	3176	22	0		0
3	Bosoqee	1	-0.113373246	3176	22	0		0

4	Feexoo	14	-0.355665358	3176	22	182		0.209195402
5	Gaatiraa	1	-0.113373246	3176	22	0		0
6	bokoluu (ras kimir)	2	-0.18053668	3176	22	2		0.002298851
7	Handoodee	1	-0.113373246	3176	22	0		0
8	gaalee naachaa	4	-0.268653736	3176	22	12		0.013793103
9	gaalee adii	2	-0.18053668	3176	22	2		0.002298851
10	guuloo (qooboo)	1	-0.113373246	3176	22	0		0
11	Heexoo	1	-0.113373246	3176	22	0		0
	Total	**30**	**1.73279536**					**0.77011494**
1	Kombolcha	1	-0.064982548	3193	23	0	4032	0
2	ebicha (girawa)	2	-0.108304247	3193	23	2		0.000496032
3	Gaatiraa	4	-0.173286795	3193	23	12		0.00297619
4	bokoluu (ras kimir)	8	-0.259930193	3193	23	56		0.013888889
5	Irreetii	10	-0.290046561	3193	23	90		0.022321429
6	Insilaala	1	-0.064982548	3193	23	0		0
7	birbirsa (zigba)	2	-0.108304247	3193	23	2		0.000496032
8	Ashikitii	7	-0.242043915	3193	23	42		0.010416667
9	Tultii	2	-0.108304247	3193	23	2		0.000496032
10	Koshiimii	19	-0.360538093	3193	23	342		0.084821429
11	Ameraroo	8	-0.259930193	3193	23	56		0.013888889
	Total	**64**	**2.04065359**					**0.85019841**
1	wedeessa (waanzaa)	3	-0.104450739	3188	24	6	10100	0.000594059
2	Gaatiraa	5	-0.148796169	3188	24	20		0.001980198
3	birbirsa (zigba)	2	-0.077662838	3188	24	2		0.00019802
4	Ashikitii	50	-0.348068075	3188	24	2450		0.242574257
5	Wulkifaa	5	-0.148796169	3188	24	20		0.001980198
6	Koshiimii	1	-0.045694263	3188	24	0		0
7	gaalee naachaa	9	-0.215456074	3188	24	72		0.007128713
8	gaalee adii	22	-0.3319774	3188	24	462		0.045742574
9	Heexoo	3	-0.104450739	3188	24	6		0.000594059
10	dogomaa (bisanaa)	1	-0.045694263	3188	24	0		0
	Total	**101**	**1.57104673**					**0.69920792**
1	wedeessa (waanzaa)	1	-0.02884976	3171	25	0	32220	0
2	Kombolcha	8	-0.138378458	3171	25	56		0.001738051
3	ebicha (girawa)	7	-0.126274038	3171	25	42		0.001303538
4	Bosoqee	13	-0.189800541	3171	25	156		0.004841713
5	Feexoo	19	-0.237343553	3171	25	342		0.010614525
6	Insilaala	8	-0.138378458	3171	25	56		0.001738051
7	Ashikitii	14	-0.198636629	3171	25	182		0.005648665
8	Tultii	19	-0.237343553	3171	25	342		0.010614525
9	Sardoo	32	-0.307061502	3171	25	992		0.03078833
10	Koshiimii	2	-0.049997885	3171	25	2		6.20732E-05
11	gaalee naachaa	7	-0.126274038	3171	25	42		0.001303538
12	arrii mukaa	6	-0.113373246	3171	25	30		0.000931099
13	dogomaa (bisanaa)	44	-0.34436532	3171	25	1892		0.058721291
	Total	**180**	**2.23607698**					**0.8716946**