JIMMA UNIVERSITY

JIMMA INSTITUTE OF TECHNOLOGY

FACULTY OF CIVIL AND ENVIRONMENTAL ENGINEERING

ENVIROMENTAL ENGINEERING POST GRADUATE PROGRAM

SPATIAL-TEMPORAL LAND USE LAND COVER CHANGE AND ITS IMPACT ON YAYU FOREST IN ILLUBABORA ZONE, OROMIA, ETHIOPIA

BY

ABEBE EMANA BARBAD

ATHESIS SUBMITTED TO JIMMA UNIVERSITY SCHOOL OF CIVIL AND ENVIRONMENTAL ENGINEERING DEPARTMENT OF WATER SUPPLY AND ENVIRONMENTAL ENGINEERING IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTERS OF SCIENCE IN ENVIRONMENTAL ENGINEERING

NOVEMBER, 2021

JIMMA, ETHIOPIA

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NOVEMBER, 2021

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DECLARATION

I, hereby declare that this thesis entitled "spatial-temporal land use land cover change and its impact on Yayu forest in Illubabora Zone, Oromia, Ethiopia" is my original work, was studied by myself, under the guidance of my Advisors, that the work contained herein is my own except where explicitly stated otherwise in the text, and it has not been presented for award of degree in Jimma University or any other University and that all sources of materials used for have been fully acknowledged.

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This thesis has been submitted for examination with our approval as university advisor and program chairperson.

Approval by the main advisor:

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Approval by co-advisor:

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All praises to the God almighty that has created this world of knowledge for us. He is the Gracious and the Merciful. He bestowed man with intellectual power and understanding, and gave him spiritual insight, enabling him to discover his “Self” know his Creator through his wonders, and conquer nature.

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ABSTRACT

Forests are important sources of livelihood for millions of people and contribute to the national economic development of many countries service. Yayu forest is the largest and most important forest for the conservation of the coffee genetic resources in the World. However, there is an accelerated reduction in its faunal and flora diversity including woody plant species as a result of man-made pressure and activities, such as uncontrolled hunting, habitat destruction for agricultural expansion, pressure by domestic animals and heavy encroachment by a human being. Thus, aim of this study was to detect the forest cover change analysis using GIS and Remote Sensing techniques over the last 29 years (between 1992 and 2021) and the software used for this study were Arc GIS 10, ERDAS IMAGINE 15 and SPSS 20. The methodology followed for this study were acquisition of Landsat image of 1992, 2002 and 2021, DEM 2014 data extracted and investigation of local community perception by using open and closed-ended questioners. The main sources of the data in this study were both primary and secondary sources to obtain information on forest cover change were collected. The major land use/land cover types in the study area have been identified as: forest land, farm land, grassland, and settlement. The study made use of Landsat images of the year 1992, 2002 and 2021 to know land-use/land cover change and the forest cover changes and rate of forest cover and loss during the different periods and the type of land cover to which the forest is changed to. The result of change detection analysis revealed that the area had remarkable land-use/land cover changes in general and forest cover change in particular. Specifically, the forest cover land increased from 59,174.60 ha in 1992 to 63,254.20 ha in 2002 and further dropped to 59,553.6 ha in the year 2021 in the study area. When compared the year1992-2002 with the 2002-2021 forest cover condition with a deforestation rate of 194.79 ha per annum were observed during the period 2002-2021. The local community perception on forest conservation strategies indicated that 42.8% of the respondents perceived conservation management was done by the residents whereas, 28.9% was conserved with a collaboration of all stakeholders. Hence, this study has provided the first useful ecological information on the problem of forest cover change is directly linked with the activity of man such as population pressure, and the socioeconomic factors like expansion of agricultural activities, demand of fuel wood and construction materials, as well as resources for income. In order to hold back the problem of forest cover change and its impact, corrective measures was suggested.

Key Words: - *Cover change detection analysis, Forest Cover, Remote Sensing and GIS, Yayu Biospheres Reserve*

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ACRONYMS

CSA	Central Statistical Authority
DEM	Digital Elevation Model
DHHSNYBR	Duration of households stay near the Yayu Biosphere Reserve.
EMA	Ethiopian Mapping Agency
EMS	Electromagnetic spectrum
ERDAS	Earth Resources Data Analysis System
ETM	Enhanced Thematic Mapper
FAO	Food and Agriculture Organization of the United Nations
GCP	Ground Control Point
GIS	Geographic Information System
GPS	Global Positioning System
IABZANRO	Ilu Aba Bor Zone Agriculture and Natural Resource Office
ISODA	Iterative Self-Organizing Data Analysis
LULC	land use land cover
MCE	Multi-Criteria Evaluation
NIR	Near Infra-Radiation
NDVI	Normalized Difference Vegetation Index
QA	Quality Assurance
QC	Quality Control
RS	Remote Sensing
SRTM	Shuttle Radar Topographic Mission
SPSS	Statistical package for social science
TM	Thematic Mapper
UNESCO	United Nations Educational, Scientific, and Cultural Organization
UTM	Universal transverse Mercator
USGS	United States Geological Survey
WGS	World Geodetic System
YBR	Yayu Biosphere Reserve

CHAPTER ONE

INTRODUCTION

1.1 Background

Globally, forests are key components of biodiversity that represent the foundation of ecosystems, through the services they provide like provisioning environmental and ecological regeneration and cultural and affect human well-being. Forests are important sources of livelihood for millions of people and contribute to the national economic development of many countries (Jenkins and Schaap, 2018).

Globally, about 29 percent of the land surface was originally under forest cover (Mohd Jaafar et al., 2020). Presently, however, it is only a fifth of this original remains undisturbed (Santoro et al., 2021). It is estimated that in Ethiopia, 40 percent of the country was covered with forests at the beginning of the 19^{th}centur (Tanqua,2020). According to Solomon (2018) 10.7 percent of Ethiopia's landmass is currently estimated to be under forest cover, with a loss of 150,000 to 200,000 hectare of natural forest per annum. One of the problems regarding forest cover in Ethiopia is lack of reliable and accurate information.

According to Steger (2020) the country's forest cover in 1989 was 12.9 percent. A decade later, in 1997, the forest cover was estimated to be only 4.2 percent (Hedden-Dunkhorst and Schmitt, 2020). The estimates of the rate of deforestation have also been variable. For example, the annual rate of deforestation estimated by (Challéat *et al.*, 2021) ranged between 150,000 and 200,000 hectares per annum. However, (Hedden-Dunkhorst and Schmitt, 2020) reported a much lower estimate of about 40,000 hectares per annum. This is probably due to lack of consistent definition of what "forest" represents in the different studies and the lack of first-hand information for generating these estimates.

A protected area is a clearly defined geographical space, recognized, dedicated and managed, through legal or other effective means, to achieve the long term conservation of nature with associated ecosystem services and cultural values. Ethiopia has designated many protected areas throughout the country that includes national parks, wildlife reserves, National Forest Priority Areas, Biosphere Reserves and community conservation areas. Biosphere Reserves are natural protected areas included in a global network organized by the UNESCO (Hedden-Dunkhorst and Schmitt, 2020).

Biosphere Reserves have three interrelated zones that aim to fulfill three complementary and mutually reinforcing functions: The core area(s) comprise of strictly protected ecosystem that contributes to the conservation of landscapes, ecosystems, species and genetic variation (Iswandaru et al.,2020). The buffer zone surrounds or adjoins the core areas, and is used for activities compatible with sound ecological practices that can reinforce scientific research, monitoring, training, and education. The transition area is the part of the reserve where the greatest activity is allowed, fostering economic and human development that is socio-culturally and ecologically sustainable (Tadese et al.,2021). In the same manner, Ethiopia has four internationally recognized bio reserves sites namely Kafa biosphere reserve nominated in 2010, Yayu Biosphere Reserve nominated in 2010, Sheka Biosphere Reserves, nominated in 2012 and Lake Tana Biosphere Reserve nominated in 2015. The country has diverse flora and fauna most of them are endemic (Iswandaru et al.,2020). Currently, Ethiopia supporting more than 2,985 described species of animals and 7,000 of higher plant species with 12% endemism, among the fauna 320 are mammals with 36 endemism, 926 birds with 24 endemism, 1,265 arthropods with 21 endemism, 200 fish with 40 endemism, 201 reptiles with 16 endemism and 73 amphibians with 30 endemism many of the biodiversity living in and around the Biosphere Reserve and critically depend on the reserve for livelihoods (Tadese et al.,2021).

Ethiopian natural forests are rapidly disappearing and today the remaining primary forest is located mostly in the country's most inaccessible areas. The national deforestation rate is estimated at 140,900 ha annually, and forest deforestation converts the remaining natural forest patches to coffee forests or open woodland (Dagnachew et al.,2020). According to the Dagnachew (2020) 11.2% or about 12,296,000 ha of Ethiopia is forested, though the percentage of natural forest is unclear. Threats to the Ethiopian forests are numerous as a result of rising population pressure, with widespread deforestation for new settlement and agricultural lands, as well as adverse urban development policies and uncontrolled private investment. Yayu forest is the largest and most important forest for the conservation of the coffee genetic resources in the World (Tadese et al.,2021). However, there is an accelerated reduction in its faunal and flora diversity including woody plant species as a result of man-made pressure and activities such as uncontrolled hunting, habitat destruction for agricultural expansion, pressure by domestic animals and heavy encroachment by a human being (Abera et al.,2021). Forest resource maps were traditionally prepared from forest inventories involving aerial photography and field work

(Ramachandran and Reddy, 2017).

Yayu BR has been known for its dense forest cover and rich biodiversity conservation but recently threatened by land pressure due to coffee plantation investment. In order to tackle such prevailing problems, it needs dynamic information about past and present land use/cover scenarios. However, no research has been carried out to analysis forest cover change on Yayu Biosphere Reserve as well as on the perception of the local community toward the Biosphere Reserve on supporting the conservation strategies. This study, therefore, aim to obtain reliable data about forest cover change and trends of forest cover change for the last 29 years using GIS and Remote Sensing techniques as well as the perception of the local community toward the Biosphere Reserve on supporting the conservation strategies.

1.2. Statement of the problem

Almost 85% of Ethiopian population live in rural areas, and a large part of this population depends directly or indirectly on natural resources (Angulo et al.,2021). The ever-increasing human population combined with unwise land use and farming systems, unsustainable forms of agricultural intensification, and catchment degradation has resulted in serious degradation of these important forest resources (Legese and Roba, 2021).

The major problems to Biosphere Reserve in Ethiopia originate from demographic pressure, settlement within the Biosphere Reserve or adjacent to them; deforestation, farmland expansion, grazing, and cutting a living tree, illegal encroachment by people, uncontrolled fire, soil erosion, and hunting (Steger et al.,2020); while conflicts between Biosphere Reserve management and local community, alien invasive species and change in fire regime are other problems of a Biosphere Reserve in the country. Despite this, few studies were conducted about this Yayu Biosphere Reserve before but they are very rare. Most of the studies conducted so far have concentrated on impacts of human use and implications for in situ conservation of wild Coffee Arabica, Diversity of anurans in forest fragments as well as studies on the impacts of human activities on wildlife, genetic variability in Yayu coffee and different case studies were conducted, but they were not focused on the continuous state of forest cover change in Yayu Biosphere Reserve (Tadese et al., 2021).

Thus, they fail to apply GIS and Remote Sensing tools to show severity of the problem on the map. This study tries to use these important tools for land use land cover change detection and it would provide relevant and easily accessible information for concerned bodies. This requires a careful in-situ investigation on the matter of spatiotemporal forest cover change in the Yayu Biosphere Reserve and perception of the local community toward the Biosphere Reserve conservation.

The results from this study provide the status of forest cover and its rate of change by means of GIS and Remote Sensing techniques, to suggest conservation measures, to protect and use the valuable forest resources of Yayu Biosphere Reserve in a sustainable manner.

1.3. Objectives of the study

1.3.1. General objective

The general objective of the study was to identify the spatiotemporal forest cover change process by using GIS and RS in Yayu Biosphere Reserve.

1.3.2. Specific objectives

1. To generate land use land cover of 1992, 2002 and 2021 in the study area.
2. To produce disturbance risk map by using various factor for forest change.
3. To assess the rate of forest cover change in the period 1992, 2002 and 2021 in the study area.
4. To assess the perception of the local community towards the forest cover change in the study area.

1.4. Research Question

1. What look like the land use land cover during 1992, 2002, and 2021?
2. What are the factors responsible for the forest land cover Change in study area?
3. By what rate the forest cover has been changing in 1992, 2002 and 2021 in the study area?

4. What are the perceptions of local community towards the existing forest cover change in the study area?

1.5. Significance of the study

To tackle the alarming rate of deforestation experienced in many parts of the country Ethiopia has been launching huge reforestation program since 2008 (Assefa, 2021). But, the rates and extent of the problem are still debatable due to limitations of reliable data and the processes involved are not clearly understood. This study haven given an important in filling of this information gap. Specifically, the result of the study would have the following contributions;

Provide an insight towards an understanding of the use of integrated techniques of using GIS and Remote sensing tools for forest cover change detection. It also provides achievable solutions for those who are responsible and interested for taking measures to mitigate the problem. It generates first-hand information on the problem of forest cover change in the study area for those who are interested to conduct further research on the issue. It has also a great input for devising forest management and protection policy formulation.

1.6 Scope of the Study

The study was conducted in the Yayu Biosphere Reserve, Oromia Regional State South-western Ethiopia. The conceptual delimitation of this study was gone on overseeing how Yayu Biosphere Reserve Forest cover has been changing between the year 1992, 2002 and 2021 using GIS and RS techniques. Geographically the investigation was focused within in the boundary of Yayu Biosphere Reserve forest area only.

CHAPTER TWO

LITERATURE REVIEW

2.1. Forest, Forest Cover and Change detection

Forest is one of the great resources of the earth. It includes natural forests and forest Plantations. The term is used to refer to land with a tree canopy cover of more than 10 percent and area of more than 0.5 ha (Sommer, 2020). World Bank funded woody biomass investment and strategy planning (Ramachandran and Reddy, 2017) also defines forest as "a relatively continuous cover of trees, which are ever green or semi-deciduous only being leafless for a short period, and then not simultaneously for all species the trees should be able to reach a minimum height of 5 m." Forests are determined both by the presence of trees and the absence of other predominant land-uses (Eisawi,2021).

Forest biodiversity is the variability among living organisms in forest ecosystems. It comprises diversity within and among species, and within and between each of the terrestrial and aquatic components of forest ecosystems (West et al.,2020). Change detection is the process of identifying differences in the state of an object or phenomenon by observing it at different times (Kim,2021). Change detection aim is to discover temporal differences of the same objects at different time.

2.2. Global overviews of forest cover change

Today, human being has taken the leading role in changing natural environment and there is increasing pressure on these nonrenewable natural resources. So making suitable or harshen it is in our own hands, i.e. our activities have essential in modification of physical or man-made environment (Rahman and Begum,2011). According to World Bank (Posza and Csapi, 2021) the world's population become above 7.8 billion and is expected to double in the next 50 years. Forests maintain conditions that make life possible.

Forests also play an important role in the global carbon balance, as both carbon sources and sinks. They have the potential to form an important component in effort to combat global climate change. When forests are transformed into agriculture, the subsequent land use systems implemented determine the amount of carbon sink potential takes place. But, now it was threatened with elimination.

A recent forest resource assessment (Nesha et al.,2021) estimated the World forest covers 30% of the total land area. This is approximately 4 billion hectares corresponding to 0.62 hectares per capita. This is unevenly distributed with 62 countries of combined population of approximately 2 billion having less than 0.1 ha per capital (Shahra,2017).

2.3 Global Causes of forest cover change

The causes of forest cover change are complex and dynamic in nature. There is stiff competition on global economy which drives the need for more money in the economically challenging tropical countries, with the most of tropical forests. Deforestation is a result of the interaction of environmental, social, cultural and political forces in a given region (Giglio, Randerson and Werf, 2013).

According to (Nesha et al.,2021) the three main causes of deforestation in the world are; agriculture (including huge investment), infrastructure expansion and wood extraction. The author asserted that the action of human beings rather than natural forces is the sources of most contemporary change for this dynamic world.

Population growth is another major cause for deforestation and obstacle for the achievement of sustainable development. Because, population growth without considering environment by itself have great impact on sustainable development, so sustainable development must be environmentally friendly (Zehra et al.,2021).

Tropical forests are world's reservoir of ecosystem and biodiversity hotspots. Most of tropical forests are in developing countries and threatened with high rate of deforestation, hence it has major effects on global climate change and loss of plant and animal species (Park, Lim and Lee, 2021).

People have indigenous knowledge and information about nature, and also forests are house of indigenous cultures. Transforming forest to wipe out indigenous people is a moral crime. Carbon trading/avoided deforestation, sustainable forest management and forest certifications are options in the world agenda for discussion as the possible ways of alleviating deforestation (West et al., 2020). A further 2.3 million ha of humid forest is apparently degraded annually through fragmentation, logging and/or fires. In the sub-humid and dry tropics, annual deforestation of tropical moist deciduous and tropical dry forests comes to 2.2 and 0.7million ha, respectively

(Mohd Jaafar et al.,2020). The forests of Africa are being converted at a similar rate to those of Latin America 0.4 to 0.5% per year (West et al.,2020).

Start from past millennium and still today humans have taken an immense role in the modification of the global environment. With increasing numbers and developing technologies, man has emerged as the major actor, most powerful and universal instrument of environmental change in the biosphere today (Thomsen et al.,2020).

According to (2005) assessment, deforestation rate was about 13 million hectares per year (Kwawuvi, Bessah and Owusu,2021). This includes 6 million of primary or frontier forests. Frontier forests are defined as "forests where there are no clearly visible indications of human activity and where ecological processes are not significantly disturbed" (Hestad, Tàbara and Thornton,2021). Primary forests have no sign of past or present human activities and are considered to be the most biologically diverse ecosystems in the world (Thomsen et al.,2020).

The key drivers of forest biodiversity loss are: population and consumption growth; increasing trade in food and agricultural products; growing demand for forest products, including biomass for energy generation; expansion of human settlements and infrastructure; and climate change (Hestad, Tàbara and Thornton, 2021). Asserts that cutting trees for the various purposes such as: obtaining wood for construction, shelter and tool making; providing fuel to keep warm; cook food; and smelt metals; and above all, creating land for cultivation has culminated in one of the main processes where by human kind has modified the worlds surface cover of forest resources.

There is substantial change in the magnitude of deforestation in the tropical areas, particularly it varies in developing countries, and large forests have been transformed for farm and settlement developments. This shows people assumes that fertile soils under the forest cover which is rich in vegetation diversity was essential for crop growth and for human settlement, and this has led to rapid forest clearance for agriculture as well as timber supply (Hestad, Tàbara and Thornton, 2021).

2.4 Extents of forest cover in Ethiopia

Ethiopia owns diverse vegetation resources, from tropical rain and cloud forests in the southwest and on the mountains to the desert scrubs in the east and north east and parkland agroforestry on the central plateau (Chencha, Mussa and Bekele, 2021). The vast terrestrial land surface with biologically productive climate and soil indicates the country has a huge forestry development potential. The forest resources are an important endowment of the country. They contribute production, protection and conservation functions. Ethiopia's flora and fauna resources are uniquely diverse. The flora comprises about 6500-7000 species of higher plants out of which 12% are endemic and the countries natural forests and woodlands covered 15.1 million ha in 1990 (Berhe et al., 2017). In 2009, the area is estimated at 12.3 million ha, 11.9 % of the total land area. Of this, the remaining closed natural high forests are 4.12 million ha or 3.37% of Ethiopia's land (Solomon *et al.*,2018). This indicates that the coverage of forest resources has been declining at an alarming rate. The area of forest is unevenly distributed in the country. Oromia, Southern Nations and Nationalities Regional State and Gambella region account for 95% of the total high forest area (Solomon et al.,2018).

2.5 The causes of forest cover change in Ethiopia

According to Ango and Börjeson (2020) the causes for forest cover change accompanied by the loss of biodiversity can be explained on two different levels: the local level and the global one. The local level includes destruction of forests caused by local inhabitants. The rural poor living around forests heavily depend on biodiversity to satisfy their basic needs such as food, water, housing and social services. The economic dependency of the people on the forest which offers firewood and area that can be converted to agricultural land is one of the main reasons for deforestation. The global level of deforestation is formed by the worldwide demand for natural resources (e.g. timber, soil, gas, oil).

In Ethiopia, forests, woodlands and mixed-use landscapes are often targeted for agricultural expansion as a means to maximize benefits from land-based investments while avoiding the displacement of cropland (West et al.,2020). Increased investment is welcomed by host country governments for its opportunity to stimulate rural economies while fostering national economic development Bank (2017).

According to (West et al.,2020) the extent destruction of natural forest was estimated to currently total about 59,000 ha per annum in the three main forested regional states of Oromia, Southern nations, nationalities and Gambella only.

The finding of (Dagnachew *et al.*,2020) also illustrates that the absence of clear institutional authority and communication between concerned agencies further retarded transparency in forest management and leads to unwise use of forest resource in Ethiopia.

2.6. Application of GIS and Remote Sensing for Forest Cover Change

2.6.1. Geographic Information System (GIS)

Different authors defined GIS from different perspectives (Lin et al.,2020) define "GIS is a Powerful tool for collecting, storing, retrieving, as well, transforming and displaying spatial data from the real world for a particular set of purpose" including location based service. On the other hand (Shahra, 2017), define "GIS is a specific information system applied to geographic data and is mainly referred to as a system of hardware, software and procedures designed to support the capture, management, manipulation, analysis, modeling and display of spatially-referenced data for solving complex planning and management problems".

What we understand from the above definitions is that, it relies mainly in a computer technology that realized digital data. Now, GIS is become popular tool because of its, rapid access to data, flexibility, easy update opportunity and other features that enable to analyze different databases (Braun, Degbelo and Kray, 2017). GIS is an information system that is designed in the way compatible with referenced data to spatial or geographic coordinates. GIS is both a database system which has specific capabilities for spatially referenced data, and a set of operation for working with data. The functions of GIS include data entry, data display, data management, information retrieval and analysis. The applications of GIS include mapping locations, quantities, finding distances and mapping and monitoring change (Roots and Overviews, 2021).

2.6.2. Remote Sensing

Remote Sensing is the science and art of obtaining information about an object, area, or phenomenon through the analysis of data acquired by a device that is not in contact with the object, area or phenomenon under investigation (Kumar and Dwivedi, 2021). The focus of remote sensing in scope of this study is to indicate areal extent of forest cover changes on map using resources of Landsat of various periods. Remote sensing satellite images are immensely used in time to time study of changes due to its repetitive coverage, especially in forest resources estimation and monitoring, and natural resources monitoring and management.

2.6.3. Forest cover change Monitoring using GIS and Remote Sensing

The potential of GIS and remote sensing in the field of forestry become established over many years through the use of aerial photos and satellite image interpretations in forest cover change detection analysis, for the generation of cover map and inventory analysis (Zhu, Zhang and Sun, 2021). Multi-temporal data provides for change detection analyses and remote sensing brings together a multitude of tools to better analyze the scope and rate of deforestation. Images of earlier years are compared to recent scenes, to tangibly measure the differences in the sizes and extents of forest cover change. Data from a variety of sources are used to provide complementary information and the Satellite image data can be used to efficiently monitor the status of existing forest and emergence of new ones, and even assess regeneration condition. In countries where cutting is controlled and regulated, remote sensing serves as a monitoring tool to ensure companies are following cut guidelines and specifications (Zhu, Zhang and Sun, 2021). So, remote Sensing is a powerful technique for surveying, mapping and monitoring earth resources and GIS facilitates in storage, manipulation and analysis for Geographic information and Socio-economic data to provide a wider application. Whereas the Land resource and environmental decision makers require quantitative information on the spatial distribution of land use types and their conditions as well as temporal changes (Sanchez-azofeifa and Arturo,2002).

2.6.4. Change detection methods

Change detection is the process of identifying differences in the state of an object or phenomenon by observing it at different times (Roots and Overviews, 2021). And according to Tewabe and Fentahun (2020) change detection involves the use of multi-temporal datasets to discriminate areas of land cover change between dates of imaging; in addition essentially, it involves the ability to quantify temporal effects using multi-temporal data sets. (Tewabe and Fentahun, 2020) also noted that change detection is useful in such diverse applications as land use change analysis, monitoring of shifting cultivation, assessment of deforestation, seasonal changes in pasture production, damage assessment, disaster monitoring, day/night analysis of thermal characteristics as well as other environmental changes. All digital change detections are affected by spatial, spectral, temporal and thematic constraints. The type of method implemented can profoundly affect the qualitative and quantitative estimates of the disturbance (Kumar and Dwivedi, 2021).

Digital change detection is a difficult task to perform. An interpreter analyzing large-scale aerial will almost always produce more accurate results with a higher degree of precision (Kumar and Dwivedi, 2021). Nevertheless, visual change detection is difficult to replicate because different interpreters produce different results (Sommer, 2020). Furthermore, visual detection acquires large data acquisition costs.

Apart from offering consistent and repeatable procedures, digital methods can also more efficiently incorporate features from the infrared and microwave parts of the electromagnetic spectrum. Many change detection methods have been developed and used for various applications. For example, there are post-classification comparison, image differencing, image rationing, image regression and principal component analysis (Sanchez-azofeifa and Arturo, 2002). However, they can be broadly divided into: post classification and spectral change detection approaches (Kumar and Dwivedi, 2021).

2.6.5. Post classification approach

Post classification is among the most widely applied techniques for change detection purpose. Numerous studies have been carried out using post-classification approach. In post classification change detection approach two images from different dates are classified and labeled. The area of change is then extracted through the direct comparison of the classification results (Roots and Overviews, 2021). Sanchez-azofeifa and Arturo (2002) forwards both advantages and disadvantages of post classification techniques. The main advantages of post-classification include: detailed “from- to” information. It bypasses the difficulties associated with the analysis of images acquired at different times of year or sensor. The main disadvantage of the post-classification approach is the dependency of the land cover change results on the individual classification accuracies. This approach can produce a large number of erroneous change indications as an error on either data gives a false indication of change.

2.6.6. Spectral change detection approach

According to Giglio, Randerson and Werf (2013) a large number of techniques are in the spectral change identification category. Spectral change detection techniques rely on the principle that land cover changes result in persistent changes in spectral signature of the affected land surface.

These techniques involve the transformation of the two original images into a new single band or multi-band image, in which the area of spectral change is highlighted. Most of the spectral change detection techniques are based on some type of image differencing or image rationing. Studies by Sanchez-azofeifa and Arturo (2002) have identified image differencing as the most accurate change detection technique. This technique is performed by subtracting images from two dates pixel by pixel. Then threshold boundaries between change and no-change pixels are determined for the difference image to produce the change map.

Among spectral change detection methods, vegetation indices are among other methods that have been reliable in monitoring vegetation change. One of the most widely used indices for vegetation monitoring is the Normalized Difference Vegetation Index (NDVI), because vegetation differential absorbs visible incident solar radiant and reflects much of the near infrared (NIR), data on vegetation biophysical characteristics can be derived from visible and NIR and mid-infrared portions of the electromagnetic spectrum (EMS) (Kim,2021). The NDVI approach is based on the fact that healthy vegetation has low reflectance in the visible portion of the EMS due to chlorophyll and other pigment absorption and has high reflectance in the NIR because of the internal reflectance by the mesophyll spongy tissue of green leaf. NDVI can be calculated as a ratio of Red and the NIR bands of a sensor system. In general, the advantage of spectral change detection techniques is that they are based on the detection of physical changes between image dates(Roots and Overviews, 2021). This avoids the errors introduced in post classification change detection where inaccuracies in the land cover classification are propagated into land cover change analysis. However, the greatest challenge to the successful application of these techniques is the discrimination of “change” and “no change” pixels. For spectral change detection, an accurate image co-registration is crucial (Kumar and Dwivedi, 2021).

2.6.7 Image classification

Image classification is the process of sorting pixels into a finite number of individual classes, or categories of data based on their data file values. If a pixel satisfies a certain set of criteria, then the pixel is assigned to the class that corresponds to those criteria (Avtar et al., 2015). There are two primary types of classification algorithm applied to remotely sensed data. These are unsupervised and supervised. Unsupervised classifications algorithms such as ISODA (Iterative Self-Organizing Data Analysis) are used to several users defined statistical parameters in an iterative fashion or until either some percentage of pixels remain unchanged or a maximum number of iterations have been performed. This method of classification is most useful when no previous knowledge or ground truth data of an area is available. An unsupervised classification approach was adopted for this study for pre-field visit purpose (Rahman and Begum, 2011).

2.6.8. Multi-Criteria Evaluation Techniques

A decision is a choice between alternatives; the alternatives may represent different courses of action, different hypotheses about the character of a feature, different classifications, and so on. The procedure by which criteria are selected and combined to arrive at a particular evaluation and by which evaluations are compared and acted upon is known as a decision rule**.** A decision rule might be as simple which applied to a single criterion or it may be as complex as one involving the comparison of several multi- criteria evaluations (Avtar et al., 2015).

According to Tewabe and Fentahun (2020) multi criteria evaluation is most commonly achieved by one of two procedures. The first involves Boolean overlay where by all criteria are reduced to logical statements of suitability and then combined by means of one or more logical operators such as intersection (AND) and union (OR). The second is known as Weighted Linear Combination (WLC) where in continuous criteria factors are standardized to a common numeric range, and then combined by means of a weighted average.

While these two procedures are well established in GIS, they frequently lead to different results, as they make very differently about how criteria should be evaluated. In the case of Boolean evaluation, a very extreme form of decision making is used. In general, the primary issue in Multi Criteria Evaluation is concerned with how to combine the information form several criteria to form a single index of evaluation. This technique also supports the post classified data to make overlay and understand spatial variation in those time interval (Tewabe and Fentahun,2020).

2.8. Attitudes of Local people towards Conservation

According to Kc, Min and Serenari (2021) sustainable and effective conservation activities are strongly influenced by the attitudes, perceptions, and impacts that local people have experienced from conservation activities. An understanding of the factors which influence people’s attitudes and perception is the key features in planning, decision making and management of the biodiversity conservation goal. Understanding the perceptions and attitudes of local people provides guidance for policy and management policy towards conservation activities (Hughes, Tanalgo and Catherine,2021).

Also (Gorsevski *et al.*,2012) revealed that, other factors such as government policy, lack of participation in decision making, protected staff or management intervention, and poor involvement of local people in planning conservation activities, influence negative perceptions.

Local people especially those living in and adjacent to Biosphere Reserve have had a long relation with these areas, and their attitudes generally depend on the costs and benefits of Biosphere Reserve and the local dependency on natural resources (Kc, Min and Serenari, 2021).The needs and attitudes of these nearby communities should be considered in the management of the Biosphere Reserve to achieve long term survival of conservation goals.

According to Kc, Min and Serenari (2021) and the effective sustainable survival of Biosphere Reserve, especially in developing countries, would be threatened if the needs and aspiration of the local people are not considered.

2.9. Research Gap

Developing new tools, methods and practices to monitor biodiversity and increase stakeholder participation is become prerequisite currently, to support and improve forest management practices, For example, new technology and mapping systems to guide forest conservation practices and inform policy (Taylor et al.,2020).

However, in Ethiopia, like most developing countries, reliable information on the vegetation resources such as their spatial coverage, distribution, changes over time (deforestation or regrowth), growing stock in the standing vegetation, regeneration and recruitment status and other essential information are lacking or difficult to get because it is scattered (Avtar et al.,2015).

Besides, previous research works related with forest cover change detection tries to apply only one or two of change detection methods and analysis the result which might raise question on accuracy of the result. In addition previously satellite images were bought from concerned institutions such as EMA in imagine format, so, there might be loosing of some most important bands which help for analysis which leads to inaccurate result. The main advantages of post-classification include: detailed "from- to" information. The main disadvantage of the post-classification approach is the dependency of the land cover change results on the individual classification accuracies (Taylor et al., 2020).

According to (Gorsevski *et al.*,2012) the advantage of spectral change detection techniques is that they are based on the detection of physical changes between image dates. So, this avoids the classification problem occurred during post classification techniques. Besides, Ground verification was applied to check whether the classification already exist on the ground. This study tries to consider above all issues and solve problems, and applies digital change detection by both post classification and NDVI approach on forest cover change and checks the accuracy of classification result by on the ground by collecting GCP points and apply accuracy assessment by using Confusion matrix. And also the researcher tries to apply method called multi criteria evaluation techniques (MCE) by using various important factor maps indicate areas which is susceptible for forest degradation.

CHAPTER THREE

MATERIALS AND METHODS

3.1. Description of the study area

The study was conducted in the Yayu Biosphere Reserve Oromia Region South-Western Ethiopia. It encompasses Yayu, Hurumu, Chora, Nopha, Alge Sachi and Doreni districts, in Illu Abba Bora Zone. Yayu Biosphere Reserve is located between 8°10’00’’ to 8°40’00’’ N and 35°40’00’’ to 36°10’00’’E (Fig.1). The Biosphere Reserve includes eastern Afromontane biodiversity hotspot and important bird areas of international significance and one of the remnant montane rainforest fragments with wild Coffee (Coffea arabica) populations in the world. The area has an economic strategy that focuses on the environment as an economic driver. The forest is characterized by rolling topography and it is dissected by small streams and two major rivers, Geba and Dogi. There is continuous forest cover along the rivers.

The land frequently changes from flat surface plateaus to very steep slopes and valley bottoms within a short distance. The elevation in the whole reserve ranges from 1,100 to 2,337 meters. The forest type in the Biosphere Reserve is predominantly Afromontane rainforest and considered to be a transition between lowland and montane forest types (Terfassa, 2021). Three plant community types exist within the Biosphere Reserve namely Coffea arabica (Cassipourea malosana, Argomuellera macrophylla) Celtis africana, and Dracaena fragrans and Telclea noblis communities (Terfassa, 2021).

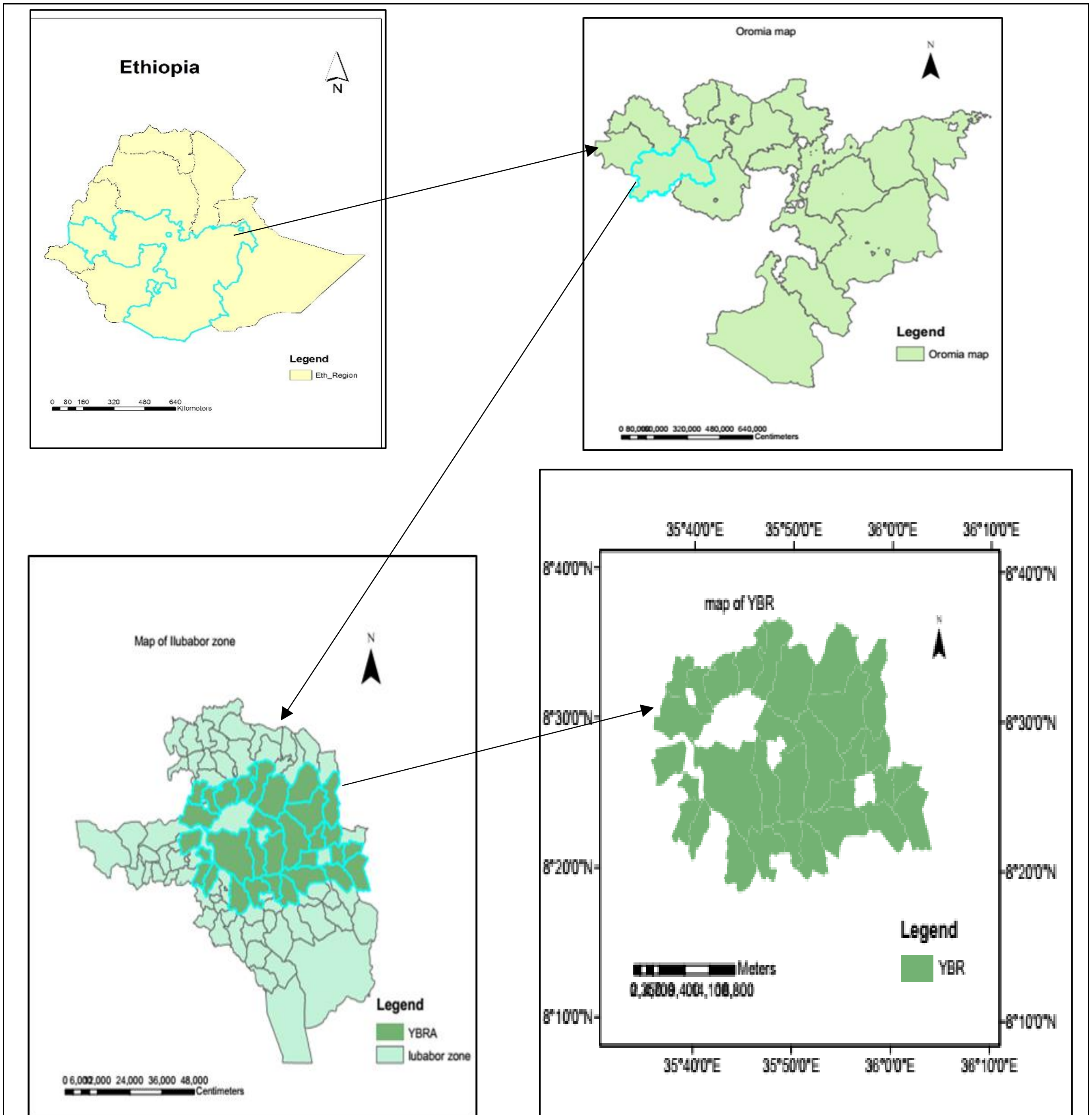

Figure.1. Map of the study area.

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3.1.2 Climate condition

According to the climate data for ten years, obtained from National Meteorology Agency (2012), the mean annual temperature of the study area is 23.76 °C and the mean annual rainfall is 1,625 mm (Campus et al.,2021). The rainfall pattern is uni-modal and it reaches its highest between May and September (wet season) and it's lowest between November and March (dry season) while there is a small amount of rainfall in April and October, although this shows variation year to year.

3.1.3 Socio-economic

Agriculture that holds both crop production and animal husbandry are the major means of subsistence for the community in the study area. The area forms the dispersal area for agriculture and most conducive to livestock grazing, wild animal conservation, and tourism. The site covers a total area of 167,021 ha of biodiversity hotspots that has three management zones namely, core zone (16.6%), buffer zone (12.9%) and transitional zone (70.5%) (Campus et al.,2021).

About 154, 300 permanent residents live in the Biosphere Reserve and mainly rely on agriculture. The designation as a Biosphere Reserve is expected to enhance ecologically sound and traditional agriculture, to foster ecotourism and to create new jobs in small businesses such as coffee, bee-keeping, spices and horticulture activities (Campus et al.,2021).

3.2. Research design and period

A mixed methods of research design were used for this study for collecting and analyzing both quantitative and qualitative data (Fig.2). Quantitative method was used to identify the spatio temporal forest cover change in the Yayu Biosphere Reserve. This was consists of acquisition of Landsat image of 1992, 2002 and 2021, DEM data extracted. Qualitative method was used to investigate perception of the local community towards conservation strategy by using the collection of both open and closed-ended questioners in response to research question. The data collection processes have been carried out within one month (March) while the collected data would be analyzed from April to October 2021.

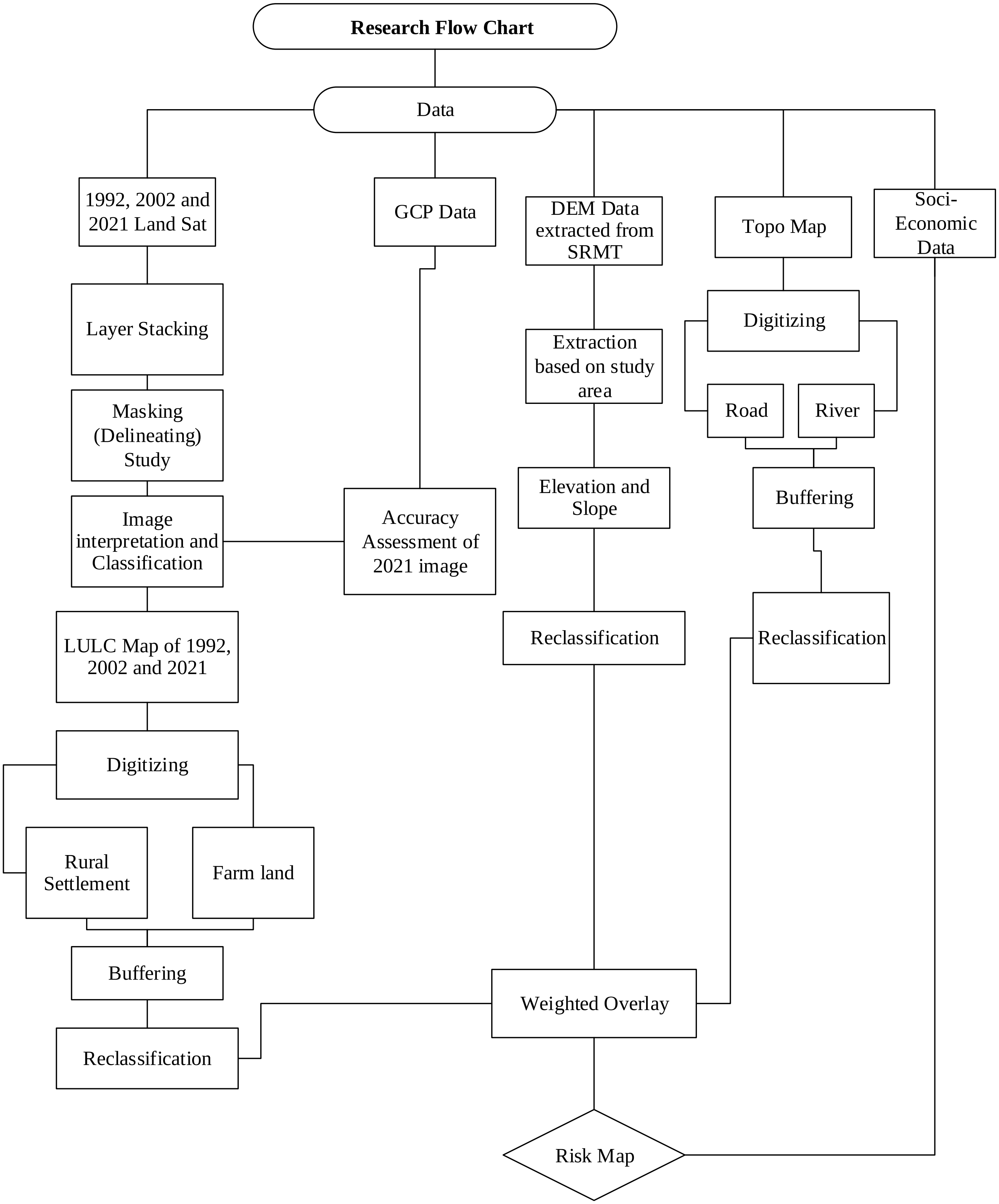

Figure 2: Research flow chart

3.3. Data types and sources

3.3.1. Primary and secondary data

The main sources of the data in this study were both primary and secondary sources. To obtain information on forest cover change both data types were collected. Accordingly, the first-hand information would observation and GCPs (ground control points) from the target study area in frequent field observation and verification.

Different secondary sources of data were used to derive the required secondary information for this study. This includes pertinent documents like; available recorded documents, literatures and review of relevant published and unpublished documents, journals and reports which were written on the subject under investigation would be taken and included in this study. Satellite imageries were collected in order to identify historical and recent land-use/land cover from USGS website. The image data have been used for this study were Landsat TM 1992, ETM+2002 and ETM+ 2021 as shown in Table 1 below

Table 1. Source of image

No	Image type	Path and row	Date of acquisition	Resolution
1	Landsat-TM	170/55	01/21/1992	30*30
2	Landsat-ETM+	170/55	01/21/2002	30*30
3	Landsat-ETM+	170/55	01/21/2021	30*30

Source: USGS website

3.4. Methods of data collection

The procedure followed in this study was presented using the flow chart (Fig. 2). It shows the steps followed beginning from the acquisition and classification of multitemporal satellite image of the study area to the extraction of the required information both secondary and primary data to answer the research questions.

3.4.1. Criteria for spatio-temporal identification (site and year selection)

The year 1992 was chosen because of the construction of new road and rural expansion settlements in the study area. The year 2002 and 2021 were chosen because of the availability of the updated information about current Land cover types.

3.4.2. Sample and Sampling Techniques

A cross-sectional survey was conducted to assess the land use land cover change types of the study area from April 1/2021 to April 30/ 2021.

3.4.2.1. Sample size determination techniques

In order to address the research objectives adequately, both probability and non-probability sampling technique were used. Non-probability sampling is that sampling procedure which does not afford any basis for estimating the probability that each item in the population has of being included in the sample. In this type of sampling, I was selected items for the sample deliberately; this choice concerning the items remains supreme. In other words, under non-probability sampling, purposively I was chose the particular units of the universe for constituting a sample on the basis that the small mass that they so select out of a huge one was typical or representative of the whole (Info and History,2021). Probability sampling is also known as 'random sampling' or 'chance sampling'. Under this sampling design, every item of the universe has an equal chance of inclusion in the sample. It is, so to say, a lottery method in which individual units were picked up from the whole group not deliberately but by some mechanical process. The results obtained from probability or random sampling can be assured in terms of probability (Info and History,2021). In light with this discussion, from probability sampling methods, systematic random sampling method will employed. To identify the individual household would be included for survey from purposively selected kebeles. Accordingly, 145 households would be sampled from a total population using systematic random sampling techniques i.e.; 15 households from Wabo, 59 households from Geche, 71 households from Witate Kebeles, respectively because of those kebeles settled in the forest area.

Based on the feasibility of the Yayu Biosphere Reserves, members of the community in the total population of each villages the sample size of the respondents for this study determined by using (Yamane, 1967) sampling formula with 92 percent confidence level).

$$n = \frac{N}{1+N(e)^2} \quad \text{.. (3.1.)}$$

Where: n = sample size

N = total number of household of the Kebele

e= margin of error.

3.4.2.2. Methods of social data collection

A. House hold survey

Both open-ended and closed-ended questions were used to collect the data for this study. The questionnaire were administered to each respondent through enumerators by translating it's to the local language (Afan Oromo) (Appendix: B). The primary data was generated based on information from sampled households through a cross-sectional survey by using pre-tested structure questionaries' organized in a logical order of presentation. The survey generates qualitative, and quantitative data about demographic characteristics, aspects of participation, Biosphere Reserve resource use and dependence.

B. Key Informant Interviews

In-depth key informant interviews were conducted with selected informants who have detail information about the Yayu Biosphere Reserve forest. Key informants contained (chairperson, kebele manager, development agent, an elder from each kebele (Appendix: D).The key informants were asked about the general information about the current and past situations of Yayu Biosphere.

C. Focus group discussion

Focus group discussion was used as an instrument to collect qualitative data in the study. Focus group discussion were selected from each sampled kebele, then three focus group discussions were be formed. Accordingly, a total of 10 participants in each focus group discussion participated (Appendix: C). For each focus group discussion, written questions were administered to each respondent on the resource utilization related to Yayu Biosphere Reserves

D. Field Observation

During the data collection, field observations were made, taking notes about the environment like infrastructure, home gardens, yards and people's reactions to the overall interviewing situation against different questions, and discussion topics. The direct observation method were used to check up the clarity, and consistency of data collected from the study site (Appendix: A).It was used thematically to record the estimated land use land cover types and its impact on forest diversity.

3.5 Materials

3.5.1. Input data of satellite image

Satellite imageries and ancillary data were collected in order to identify successive forest cover changes. The image data that is used for this study were Landsat TM& ETM+, Topographic maps at the scale of 1:50,000 was procured from the Ethiopian Mapping Agency (EMA). Study area boundary was generated from Central Statistical authority (CSA) and Digital Elevation Model (DEM) of the study area was generated from SRTM (Shuttle Radar Topographic Mission) new version of ERDAS Imagine 2015 of raster tool using Interferometry tool box, which is downloaded from global land cover facility provided by Colombia University at row 55 and path 170. This data helped to observe and understand the relationship between topography, mainly altitude and slope for forest cover change and for production of disturbance risk map by using 3DEM and ArcGIS 10.0 software. GPS Garmin-72 recorder was also most important tool for ground assessment, or to make ground verification.

The majority of primary data necessary for the study were extracted from satellite images. Forest cover types at various times were extracted from Landsat-TM (1992), ETM+ (2002) and ETM+ (2021) images. Altitude and slope were generated from DEM (Digital Elevation Model) 30m resolution data. Topographic maps of 1: 50,000 scales was obtained from Ethiopian mapping agency (EMA) and river and various road category networks were generated from topographic maps through manual digitizing and georeferenced according to WGS 1984 UTM ZONE 37N.

3.5.2 Tools and Instrument/materials

The following table shows the tools and software which were employed for the investigation.

Table 2. List of tools and software

Materials/ tools and Software	Purpose /use
Arc GIS software (Arc map 10)	For spatial and non-spatial data analysis
SPSS	Used to analysis socioeconomic data
ERDAS Imagine 2015 software	Image analysis (preprocessing, classification, accuracy assessment)
GPS- Garmin 72	used to collect control points
Toshiba Laptop-core i5	Used to organize the documents
Smart phone	Used to captured photos

3.6. Data analysis

After collecting all necessary data, data analysis and processing were follow the procedure of cover map analysis, disturbance risk map analysis, change detection analysis and community perception analysis using ERDAS IMGINE2015, ArcGIS10.0 and SPSS software. Furthermore, some simple statistical methods, such as percentage, average and graphic tabulation were employed for the analysis and interpretations. Depending on the specific objectives of the study the procedure of the data analysis was describes as follow.

3.6.1. Map analysis

Land sat TM of 1992, Landsat ETM+ of 2002 and Landsat ETM+ of 2021 image were downloaded from www.Earth explorer.usgs.gov website. The image had 30m of spatial resolution and it used to prepare land use/cover map of the study area through ERDAS IMAGINE 2015 processing software. For the preparation of land use /cover map analysis of the study area the following main steps were followed.

3.6.1.1. Image pre-processing

In their raw form, as received from imaging sensors mounted on satellite platforms, remotely sensed data generally contain flaws or deficiencies (Dierssen *et al.*,2021). Some of the distortions are radiometric distortions, geometric distortion and noise or atmospheric effect. Such errors can be corrected by using pre-processing techniques like radiometric correction, geometric correction and noise removal or atmospheric corrections, which should be applied in raw imageries. The image used in this study was found in three paths and rows and have distortions like mentioned above. Therefore, the images were perfectly corrected by applying the necessary pre-processing techniques. And also all images were georeferenced in to appropriate datum and projections of Ethiopia because datum conflict may distort the data or limit the use of overlay techniques.

3.6.1.2. Image enhancement and its classification

These techniques were applied to images in order to display more effectively or record the data for subsequent visual interpretation. All spatial, radiometric and spectral enhancements were deemed necessary to increase the interpretability of raw images. Specifically for this study resolution merge, contrast stretching and histogram equalization were applied to enhance the visual interpretability of the image. Contrast stretching is a technique to expand the narrow range of brightness values typically present in an output image over a wider range of gray value (Wong et al.,2021).

Image classification is the process of creating thematic maps from satellite imagery. A thematic map is an information representation of an image that shows the spatial distribution of particular theme (Rohith and Kumar,2021). Remotely sensed data of the earth may be analyzed to extract useful thematic information for different purposes. The overall objective of image classification procedures is to automatically categorize all pixels in an image into land use / land cover classes or themes (Wong *et al.*,2021).

In classifying the images, supervised image classifications techniques were applied. Supervised image classification was computed after the collection of training 100 GCP samples in filed survey. Finally, the different land use/land cover was classified (grouped) and maps composed using ERDAS IMAGINE 2015 and ArcGIS 10.0 software.

3.6.1.4. Accuracy assessment

Accuracy assessment is a general term for comparing the classification to geographical data that are assumed to be true in order to determine the accuracy of the classification process. The data used to cross-check the accuracy are usually collected from ground truth and calculated using a set of reference pixels. Reference pixels are points on the classified image for which actual data are represented and are randomly selected (Roots and Overviews, 2021). In this study 100 collected GCPs were used for this purpose based on the Kappa coefficient rule.

The kappa value is a measure of the agreement between classification and reference data with the agreement due to chance removed. The kappa values, ranging from -1 to 1, into 3 groups: 1) those greater than 0.80 represented strong agreement between the classification and reference data; 2) those between 0.40 and 0.80 represented moderate agreement; and 3) those less than 0.40 represented poor agreement.

The Kappa value was calculated using the following formula (Developed from Stephen V. S., 2004)

K= r 0i-ei 2/ (1-rei)…………………………………………………………………… (3.2)

Where

K= kappa coefficient

r = relative

Oi = Observed value or GPS value on the ground

ei= expected value during supervised classification

In the study the Kappa coefficient lies typically on a scale between 0 and 1, where the latter indicates complete agreement, and is often multiplied by 100 to give a percentage measure of classification accuracy. The result obtained in this study fits to the view of (Gorsevski *et al.*,2012) who stated the minimum level of accuracy in the identification of Land cover categories from remote sensor data should be at least 80 %. The classification accuracy of the study meets this requirement.

Table 3. The kappa coefficient value

Class name	Producer accuracy	User accuracy	Commission	Omission	Overall accuracy	Kappa coefficient
Settlement	97.5	100	1	1	0.9566	0.9469
Grass Land	100	95.2	1	0.7		
Farm Land	77.5	81.2	1	1		
Forest	100	100	1	1		

Source: Own Computation

As the above table indicates all land covers/ land uses forest cover and agricultural land were classified with high accuracy. Totally classification was at higher accuracy level. The land cover or use of the study area was classified with overall accuracy of 95.66% and kappa coefficient of 0.9469.The kappa coefficient of 0.9469 of land use or cover classification in the study area represents a strong agreement according to (Info and History,2021).

3.6.2. Disturbance risk map analysis

In order to generate disturbance risk map of the study area the year 2021 forest cover map was produced and considered to be the base line for this analysis. Forest disturbance is understood that the forest resources can be influenced or degraded by different factors like human activities and natural factors. However, in this study human activities were taken into consideration because the unplanned actions such as agricultural expansion, road construction, exploitation of forest resources for fuel wood and charcoal production as well as expansion of rural settlement along the margin and inside the forest cover areas were contributing factors that caused forest disturbance and those factors were analyzed under the following subtopics.

3.4.1.5. Slope

SRTM satellite image was used to derive slope map of the study area. And the slope map was reclassified to achieve the required slope status. The slope map was reclassified to forest disturbance according to global agro ecological zone (2012).

Table 4. Forest disturbance suitability sub class of slope

Slope class	% range	Conditions	Rank
Very flat	0-0.5	Highly risk	1
Flat	0.5-2		
Gently slope	2-5		
Undulating	5-8	Moderately risk	2
Rolling	8-16	Marginally risk	3
Hilling	16-30	Low risk	4
Steep	30-45		
Very steep	>45		

Source: GAEZ, 2012

3.6.2.1. Elevation

Altitude is one of the major environmental variables that determine the convenience of a certain area for various uses including human settlement. Therefore to produce the risk of forest disturbance, altitude of the area was clipped from SRTM DEM 2014 of the study area. This factor was rasterized, reclassified and evaluated to understand the level of disturbance in the area. Finally MCE using ArcGIS 10.0 and ERDAS 15 software were applied to develop disturbance risk map which was helpful to develop risk class of forest land for the future as shown in Table 5.

Table 5. Forest disturbance suitability sub- class of Altitude

Altitude Class	Risk class	Rank
1100-1500	Highly risk	1
1500-1800	Moderately risk	2
1800-2100	Marginally risk	3
>2100	Low risk	4

Source: set up by author

3.6.2.3. Proximity to river

The stream flow data were derived from SRTM DEM of 2014 with spatial resolution of 30m. The topography map was used as based map for identification of specific stream. By using the hydrological tool, the steam network and basins were developed. For identification of river potential area, according to (Jayantari et al.,2021) the stream flow data were categorized or ordered according to its supply of cell count or fallow accumulation. Areas of higher values of cell count were where water collects and drains; areas of very high values were likely perennial streams or rivers; areas with lower value may be intermittent streams. Depending on the flow accumulation of the stream, the three perennial rivers were used to identify. The identified perennial rivers were used to identify risk class of the forest area. The distances from identified perennial river to a specific area were measured by multiple ring buffer tool. Finally, the vector format data of river were converted to raster format in order to match with the study (Table 6).

Table 6. Forest disturbance suitability sub class of river

River Distance in km	Risk class	Rank
0-0.5	Highly risk	1
0.5-1	Moderately risk	2
1-3	Marginally risk	3
>3	Low risk	4

Source: Extracted by the author.

3.6.2.4. Proximity to main road

In order to generate the road geometry from raster maps supervised approach for extracting road pixels of the area were analyzed as shown in table 7. The table shows forest nearest to the main road was highly risked rather than far from main road.

Table 7. Forest disturbance suitability subclass of road

Road distance (km)	Risk class	Rank
0-0.3	Highly risk	1
0.3-0.5	Moderately risk	2
0.5-1	Marginally risk	3
>1	Low risk	4

Source: own processing

3.6.3 Change detection

In order to detect and assess the changes of land-use/land cover as well as forest cover ecosystem over the year 1992, 2002 and 2021, multi-temporal Landsat data were acquired. To carry out change detection, NDVI and post-classification change detection comparison methods were employed in this study.

To examine the forest cover change and the rate of its changes, post classification comparison change detection method was employed. This kind of change detection method identifies where and how much change has occurred. In this study, three dates of satellite imageries were used to determine the changes by generating quantitative information on spatial and temporal distribution. Four aspects of forest cover change detection characteristics are identified such as; detecting the changes that have occurred, identifying the nature of the change, measuring the temporal and areal extent of the change, and assessing the spatial pattern of the change were investigated. The rate of forest cover change was computed using equation (3.3)

$$r = (\mathrm{Q2} - \mathrm{Q1}) \div \mathrm{t} \quad (3.3.)$$

Where,

r= rate of change

Q_2= Recent year forest cover in ha

Q_1= Initial year forest cover in ha and

t= Interval between initial year and recent year

From land-use/land cover maps of the year 1992, 2002 and 2021, three date's polygons representing the forest areas were extracted. This was done by converting the classified forest areas in raster format into vector format and the forest polygon was extracted to get the forest data in particular for each year for subsequent analysis.

3.6.4 Socio economic data analysis

The formal survey data was cleaned, coded then descriptive statistics (mean, standard deviation, frequency and percentages) were analyzed with the help of statistical package for social science (SPSS) version 20 software. The relationship between on forest resources and individual attitude were analyzed using Pearson's chi-square tests.

3.7. Data quality assurance and data quality control

Quality assurance activities include a planned system of review procedures conducted by personnel not directly involved in the inventory compilation/development process. Data quality assurance was the process of data profiling to discover inconsistencies and other anomalies in the data, as well as performing data cleansing activities (e.g., removing outliers, and missing data interpolation) to improve the data quality. Quality control is a system of routine technical activities, to measure and control the quality of the inventory as it is being developed. Data quality control is the process of controlling the usage of data for an application or a process. This process is performed before and after a data quality assurance process, which consists of discovery of data inconsistency and correction.

Therefore, in order to assure data quality the ArcGIS10 and ERDAS Imagene15 procedures manual were used depending on the types of parameters to be analyzed for this study.

CHAPTER FOUR

RESULTS AND DISCUSSIONS

4.1. Land use land cover map of the year 1992, 2002 and 2021

Land use/land cover unit of the study area were categorized in to four types. Namely forest cover, farm land, settlement area and grass land. The land use land cover in the study area has been classified based on variation in tone and field verification. The three dates of land use/land cover classification map of the study area were presented in the Fig. (3, 4 and 5).

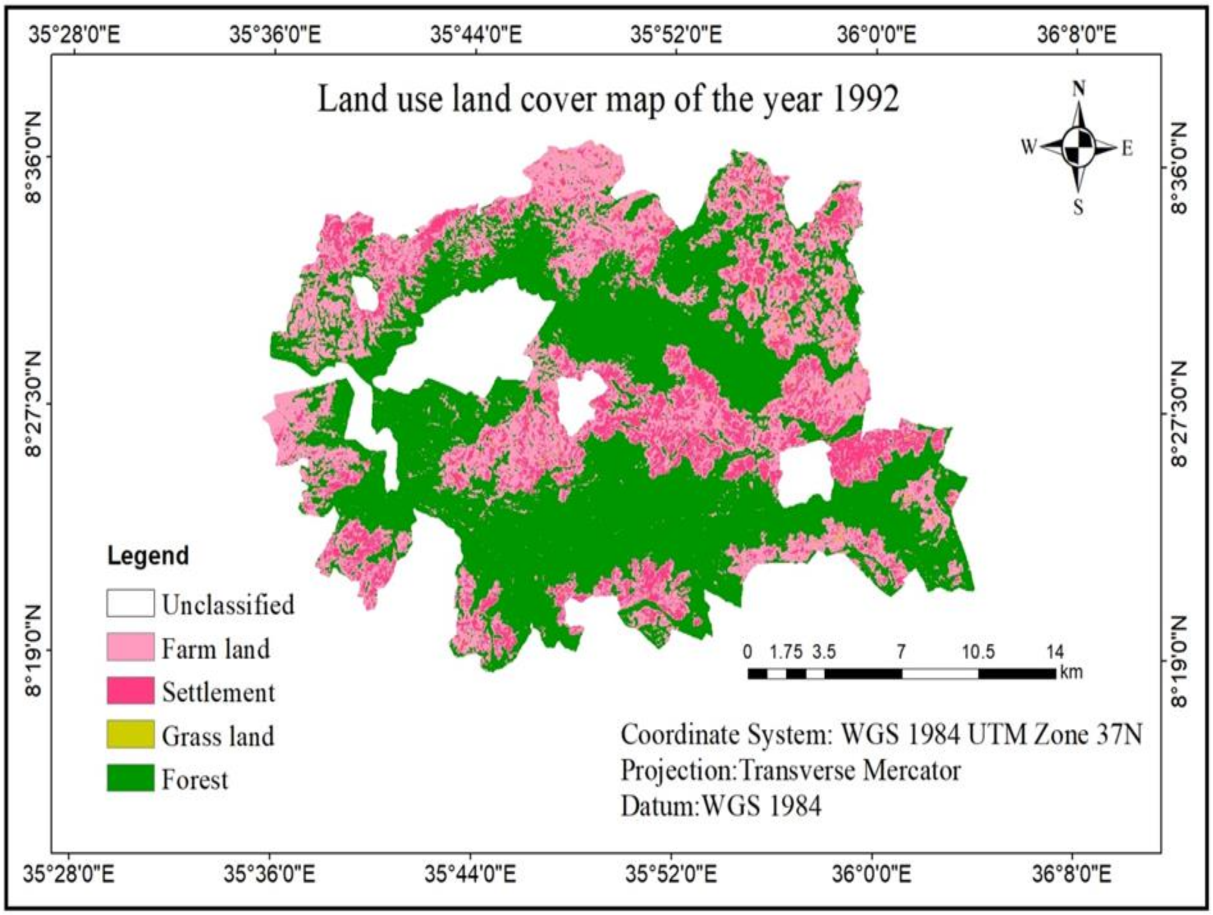

Figure3. LULC map of year 1992

From the 1992 land use and land cover map interpretation of YBR area was covered the total area of 102,316.1ha of land. Out of this the land use land cover of farm land was 36,852.10 ha (36.2%), settlement 5,334.30 ha (5.2%), grassland 955.1 ha (0.933%) and forest 59,174.6 ha (57.83%) from the total study area respectively (Table 8).

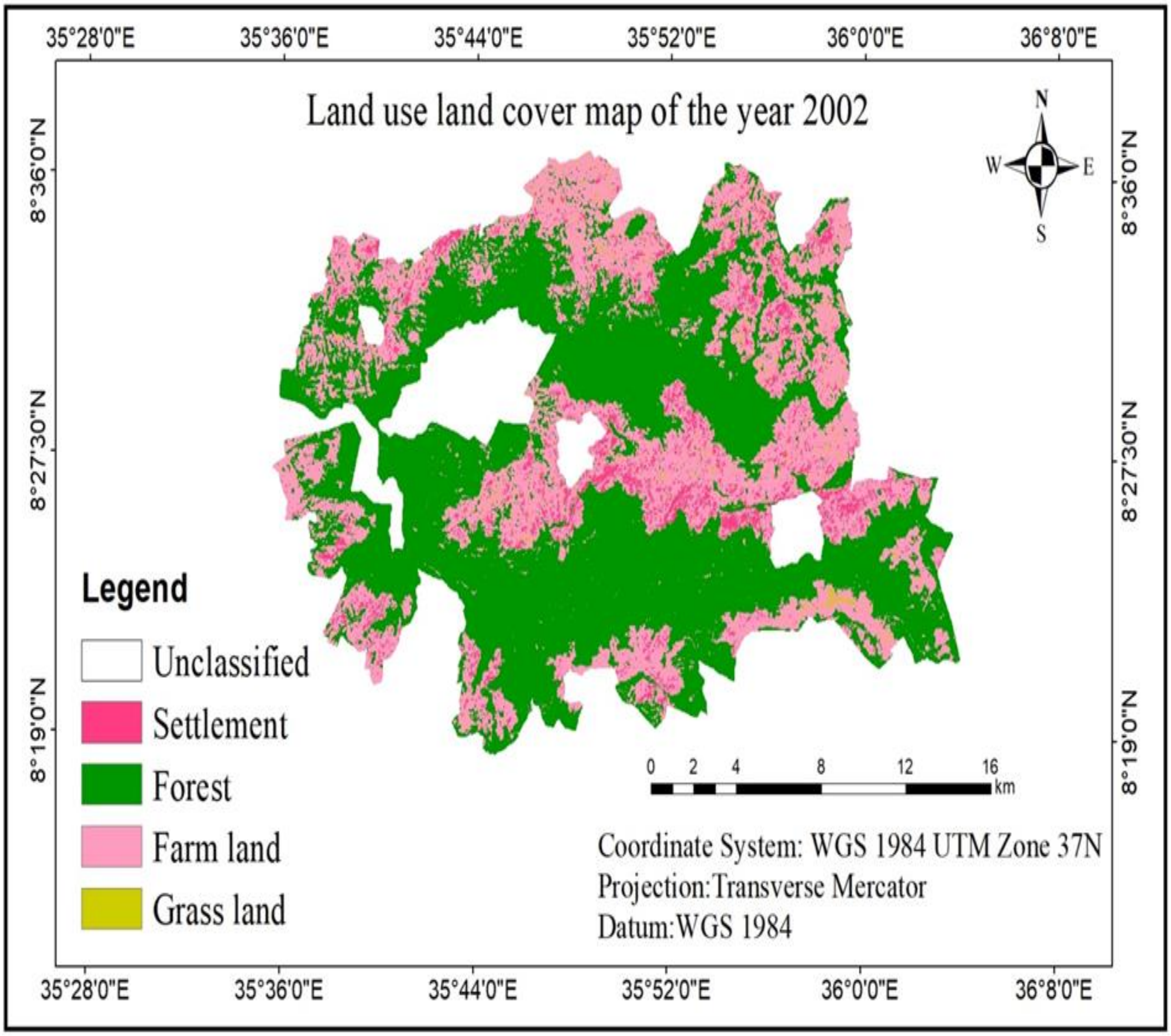

Figure4. Forest cover map of year 2002

From the total land coverage, farmland were accounted for about 34,201.9 ha (33.41%) in the year 2002. Forest land take the share of 63,254.2 ha (61.82%) and the remaining area was covered with settlement and grassland 4105ha (4.01%), 755 ha (0.74%) respectively (Fig.4 and Table 8). When compared to the year 1992, 4,079 ha (3.99%) of another land use land cover was changed to forest land.

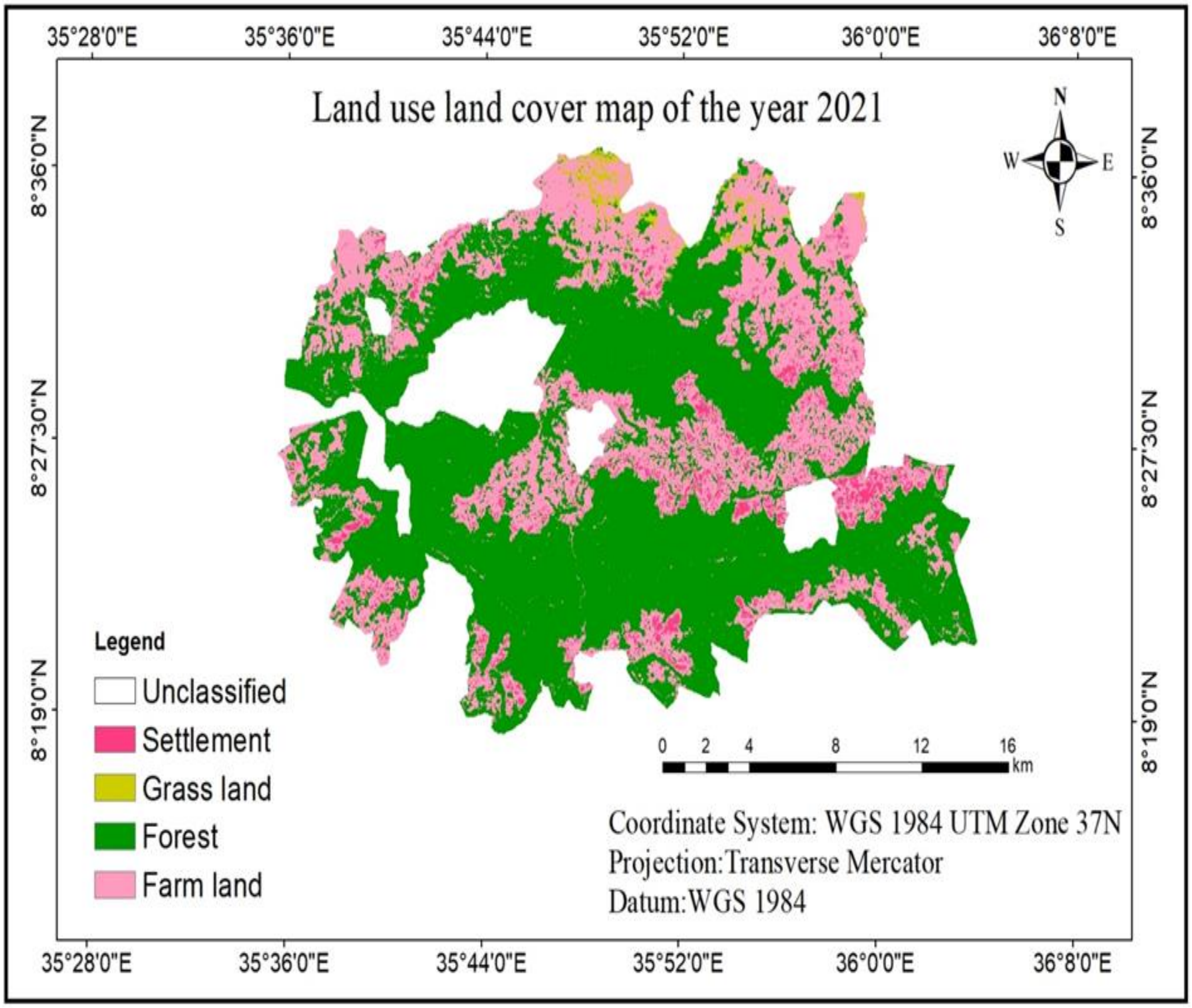

Figure 5. Forest cover map of the year 2021

In 2021 the forest areal coverage units was about 59,553.4 ha or 58.4% of the total area and farm land accounts about 34,594.60 ha (33.81%). Land category under, settlement and grassland accounted around 6750 ha (6.597%) and 1,277.0ha (1.25%) respectively.

The results of land-use/ land cover map (Fig.3,4,5 & Table 8) show that the area of forest declined in period of 2021 due to increase of farm land, settlement and grass land. Grassland class shows a sharp decrease in the first period and increase in the second period due to decline of forestland. Farmland and settlement show general trend of increase in 2021 period. This is just the general impression of land cover dynamics based on comparison of individual land cover maps.

Table 8. Summary statistics of land use land cover units in the year 1992, 2002 and 2021

Class Name	Year					
	1992		2002		2021	
	ha	%	ha	%	ha	%
Forest land	59,174.60	57.83	63,254.20	61.82	59,553.4	58.4
Settlement	5,334.30	5.2	4105.0	4.012	6,750	6.597
Farmland	36,852.10	36.02	34,201.9	33.41	34,594.60	33.81
Grass land	955.10	0.933	755.0	0.74	1,277.0	1.25
Total	102,316.10	100	102,316.10	100	102,316.10	100

Source: computed by Arc map raster calculation

4.2. Disturbance risk mapping

In order to examine forest cover change and generate human disturbance risk map of the study area, the year 2021 forest cover map was produced, which was extracted from land cover map of 2021 and considered to be the base line for analysis. This map was generated from the land use land cover map of the year 2021 satellite image. Forest disturbance is understood that the forest resources can be influenced or degraded by human activities. In reality, forest resources are degraded not only by human activities but also due to other natural factors. However, in this study human activities were taken into consideration because the unplanned actions such as environmentally unfriend investment, exploitation of forest resources for fuel wood and charcoal production as well as expansion of rural settlement along the margin and inside the forest areas would be the contributing factors for forest disturbance.

In the current study, through close examination of the spatial forest change pattern in the study area, five factors have been identified for evaluation. These factors include: altitude, settlement, proximity to the major rivers, slope, and proximity to various road categories as indicated in the subsection.

4.2.1. Factors Influencing Forest Disturbance

4.2.1.1. Altitude

Altitude is one of the major environmental variables that determine the convenience of a certain area for various uses including human settlement. Agricultural practices and settlement pattern are highly governed by altitude (Haile, 2021). In the current study area, clear deforestation had a strong correlation with altitude. Within the context of the current remnant forest under consideration, destruction of the forest ecosystem for the purpose of crop cultivation, settlement and agricultural investment, low altitudes were the most important in the study area. The spatial extent of forest cover change pattern indicates that complete forest clearance occurred on the relatively lower altitudes (1100-1500masl) of the study area, which were more convenient for human settlement, farm land and grassland. On the other hand, the disturbance of the natural forest for the purpose of income generation, fuel wood, charcoal production, and vast expansion of coffee plantation mainly occurred in relatively medium to high altitude parts of the study area. Hence, lower altitudes which were convenient for crop production, grass land and settlements were more prone to disturbance than the moderately altitude within the current context of the study area. Therefore, higher disturbance value was assigned to the lower altitudes, followed by the medium ones.

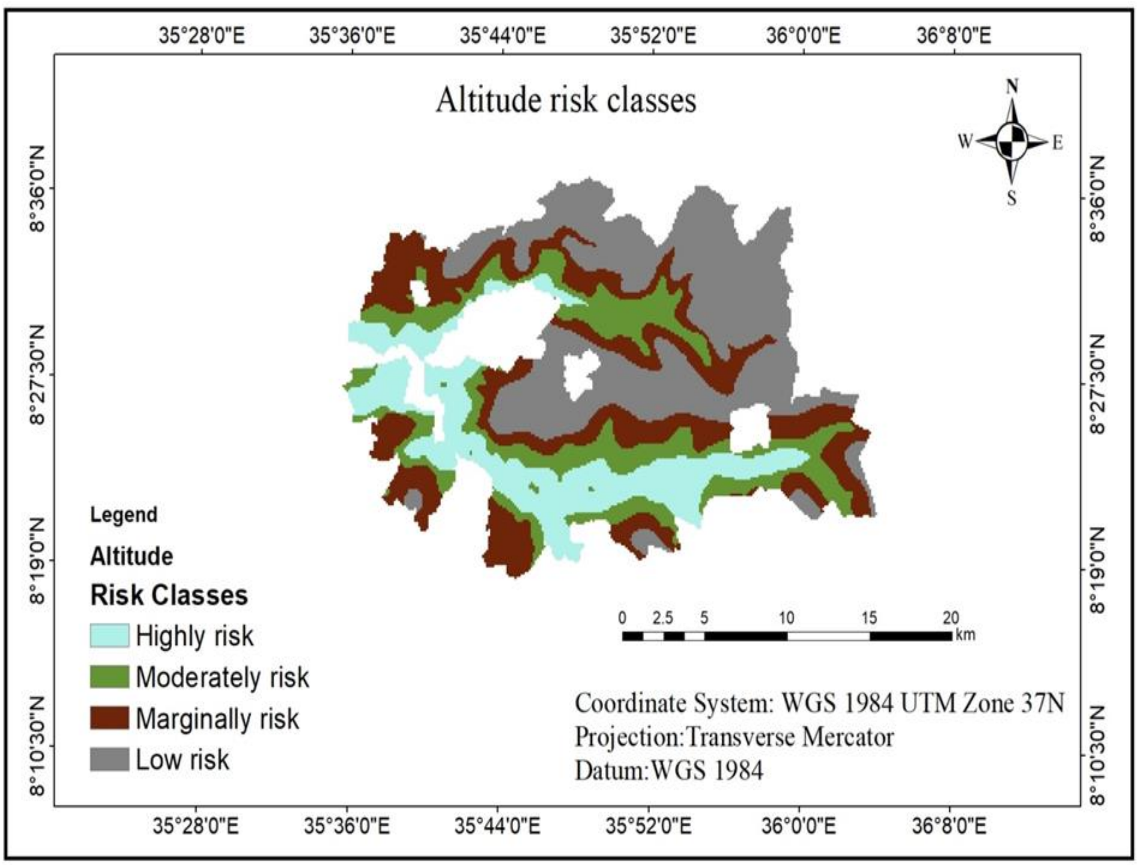

Figure 6. Reclassified of elevation factor

Source: prepared from elevation map

Table 9. Reclassified elevation

Altitude class (m)	Risk class	Rank	Area in (ha)	Area in (%)
1100-1500	Highly risk	1	38,647.3	37.8
1500-1800	Moderately risk	2	8,006.3	7.8
1800-2100	Marginally risk	3	41,834.3	40.8
>2100	Low risk	4	13,828.2	13.6
Total			102,316.1	100

Source: computed from attribute table of reclassified elevation map.

As shown in Table 9 areas that found 1100-1500 meter elevation intervals encompass about 38,647.3 ha land are more prone to human disturbance risk. During the field observation it has been witnessed that the majority of rural settlement and agricultural activities are practiced in lower elevated areas of the study area that has been supported by World Bank (Haile, 2021).So, low altitude is more preferable for settlement and agricultural activities.

After settling and standardizing altitude dataset, the output reclassified altitude dataset map (Fig. 6) was developed based on MCE (multi criteria evaluation) techniques. The forest cover areas shaded with brown and deep green colors were more prone to disturbance than forest cover areas shaded with grey and light brown colors.

4.2.1.2. Settlement

Proximity to rural settlement dataset also rasterized and standardized in order to reclassify and to distinguish the feature of forest disturbance in the study area. Around the major settlement centers farm lands were expanding at the expense of natural forest. This idea is also supported by USEPA (Vol, 2018) forwards that the forests nearer to rural settlement or residential sites (to the minimum 0-1Km) are more prone for human disturbance. For this reason, proximity to rural settlement has been considered as one of the major factor in the forest disturbance analysis. The reclassified rural settlement proximity raster map with respect to forest cover is shown in Fig.7. The forest cover land shaded with light yellow color is highly prone to disturbance than the forest cover found far away from rural settlement.

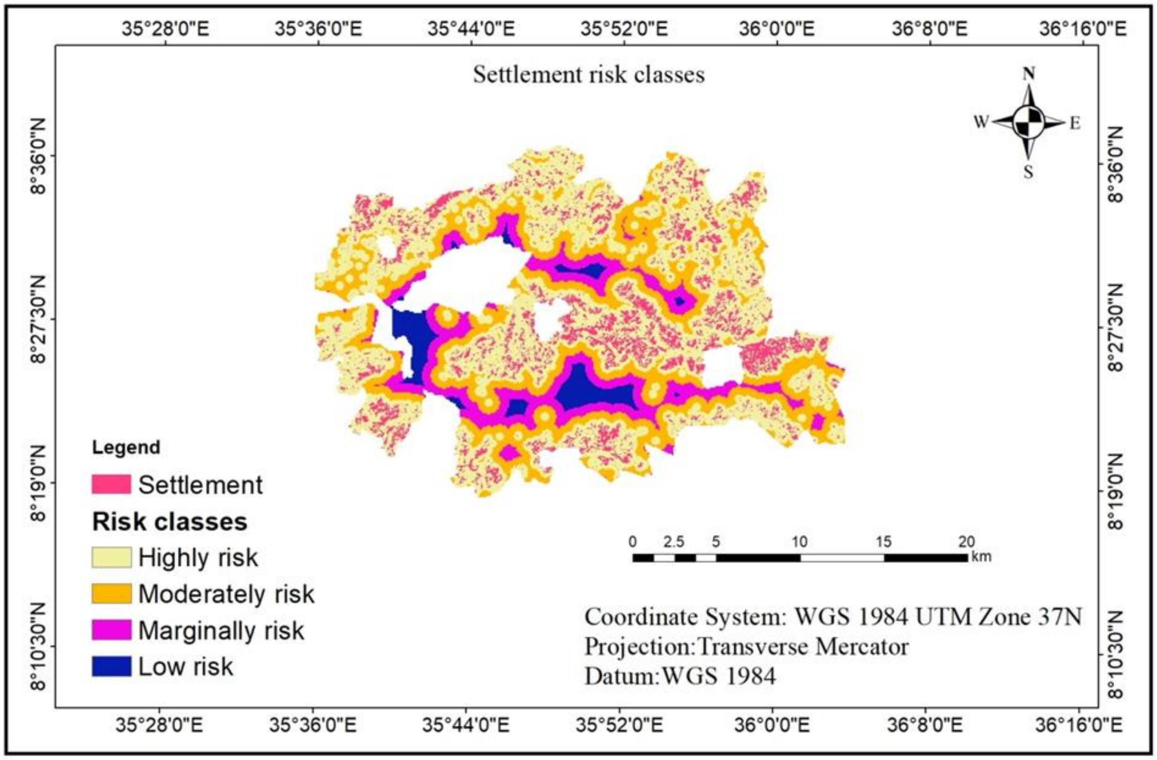

Figure 7. Reclassified settlement factor

Source: prepared from settlement map

Table 10. Reclassified settlement

Distance from Settlement in km	Risk Class	Rank	Area in (ha)	Area in (%)
0-1	Highly risk	1	46,071.7	50.4
1-2.5	Moderately risk	2	23,495.7	22.4
2.5-3	Marginally risk	3	19,501.7	17.5
>3	Low risk	4	13,247	9.7
Total			102,316.1	100

Source: computed from attribute table of reclassified settlement map

As shown in Table 10 areas that found 0-1km intervals encompass about 46,071.7 ha land were more prone to human disturbance risk. So, Table 10 reveal that the forest near the settlement was more disturbed than that of far away from the settlement.

4.2.1.3. Proximity to Roads

Similar to the above factor maps, proximity to road dataset also rasterized and standardized in order to reclassify and to distinguish the future forest disturbance problem in the study area. According to USEPA (Vol, 2018) people prefer to settle around the major roads for various reasons mainly its access for transportation. But, legally or culturally protected environment such as dense forest, parks and areas which found around spring water must far from any disturbing human related and investment activity in a distance of at least above 0.5 km and not more than 3-5km. So, major settlements in the study area were strongly correlated with major road. And rural settlements were expanding at the expense of natural forest following road network. For this reason, proximity to roads has been considered as one of the major factor in the forest disturbance. The reclassified road proximity raster map with respect to forest cover was presented in (Fig.8). The forest cover land shaded with light yellow color is highly prone to disturbance than the forest cover found far away from road.

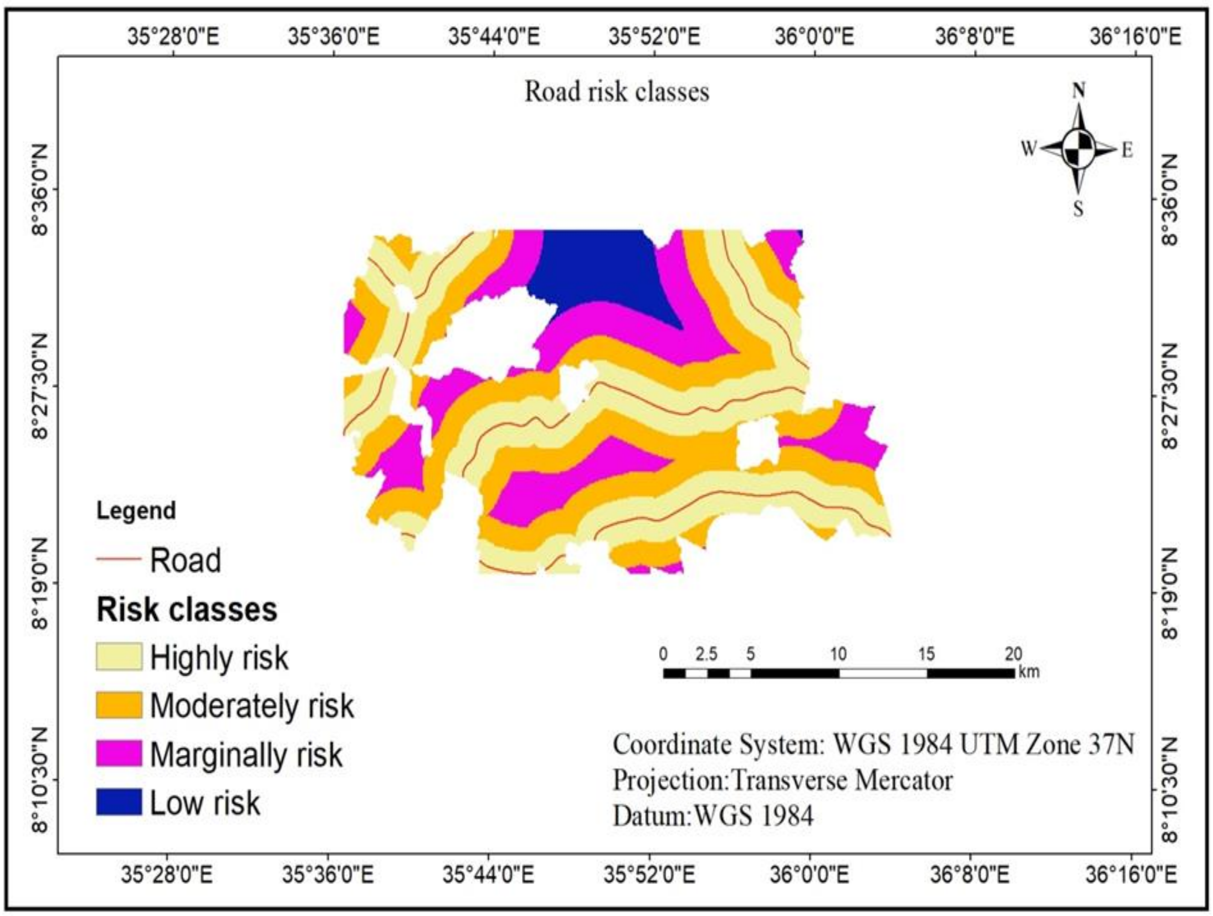

Figure 8. Reclassified road factor

Source: prepared from road map

Table 11. Reclassified road

Road distance in km	Risk class	Rank	Area in (ha)	Area in (%)
0-0.3	Highly risk	1	33,222.1	32.5
0.3-0.5	Moderately risk	2	27,267	26.6
0.5-1	Marginally risk	3	22,206	21.7
>1	Low risk	4	19,621	19.2
Total			102,316.1	100

Source: computed from reclassified road buffer map

As shown in Table 11 areas that found 0-0.3km intervals encompass about 33,222.1ha (32.5%) land were more prone to human disturbance risk due to near to the road. Areas that found 0.3-0.5km (26.6%), 0.5-1 km (21.7%) and >1km (19.2%) land were medium to low prone to human disturbance risk. So, Table 11 indicated that the forest near to the road was more disturbed than that of far away from the road network.

4.2.1.4. Proximity to river

Areas near the major rivers were steep and rugged and hence less workable and therefore less preferred by people in the study area. On the other hand, farmers have pointed out that areas near the vicinity of the major rivers in the study area were more prone to both human and livestock diseases and therefore less convenient for settlement. From the reclassified river proximity (Fig. 9) dataset forest cover areas having low distance value from river location have less susceptible to disturbance than those located to high distance. Therefore areas near the major rivers were less prone to human disturbance and gave less rank and vice versa. From reclassified river factor map (fig. 9) blue and red color were indicate areas which found in high risk whereas light yellow color shows forest areas which found in low risk.

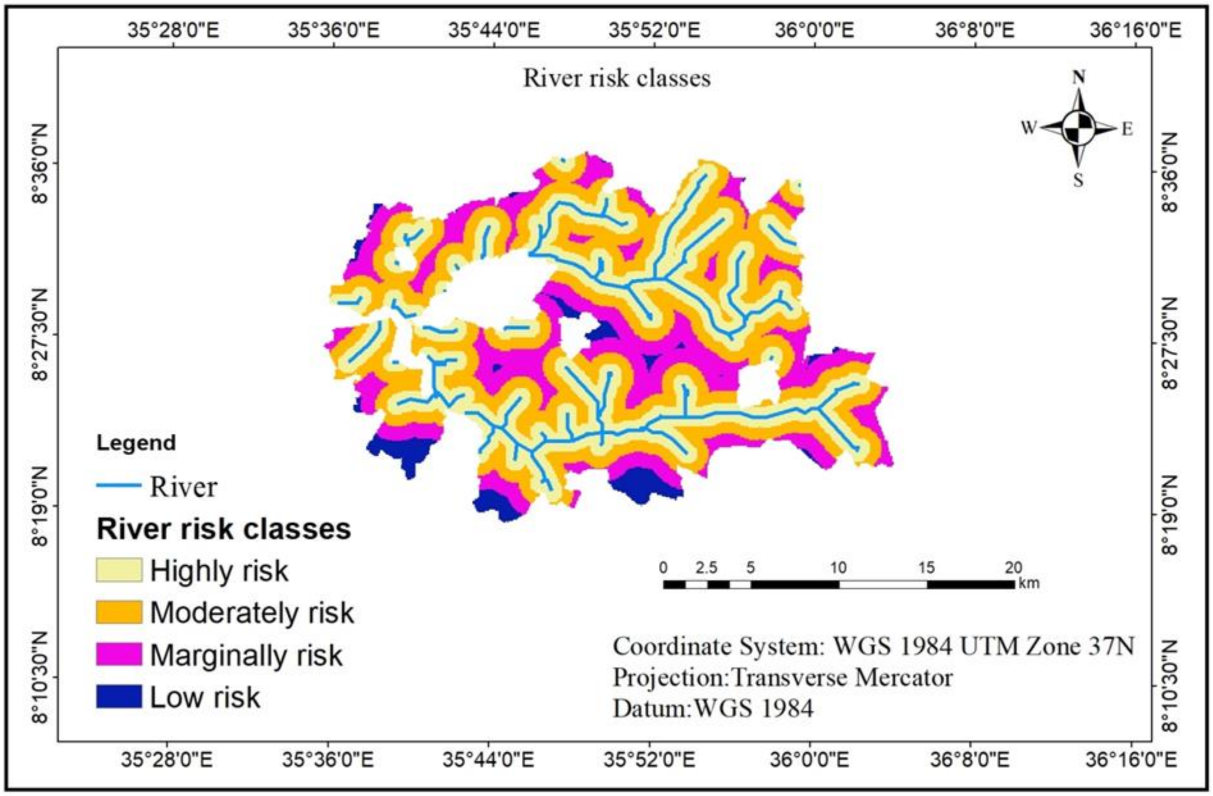

Figure 9 Reclassified of river factor

Source: prepared from river map

Table 12. Reclassified river

River Distance in km	Risk class	Rank	Area in (ha)	Area in (%)
0-0.5	Low Risk	4	11,122.3	10.8
0.5-1	Marginally Risk	3	25,958.3	25.5
1-3	Moderately Risk	2	31,812.3	31.1
>3	Highly Risk	1	33,423.2	32.6
Total			102,316.1	100

Source: computed from Reclassified river buffer map

As shown in Table 12 areas that found 0-0.5km intervals encompass about 11,122.3 ha (10.8%) land were low prone to human disturbance risk due to near to the river. Areas that found 0.5-1.0km (25.5%), 1-3 km (21.7%) and >3km (19.2%) land were medium to high prone to human disturbance risk. So, Table 12 indicated that the forest far from the river was more disturbed than that of near the river network.

4.2.1.5. Slope

Gentler slopes are preferred over steepy ones by human for various agricultural uses. This is because steepy slopes are prone to erosion, less workable and have shallower soil depth as compared to the gentler slopes. Based on this fact, steeper slopes are given lower values in terms of their influence on forest disturbance by human.

From the reclassified slope proximity (Fig.10) dataset forest cover areas having slope class of 0-5% have high susceptible to disturbance than those located to greater than 16% of slope class.

Therefore areas near to the gentler slopes were high prone to human disturbance and gave high rank and vice versa. From reclassified slope factor map (fig.10) green color indicate areas which found in high risk whereas red color shows forest areas which found in low risk.

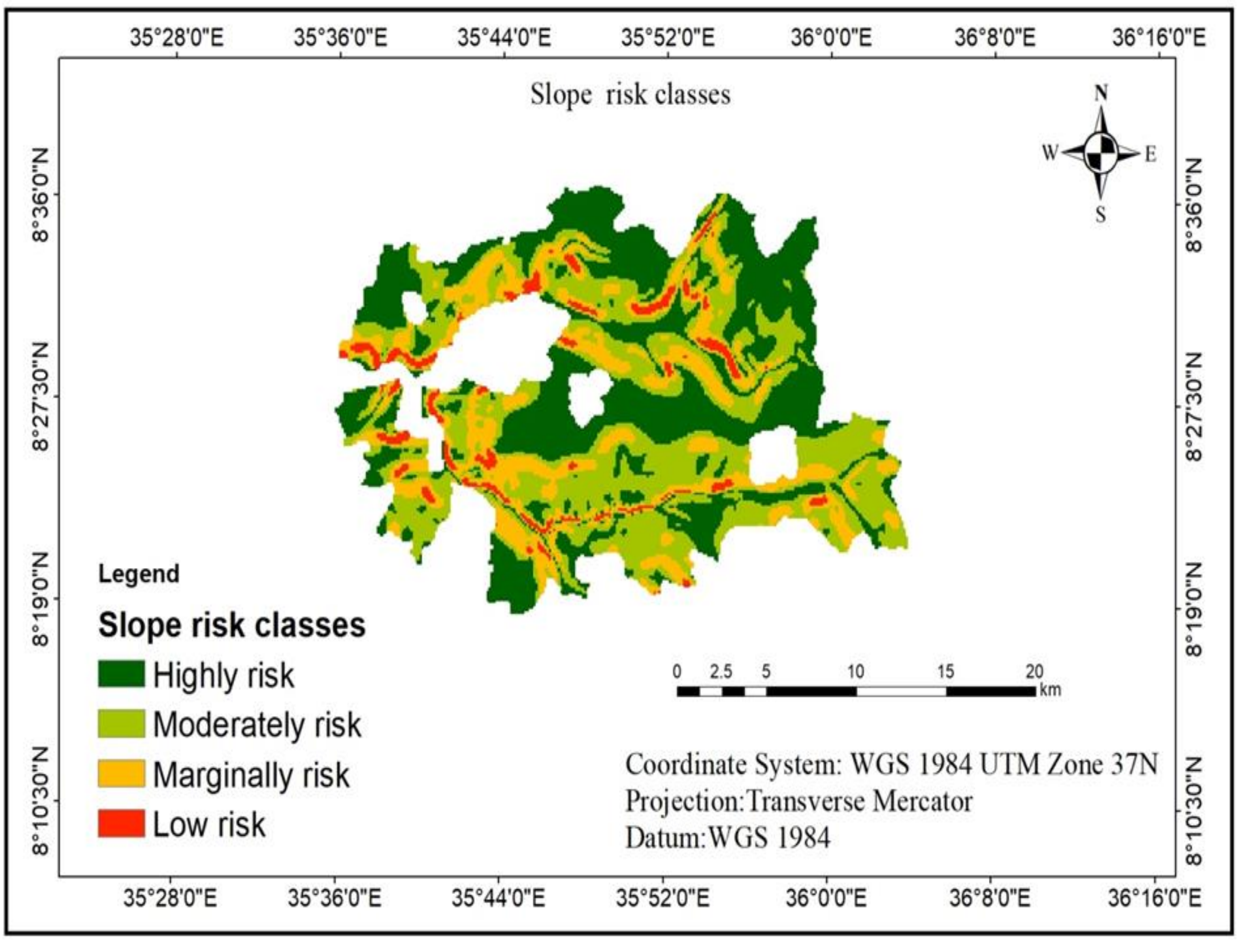

Figure 10: Slope risk class

Table 13. Slope factors of forest disturbance

Slope Class in %	Risk class	Rank	Area in (ha)	Area in (%)
0-5	Highly risk	1	41,834.3	40.8
5-8	Moderately risk	2	38,647.3	37.8
8-16	Marginally risk	3	13,828.3	13.6
>16	Low risk	4	8006.3	7.8
Total			102,316.1	100

Source: computed from Reclassified slope buffer map

As shown in Table 13 areas that found 0-0.5% intervals encompass about 41,834.3ha (40.8%) land were high prone to human disturbance risk due its gentler slope. Areas that found 5-8% (37.8%), 8-16% (13.6%) and >16% (7.8%) land were medium to low prone to human disturbance risk. So, Table 13 shown that the forest around gentler slope was more disturbed than that of found around undulating slope.

4.2.2. Dataset preparation and overlay analysis

Assigning weights for each datasets and combining together based on their weight is the subsequent procedure for conducting MCE in the present study. Weighting is used to express the relative importance of each factor relative to other factor. The larger the weight the more important is the factor in overall usefulness. The various comparisons indicated that highest weight was for the slope dataset followed by the proximity to settlement, altitude, road proximity and proximity to river value dataset (Table 14).

Table 14. Overlay criteria

No	Dataset	Range	Rank	Scale	Weight
1	Altitude (m.a.s.l.)	1100-1500	Highly risk	4	0.1472
		1500-1800	Moderately risk	3	
		1800-2100	Marginally risk	2	
		>2100	low risk	1	
2	Proximity to river (km)	0-0.5	Low risk	1	0.0814
		0.5-1	Marginally risk	2	
		1-3	Moderately risk	3	
		>3	Highly risk	4	
3	Proximity to road (km)	>1	Low risk	1	0.1162
		0.5-1	Marginally risk	2	
		0.3-0.5	Moderately risk	3	
		0-0.3	Highly risk	4	
4	Slope (%)	>30	Low risk	1	0.3427
		16-30	Marginally risk	2	
		8-16	Moderately risk	3	
		0-8	Highly risk	4	
5	Proximity to settlement (km)	>3	Low risk	1	0.3126
		2.5-3	Marginally risk	2	
		1-2.5	Moderately risk	3	
		0-1	Highly risk	4	

In order to produce the forest disturbance risk map of the area, the above raster layers along with their weighted values was developed in to equation (4.1) and then fed in to the spatial analyst raster calculator of the ArcGIS 10.0 software.

Disturbance Risk *= Altitude* 0.1472+Distance from river* 0.0814+ Proximity to Road* 0.1162 + Slope* 0.3427+ Proximity to settlement* 0.3126 ……………………………………….. (4.1)*

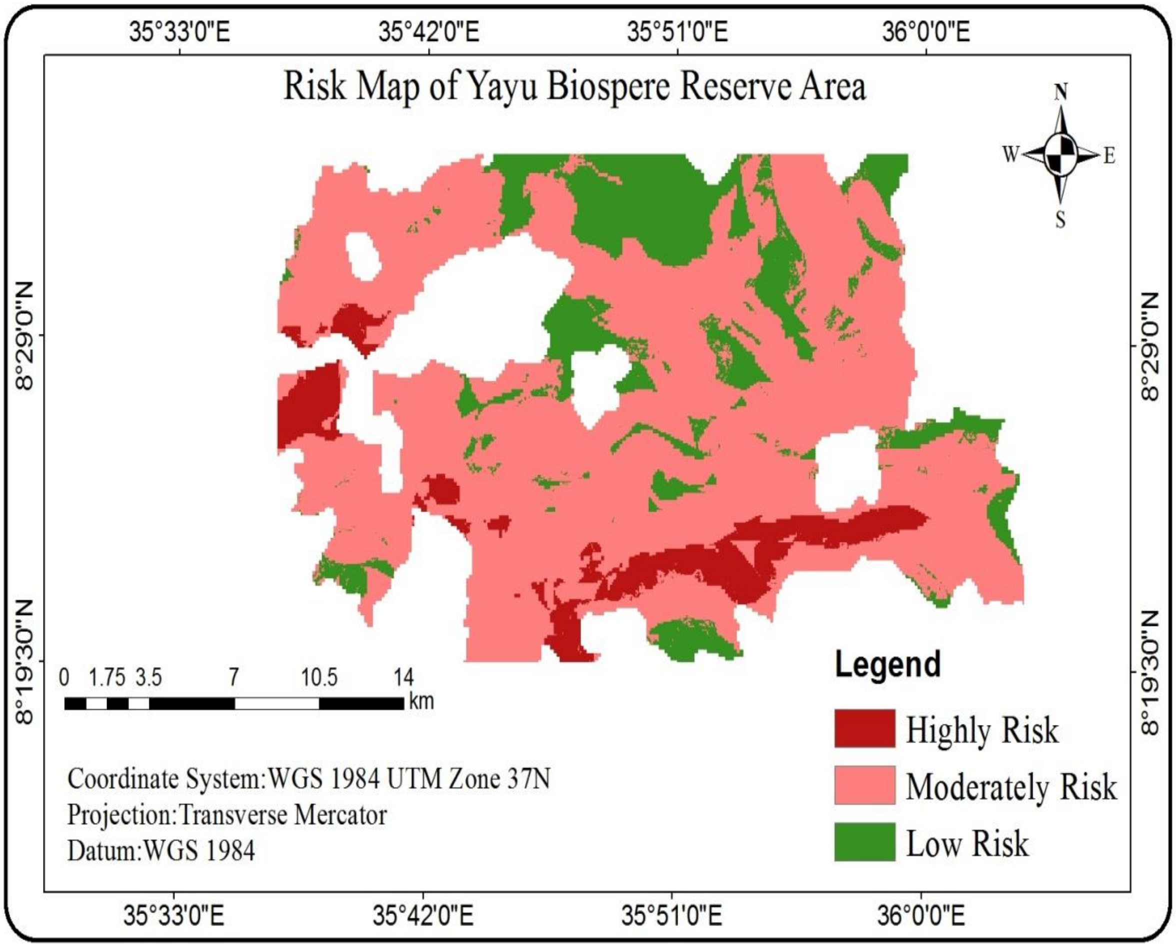

Figure 11: Sensitive to human disturbance map

Based on equation (4.1) forest disturbance risk map (Fig.11) was obtained. It shows the proneness of the forest to disturbance. The green areas indicate parts of the forest that were less prone to disturbance while the red areas indicated parts that were most prone and therefore at high risk of disturbance.

Table 15. Areal coverage of forest disturbance risk

Disturbance level	Rank	Area in (ha)	Area in (%)
Highly risk	1	29,101	28.4
Moderately risk	2	42,485	41.5
Low risk	3	30,730	30.1
Total		102,316.1	100

Source from figure 11

Based on the total forest cover area of the year 2021, about 30,730ha (30.1%) of forest cover was categorized under low risk of disturbance. On the other hand, 42,485 ha (41.5%) and 29,101ha (28.4%) forest cover lands were considered to be moderately and highly disturbance to forest degradation respectively.

4.3. Rate of Forest Cover Change

Under this section the third objectives of the study has been addressed that is related to detection of land cover changes at different period of time.

4.3.1. Change between 1992 and 2002

The major land cover changes observed during this period has been increase in the area of forests land, 3,438.5 ha. A considerable decrease in the overall areas of farm land, grassland and settlements by 2,650.2, 200.1 and 1,229.3 ha has been observed (Table16).

As indicated in Table 16, another land use land cover has been changed to forest land. Therefore, illegal occupation of settlement and illegal expansion of farm land has been decreased during this period.

Table 16. Land use land cover change matrix between 1992 and 2002

		1992 (Initial)									
		Forest land		Settlement		Farmland		Grass land		**Total**	
2002		Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)	%
	Forest land	52,843.7	88.70	287.6	5.4	2577.5	6.9	27.3	2.8	63,254.2	61.82
	Settlement	193.5	0.32	3349.0	62.8	8539.2	23.2	198.4	20.8	4105	4.01
	Farmland	6137.4	10.4	1628.1	30.5	25350.6	68.8	684.6	71.7	34,201.9	33.43
	Grass land	255	0.43	69.6	1.3	384.8	1.1	44.8	4.7	755	0.74
	Total	59,174.6	100	5,334.3	100	36,852.1	100	955.1	100	102,316.1	100

Source: Computed Arc GIS 10 software

Note: The number in the class total row indicate final state where as the class total column indicate the initial state.

4.3.2. Change between 2002 and 2021

This period shows increase in huge amount of farm land, grass land and settlement had been observed than previous period due to declined observed on forest land. The major changes observed during this period were decrease in the overall area of forest from 63,254.2 ha in 2002 to 59,553.2 ha (by 3,701 ha) in 2021 (Table 17). Therefore, illegal occupation of settlement and illegal expansion of farm land has been increased during this period.

Table 17. Land use land cover change matrix between 2002 and 2021

		2002									
		Forest land		Settlement		Farmland		Grass land		**Total**	
		Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)	%
2021	Forest land	55,935.1	88.4	564.2	13.4	2688.0	7.8	365.9	48.48	59,553.2	58.2
	Settlement	267.9	0.4	1441.9	35.125	3602.8	10.5	25.5	3.31	6750	6.597
	Farmland	7017.6	11.1	2058.8	50.15	27039.2	79.1	353.4	46.80	34,594.6	35.64
	Grass land	33.6	0.1	40.1	0.97	871.9	2.6	10.2	1.35	1,277	1.25
	Total	63,254.2	100	4105	100	34,201.9	100	755	100	102,316.1	100

Source: Computed from Arc GIS 10 software

4.3.3. Change between 1992 and 2021

Image differencing of the two extreme times, 1992 and 2021 indicated that dense forest cover increased from 59,174.6 to 59,553.2 ha (378.6 ha) due to the vast decrement on farm land by 2,257.5 ha (Table 18). This indicate the farm land and forest has inversely correlation.

Table 18. Land use land cover change matrix between 1992 and 2021

		1992									
		Forest land		Settlement		Farmland		Grass land		Total	
		Area(ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)	%
2021	Forest land	52,293.2	88.37	94.0	1.76	6,730.5	18.26	436.4	45.69	59,553.2	58.2
	Settlement	193.1	0.33	2295.6	43.	4,207.5	11.42	53.9	5.64	6,750	6.59
	Farmland	6,680.2	11.29	1,669	31.3	25,786	69.97	459.4	48.09	34,594.6	33.8
	Grass land	8.1	0.014	815.9	15.3	447.6	1.22	5.4	0.57	1,277	1.25
	Total	59,174.6	100	5,334.3	100	36,852.1	100	955.1	100	102,316.1	100

Source: Computed from Arc GIS 10 software

4.3.4. Distribution and Rate of Forest Cover Change

The distribution of forest cover change has been studied. First, to makes it possible to visualize and analyze the spatial pattern of change, which would help to identify the various factors that cause forest loss and determine their relative importance for the successive disturbance risk analysis and management strategy formulation.

Second, to highlight the seriousness of the forest cover change dynamics which strengthens the need for protected forest cover establishment using remote sensing and GIS techniques with the integration of field survey. In this study, three Landsat satellite images were used to visualize the distribution and rate of forest cover change. During the analysis stage, digital image interpretation of forest cover area for each year was performed and total area of the forest cover and its percentage from each date were computed and summarized in Table 19.

Table 19. Temporal distribution of forest covers in the year 1992, 2002 and 2021

Year	Forest cover from the total area (ha)	Forest cover in (%)
1992	59,174.60	57.83
2002	63,254.20	61.82
2021	59,553.2	58.2

Source: computed

From this result (Table 19) about 59,174.60 ha (57.83%) of the study area was covered with forest resources in the year 1992. Meanwhile, the forest cover land of the study area was accounted for 63,254.20 ha (61.82%) and 59,553.4 ha (58.4%) in the year 2002 and 2021 respectively. From 1992 to 2002 about 4,079.6 ha (3.99%) of another land use land cover were covered by forest whereas from year (2002-2021) about 3,700.8 ha (3.62%) of total forest area were converted to another land use land cover.

The expansion of settlement and farm land were decreased from the year 1992 to 2002 due to increment of forest cover and vice versa from the year 2002 to 2021.

Table 20. Rate of forest cover change

Forest cover class	Year			Rates of change (ha)		
	1992	2002	2021	1992-2002	2002-2021	1992-2021
Forest cover & loss ha	59,174.6	63,254.2	59,553.4	4,079.60	-3,701.2	378.8
Forest cover & loss per year (ha)	Ha			407.96	-194.8	13.06

Source: computed

As shown in Table 20 forwards that in the first 10 years variation (1992-2002) about 4,079.60 ha of land was covered by forest land (407.96 ha) per year. In addition the second 19 years variation (2002-2021) about -3,701.2 ha of forest land was converted into other cover land (-194.ha) loss per year.

Besides, the annual rate of forest cover change from the entire period (1992 to 2021) is 378.8 ha (13.06 ha) per year.

4.3.5. The causes for forest cover change

Human beings have attempted to domesticate tropical ecosystems and landscapes in order to channel a large number of primary productions toward their own consumption. This was started from subtle way by enriching forest close to living garden with useful plant species or clearing small patches of forest with handmade tools and fire. But as human population and their technological capabilities increased and market for agricultural products developed, the impact of agriculture on tropical ecosystems and landscapes became more dramatic (Singh *et al.*, 2017). The forest cover change and its driven factors studied in Yayu Biosphere Reserve forest priority area also reaffirm this phenomenon.

In the study area change of forest cover was triggered by various factors, of which man are responsible. For the purpose of clarity in the present study, the factors have been grouped into population pressure and its resultant effects such as the prevalence of various types of agricultural activities, fire wood and charcoal production, cutting trees to satisfy the demand of constructional materials, settlement expansion and income generation. Each of the factors has been discussed in the sub-sections.

4.3.5.1. Population pressure

The total population of the project area was increased from 284,284 in the year 1992 to 333, 466 in the year 2021 (Ilu Ababor Economic office, 2021). Population growth is the major factor, which affect forest resources. The forces behind the forest cover change were partly population pressure and increasing demand for various types of forest products such as fuel wood, building poles and making furniture as well as to obtain adequate agricultural lands. According to interviewing local people and field observation data, due to the alarming increase for the demand of forest products, both the natural as well as plantation forests which were grown in the study area were seriously depleted, for this reason the rate of forest cover change was lower in the period 2002-2021 than the rate in the period 1992-2002. This is because in the year 2002 there was high establishment of integrated forest management project in the study area in local language Waldaa Jiraatoota Bosona (WAJIB) approach which mean forest dweller association.

4.3.5.2. Agriculture land expansion

The agro-ecological conditions of the study area is convenient for agriculture. It has also been noted that agriculture is the major livelihood of the study area. Due to this, crop production and animal husbandry are the basic elements of the subsistence production system and the products obtained are used as supplementary food sources for peasants who are inhabited of the area. Most of the farmers in the area and surroundings rear livestock and want to have larger numbers farm land. According to the information gathered from local people, having the larger number of farm land in a given family is both a source of wealth and prestige. For this reason there was forest cover change is occurred due to expansion of farm land.

4.3.5.3. Fire wood and charcoal production

In the rural areas, fire wood (collected from the nearby forest areas) and cow dung are the two most important sources of energy. According to information from local people, fire wood was commercialized as its demand has increased particularly in those areas which are devoid of trees and in the urban place of the study. Besides, the area is the core supplier of charcoal and fire wood to nearby towns. Some amount of charcoal is even transported all the way to the nearby urban areas.

For instance, Lelisa (2019), indicate that the average per capita consumption rates of fuel wood in Yayu area are 0.51 m^3. Based on this figure, the annual demand of fuelwood in the study area is $102{,}000m^3$. Moreover, the respondents in the local community identified fire wood and charcoal productions as the major causes of forest cover change. Hence, the increasing demand of forest products, in the form of firewood and charcoal within and outside the study area is the cause of deforestation.

4.3.5.4. Settlement expansions

Between the year 2002 and 2021, about 6750 ha of forest cover was converted into built up land-use units (Table 8). Hence, settlement expansion is considered to be one cause of forest cover changes in the study area.

4.4 Local community perceptions in Yayu Biosphere Reserve

The fourth objective of the study was to assess the community's perception that helps to devise conservation techniques inside the YBR. These perceptions are vital because they affect the community's willingness to take part in the conservation of the forest resource. Selected individuals of the community have been asked to state who they believed become supported to conserve or control the forest. Among the six perceptions, four perception questions were statistically significant with all independent variables described in (Table 21). Gender was statistically significant in almost all (4 out of 6) of the perceptions statements. Age, education, and duration of household stay near the YBR were also statistically significant in some perceptions (Table 21). Other independent variables such as religion, marital status, occupation, land size and household size of the participants were not significantly different in any perception questions, they were therefore not be included in the further tests.

Table 21. Significance level of chi-square tests of community perception

Perceptions	1.Age	2.Gender	3.Education	DHHSNYBR
	P. Value	P. Value	P. Value	P. Value
Who Should Conserve Yayu Biosphere Reserve	0.041**	0.044**	0.048**	0.046**
Awareness of importance of the YBR	**0.289**	**0.479**	**0.759**	**0.899**
Conservation knowledge of the HHs in YBR	0.005**	0.014**	0.013**	0.027**
Awareness about the conservation programs in YBR	0.005**	0.041**	0.031**	0.037**
Current situation of Yayu Biosphere Reserve	0.004**	0.032**	0.041**	0.045**
Overall view of YBR (satisfied / unsatisfied)	**0.048**	**0.273**	**0.904**	**0.702**

Note: Implies significant values in bold & non-significance values in not bold):

4.4.1 Perception on who should conserve Yayu Biosphere Reserves?

An examination of (Fig.12) reveals the respondents‟ views on who should bear the responsibility of conserving the forest. 62 respondents (42.8%) believe that the residents should take charge of conserving the forest. 42 respondents (28.9%) believe that all stakeholders should be involved in conservation, 24 respondents (16.6%) believe that governmental parties should involve in YBR. Only 6.9% and 2.1% of respondents felt that the role of conservation should be left to the local authority and done by the non-governmental organizations.

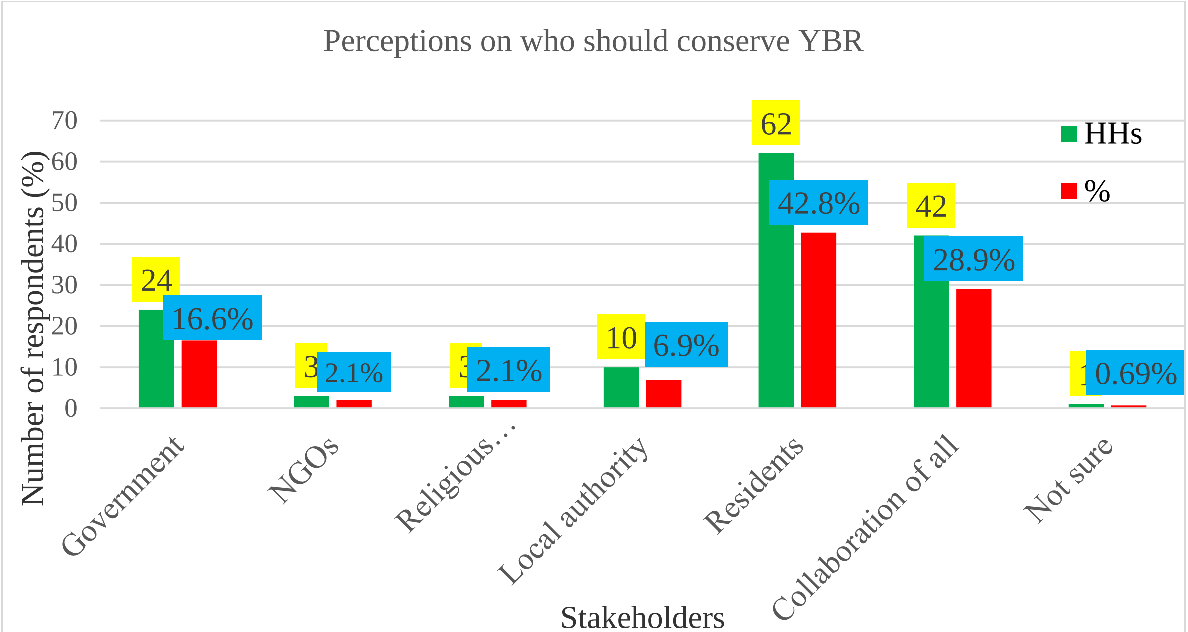

Figure 12: Respondents' view on who should conserve YBR

One respondent (0.69%) believe that he is not sure about who should have the accountability of maintaining the YBR. Statically there is highly significantly differed between a dependent variable and independent variable in YBR groups who should conserve the Biosphere Reserve point of views more than a half percent of the male respondent view that residents should take charge of conserving the forest than female respondents (χ^2 =9.66, DF = 1, P<0.05; Table 21, Fig. 12).

Fig.12 shows that 42.8% of respondents thought that the residents have the responsibility of conserving the forest. This shows that approximately half of the community members are willing to involve in the conservation activities. (Fig.12) also shows that 28.9% of respondents feed that all stakeholders should participate in conserving the forest and only 16.6% and 6.9% of respondents view that only forest officers or governmental organizations and local authorities should be tasked with the role of conserving the forest respectively. One respondent (0.69%) view that he is not sure about who should have the responsibility of conserving the YBR.

These findings suggest that the local community is willing to take part in conserving the forest if the local people are involved. The current result agree with report of Tesfaye (2017) who reported that most of his respondents were aware of the conservation of Chilimo-Gaji forest, and more than half agreed with the necessity for conserving the forest. It is important for the communities that exploit forest resources to be involved in conservation (Areole, 2016).

4.4.2 Conservation knowledge of the participants to support conservation strategies in YBR.

More than half of the members responded that they know the conservation activities of Yayu Biosphere Reserve. A much higher frequency of female participants responded that they do not know any of the conservation activities than male participants ($\chi^2 = 6.60$, DF = 1, $P<0.05$, Table 21, Fig.13). Male participants knew the human impacts on the Yayu Biosphere Reserve better than females, probably due to the better education and knowledge about conservation activities.

San (2017) also suggested that women were important for the conservation of the Biosphere Reserve and required special efforts to target women in conservation activities. It is strongly recommended for targeting women for conservation activities together with well-trained women staff. Extension programs should also plan to listen to local people together with information sharing.

Conservation knowledge's also significantly differed between different age groups whereas middle-age people have more knowledge than other age groups ($\chi^2 =9.44$, DF = 3, $P<0.05$; Table 21, Fig. 13). Male participants said that they knew more conservation activities than females. This can be because most of the extension programs are focused on male participants. The present study found that the middle male age group people (40-49 years of age) were the most targeted group for the extension programs. This can be because the middle age group people are mostly males and the leader of the family. Participants described that YBR is protected not only for nature, biodiversity, and tourism but also for their cultures and traditions.

This findings agree with the Htun *et al.* (2012) who reported that, conservation activities described by the participants include extension programs, patrolling, and prohibition for logging, hunting, orchids and forest fire protection. The finding from the current study suggests that conservation education programs should also include all households, younger generation and women in YBR.

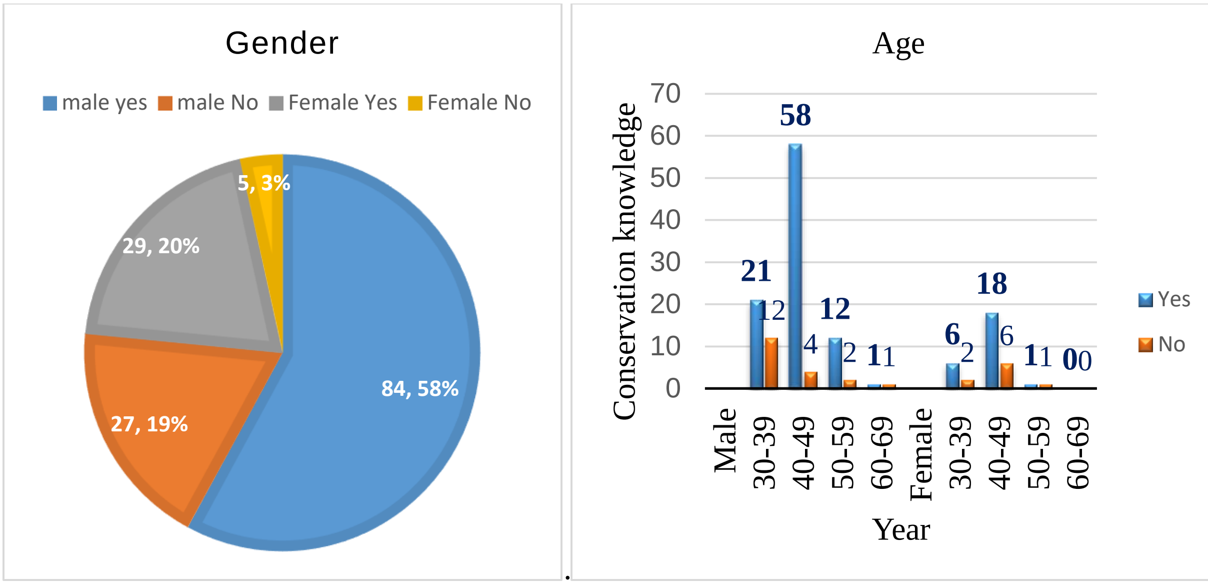

Figure 13: Differences in conservation knowledge in relation to gender and age

4.4.3 Awareness about the conservation programs in YBR

The respondents were asked to indicate which programs they know being done to conserve the forest. They were asked to choose between two options, planting trees or protection operations.

They could also state other programs in addition to these two. Table 21 shows how the community members responded to conservation programs.

Table 22. Known conservation programs being done in YBR

Program	Frequency	Percent
Planting new trees	107	73.8%
Protection operations	38	26.2%
Others	0	0.0%
Total	145	100%

As shown in Table 22, the community members are only aware of the two approaches, namely; planting new trees and protection operations. More people were aware of the tree planting strategy (73.8%) compared to the protection operations (26.2%). More than half of the participants responded that they know only one conservation program being done in YBR.

A much higher frequency of female participants responded that they do not know any of the conservation programs than male participants (χ^2 = 4.71, DF = 1, P<0.05; Table 21). Known of conservation programs also significantly differed between different age groups in which middle-aged group had more knowledge than other age groups (χ^2 =18.79, DF = 3, P<0.05; Table 21).

Educated people responded more conservation programs for Yayu Biosphere Reserve was the second most important factor for the sustainability of the Yayu Biosphere Reserve. Approximately, one third of none educated people did not have any answer (χ^2 = 6.71, DF = 2, P<0.05; Table 21). The literate respondents strongly support the Biosphere Reserve conservation approach. This finding is in line with report of (Jianying, 2005) who reported that respondents with better education expressed an objective opinion about the Reserve: it brought both benefits and losses. They perceived more benefits because they had better environmental awareness and advantages in the Biosphere Reserve.

Awareness conservation programs also significantly differed between different duration of HHs stay near the YBR groups in which the households who stay greater than last 25 years had more known conservation programs than other duration of HHs stay near the BR groups, because of the respondents were inhabitants along period of time in and around the areas are likely to be familiar with the forest, the incomes derived from it and the challenges facing the forest (χ^2 =9.24, DF = 4, P<0.05; Table 21). As shown in Table 21 the local community is only aware of two forms of conservation measures that are being implemented in Yayu Biosphere Reserve namely; planting trees and protection operations. This leads to the conclusion that the local community is not well-informed about all the conservation programs being undertaken.

The current study agree with report of Tesfaye (2017) who reported that most of his respondents were aware of the conservation of Chilimo-Gaji forest, and more than half agreed with the necessity for conserving the forest. At the same time, these findings suggest that there is a need to educate the public more about different conservation programs that carry out in the Biosphere Reserve.

4.4.4 Local community Perception on current situation of Yayu biosphere reserve

Participants were also asked whether the situation in YBR is currently better or worse than in the past. The majority of the participant said people's actions (logging, hunting, conversion of forest land into coffee, cultivated land, and expansion of any investment, as well as sandy soil extraction by user groups in the core zone of the Biosphere Reserve, makes Yayu Biosphere Reserve become worse. Significant differences were found between different education levels.

Literate people pointed out the ineffectiveness of management and land expansion for the coffee plantation inside the Biosphere Reserve is the second important factor making Yayu Biosphere

Reserve be worse. Another factor making Yayu Biosphere Reserve worse is the lack of sufficient compensation for their resources which lost during the forest boundary demarcation. Low level educated people described a lack of support for local people as the second most important factor to cause a worse situation for Yayu Biosphere Reserve ($\chi^2 = 13.67$, DF = 2, $P<0.05$; Table 21).

Knowing current situation of the YBR also significantly between different duration of household stays in the YBR groups whereas the households who stay greater than last 25 years more better the current situation of the YBR than other duration of household stay in the YBR groups, because of the household were a life a long period of time in and around the areas and are likely to be well know the forest, improved their livelihood derived from it and the challenges facing the forest ($\chi^2 = 26.12$, df = 4, $P<0.05$; Table 21).

Most of the participants mentioned that Yayu Biosphere Reserve is becoming worse nowadays than it used to be in the past. According to them, the major driver is human actions. Senavirathna *et al.* (2014) found that poaching, unsustainable forest harvesting, as well as lack of community participation are threatening the Biosphere Reserves. Participants from the current study believed that increasing human population and fewer job opportunities, more hunting, shifting cultivation, and more logging all of which are destroying the Biosphere Reserve.

Lack of support from the government for their survival is a major concern of the respondents.

Literate people claim that ineffective management for Biosphere Reserve is a major concern. The attitudes of the local communities toward the YBR in all selected kebeles were almost the same. They need to live harmoniously with the conservation area, by utilizing the Biosphere Reserve resources as a free grazing land for their livestock, forest land for coffee plantation, extraction of the timber, farmland and fuel wood collection site. The challenge remain to determine how many benefits would be enough to change the negative perceptions of local people towards conservation. Therefore, the need for the involvement and participation of the key stakeholders, such as local people, is important in achieving conservation strategies. According to San, (2017) and Allendorf (2013) biodiversity loss is related to a lack of proper management. The current study suggested that it is important to improve participatory forest management approaches than assign a sufficient number of guards and necessary to provide basic facilities for the Biosphere Reserve staff for the successful conservation YBR.

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.1. Conclusions

In general the current study area were composed of four major land use land cover types; forest land, settlement, farmlands and grassland. The result of the land use land cover map of the year 1992, 2002 and 2021 were show different coverage of land use land cover types. The findings indicated that the forest coverage were 57.83%, 61.82% and 58.4% during the year 1992, 2002 and 2021 respectively. This indicate that there was a temporal change with respect to another land use land cover.

The disturbance risk map of the study area was produced based on the settlement, proximity to road, proximity to river, altitude and slope. The evaluation of these factor indicated that the forest near settlement and road were more disturbed than the forest far from settlement and road and vice versa for the forest proximity to river. The evaluation also indicted that the forest at low altitude and gentle slope were more disturbed than the forest at high altitude and steepy slope.

The magnitude of land-use land-cover in general and forest cover change in particular was observed between the year 1992 and 2021 in the study area. Particularly, expansion of farm land, settlement and grassland were decline during the period of 2002 due to the increase of the forest land observed. The findings indicated that from the total area of the forest about 63,254.6 ha of land were covered with forest in 2002. But, this figure decreased to 59,553.4 ha in the year 2021. Moreover, for the annual rate of forest cover change between 2002 and 2021, the computed result indicated that about 194.79 ha of forest land was converted to another land use land cover per year. Hence, this type of data was very useful for the concerned bodies in protecting the remaining forest resources from distraction.

Regarding community perception towards conservation strategy, three accommodations of the respondents were of the view that conservation should be done by the residents and by a collaboration of all the stakeholders. This finding is very important for the government because it shows that the community is aware of its role in conservation and is willing to be involved in the efforts to conserve in the Yayu Biosphere Reserve.

5.2. Recommendations

From the whole study the following feasible suggestions are forwarded based on the findings.

- ✓ Wood cutting for household energy consumption was identified as one of the causes that accelerated forest degradation. Hence, in order to save energy, improved biogas that is appropriate to the rural areas has to be introduced. Besides, most of the towns of YBR dwellers depend on fire wood for energy consumption. This encourages those groups of people who are engaged in the activity of illegal tree cutting and harvesting to further exploitation of the existing forest resources found in the study area. Therefore, the urban population should be encouraged to use alternative energy source and fuel efficient stores.
- ✓ Settlement expansion is identified as a problem in the study area. Thus, to prevent the population pressure and its impact on the forest resources and there by improve the living conditions of the inhabitants, family planning awareness creation campaigns with adequate health services should be introduced.
- ✓ Farm land expansion is identified as forest destruction in study area, to realize the impact of deforestation as well as how to use this precious resource with a sustainable manner awareness should be created by YBR.
- ✓ The agriculture sector package should be implemented as a strategic option for conservation and sustainable use of remaining natural forests according to the climate-resilient green economic policy under implementation.
- ✓ Generally, good governance, continuous monitoring, and evaluation of Biosphere Reserve management activities at different levels (national, regional, and local levels) are crucial for positive outcomes and for the reduction of human disturbance related problems.

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APPENDIX

Appendix-A. Household Survey

Introduction

My Name is Abebe Emana Barbad I am a master student, studying Environmental Engineering at the Jimma University institute of Technology, Specialization in Environmental Engineering. The aim of my study is to acquire knowledge about the perception of local people living near the Yayu Biosphere Reserve.

This study is important both for the conservation of biodiversity and the local people who is dependent on the Yayu Biosphere Reserve. I hope you would like to give me some time to answer my questions. Feel free to answer my questions, I will not show your identity in my thesis. I just want to know your opinion and your knowledge for my study.

Thank you so much for your kind participation!

Date & Time………………………............................

Village Name………………..……………………….

GPS position…………………………………………

Demographic Information

1. Name of respondent____
2. Age: 30–40 ( ) 41–50 ( ) 51–60 ( ) 61–70 ( )

(3) Gender________ Female ( ) Male ( )

(4) What is your religion? ____

(4) What is your ethnicity/ community? ______ ___________________________________

(5) Marital status -Single ( ) Married ( ) Widow (HWAW) ( ) Divorced (Kan hiike) ( )

(6) Education - illiterate ( ) - Primary ( ) - Secondary ( ) - Other (specify) ( )

(7) What is your occupation (jobs)? ____

(8) How many people are living in your household? ________________________________

Age___________________________Sex_______________Occupation____________Education Relation____

Perceptions

(9) Do you know what the main purpose of the Yayu Biosphere Reserve is?

- Nature protection/biodiversity conservation ( )-Tourism ( )-Watershed ( )-Don't know ( ) - Other (specify) ( ) ____________________

(10) Do you think that the Yayu Biosphere Reserve is necessary for the conservation of remaining natural resources? Yes ( ) No ( ) don't know ( )

(11) Do you think local people get any advantages from the existence of the Yayu Biosphere Reserve? Yes ( ) No ( ) don't know ( )

(12) Do you rely to some extent on resources located within the park boundary? Yes ( ) No ( )

If yes, please rate the following resources according to their value to you.

Least Value Most Value: Timber 1 2 3 4 5 Pasture 1 2 3 4 5 Wild Animals 1 2 3 4 5 Water 1 2 3 4 5 Other 1 2 3 4 5

(13) Have you heard about the conservation activities within the Biosphere Reserve? Yes ( ) No (

If yes, please describe some activities

____

(14) Are you involved in some way in conservation activities of the Yayu Biosphere Reserve?

Yes ( ) No ( )

If yes, please describe in what way you involved in conservation activities?

____

(15) Do you have knowledge about the protected species in Yayu Biosphere Reserve? Yes ( ) No

If Yes, Can you tell me some rare species you know in Yayu Biosphere Reserve? –Animals ( ) –Birds ( ) -Medicinal Plants Orchids ( )–Others (specify) ( )

(16) Do you think that local people take full advantage of the area's economic potential related to tourism? -No, definitely not ( ) -No, not really ( ) -Do not know ( ) -Yes to some extent ( )-Yes definitely ( )

(17) What is your overall view of the Yayu Biosphere Reserve? - Not all satisfied ( )-Somewhat dissatisfied ( ) -Neutral / Do not know ( )-Somewhat satisfied ( )-Very satisfied ( )

(18) How do you think of the situations of Yayu Biosphere Reserve in the past and now?

Better ( ) Similar ( ) Worse ( ) don't know ( ) Why? ____________________

(19) Please indicate the level regarding your

	(Very Low)	(low)	(Neutral/don't 'know)	(High)	(V.High)
Awareness of the importance of YBR	1	2	3	4	5

Knowledge about the rare species	1	2	3	4	5
Observing the changing climate	1	2	3	4	5
Concern regarding environmental issues	1	2	3	4	5
Understanding the laws and regulations	1	2	3	4	5
Participation in conservation activities	1	2	3	4	5
Impacts on the biodiversity in the BR	1	2	3	4	5
Others (specify)	1	2	3	4	5

(20) Could you tell me what kind of impacts do local people have on the biosphere Reserve in the PAs? ____

(21) With the current population growth, more people will live here in 20 years. How do you think of this effect on the woody plant diversity in the PAs? Low ( ) Relatively Low ( ) don't know ( ) Relatively High ( ) High ( )

(22) What possible changes could be made to improve the overall effectiveness of YBR in nature conservation? ____

(23) Do you think that any infrastructure which used by the local communities impacts on the Yayu biosphere reserve? By what means? ____

(42) Do you think that any expansion of investment in the protected areas which carried out by another bodies impacts on the Yayu biosphere reserve? Low ( ) medium ( ) high ( ) don't know ( ), others specify ( ) ____

(24)According to you, who is/are among the following, is/are supposed to conserve or manage Yayu forest? Use a tick Government Forest department ( ), NGOs ( ), Religious Institutions ( ), local authority ( ), residents (), Collaboration of all ( ), not sure ( ) others (

(25) Do you think the forest is stable in terms of resource richness? Use a tick 1=strongly agree ( ), 2= agree ( ), 3=disagree ( ),4=strongly disagree ( ).

Appendix B: Focus group discussion

Expert/person Interviewed: ____________________ Interview completed by______________

Date: _____________________

My name is Abebe Emana Barbad MSc fellow at Jimma University. The purpose in meeting with you today is to learn about your thoughts, feelings, and experiences with regard to ‘‘Perception on protected areas: The Case of Yayu Biosphere Reserve, South-Western Ethiopia". Your contribution has a vital role in the success of the study. Your participation in this interview is totally voluntary. I would like to assure you that the information that you are giving used only for this study and honestly there is no any risk to you.

Are you willing to answer the questions?

What is the extent of community in resource use in the park?

How do you evaluate the current socioeconomic strength of the local people in times of income and education?

Does low-level of income and education limits on the use of park resource?

Do you think the presence of the park close to your area benefited the community?

In what way and what benefits have been realized up until now?

Do you think that local people and livestock affect wildlife?

What do you think are the factors that promote local people to use park resource?

What is the extent of tangible socio and economic benefit that the community member receives as individually and group?

To increases the local community benefits and at the same time securing the park, what should be done?

A. by the local community

B. by conservationists.

In order to bring sustainable development for both the park and the local community, what do you suggest?

Park dependents livelihood condition and perception. .

What type of resource do you use from the park?

What is the major benefit do you get from the park?

Are you satisfied by gazing the area in to the park?

What challenges do you get from demarcation of the area in to park?

What solution do you propose?

Have traditional hunters in your community?

What type of plants they hunt?

Do you practice your livestock grazing in the park?

Why? Do you believe accidental fire occurs in the park?

When? By whom? Is there a conflict with the local community people park resource?

How conflicts often occur? How are conflicts resolved?

Appendix C: Checklist of questions for key informant interviews

Expert/person Interviewed: ____________________ Interview completed by______________

Date: _____________________

My name is Abebe Emana Barbad MSc fellow at Jimma University. The purpose in meeting with you today is to learn about your thoughts, feelings, and experiences with regard to ''human perception on protected areas: The Case of Yayu Biosphere Reserve, South-Western Ethiopia". Your contribution has a vital role in the success of the study. Your participation in this interview is totally voluntary. I would like to assure you that the information that you are giving used only for this study and honestly there is no any risk to you. Are you willing to answer the questions?

What is the extent of community in resource use in the park?

How do you evaluate the current socioeconomic strength of the local people in times of income and education?

Does low-level of income and education limits on the use of park resource?

Do you think the presence of the park close to your area benefited the community?

In what way and what benefits have been realized up until now?

Do you think that local people and livestock affect woody plant diversity?

What do you think are the factors that promote local people to use park resource?

What is the extent of tangible socio and economic benefit that the community member receives as individually and group?

To increases the local community benefits and at the same time securing the park, what should be done?

A. by the local community

B. by conservationists

In order to bring sustainable development for both the park and the local community, what do you suggest?

Park dependents livelihood condition and perception.

What type of resource do you use from the park?

What is the major benefit do you get from the park?

Are you satisfied by gazing the area in to the park? What challenges do you get from demarcation of the area in to park? What solution do you propose?

Have traditional hunters in your community? What type of animal they hunt?

Do you practice your livestock grazing in the park? Why?

Do you believe accidental fire occurs in the park? When? By whom?

Is there a conflict with the local community people park resource? How conflicts often occur?

How are conflicts resolved?

Non –park resource users

Who owns the area before the introduction of national park?

And in what condition?

Which community groups and individuals are you think currently engaged to use park resource?

What do you think are the criteria used to guaranty to protecting the park?

Do you think that the park reserved needs to be managed properly?

For what purposes do you use the area before gaze ting the national park? How about know?

Do you any involvement in using resource in the park?

Do you understand illegal tree cutting in the park? For examples which types of tree?

Do you understand accidental fire occurs in the park? When?

Appendix: D: Photos of agriculture land expansion

Appendix: E: Photos for fire wood and charcoal production